SAARC Journal of Agriculture (SJA), a peer reviewed, half yearly journal published by the SAARC from SAARC Agriculture Centre (SAC), Dhaka, Bangladesh. The journal serves as a platform for exchange of latest knowledge on the topics that are of concerns of researchers, extension specialists, policy makers and students. It aims to capture the first hand knowledge on researches in agriculture, fisheries, livestock, forestry and allied disciplines. SAARC Journal of Agriculture welcomes feedbacks and suggestions for improving its quality.

SAARC JOURNAL OF AGRICULTURE

Vol. 22, Issue 2, 2024 ◆ SAC

Vol. 22 Issue 2 December 2024

ISSN: 1682-8348 (Print), 2312-8038 (Online)

SAARC Journal of Agriculture

SAARC Agriculture Centre

www.sac.org.bd

SAARC JOURNAL OF AGRICULTURE (SJA)

Volume 22, Issue 2, 2024
ISSN: 1682-8348 (Print), 2312-8038 (Online)

© SAC

The views expressed in this journal are those of the author(s) and do not necessarily reflect those of SAARC Agriculture Centre

Published by

SAARC Agriculture Centre (SAC)
BARC Complex, Farmgate, Dhaka-1215, Bangladesh
Phone: 880-2-8141665, 8141140; Fax: 880-2-9124596
Email: saarcjournal@yahoo.com Website: https://www.sac.org.bd/journals/

Editor-in-Chief
Dr. Md. Harunur Rashid
Director, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

Managing Editor
Dr. Ganga Dutta Acharya
Senior Program Specialist, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

Associate Editor
Md. Monirul Islam
Senior Program Officer, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

Printed at
Natundhara Printing Press, 314/D, Elephant Road, Dhaka-1205, Bangladesh
Cell: 01711019691, 01911294855, Email: natundhara2014@gmail.com

ISSN: 1682-8348 (Print), 2312-8038 (Online)

SAARC JOURNAL OF AGRICULTURE

VOLUME 22 ISSUE 2 DECEMBER 2024

SAARC Agriculture Centre

www.sac.org.bd

EDITORIAL BOARD

Editor-in-Chief
Dr. Md. Harunur Rashed
Director, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

Managing Editor
Dr. Ganga Dutta Acharya
Senior Program Specialist, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

Associate Editor
Md. Monirul Islam
Senior Program Officer, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

Members

Prof. Dr. Md. Shahidur Rashid Bhuiyan
Ex-Vice Chancellor
Sher-e-Bangla Agricultural University
Dhaka, Bangladesh
Email: bhuiyansau1983@gmail.com

Prof. Dr. M. Jahiruddin
Department of Soil Science, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh, Bangladesh
Email: m_jahiruddin@yahoo.com

Dr. A.K. Singh
Director
Indian Agricultural Research Institute
Pusa, New Delhi, INDIA
Email: director@iari.res.in

Dr. P. Pravin
Assistant Director General (Marine Fisheries)
Krishi Anusandhan Bhawan-II
Pusa, New Delhi, INDIA
Email: pravinp2005@gmail.com

Dr. Pratap Singh Birthal
Director
National Institute of Agricultural Economics and Policy Research
D.P.S. Marg, Pusa, New Delhi, India
Email: psbirthal@yahoo.com

Dr. Pranab Kumar Mandal
Principal Scientist
ICAR-National Institute for Plant Biotechnology
LBS Centre, IARI, PUSA, New Delhi
Email: pranabkumarmandal@gmail.com

Dr. Sangram Ketan Sahoo
Principal Scientist
ICAR-Central Institute of Freshwater Aquaculture
Kausalyaganga, Bhubaneswar
Email: sksahoo100@rediffmail.com

Dr. Bhim Bahadur Khatri
Senior Scientist (Horticulture)
Nepal Agricultural Research Council (NARC), Kathmandu, Nepal
Email: bhimkhatri058@gmail.com

Dr. Muhammad Musa
Chief Scientist (Research)
Agronomic Research Institute
AYUB Agricultural Research Institute
Faisalabad, Pakistan
Email: mum96@hotmail.com

Dr. Badar Naseem Siddiqui
Department of Agriculture Extension & Communication
PMAS-Arid Agricultural University
Rawalpindi, Pakistan
Email: abq678@gmail.com

Dr. P.B. Dharmasena
Independent Consultant
SriLanka
Email: dharmasenapb@gmail.com

CONTENTS

Title	Page
APPROACHES TO SUSTAINABLE AGRICULTURE: A RETROSPECTIVE ANALYSIS FOR SOIL HEALTH IMPROVEMENT	1
S. Katherasala	
EFFECT OF CONCENTRATE FEED SUPPLEMENTATION ON PERFORMANCE OF INDIGENOUS GRAZING SHEEP	15
M.A. Sun, S.S. Islam, M.S. Islam and M. Dey	
RECENT ADVANCEMENT AND FUTURE PROSPECTS OF PLASMA TECHNOLOGY FOR THE QUALITY AND QUANTITY ENHANCEMENT OF AGRICULTURAL PRODUCTION	29
H.K. Shastri, V.H. Trivedi and M.T. Thakker	
COMPARATIVE PRODUCTIVITY AND PROFITABILITY OF BANANA INTERCROPPING WITH VEGETABLES	43
M.A.H. Khan, M.M. Rahman, T. Tasmima and M.A. Hossain	
CUCUMIS SATIVUS L. FOAMY EXTRACT INDUCES APOPTOSIS IN MDA-MB-231 CELLS	55
L. Kumaraswamy and P.N. Tallur	
PRODUCTIVITY OF ZERO-TILLED DIBBLED SUNFLOWER UNDER DIFFERENT PLANTING DENSITIES IN SALT AFFECTED SOILS OF BANGLADESH	67
M.H. Rashid, P.C. Goswami and T.T. Raisa	
PHYSICO-CHEMICAL PROPERTIES AND FERTILITY STATUS OF FOREST SOILS UNDER AEZ-29 (NORTHERN AND EASTERN HILLS) OF BANGLADESH	81
M.J. Tania, N.J. Mim, A.Z.M. Moslehuddin and T.S. Hoque	
NITROGEN APPLICATION ALTERS GROWTH AND YIELD OF BRRI DHAN28	99
M. Biswas, K.G. Quddus and M.S. Jahan	
WHEAT CROP PRODUCTIVITY IN BERSEEM- RICE - WHEAT CROPPING SYSTEM IN COMPARISON WITH THE CONVENTIONAL WHEAT- RICE- WHEAT CROPPING SYSTEM PLANTED IN RICE-WHEAT AREA OF PUNJAB PAKISTAN	115
S.K. Tanveer, I. Hussain, M. Hussain, M. Sohail, S.H. Abbas, M. Qamar, M.F. Iqbal, Z. Mahmood and S. Waqar	
EFFICACY AND COST ECONOMICS OF BIO-PESTICIDES AND BOTANICAL EXTRACTS AGAINST CABBAGE BUTTERLY *Pieris brassicae nepalensis* Doubleday IN CAULIFLOWER CROP IN ILAM, NEPAL	127
A. Subedi, S. Tiwari and N. Mishra	
EVALUATION OF TOMATO SEED HEALTH AND SUSTAINABLE MANAGEMENT PRACTICES USING BIOLOGICAL AND CHEMICAL APPROACHES	139
M.S. Naznin, M.H. Kabir, M.M.H. Chowdhury and M. L. Hasan	

Title	Page
RESOURCE UTILIZATION AND PROFITABILITY OF RICE PRODUCTION IN THE TERAI REGION OF NEPAL	153
L.K. Shrestha, Y.B. Thapa, S.C. Dhakal and D. Gauchan	
SELECTION OF THE BEST TIME SERIES ARIMA MODEL TO FORECAST ONION PRODUCTION IN BANGLADESH	169
M.R. Hasan and N. Khatun	
CHITOSAN-BASED ZINC OXIDE AND SILVER NANOPARTICLES COATING ON POSTHARVEST QUALITY OF PAPAYA	181
S. Timilsina, R. Adhikari, P.P. Khatiwada, G. Devkota and K.C. Dahal	
EFFICACY ASSESSMENT OF DIFFERENT BOTANICALS AGAINST RICE WEEVIL (*SITOPHILUS ORYZAE)* IN STORED RICE	197
T.K. Roy, A. Sannal, S. Akter, M.M.M. Kabir, M.N. Bari and S.S. Haque	
TRADITION OF CULTIVATING BEAN MIXTURE FOR MULTIPLE BENEFITS AND SUSTAINABLE PRODUCTION SYSTEM IN MOUNTAIN AGRICULTURE	209
B.K. Joshi, R.C. Prasad, R. Gurung, S. Gautam, A. Subedi, A. Karkee, A.R. Adhikari and D. Gauchan	
EVALUATION OF DIFFERENT CHEMICAL INSECTICIDES AND BIOPESTICIDES AGAINST VEGETABLE LEAF MINER, *LIRIOMYZA SATIVAE* IN TOMATO	227
K.R. Das, M.A. Latif, M.M. Rahman, M.S. Hossain and A. K. Paul	
GENETIC PARAMETERS ESTIMATION AND IDENTIFICATION OF PROMISING RICE GENOTYPES GROWN IN RAINFED CONDITION USING MGIDI INDEX IN RAMPUR, CHITWAN	239
P. Roka, B.N. Adhikari, S. Shrestha, D. Roka, A. Adhikari and B. Shreepaili	
ASSESSMENT OF FOOD SAFETY REGULATION AND ASSURANCE SYSTEM IN BANGLADESH'S MILK VALUE CHAIN: ADDRESSING DISCREPANCIES AND STRATEGIES FOR IMPROVEMENT	257
S.M.R. Rahman, M Gallo and J. Woodford	
COCONUT OIL AND BEES WAX EDIBLE COATING FOR POSTHARVEST QUALITY MAINTENANCE OF BARI MALTA-1 AT AMBIENT STORAGE	275
T.A.A. Nasrin, M.A. Rahman, M.S. Arfin, M. Afroz, M.M. Molla, A.A. Sabuz, M.T. Naznin and M.A. Matin	
EFFECT OF GROWING MEDIA ON SEED GERMINATION AND SEEDLING GROWTH OF CHILI (*Capsicum annuum* L.)	289
M.S. Shakhidar, N. Akter and M.A. Sobahan	
GUIDE FOR AUTHORS	303

SAARC J. Agric., 22(2): 1-13 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.71458*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Approaches to Sustainable Agriculture: a Retrospective Analysis for Soil Health Improvement

S. Katherasala*

Senior Research Fellow, Department of Social Work, Osmania University
Hyderabad, Telangana, India.

Abstract

Gaining insight into farmers' viewpoints is essential for attaining Sustainable Development Goals in agriculture. By actively involving farmers and integrating their perspectives, it is possible to foster novel strategies that enhance soil quality and bolster the agricultural ecosystem. It is possible to improve soil health and reduce reliance on outside inputs by using regenerative farming methods that are based on agroecological principles and precision farming technologies. Engaging in collaboration with researchers, policymakers, and agricultural communities is crucial to jointly develop creative artificial intelligence (AI), which has the potential to enhance economic expansion, reduce inefficiencies, and provide nutrients directly to plant roots. This transformation revolves around the recognition of solutions that effectively tackle the Sustainable Development Goals (SDGs) and advance the improvement of soil health. The study regenerated with previous understanding and recommended that farmers investigate the intricate correlation between bacteria and nutrients to discover more effective approaches to soil management. Several natural alternatives include cyanobacteria, biofertilizers, plant growth-promoting rhizobacteria (PGPR), and livestock manure. Optimal soil health is crucial for the overall functioning and sustainability of entire ecosystems. The study emphasized the significance of prioritizing farmers' practices and adopting their perspectives to comprehend the real-time decision-making process. Furthermore, the study suggested some effective recommendations, that farmers should receive to practice land tilling, smart

* Corresponding author: sri.katherasala@osmania.ac.in

Received:11. 02. 2024 *Accepted: 11. 11. 2024*

farming adoption, residues and weed management. These potential strategies significantly enhance agricultural productivity.

Keywords: Biofertilizers, Environmental health, Nanotechnology, Sustainable agriculture, Soil health, Synthetic fertilizers.

Background

It is crucial to safeguard our land from harmful practices. The soil is considered a living entity, and its natural organic matter has seen a degradation of 40% (Bossio et al., 2010). This is a serious issue that requires immediate attention. The preservation of soil is currently of utmost importance, since it is crucial to halt any further deterioration of this key natural asset. Soil is an intricate combination of organic and inorganic substances that facilitate plant growth and serves as a habitat for many species. It encompasses plant residues, decaying organic matter, minerals, rocks, and various chemical compounds. Livestock manure contributes organic nutrients, while insects and microorganisms play pivotal roles in nutrient cycling and soil health. Synthetic fertilizers alter soil composition by introducing concentrated nutrients, affecting pH and microbial activity. Excessive use of synthetic fertilizers can harm beneficial soil microorganisms and lead to a decline in soil organic matter. Understanding this intricate interplay is crucial for sustainable soil management (Dinel et al., 2017). Since the advent of intensive agriculture, farmers have discontinued the use of natural manure. Instead, farmers have exclusively depended on synthetic chemicals, leading to the full deterioration of the soil.

Soil degradation includes processes such as erosion, salinization, acidity, compaction, and loss of cover (Gomiero, 2016). Regrettably, the act of providing sustenance to an excessively large population and the pursuit of economic incentives are having detrimental effects on our environment and putting significant pressure on the balance of the soil. An urgent and comprehensive endeavour is required to protect the inherent characteristics of our soil for the benefit of future generations.

Cause of Degradation of Soil

Soil degradation is a growing concern in agricultural practices, mainly due to the excessive use of chemical fertilizers and less use of organic manure. These fertilizers, while initially increasing crop yields, often lead to a decline in natural fertility and overall soil health over time (Aulakh and Sidhu, 2015). Chemical fertilizers provide nutrients to plants but do not address the long-term health of the soil ecosystem. As a result, the repeated use of chemical fertilizers can disrupt the balance of nutrients and microorganisms in the soil, leading to reduced organic matter content and diminishing natural fertility (Jacoby et al., 2017).

a. Use of synthetic fertilizers

The extensive use of synthetic fertilisers, necessitated by the critical need to close the supply-and-demand mismatch in agricultural production, has been prompted principally by economic factors. Chemical fertilisers are undoubtedly a significant step toward addressing the nutrient shortage, however it involves a serious risk to the environment and resource depletion facing humanity (Kaur et al., 2014). Due to their hasty and practical nature, farmers adopt these techniques without being cognizant of their potential long-term repercussions. Sadly, the consequences of the intensive fertiliser use of the present day reach far beyond economic benefits; they have significant effects on both human health and the environment (Tripathi et al., 2020).

b. Soil erosion and faulty land use

Natural processes such as wind, water, and climatic events cause fine soil particles to separate and move, a process known as soil erosion (Lal, 2017). Regrettably, poor land management techniques make erosion worse and cause the soil to lose important organic matter. The implementation of knowledge-based erosion protection systems requires immediate attention (Telles et al., 2011). Although some farmers believe that soil erosion is an unstoppable force, there is hope for reducing its effects and protecting our essential soil resources when a planned approach is combined with technical improvements.

Degradation of the soil is further exacerbated by improper land use practises. Overgrazing and monoculture are examples of unsustainable farming practises that deplete vital nutrients. CO2 initiated in plant biomass that climate change may impact soil erosion (Mullan, 2013). The issue is made worse by accelerated processes such erosion, flooding, drought, and salinization (Hossain et al., 2020). Excessive irrigation can cause salinization, which makes the land unusable by leaving behind salt deposits. Drought parches topsoil, affecting crop output and the general health of the soil (Potopová et al., 2020). Flooding erodes this soil. We must strike a balance between environmental care and productivity to ensure a sustainable future, keeping in mind that robust soils are essential to both food security and ecological resilience.

c. Canals for large-scale irrigation and deforestation

Erosion, salinization, and waterlogging can result from improper canal design and upkeep. Natural habitats are disrupted by deforestation together with such indirect effects as drought which is fuelled by industrial expansion and urbanisation. When trees are taken down, the soil's structure becomes unstable, making it more susceptible to erosion and nutrient loss.

d. Greenhouse gas emissions and global warming

Changes in soil properties cause nitrous oxide and carbon dioxide to be released into the atmosphere. These pollutants feed a vicious cycle by making global warming worse (Noyes et al., 2009). A feedback loop is created when soil health continues to decline as temperatures rise.

e. Decreased farm productivity and uncertainty in the soil

The productivity of agriculture decreases with nutrient depletion, loss of soil structure, and decreased water-holding ability (Bhattacharya, 2021).

Protentional Soil Health Improvement Factors

To counteract soil degradation and enhance the organic matter of the soil, it is crucial to understand the role of microorganisms and nutrients in maintaining soil health and fertility (Pankhurst and Lynch, 1995). Microorganisms including bacteria, fungi, and protozoa play a vital role in the decomposition of organic matter and the recycling of nutrients in the soil (Sahu et al., 2019), and also contribute to improve soil structure by producing glues and binding agents (Huang, 2004).

a. Traditional approaches for sustainable practice

Research studies show that fields cultivated using traditional agricultural methods (TAM) represents a time-tested approach to farming deeply rooted in ecological principles. Unlike modern intensive agriculture, which relies heavily on external inputs, TAM emphasizes harmony with nature. It minimizes energy use by employing animals (such as bulls) for tasks like ploughing. Soil fertility is enhanced through organic manure and biofertilizers, minimizing chemical fertilizers. TAM embodies a climate-smart, sustainable approach to food production, safeguarding the environment for future generations. TAM may yield less compared to those treated with fertilizers or modified compost (Diop, 1999), however systematically practiced TAM, can significantly enhance crop production. BTAM fosters a balanced ecosystem where productivity thrives while minimizing environmental impact. Implementing agricultural tactics such as intercropping, residual mulching, and minimal tilling is recommended as a profitable and environmentally sustainable farming practice in TAM (Tabriz et al., 2021). These tactics can facilitate the advancement of sustainable agriculture and guarantee the welfare of both individuals and the environment.

b. Conservation agriculture as sustainable practice

In the last half century, there has been a substantial overhaul of the global agriculture industry. This type of agriculture necessitates a greater amount of fossil fuel energy, water, synthetic pesticides, and fertilizers, resulting in detrimental effects on the air, soil, water, and biodiversity (Hiranandani, 2010). Conservation agriculture has gained significant attention in the past decade as a way of "sustainable intensification." The objective of this approach is to encourage the use of economically feasible and environmentally conscious farming methods. Nevertheless, the efficacy of conservation agriculture in enhancing intensive smallholder farming remains unsubstantiated (Jat et al., 2020). Promoting economically feasible and environmentally responsible, sustainable farming practices is crucial. Through the implementation of conservation agriculture and other

sustainable agricultural techniques, can guarantee the security of global food supplies while simultaneously safeguarding the environment and public health.

c. Policy approach for sustainable practice

The perceived importance of sustainable agricultural practices is positively correlated with socio-economic position, increased extension support services, higher level of education, and property ownership (Füsun Tatlidil et al., 2009). Nevertheless, this requires considerably larger number of farming households, substantial legislative, institutional, and professional changes (Pretty, 1999).

d. Regulatory measures

Investment subsidies enhance eco-efficiency by efficiently allocating resources, ensuring a balance between economic and environmental considerations. They promote the adoption of environmentally sustainable practices by enterprises, which include minimizing the consumption of fossil fuels and water. Additionally, they actively foster the advancement of sustainable technologies, advocating for sustainable agriculture and striving for a more sustainable future for forthcoming generations. (Czyżewski et al., 2021). Successful implementation requires the crucial elements of stakeholder awareness and involvement (Badsar et al., 2023). It requires incentives to encourage firms to embrace environmentally sustainable practices, thereby decreasing their reliance on fossil fuels and synthetic pesticides. Advocating for the use of sustainable farming methods fosters environmentally conscious habits and ensures a sustainable future for both present and future generations.

e. Rekindling enthusiasm for the promotion of nutritious soils

Organic fertilizers enhance eco-efficiency by efficiently allocating resources and achieving a balance between economic and environmental factors. They enhance soil fertility and productivity while minimizing reliance on artificial fertilizers, promoting abundant crop yield. Organic fertilizers have a vital role in promoting sustainable agriculture and protecting the environment (Strauss et al., 2023). Soil pH, organic matter content, nutrient concentrations, and salt levels all have a significant impact on the growth and development of plants. These factors influence the accessibility of nutrients, water, and oxygen to roots, hence impacting plant health and productivity. Ensuring the ideal levels is crucial for the well-being and efficiency of plants (Adderley et al., 2023).

i. Manure

The utilization of cow dung is an asset for achieving eco-efficiency by facilitating optimal allocation of resources and maintaining a balance between economic and environmental considerations. It functions as an inoculant for microorganisms, stimulating soil health and enhancing plant growth.

ii. Bacteria

Plant growth promoting rhizobacteria (PGPR), a common term for beneficial soil bacteria (Hayat et al., 2010), play a major role in both soil health and plant growth.

These microbes live in symbiotic relationships with plant roots, carrying out several vital tasks (Harman and Uphoff, 2019). They produce plant hormones, fight infections, improve nutrient availability, stabilise soil structure, and store organic materials (Hamid et al., 2021). Unfortunately, these helpful microorganisms are unintentionally impacted by the extensive use of synthetic chemicals, such as herbicides. We must find a balance between meeting crop protection demands and maintaining the microbial ecosystem to achieve sustainable agriculture. Robust ecosystems, improve soil fertility, and promote healthy plant development by utilising the potential of PGPR (Hakim et al., 2021).

iii. Carbon

Soil organic carbon has a crucial role in maintaining soil health, promoting plant growth, and mitigating erosion. Sustainable farming practices are both economically feasible and environmentally conscientious efforts to enhance soil carbon, to guarantee food safety and safeguarding public (Ayub Bagwan et al., 2023b).

iv. Biochar

Biochar is environmentally and economically efficient soil amendment that helps maintain soil fertility. It can efficiently decrease the presence of metal in soil by improving soil characteristics and promoting the growth of microbial communities

Nanotechnology for Sustainable Soil Management and Crop Yield

Nanotechnology is a potent instrument that can enhance eco-efficiency by facilitating the optimal allocation of resources. This technology has the potential to harmonize economic and environmental factors, thereby contributing to a more sustainable future. It enhances soil fertility, diminish the need for synthetic fertilizers, and sustain crop productivity, rendering them a potent instrument (Arora et al., 2024).

Nanotechnology has garnered significant acclaim as the forthcoming scientific revolution because of its purported properties that include expedited computing systems, and resolutions to energy challenges, among others. Nevertheless, the benefits and drawbacks of nanotechnology are context-dependent. At the atomic and molecular levels, nanotechnology manipulates and controls materials, leading to the creation of innovative materials and devices with exceptional qualities and functionalities (Yadav et al., 2023). In addition to improving physiological parameters like enhanced photosynthetic activity and nitrogen metabolism in many crop plants, the positive morphological effects of nanomaterials include enhanced germination percentage and rate, length of root and shoot and their ratio, and vegetative biomass of seedlings (S. Kumar, Samiksha, et al., 2020).

Conclusion and Recommendation

Excessive use of synthetic chemicals has significantly degraded soil fertility. Long-term reliance on chemical fertilizers is not a viable solution for future agricultural growth and soil sustainability (Syers, 1997). Economic incentives have driven farmers to adopt these practices, but urgent attention is required to develop

alternative measures that mitigate impending destruction. Soil erosion, whether natural or human-induced, contributes significantly to nutrient depletion. As a vital livelihood for all living beings, agriculture relies solely on soil. Neglecting soil health not only impacts human well-being but also disrupts ecological balance. Urgent regulatory policies are imperative to sustain soil quality and ensure effective management.

Conflict of Interest

The author as no conflict of interest to publish this work, and no organization or institution supported any fund for this work.

Acknowledgement

The author sincerely acknowledges that this article represents original work and has not been previously published. Furthermore, it has not been submitted to any other journal for consideration. Grateful appreciation is extended to Dr. Ram Shepherd Bheenaveni, the research supervisor, for invaluable guidance and unwavering support during the literature collection process.

References

Adderley, A., Wallace, S., Stubbs, D., Bowen-O'Connor, C., Ferguson, J., Watson, C., and Gustave, W. (2023). Sargassum sp. as a biofertilizer: is it really a key towards sustainable agriculture for The Bahamas? *Bulletin of the National Research Centre 2023 47:1*, *47*(1), 1–11. https://doi.org/10.1186/S42269-023-01087-W

Adetunji, C. O., and Osarenotor, O. (2021). Essential Soil Functions for Enhanced Agricultural Productivity and Food Production. *Applied Soil Chemistry*, 215–233. https://doi.org/10.1002/9781119711520.CH12

Andrade, G. S. M., and Rhodes, J. R. (2012). Protected areas and local communities: An inevitable partnership toward successful conservation strategies? *Ecology and Society*, *17*(4). https://doi.org/10.5751/ES-05216-170414

Arora, D., Arora, A., Panghal, V., Singh, A., Bala, R., Kumari, S., and Kumar, S. (2024). Unleashing the Feasibility of Nanotechnology in Phytoremediation of Heavy Metal–Contaminated Soil: A Critical Review Towards Sustainable Approach. *Water, Air, and Soil Pollution 2024 235:1*, *235*(1), 1–20. https://doi.org/10.1007/S11270-023-06874-9

Aulakh, M. S., and Sidhu, G. S. (2015). Soil degradation in India: Causes, major threats, and management options. *National Institute for Agro-Environmental Sciences*, 151–156. https://www.researchgate.net/publication/311455356

Awais, M., Naqvi, S. M. Z. A., Zhang, H., Li, L., Zhang, W., Awwad, F. A., Ismail, E. A. A., Khan, M. I., Raghavan, V., and Hu, J. (2023). AI and machine learning for soil analysis: an assessment of sustainable agricultural practices. *Bioresources and Bioprocessing 2023 10:1*, *10*(1), 1–16. https://doi.org/10.1186/S40643-023-00710-Y

Ayub Bagwan, W., Ravindra, Gavali, S., and Maity, · Ashis. (2023). Quantifying soil organic carbon (SOC) density and stock in the Urmodi River watershed of Maharashtra, India:

implications for sustainable land management. *Journal of Umm Al-Qura University for Applied Sciences 2023 9:4*, *9*(4), 548–564. https://doi.org/10.1007/S43994-023-00064-3

Badsar, M., Moghim, M., and Ghasemi, M. (2023). Analysis of factors influencing farmers' sustainable environmental behavior in agriculture activities: integration of the planned behavior and the protection motivation theories. *Environment, Development and Sustainability*, *25*(9), 9903–9934. https://doi.org/10.1007/S10668-022-02468-3/METRICS

Balkrishna, A., Arya, V., Bhat, R., Chaudhary, P., Mishra, S., Kumar, A., Sharma, V., Sharma, V., Sharma, N., and Gautam, A. K. (2023). Organic farming for sustainable agriculture and public health: Patanjali's perspective. *Vegetos*, 1–10. https://doi.org/10.1007/ S42535-023-00717-Y/METRICS

Bhattacharya, A. (2021). Effect of Soil Water Deficit on Growth and Development of Plants: A Review. *Soil Water Deficit and Physiological Issues in Plants*, 393–488. https://doi.org/10.1007/978-981-33-6276-5_5

Bhattacharya, S. (2023). Application of nanotechnology to monitor agricultural parameters that promote health and nutritional crop growth in order to provide sustainable economic growth in Aatma Nirbhar Bharat. *Nanotechnology for Environmental Engineering*, *8*(1), 177–182. https://doi.org/10.1007/S41204-022-00285-7/METRICS

Bhuyan, P. P., Nayak, R., Jena, M., and Pradhan, B. (2023). Convoluted role of cyanobacteria as biofertilizer: an insight of sustainable agriculture. *Vegetos*, *36*(2), 309–321. https://doi.org/10.1007/S42535-022-00415-1/METRICS

Blaser, W. J., Oppong, J., Hart, S. P., Landolt, J., Yeboah, E., and Six, J. (2018). Climate-smart sustainable agriculture in low-to-intermediate shade agroforests. *Nature Sustainability*, *1*(5), 234–239. https://doi.org/10.1038/S41893-018-0062-8/METRICS

Boardman, J., Poesen, J., and Evans, R. (2003). Socio-economic factors in soil erosion and conservation. *Environmental Science and Policy*, *6*(1), 1–6. https://doi.org/10.1016/ S1462-9011(02)00120-X

Bossio, D., Geheb, K., and Critchley, W. (2010). Managing water by managing land: Addressing land degradation to improve water productivity and rural livelihoods. *Agricultural Water Management*, *97*(4), 536–542. https://doi.org/10.1016/J.AGWAT.2008.12.001

Cotrufo, M. F., and Lavallee, J. M. (2022). Soil organic matter formation, persistence, and functioning: A synthesis of current understanding to inform its conservation and regeneration. *Advances in Agronomy*, *172*, 1–66. https://doi.org/10.1016/bs.agron.2021.11.002

Czyżewski, B., Matuszczak, A., Grzelak, A., Guth, M., and Majchrzak, A. (2021). Environmental sustainable value in agriculture revisited: How does Common Agricultural Policy contribute to eco-efficiency? *Sustainability Science*, *16*(1), 137–152. https://doi.org/10.1007/S11625-020-00834-6/TABLES/4

Dinel, H., Schnitzer, M., and Mehuys, G. R. (2017). Soil Lipids: Origin, Nature, Content, Decomposition, and Effect on Soil Physical Properties. *Soil Biochemistry*, 397–430. https://doi.org/10.1201/9780203739389-8

Diop, A. M. (1999). Sustainable agriculture: New paradigms and old practices? Increased production with management of organic inputs in Senegal. *Environment, Development and Sustainability*, *1*(3–4), 285–296. https://doi.org/10.1023/A:1010026922142/ METRICS

Duddigan, S., Shaw, L. J., Sizmur, T., Gogu, D., Hussain, Z., Jirra, K., Kaliki, H., Sanka, R., Sohail, M., Soma, R., Thallam, V., Vattikuti, H., and Collins, C. D. (2023). Natural farming improves crop yield in SE India when compared to conventional or organic systems by enhancing soil quality. *Agronomy for Sustainable Development*, *43*(2), 1–15. https://doi.org/10.1007/S13593-023-00884-X/TABLES/5

Füsun Tatlidil, F., Boz, I., and Tatlidil, H. (2009). Farmers' perception of sustainable agriculture and its determinants: A case study in Kahramanmaras province of Turkey. *Environment, Development and Sustainability*, *11*(6), 1091–1106. https://doi.org/10.1007/S10668-008-9168-X/METRICS

Garcia, S. N., Osburn, B. I., and Jay-Russell, M. T. (2020). One Health for Food Safety, Food Security, and Sustainable Food Production. *Frontiers in Sustainable Food Systems*, *4*, 481782. https://doi.org/10.3389/FSUFS.2020.00001/BIBTEX

Gashash, E. A., Osman, N. A., Alsahli, A. A., Hewait, H. M., Ashmawi, A. E., Alshallash, K. S., El-Taher, A. M., Azab, E. S., Abd El-Raouf, H. S., and Ibrahim, M. F. M. (2022). Effects of Plant-Growth-Promoting Rhizobacteria (PGPR) and Cyanobacteria on Botanical Characteristics of Tomato (Solanum lycopersicon L.) Plants. *Plants 2022, Vol. 11, Page 2732*, *11*(20), 2732. https://doi.org/10.3390/PLANTS11202732

Gomiero, T. (2016). Soil Degradation, Land Scarcity and Food Security: Reviewing a Complex Challenge. *Sustainability 2016, Vol. 8, Page 281*, *8*(3), 281. https://doi.org/10.3390/SU8030281

Hakim, S., Naqqash, T., Nawaz, M. S., Laraib, I., Siddique, M. J., Zia, R., Mirza, M. S., and Imran, A. (2021). Rhizosphere Engineering With Plant Growth-Promoting Microorganisms for Agriculture and Ecological Sustainability. *Frontiers in Sustainable Food Systems*, *5*, 617157. https://doi.org/10.3389/FSUFS.2021.617157/BIBTEX

Hamid, B., Zaman, M., Farooq, S., Fatima, S., Sayyed, R. Z., Baba, Z. A., Sheikh, T. A., Reddy, M. S., Enshasy, H. El, Gafur, A., and Suriani, N. L. (2021). Bacterial Plant Biostimulants: A Sustainable Way towards Improving Growth, Productivity, and Health of Crops. *Sustainability 2021, Vol. 13, Page 2856*, *13*(5), 2856. https://doi.org/10.3390/SU13052856

Harman, G. E., and Uphoff, N. (2019). Symbiotic root-endophytic soil microbes improve crop productivity and provide environmental benefits. *Scientifica*, *2019*. https://doi.org/10.1155/2019/9106395

Haroun, M., Xie, S., Awadelkareem, W., Wang, J., and Qian, X. (2023). Influence of biofertilizer on heavy metal bioremediation and enzyme activities in the soil to revealing the potential for sustainable soil restoration. *Scientific Reports*, *13*(1), 1–13. https://doi.org/10.1038/S41598-023-44986-8/TABLES/5

Hayat, R., Ali, S., Amara, U., Khalid, R., and Ahmed, I. (2010). Soil beneficial bacteria and their role in plant growth promotion: a review. *Annals of Microbiology 2010 60:4*, *60*(4), 579–598. https://doi.org/10.1007/S13213-010-0117-1

Hazard, L., Steyaert, P., Martin, G., Couix, N., Navas, M. L., Duru, M., Lauvie, A., and Labatut, J. (2018). Mutual learning between researchers and farmers during implementation of scientific principles for sustainable development: The case of biodiversity-based agriculture. *Sustainability Science*, *13*(2), 517–530. https://doi.org/10.1007/S11625-017-0440-6/METRICS

Hiranandani, V. (2010). Sustainable agriculture in Canada and Cuba: A comparison. *Environment, Development and Sustainability*, *12*(5), 763–775. https://doi.org/10.1007/S10668-009-9223-2/METRICS

Hossain, A., Krupnik, T. J., Timsina, J., Mahboob, M. G., Chaki, A. K., Farooq, M., Bhatt, R., Fahad, S., and Hasanuzzaman, M. (2020). Agricultural Land Degradation: Processes and Problems Undermining Future Food Security. *Environment, Climate, Plant and Vegetation Growth*, 17–61. https://doi.org/10.1007/978-3-030-49732-3_2/COVER

Hu, W., Zhang, Y., Rong, X., Zhou, X., Fei, J., Peng, J., and Luo, G. (2024). Biochar and organic fertilizer applications enhance soil functional microbial abundance and agroecosystem multifunctionality. *Biochar*, *6*(1), 1–17. https://doi.org/10.1007/S42773-023-00296-W/FIGURES/7

Huang, P. M. (2004). Soil Mineral–Organic Matter--Microorganism Interactions: Fundamentals and Impacts. *Advances in Agronomy*, *82*, 391–472. https://doi.org/10.1016/S0065-2113(03)82006-0

Jacoby, R., Peukert, M., Succurro, A., Koprivova, A., and Kopriva, S. (2017). The Role of Soil Microorganisms in Plant Mineral Nutrition—Current Knowledge and Future Directions. *Frontiers in Plant Science*, *8*. https://doi.org/10.3389/FPLS.2017.01617

Jat, M. L., Chakraborty, D., Ladha, J. K., Rana, D. S., Gathala, M. K., McDonald, A., and Gerard, B. (2020). Conservation agriculture for sustainable intensification in South Asia. *Nature Sustainability*, *3*(4), 336–343. https://doi.org/10.1038/S41893-020-0500-2/METRICS

Kangyan Li, and Yao, H. (2023). Revitalizing our earth: unleashing the power of green energy in soil remediation for a sustainable future. *Environmental Science and Pollution Research*, *30*(50), 109007–109020. https://doi.org/10.1007/S11356-023-29672-6/METRICS

Katherasala. (2023, December 8). *Smart farming and small-holder farmers: Difficulties, Impact and Adaptation - Wikifarmer*. WIKIFARMERS. https://wikifarmer.com/smart-farming-and-small-holder-farmers-difficulties-impact-and-adaptation/

Katherasala. (2024, January 9). *A Traditional Treatment for Crop Health and Pest Management - Wikifarmer*. WIKIFARMER. https://wikifarmer.com/a-traditional-treatment-for-crop-health-and-pest-management/

Kaur, R., Research, S. K.-I. J. of A., and 2018, undefined. (2014). Biological alternates to synthetic fertilizers: efficiency and future scopes. *Indianjournals.Com*, *30*(2), 191–194. https://www.indianjournals.com/ijor.aspx?target=ijor:ijar2andvolume=52andissue=6andarticle=001

Kumar, C., Verma, S. B., and Singh, A. K. (2023). Sustainable Management of Soil Salinity with Special Reference to Smart Fertigation Systems. *Proceedings of the National Academy of Sciences India Section B - Biological Sciences*, 1–14. https://doi.org/10.1007/S40011-023-01522-Y/METRICS

Kumar, S., Rao, D. U. M., Thombare, P., and Kale, P. (2020). Small and Marginal Farmers of Indian Agriculture: Prospects and Extension Strategies. *Indian Res. J. Ext. Edu*, *20*(1).

Kumar, S., Samiksha, and Sukul, P. (2020). Green Manuring and Its Role in Soil Health Management. *Soil Health*, 219–241. https://doi.org/10.1007/978-3-030-44364-1_13

Lal, R. (2017). Soil erosion by wind and water: problems and prospects. *Soil Erosion Research Methods*, 1–6. https://doi.org/10.1201/9780203739358-1/SOIL-EROSION-WIND-WATER-PROBLEMS-PROSPECTS-LAL

Li, J., Ma, W., Wang, P., and Meng, X. (2023). Farmers' willingness to transform untreated livestock manure into organic fertilizer: does information technology adoption make a difference? *Environment, Development and Sustainability*, 1–21. https://doi.org/10.1007/S10668-023-02920-Y/TABLES/5

Likhi, A. (2020). Strengthening Market Access for Small and Marginal Farmers Through Farmer Producer Companies in India: Issues and Way Forward. *National Institute of Agricultural Extension Management (MANAGE)*.

Mishra, D., and Satapathy, S. (2022). Modified reaper for small-scale farmers: an approach for sustainable agriculture. *Environment, Development and Sustainability*, 1–30. https://doi.org/10.1007/S10668-022-02768-8/METRICS

Mukherjee, A., Lal, R., and Zimmerman, A. R. (2014). Effects of biochar and other amendments on the physical properties and greenhouse gas emissions of an artificially degraded soil. *Science of The Total Environment*, *487*(1), 26–36. https://doi.org/10.1016/J.SCITOTENV.2014.03.141

Mullan, D. (2013). Soil erosion under the impacts of future climate change: Assessing the statistical significance of future changes and the potential on-site and off-site problems. *CATENA*, *109*, 234–246. https://doi.org/10.1016/J.CATENA.2013.03.007

Negi, M., Sharma, S., Sharma, U., Kumar, P., Sharma, U., and Sharma, K. (2022). Aspects of the Current and Prospective Sustainable Usage of Nanofertilizers in Agriculture and Their Effects on Health of the Soil: an Updated Review. *Journal of Soil Science and Plant Nutrition 2022 23:1*, *23*(1), 594–611. https://doi.org/10.1007/S42729-022-01068-4

Nortcliff, S. (1988). Soil and Land Evaluation. *Outlook on Agriculture*, *17*(4), 169–174. https://doi.org/10.1177/003072708801700406

Noyes, P. D., McElwee, M. K., Miller, H. D., Clark, B. W., Van Tiem, L. A., Walcott, K. C., Erwin, K. N., and Levin, E. D. (2009). The toxicology of climate change: Environmental contaminants in a warming world. *Environment International*, *35*(6), 971–986. https://doi.org/10.1016/J.ENVINT.2009.02.006

Ouyang, P., Narayanan, M., Shi, X., Chen, X., Li, Z., Luo, Y., and Ma, Y. (2023). Integrating biochar and bacteria for sustainable remediation of metal-contaminated soils. *Biochar*, *5*(1), 1–19. https://doi.org/10.1007/S42773-023-00265-3

Pahalvi, H. N., Rafiya, L., Rashid, S., Nisar, B., and Kamili, A. N. (2021). Chemical fertilizers and their impact on soil health. *Microbiota and Biofertilizers, Vol 2: Ecofriendly Tools for Reclamation of Degraded Soil Environs*, 1–20. https://doi.org/10.1007/978-3-030-61010-4_1/COVER

Pandey, S. N., Abid, M., and Abid Ali Khan, M. M. (2018). Diversity, Functions, and Stress Responses of Soil Microorganisms. *Plant Microbiome: Stress Response*, 1–19. https://doi.org/10.1007/978-981-10-5514-0_1

Pankhurst, C. E., and Lynch, J. M. (1995). 12 The role of soil microbiology in sustainable intensive agriculture. *Advances in Plant Pathology*, *11*(C), 229–247. https://doi.org/10.1016/S0736-4539(06)80014-0

Pokrajac, L., Abbas, A., Chrzanowski, W., Dias, G. M., Eggleton, B. J., Maguire, S., Maine, E., Malloy, T., Nathwani, J., Nazar, L., Sips, A., Sone, J., Van Den Berg, A., Weiss, P. S., and Mitra, S. (2021). Nanotechnology for a Sustainable Future: Addressing Global Challenges with the International Network4Sustainable Nanotechnology. *ACS Nano*, *15*(12), 18608–18623. https://doi.org/10.1021/ACSNANO.1C10919/ASSET/IMAGES/MEDIUM/NN1C10919_0018.GIF

Potopová, V., Trnka, M., Hamouz, P., Soukup, J., and Castraveț , T. (2020). Statistical modelling of drought-related yield losses using soil moisture-vegetation remote sensing and multiscalar indices in the south-eastern Europe. *Agricultural Water Management*, *236*, 106168. https://doi.org/10.1016/J.AGWAT.2020.106168

Pretty, J. (1999). Can sustainable agriculture feed africa? New evidence on progress, processes and impacts. *Environment, Development and Sustainability*, *1*(3–4), 253–274. https://doi.org/10.1023/A:1010039224868/METRICS

Pulleman, M. M., de Boer, W., Giller, K. E., and Kuyper, T. W. (2022). Soil biodiversity and nature-mimicry in agriculture; the power of metaphor? *Outlook on Agriculture*, *51*(1), 75–90. https://doi.org/10.1177/00307270221080180

Renee Cho. (2012, April 12). *Why Soil Matters*. AGRICULTURE, EARTH SCIENCES, GENERAL CLIMATE SCHOOL. https://news.climate.columbia.edu/2012/04/12/why-soil-matters/

Sagar, S., Singh, A., Bala, J., Chauhan, R., Kumar, R., Bhatia, R. K., and Walia, A. (2023). Insights into Cow Dung-Based Bioformulations for Sustainable Plant Health and Disease Management in Organic and Natural Farming System: a Review. *Journal of Soil Science and Plant Nutrition 2023*, 1–24. https://doi.org/10.1007/S42729-023-01558-Z

Sahu, P. K., Singh, D. P., Prabha, R., Meena, K. K., and Abhilash, P. C. (2019). Connecting microbial capabilities with the soil and plant health: Options for agricultural sustainability. *Ecological Indicators*, *105*, 601–612. https://doi.org/10.1016/J.ECOLIND.2018.05.084

Sannagoudar, M. S., Kumar, G. K. P., Khandibagur, V., Ghosh, A., Singh, A. K., Rajanna, G. A., Halli, H. M., Wasnik, V. K., Praveen, B. R., and Babu, R. T. C. (2023). Potentials and opportunities of agroforestry under climate change scenario. *Molecular Interventions for Developing Climate-Smart Crops: A Forage Perspective*, 161–181. https://doi.org/10.1007/978-981-99-1858-4_9/COVER

Scanes, C. G. (2018). Human Activity and Habitat Loss: Destruction, Fragmentation, and Degradation. *Animals and Human Society*, 451–482. https://doi.org/10.1016/B978-0-12-805247-1.00026-5

Singh, P., Singh, A., Singh, V. K., and Singh, O. (2022). Green Manuring for Sustainable Agriculture. *Encyclopedia of Green Materials*, 1–6. https://doi.org/10.1007/978-981-16-4921-9_261-1

Srivastav, A. L., Patel, N., Rani, L., Kumar, P., Dutt, I., Maddodi, B. S., and Chaudhary, V. K. (2023). Sustainable options for fertilizer management in agriculture to prevent water contamination: a review. *Environment, Development and Sustainability 2023*, 1–25. https://doi.org/10.1007/S10668-023-03117-Z

Strauss, V., Paul, C., Dönmez, C., Löbmann, M., and Helming, K. (2023). Sustainable soil management measures: a synthesis of stakeholder recommendations. *Agronomy for Sustainable Development 2023 43:1*, *43*(1), 1–26. https://doi.org/10.1007/S13593-022-00864-7

Syers, J. K. (1997). Managing soils for long-term productivity. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *352*(1356), 1011–1021. https://doi.org/10.1098/RSTB.1997.0079

Tabriz, S. S., Kader, M. A., Rokonuzzaman, M., Hossen, M. S., and Awal, M. A. (2021). Prospects and challenges of conservation agriculture in Bangladesh for sustainable sugarcane cultivation. *Environment, Development and Sustainability*, *23*(11), 15667–15694. https://doi.org/10.1007/S10668-021-01330-2/METRICS

Telles, T. S., de Fátima Guimarães, M., and Dechen, S. C. F. (2011). The costs of soil erosion. *Revista Brasileira de Ciência Do Solo*, *35*(2), 287–298. https://doi.org/10.1590/S0100-06832011000200001

Tripathi, S., Srivastava, P., Devi, R. S., and Bhadouria, R. (2020). Influence of synthetic fertilizers and pesticides on soil health and soil microbiology. *Agrochemicals Detection, Treatment and Remediation: Pesticides and Chemical Fertilizers*, 25–54. https://doi.org/10.1016/B978-0-08-103017-2.00002-7

Tubiello, F. N., Salvatore, M., Rossi, S., Ferrara, A., Fitton, N., and Smith, P. (2013). The FAOSTAT database of greenhouse gas emissions from agriculture. *Environmental Research Letters*, *8*(1), 015009. https://doi.org/10.1088/1748-9326/8/1/015009

Upadhyay, S. K., Rajput, V. D., Kumari, A., Espinosa-Saiz, D., Menendez, E., Minkina, T., Dwivedi, P., and Mandzhieva, S. (2022). Plant growth-promoting rhizobacteria: a potential bio-asset for restoration of degraded soil and crop productivity with sustainable emerging techniques. *Environmental Geochemistry and Health 2022 45:12*, *45*(12), 9321–9344. https://doi.org/10.1007/S10653-022-01433-3

Walter, G. (1992). Communication and sustainable agriculture: Building agendas for research and practice. *Agriculture and Human Values*, *9*(2), 27–37. https://doi.org/10.1007/BF02217624/METRICS

Watson, G. A. (1979). Foreword: Management of soil under adverse conditions. *Outlook on Agriculture*, *10*(1), 2–4. https://doi.org/10.1177/003072707901000101

Yadav, S., Sawarni, N., Dahiya, T., Rana, J. S., Sharma, M., and Batra, B. (2023). Nanoagriculture: Advantages and Drawbacks. *Agricultural and Environmental Nanotechnology*, 3–42. https://doi.org/10.1007/978-981-19-5454-2_1

Zaidel'man, F. R. (2009). Degradation of soils as a result of human-induced transformation of their water regime and soil-protective practice. *Eurasian Soil Science*, *42*(1), 82–92. https://doi.org/10.1134/S1064229309010116/METRICS

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Effect of Concentrate Feed Supplementation on Performance of Indigenous Grazing Sheep

M.A. Sun[1*], S.S. Islam[1], M.S. Islam[1] and M. Dey[1]

[1]Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh

Abstract

Sheep may not receive enough nutrition by grazing poor pastures, particularly during the dry season. Supplementing concentrated feed may be a useful approach to maximize rumen microbial activity by providing a balanced amount of energy and protein. An experiment was carried out to optimize the supplementation of concentrate feed for native coastal sheep in southwest Bangladesh. Five treatment groups consisting of twenty female sheep each were randomly assigned to receive five different degrees of concentrate feed. A randomized complete block design (RCBD) was the basis for the experimental setup. The five treatment groups were assigned a concentrate mix of 0, 100, 150, 200, and 250 g sheep-1 day-1, respectively. The energy and crude protein content of the concentrate mixture were 12.00 MJ and 219.0g kg DM^{-1}. Every day, from 8 a.m. to 6 p.m., all groups of sheep were permitted to graze for ten hours. Before allowing them to concentrate feeding and grazing, empty body weight measurements were recorded every two weeks. Body weight of sheep fed different levels of concentrate was similar ($p>0.05$). The growth rate varied significantly among different concentrate supplemented group only at week 10 ($p=0.029$) and at week 14 ($p=0.013$) however, at other cases the growth rate was statistically similar ($p>0.05$). This implies that the nutrient intake from grazing was likely sufficient for maintaining similar growth across groups outside the weights at week 10 and 14. In summary, the absence of a significant variation in weight gain despite higher concentrate feed supplementation likely reflects the complex interplay of biological, genetic, and environmental factors that regulate weight gain.

Keywords: Body weight, coastal sheep, pasture, growth rate, lambing interval, reproductive traits

[*] Corresponding author: abedinsun44@gmail.com

Received: 13. 05. 2024 *Accepted: 13. 11. 2024*

Introduction

Livestock is one of the most significant agricultural subsectors in Bangladesh and is crucial to the growth of the national economy of the nation (Sharma et al., 2014). Sheep farming is becoming more and more popular in our nation among all small ruminants. Because of their adaptability to hard agro-climatic conditions, inadequate management, and poor feeding methods, sheep are a useful animal that are easy to maintain in rural areas. Sheep farming can help alleviate part of Bangladesh's animal product scarcity to some extent. The country as a whole have about 3.401 million sheep heads (DLS, 2017). While some hybrid sheep are retained, the majority of sheep are native breeds (Bhuiyan, 2006). Professional sheep farming is being practiced by landless and marginal farmers because sheep don't require a lot of area. Sheep don't need a lot of food, and more significantly, they don't have a set feeding schedule. They are able to consume grass and leaves straight from the pasture. Sheep are raised on roadsides, in canals, and on fallow land, depending on the type of feed that is typically used (Sultana et al., 2010). Because of this, they don't need a lot of labor to maintain. Taking care of a sheep farm doesn't need much skill, even for illiterate men, women, and kids.

Sheep are primarily raised in Bangladesh under extensive grazing conditions without concentrate feed additives by poor farmers and women. Sheep may not receive enough nourishment from inadequate pastures, particularly during the dry season (Sultana et al., 2011). According to Chaturvedi et al. (2003), the majority of sheep flocks in semi-arid areas do not supplement concentrate diet to their pregnant and lactating sheep. Concentrate supplementation can be a useful strategy for improving rumen microbial activity in sheep grazing unsatisfactory pastures by providing a balanced amount of fermentable carbohydrates and nitrogen. Concentrate supplementation decreases N loss, particularly urine N excretion (Hoekstra et al., 2007; Zhao et al., 2015), and CH_4 emissions (Yan et al., 2010). The main constraint to sheep production in Bangladesh is the lack of and poor quality of feed resources. Previous studies suggest that concentrate supplementation to indigenous sheep fed green grass can improve their productivity (Reddy et al., 2017; Salim et al., 2003). Feeding systems for the productive and reproductive performance of native sheep in Bangladesh have not been investigated (Sultana et al., 2011). Therefore, the present study was undertaken to optimize concentrate supplementation for indigenous grazing sheep in the southwestern coastal region of Bangladesh.

Materials and Methods

Design of experiment

There were twenty native female sheep split up into five treatment groups. Based on their initial live weight, the experimental animals were weighed individually, divided into five groups, and randomly allocated to five distinct concentrate mixes containing 0, 100, 150, 200, and 250 g sheep^{-1} day^{-1}. Randomized Complete Block Design

(RCBD) was the basis for the experimentation and data analysis. Ensuring that all factors (surroundings and amenities), except for the concentrate mixture supplementation, are kept constant across all groups. By maintaining uniformity in the surroundings and amenities for all the sheep, the study ensures that any observed differences in outcomes such as growth rate or weight can be attributed solely to the different levels of concentrate supplementation.

Housing and management of sheep

Sheep were housed in individual pens with slate floors (made of bamboo). The sheep shed was equipped with adequate ventilation systems. Waterers, feeders, and sheds were consistently cleaned. To avoid infection, the proper biosecurity precautions were implemented. An anthelmintics injection (A-mectin plus) was used to deworm all sheep, and the procedure was repeated three months later. All sheep received vaccinations against infectious diseases. Sheep were grazed on the Khulna University campus's playground, roadside, and field laboratory. Sheep were grazed daily 8 AM to 6 PM. All the sheep have free access to clean drinking water at all times.

Type and quality of pasture

The pasture was a natural grassland composed primarily of native grasses and sheep were allowed under rotational grazing management to maintain health and productivity of pasture. At the time of the study, the pasture was moderately grazed, with sheep rotating between paddocks to allow for pasture recovery. The pasture had a mix of different grasses like Arail (*Leersia hexandra*), German lata (*Mikania cordata*), Durba (*Cynodon dactylon*), Gitlaghash (*Paspalum distichum*), Chanchi (*Alternanthera sessilis*) and Kakpaya ghash (*Dactyloctenium aegyptium*) providing adequate forage biomass. However, forage availability varied seasonally, with reduced quality observed in late summer. The composition of the available forages is detailed in a separate article authored by the researcher, which was part of an independent experiment (Rumpa et al., 2022). Pasture quality, measured by crude protein and fiber content, was highest in spring and early summer, with a decline in quality during late summer and fall due to reduced rainfall and heat stress.

Vaccination schedule for experimental sheep

The experimental sheep were vaccinated at various intervals with multiple vaccines, including A-mectin plus, FMD, Hemorrhagic septicemia, Anthrax, Sheep pox, and PPR vaccines. The vaccinations were administered subcutaneously in varying doses, with A-mectin plus given as a regular treatment at intervals throughout the study period, while the other vaccines were provided according to the required schedule.

Concentrate supplementation

Concentrate mixture at the rate of 0, 100, 150, 200, and 250 g $sheep^{-1}$ day^{-1} were allocated to the sheep under the five treatment groups, respectively. The allocated concentrate mixture was divided into two equal portions and given to them in the morning and evening every day. The concentrate mixture contains 12.00MJ ME and

219.0g crude protein kg^{-1} DM. The chemical composition and ingredient composition of the concentrate mixture are shown in Table 1 and Table 2, respectively.

Table 1. Chemical compositions (Mean ± SE) of concentrate feed ingredients.

Feed ingredients	Dry matter (DM)	ME (MJ/kg)	Crude protein (%)	Ether extract (%)	Crude fiber (%)	Ash (%)
Cracked maize (*Zea mays*)	91.11±3.70	13.30	8.27±0.07	2.88±0.33	1.82±0.33	0.50±0.00
Wheat (*Triticum vulgare*) bran	91.50±3.26	11.82	17.08±0.64	2.69±0.65	5.30±0.60	2.50±0.29
Rice (*Oryza sativa*) polish	90.65±1.02	9.93	18.12±0.93	21.12±1.87	6.97±0.72	7.53±0.91
Mustard (*Brassica spp.*) oil cake	94.77±1.81	12.49	41.57±0.19	12.55±2.89	11.08±1.04	8.81±1.02
Soybean (*Glycine max*) meal	92.53±3.20	12.30	50.75±0.75	9.26±1.03	8.33±1.18	6.40±0.22

Table 2. Ingredient composition of the concentrate mixture.

Sl. No.	Ingredients	Quantity (kg/100kg)
1	Cracked maize (*Zea mays*)	40
2	Wheat (*Triticum vulgare*) bran	15
3	Rice (*Oryza sativa*) polish	12
4	Mustard (*Brassica spp.*) oil cake	15
5	Soybean (*Glycine max*) meal	15
6	Dicalcium phosphate (DCP)	2
7	Common salt	0.75
8	Vitamin mineral premix	0.25
	Total	**100**
	Nutrient composition (kg^{-1} DM)	
	Metabolizable energy (MJ)	12.00
	Crude protein (g)	219.0

Data collection and analyses

The body weight, the date of conception, the commencement of estrus, vaccinations, deworming, and medicines were monitored and recorded regularly and entered into a computer. Before they could graze, empty body weight measurements were recorded every two weeks. The data were analyzed using the General Linear Model (GLM) approach in SAS version 9.1.3 (SAS, 2009). Analysis of variance was use to investigate the effects of concentrated supplementation, and Duncan's Multiple Range Test (DMRT) was employed to compare treatment means, with a significance level of $p < 0.05$.

Results and Discussion

Body weight

Concentrate supplementation showed no significant variation ($p>0.05$) in the body weight of sheep in all weight categories under study (Figure 1). However, body weight increased numerically ($p>0.05$) with the increasing level of concentrate supplementation. The graph (Figure 1) illustrates the trend of body weight gain in indigenous coastal sheep over 26 weeks, supplemented with different levels of concentrate feed (0 g, 100 g, 150 g, 200 g, and 250 g). All supplementation levels showed an increase in body weight over the study period, with the highest gains in the 250 g group and the least in the 0 g group. Sheep fed with 250 g concentrate consistently gained weight at the fastest rate, starting from an initial weight of 12.8 kg to 19.6 kg at week 26 ($p>0.05$). Groups with intermediate supplementation levels (100-200 g) showed moderate weight gain trends. This aligns with the physiological need for increased energy and nutrients to support growth in sheep. The trend suggests diminishing returns at lower supplementation levels, with the 100 g and 150 g groups showing similar weight trajectories. This indicates that moderate supplementation might only marginally benefit weight gain, and higher supplementation levels are required for optimal growth. The findings highlight the importance of adequate concentrate supplementation in promoting growth in sheep, particularly in coastal breeds that may have specific dietary requirements due to environmental conditions. However, further studies should explore cost-effectiveness, feed conversion efficiency, and the potential effects on overall health and productivity.

Significance level considered at $p < 0.05$

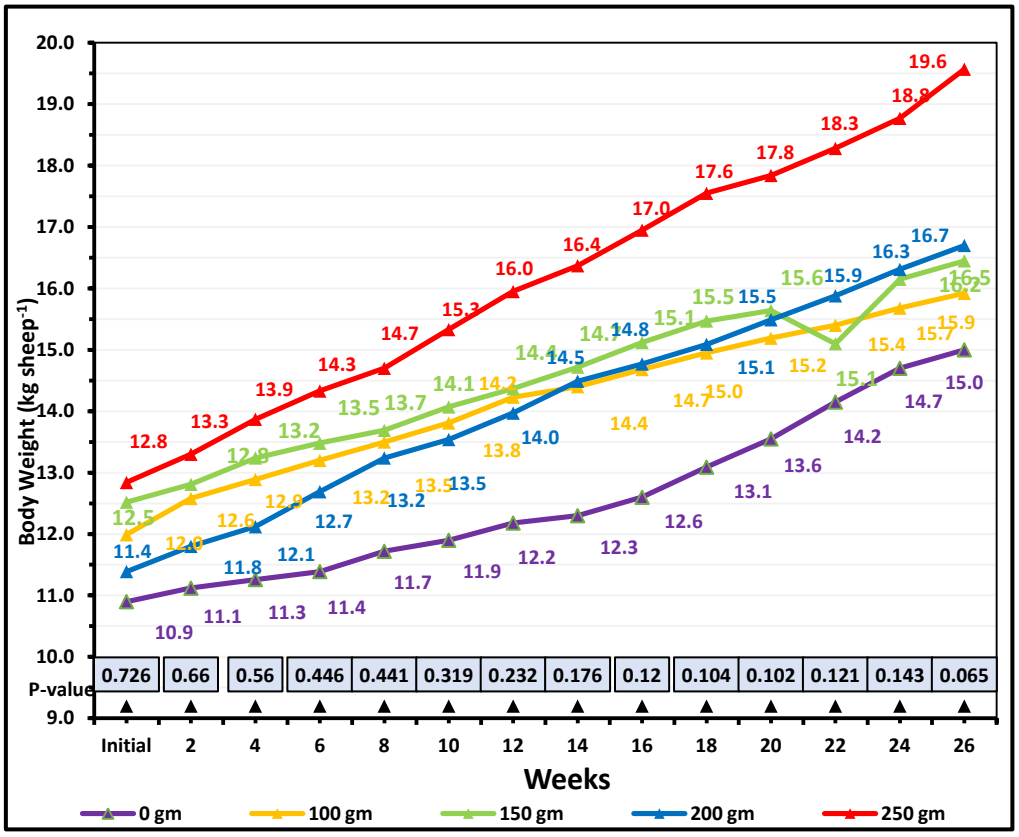


Fig. 1. Trends of body weight gain (kg sheep^{-1}) at two week interval of indigenous coastal sheep supplemented with different levels of concentrate feed.

Growth rate

Table (3) presents the average growth rate of indigenous sheep fed different amounts of concentrated mixture at two-week intervals. According to data from the Table 3, the average growth rate of grazing sheep differed significantly at week 10 ($p=0.029$) and week 14 ($p=0.013$) of the feeding trial across the sheep groups fed varying amounts of concentrate mix. In the remaining weight cases, there was no significant mean differences observed ($p>0.05$). The growth rate (g d^{-1}) at week 10 varied from 12.33±4.02 in the group that did not receive concentrate to 42.00±5.88 in the group that received concentrate at a rate of 250g sheep^{-1}d^{-1}. There were significant variations ($p<0.05$) in the growth rate of sheep at week 14 as well; the growth rate of sheep fed 200g of concentrate sheep^{-1} d^{-1} was highest (34.67±9.55), while the growth rate of sheep fed no concentrate (8.18±0.95) was lowest. Similar findings about the

effect of dietary concentrate on Tibetan sheep were observed in a study (Liu et al., 2019), wherein growth performance was improved by increasing the concentrate content in the diet. Concentrate supplementation changed the rumen fermentation from acetate to propionate, which improved the energy utilization efficiency of Tibetan sheep. The group with 60% concentrate and 40% roughage exhibited the best growth performance, with an average daily gain of 134.38 ± 22.41g (Liu et al., 2019). Concentrate increases dry matter intake (DMI), organic matter intake (OMI), and nutritional digestibility when fed to Thalli lambs at 20% and 40% of their meal (Chishti et al., 2022). According to Sultana et al. (2011), the pre-weaning growth rate of native sheep in Bangladesh under semi-intensive settings was observed to be 65.0g d^{-1}. According to Zohara et al. (2014), the native ewes in Bangladesh gained weight on a daily basis at a rate of 21.19 and 40.95 g d^{-1}, respectively, for the grazing and concentrate supplemented groups. The growth rate of native coastal sheep was measured by Pervage et al. (2009) and was 51.21g d^{-1}. According to Ahmed et al. (2018), coastal sheep in Bangladesh grow at a rate of 91.29g d^{-1} when raised in intensive conditions. Lambs from coastal regions had the greatest daily gain, followed by lambs from the Barind and Jamuna River basins (Ahmed et al., 2018). Different authors have reported varying values for the daily growth rate of Bengal lambs in the 4–9 months age range (Sultana et al., 2011; Ahmed et al., 2015; Sultana et al., 2017). Sultana et al. (2017) discovered greater values for daily growth (118.17-134.33 g d^{-1}) among them, but other studies showed significantly lower values, which may have been caused by variations in feed, the age of the lambs, or the quality of the trials.

In contrast to numerous studies that show positive effects of concentrate supplementation, this study did not observe significant improvements in weight gain or reproductive performance, likely due to the high-quality pasture available during the study period. Pasture composition, could have provided adequate nutrition, thus reducing the need for additional concentrate supplementation. While studies such as those by Smith et al. (2020) and Jones et al. (2018) report significant increases in body weight gain with concentrate supplementation under more controlled or limited grazing systems.

Table 3. Growth rate (g d^{-1}; Mean ± SE) of indigenous coastal sheep fed different levels of concentrate feed at fortnight interval.

Week of weigh	Concentrate supplementation (g $sheep^{-1}$ d^{-1})					P-value
	0	100	150	200	250	
Week 2	15.33±5.21	38.83±10.25	18.83±11.39	28.50±4.80	30.33±5.77	0.284
Week 4	9.17±4.40	20.83±7.40	28.83±8.37	21.00±3.54	37.50±10.54	0.136
Week 6	7.75±2.37	21.17±7.43	15.67±4.33	37.67±9.74	31.50±15.12	0.184
Week 8	22.67±8.20	20.00±7.33	13.83±2.10	36.83±19.32	24.50±6.50	0.630
Week 10	12.33±4.02	20.10±6.20	25.33±7.30	20.00±4.95	42.00±5.88	0.029
Week 12	18.25±7.32	28.00±9.24	19.83±8.60	28.50±8.78	41.50±12.20	0.452
Week 14	8.18±0.95	10.67±4.88	24.17±3.78	34.67±9.55	27.00±2.50	0.013
Week 16	19.75±8.25	18.50±7.37	26.83±5.85	18.50±6.20	39.67±11.10	0.316
Week 18	32.74±10.39	18.91±3.11	22.50±10.89	21.09±2.75	39.67±12.70	0.453
Week 20	30.83±6.00	15.41±6.60	11.67±5.53	26.91±11.90	19.67±4.37	0.367
Week 22	40.50±9.95	13.67±6.12	23.83±6.71	26.09±13.14	28.59±8.13	0.390
Week 24	36.33±11.10	18.50±11.15	10.17±3.91	29.41±8.05	32.83±6.67	0.231
Week 26	20.33±5.88	17.17±5.14	20.00±5.24	24.83±10.02	53.41±20.01	0.164

Significance level was at $p < 0.05$

Weight at maturity

Data in the Table 4 showed that the average maturity weight (kg $sheep^{-1}$) was highest in sheep group fed concentrate feed at 250g day^{-1} (11.99±1.00) and lowest in the 150g supplemented group (10.50±1.80). Mean differences among different levels of concentrate feed-supplemented groups were not significant.

Weight of ewes

There were no significant effects of concentrate feed supplementation on the weight of ewes (kg $sheep^{-1}$) at first lambing (Table 4). Numerically highest ($p>0.05$) weight at maturity was observed in the 250 g supplemented group (13.49±1.13) followed by 200 g (12.27±0.36), 100 g (11.97±1.26), no concentrate group (11.78±0.45) and 150 g (11.33±0.75) supplemented group. Data in the Table 5 showed that the weight of ewes at second lambing (kg $sheep^{-1}$) was highest in the sheep group fed concentrate feed at the rate of 100g $sheep^{-1}day^{-1}$ (13.79±1.26) followed by 150 g (13.50), no concentrate (13.43±0.45), 250 g (13.30) and 200 g group (12.85±0.75). The effects of concentrate feed supplementation on the weight of ewes at second lambing were not significant ($p>0.05$).

Table 4. Production and reproductive performance of ewes at first lambing fed different levels of concentrates

Parameters		Concentrate supplementation (g sheep^{-1} d^{-1})					P-value
		0	100	150	200	250	
Weight at maturity (kg)		11.20±1.09	10.77±0.93	10.50±1.80	11.68±0.31	11.99±1.00	0.847
Weight of ewes at first lambing (kg)		11.78±0.45	11.97±1.26	11.33±0.75	12.27±0.36	13.49±1.13	0.590
Litter size (number)		1.33±0.33	1.25±0.25	1.00±0.00	1.00±00	1.33±0.33	0.698
Sex of lambs (%)	Male	33.33	50	33.33	100	66.67	
	Female	66.67	50	66.67	0	33.33	
Birth weight of lamb (kg)		1.10±0.25	1.64±0.21	1.42±0.26	1.53±0.11	1.57±0.30	0.505
Weaning age (days)		155.00	148.75±2.50	141.67±1.20	147.33±5.49	154.50±5.50	0.268
Weaning weight (kg)		7.43	9.92±1.61	9.87±1.56	9.23±0.74	6.94±2.84	0.729
Post-partum heat (days)		73.00±17	74.67±19.62	33.00	53.00±8.08	56.00	0.623
Lambing interval (days)		234.00±11	220.33±16.84	211.00	214.67±6.36	213.00	0.836

significance level considered at $p < 0.05$

Litter size

There were no significant effects of concentrate supplementation on the litter size of sheep being highest in 250 g and no concentrate supplemented group (1.33±0.33) and lowest in 150 g and 200 g supplemented group (Table 4). Litter size at 2nd lambing was found highest (2.00) in the sheep group fed no concentrate feed followed by 100 g (1.67±0.33), 200 g (1.33±0.33), 150 g (1.00), and 250 g group (1.00) (Table 5). The effects of concentrate feed supplementation on litter size at second lambing were not significant ($p>0.05$).

Sex of lambs

Sheep groups fed concentrate feed at the rate of 200 g and 250 g sheep^{-1}day^{-1}, gave birth to more male lambs than other groups (Table 4). On the other hand, groups of sheep fed 150 g concentrate mix gave birth to more female lambs.

Birth weight of lambs

Birth weights (kg sheep^{-1}) of lambs at first lambing were found highest (1.64±0.21) in the sheep group fed 100g concentrate mix sheep^{-1}day^{-1} followed by 250g (1.57±0.30), 200g (1.53±0.11), 150g (1.42±0.26) and no concentrate feed group

(1.10±0.25) (Table 4). The effects of concentrate feed supplementation on the birth weight of lambs at first lambing were not significant ($p>0.05$). Birth weights of lambs at second lambing were found highest in the sheep group fed 150g concentrate feed sheep^{-1}day^{-1} (2.50) followed by 250g (2.40), 200g (1.77±0.37), 100g (1.77±0.38), and no concentrate feed group (1.72±0.08), respectively (Table 5). The effects of concentrate feed supplementation on the birth weight of lambs at second lambing were not significant ($p>0.05$).

Weaning age and weight

Data in the Table 4 showed that the weaning age (days) of lambs at first lambing was highest (155.00) in the sheep group fed no concentrate feed followed by 250 g (154.50±5.50), 100 g (148.75±2.50), 200 g (147.33±5.49) and 150 g group (141.67±1.20). The effects of concentrate feed supplementation on the weaning age of lambs at first lambing were not significant ($p>0.05$). Weaning weights of lambs (kg) at first lambing were found highest (9.92±1.61) in the sheep group fed 100g concentrate feed per sheep per day followed by 150g (9.87±1.56), 200g (9.23±0.74), no concentrate feed (7.43) and 250g group (6.94±2.84) (Table 4). The effects of concentrate feed supplementation on the weaning weight of lambs at first lambing were not significant ($p>0.05$). According to another study that body weight, daily weight growth, and the behavior of newborn lambs until they are weaned were all positively impacted by higher concentrate levels in the diet (Omar et al., 2019).

Post-partum heat

There were no significant effects of concentrate supplementation on post-partum heat of ewes (days) (Table 4). Numerically highest ($p>0.05$) post-partum heat of ewes (days) was observed in sheep group fed concentrate feed at the rate of 100g sheep^{-1}day^{-1} (74.67±19.62), followed by no concentrate (73.00±17.00), 250 g (56.00), 200 g (53.00±8.08), and 150 g group (33.00), respectively.

Lambing interval

Lambing intervals (days) were found highest (234.00±11.00) in the sheep group fed no concentrate feed, followed by 100 g (220.33±16.84), 200 g (214.67±6.36), 250 g (213.00), and 150g (211.00) concentrate feed group, respectively (Table 4). The effects of concentrate feed supplementation on lambing interval were not significant ($p>0.05$).

Table 5. Production and reproductive performance of ewes at second lambing fed different levels of concentrates

Parameters	Concentrate supplementation (g sheep^{-1}d^{-1})					P-value
	0	100	150	200	250	
Weight of ewes at 2nd lambing (kg)	13.43±0.45	13.79±1.26	13.50	12.85±0.75	13.30	0.965
Litter size (number) in 2nd lambing	2.00±0.00	1.67±0.33	1.00	1.33±0.33	1.00	0.450
Birth weight of lamb (kg) in 2nd lambing	1.72±0.08	1.77±0.38	2.50	1.77±0.37	2.40	0.693

significance level considered at $p < 0.05$

Mortality

Effects of concentrate supplementation were not significant on the mortality of lambs ($p>0.05$). The highest lamb mortality (50.00±28.87) was observed in the sheep group fed no concentrate feed followed by 200 g (37.50±23.94), 250 g (16.67±16.67) and 100 g supplemented group (12.50±12.50). (Table 6). The lack of lamb mortality in the group fed 150 g concentrate supplementation per sheep per day could be attributed to the optimal balance of nutrients provided, which supported healthy growth without overloading the animals' physiological capacity. Higher levels of concentrate feed may have exceeded the animals' ability to process and utilize the nutrients effectively, leading to stress or metabolic imbalances that contributed to higher mortality rates. Additionally, environmental factors and health conditions may have played a role in the different outcomes observed across supplementation levels.

Table 6. Mortality and dystocia problems of sheep fed different levels of concentrates

Parameters	Concentrate supplementation (g sheep^{-1}d^{-1})					P-value
	0	100	150	200	250	
Lamb mortality (%)	50.00±28.87	12.50±12.50	00	37.50±23.94	16.67±16.67	0.442
Incidence of dystocia (%)	100	75.00	66.67	50.00	100	-

significance level considered at $p < 0.05$

Incidence of Dystocia

In cent percent of cases, dystocia was observed in sheep groups fed 250 g concentrate feed sheep^{-1} day^{-1} whereas the lowest percentage of dystocia was observed in 200 g concentrate feed group (Table 6).

Conclusion

The productive and reproductive characteristics of native grazing sheep were not significantly affected by concentrate feed supplementation ($p>0.05$). The results of this study indicate that the native sheep were able to meet their nutritional requirements through ten hours of daily grazing, with minimal supplementation needed. This suggests that grazing alone can provide adequate nutrition for the sheep under the conditions tested, highlighting the importance of grazing time in meeting their dietary needs. Further research may be necessary to evaluate the effects of different grazing durations and supplementation levels on health and productivity of indigenous sheep.

Acknowledgement

The Grant of Advanced Research in Education (GARE), Bangladesh Bureau of Educational Information and Statistics (BANBEIS), Ministry of Education, Government of the People's Republic of Bangladesh, are acknowledged by the researchers for their financial assistance in carrying out the study.

References

Ahmed, S., Khatun, J., Islam, M.M., Khan, M.K., Mahmud, S.N., Al Noman, M.A. and Islam, M.Z. (2015). Effect of beef tallow on growth performance, carcass characteristics, meat composition, and lipid profile of growing lambs. *Journal of Advanced Veterinary and Animal Research*, 2(3), 346–352. https://doi.org/10.5455/javar.2015.b96

Ahmed, S., Rakib, M.R.H., Yesmin, M., Sultana, N., Jahan, N. and Ershaduzamman, M. (2018). Evaluation of lamb production potentiality of the Barind, Jamuna river basin and coastal region sheep of Bangladesh under intensive management. *Journal of Advanced Veterinary and Animal Research*, 5(1), 37-43. http://doi.org/10.5455/javar.2018.e243

Bhuiyan, A. K. F. H. (2006). Livestock Genetic Resources in Bangladesh: Preservation and Management. International Conference on Livestock Services, Chinese Academy of Agricultural Science (CAAS), Beijing, China.

Chaturvedi, O.H., Bhatta, R., Santra, A., Mishra, A.S. and Mann, J.S. (2003). Effect of supplementary feeding of concentrate on nutrient utilization and production performance of ewes grazing on community rangeland during late gestation and early lactation. *Asian-Australasian Journal of. Animal. Science*, 16 (7), 983-987.

Chishti, M. F. A., Rahman, M. A. U., Jatta, K., Khan, S., Riaz, M., Bilal, Q., Anwar, U., Ahmad, S., Bajwa, H. M. and Rasul, F. (2022). Effect of forage to concentrate ratio on growth performance and feeding behavior of Thalli lambs. *Tropical Animal Health and Production*, *54*(4), 236. https://doi.org/10.1007/s11250-022-03226-3

DLS. (2017). Department of Livestock Services, General information related to livestock. Annually Fisheries and Livestock Bulletin, published by Fisheries and Livestock Information Office, Khamarbari, Farmgate, Dhaka, Bangladesh.

Hoekstra, N.J., Schulte R.P.O., Struik, P.C. and Lantinga, E.A. (2007). Pathways to improving the N efficiency of grazing bovines. *European. Journal of. Agronomy*, 26:363–374. https://doi.org/10.1016/j.eja.2006.12.002

Jones, A., K., Hoffman M. L., Pillai, S. M., McFadden K. K., Govoni K. E., Zinn S. A., Reed S. A. (2018). Gestational restricted- and over-feeding promote maternal and offspring inflammatory responses that are distinct and dependent on diet in sheep, *Biology of Reproduction*, 98 (2), 184–196, https://doi.org/10.1093/biolre/iox174

Liu, H., Xu, T., Xu, S., Ma, L., Han, X., Wang, X., Zhang, X., Hu, L., Zhao, N., Chen, Y., Pi, L. and Zhao, X. (2019). Effect of dietary concentrate to forage ratio on growth performance, rumen fermentation and bacterial diversity of Tibetan sheep under barn feeding on the Qinghai-Tibetan plateau. *PeerJ*, 7, 1–22. https://doi.org/10.7717/peerj.7462

Omar, A., Gharib, H. and Said, E. (2019). Effect of feeding different concentrate roughage ratio on growth, reproductive performance and behavior of sheep. *Slovenian Veterinary Research*, *56*(22), 433–443. https://doi.org/10.26873/SVR-781-2019

Pervage, S., Ershaduzzaman, M., Talukder, M.A.I., Hasan, M.N. and Khandoker, M.A.M.Y. (2009). Phenotypic characteristics of indigenous sheep of Bangladesh. *Bangladesh Journal of Animal Science*, 38(1&2), 1 – 6. DOI: https://doi.org/10.3329/bjas.v38i1-2.9906

Reddy, Y., Kumari, N., Reddy, M. and Sridhar, K. (2017). Effect of Concentrate Supplementation on Growth Performance and Carcass Traits of Grazing Deccani Ram Lambs. *International Journal of Livestock Research*, 7(3), 115-122. https://doi.org/10.5455/ijlr.20170228063018

Rumpa, S. P., Islam, S. S., Islam, M. S. and Sun, M. A. (2022). Evaluation of Nutritional Composition of Small Ruminants' Feed stuffs widely grown in Khulna Region of Bangladesh. *South Asian Journal of Agriculture*, 9 (1 & 2), 31-38. https://www.banglajol.info/index.php/SAJA/article/view/69614/47256

Salim, H.M., Shahjalal, M., Tareque, A.M.M. and Akter, N. (2003). Intake and Growth Performance of Female Goats and Sheep Given Concentrate Supplement under Grazing Condition. *Pakistan Journal of Biological Sciences*, 6, 1304-1309. https://scialert.net/abstract/?doi=pjbs.2003.1304.1309

SAS. (2009). Statistical Analysis System, Computer Software, Version 9.1.3: Statistics SAS Institute Inc. Cary, NC 27513, NC27513, USA.

Sharma, P.K., Raha, S.K. and Jorgensen, H. (2014). An economic analysis of beef cattle fattening in selected areas of Pabna and Sirajgonj district. *Journal of Bangladesh Agricultural University*. 12(1), 127-134. http://dx.doi.org/10.3329/jbau.v12i1.21402

Smith, J., Griffith, D., White, A., Baker, P., Watkins, D., Drummond, M. and Semlow, A. (2020). COVID-19, Equity and Men's Health. International Journal of Mens Social and Community Health, 3 (1), e48-e64. ISSN 2561-9179 DOI: https://doi.org/10.22374/ijmsch.v3i1.42

Sultana, N., Hasan, M.N., Iqbal, A., Ershaduzzaman, M., Talukdar, M.A.I. and Dey, S. (2011). Effect of Intensive and Semi-intensive Feeding System on Productive and Reproductive Performances of Native Sheep. *Journal of Scientific Research*, 3(3), 693-698. http://dx.doi.org/10.3329/jsr.v3i3.7129

Sultana, N., Hossain, S.M.J., Chowdhury, S.A., Hassan, M.R. and Ershaduzzaman, M. (2010). Effects of age on intake, growth, nutrient utilization and carcass characteristics of castrated native sheep. *The Bangladesh Veterinarian*, 27, 62–73. http://dx.doi.org/10.3329/bvet.v27i2.7556

Sultana, N., Rakib, M.R.H., Hossain, S.M.J., Ahmed, S., Ershaduzamman, M. and Talukder, M.A.I. (2017). Effect of Replacement of conventional concentrate in a rice straw diet by moringa foliage on lamb production performances. *Journal of Experimental Agriculture International*, 15(5),1–14. https://doi.org/10.9734/JEAI/2017/31329

Yan, T., Mayne, C.S., Gordon, F.G., Porter, M.G., Agnew, R.E., Patterson, D.C., Ferris, C.P., and Kilpatrick, D.J. (2010). Mitigation of enteric methane emissions through improving efficiency of energy utilization and productivity in lactating dairy cows. *Journal of Dairy Science*, 93, 2630–2638. https://doi.org/10.3168/jds.2009-2929

Zhao, Y.G., Aubry, A., O'Connell, N.E., Annett, R. and Yan, T. (2015). Effects of breed, sex, and concentrate supplementation on digestibility, enteric methane emissions, and nitrogen utilization efficiency in growing lambs offered fresh grass. *Journal of Animal Science*, 93, 5764–5773. https://doi.org/10.2527/jas.2015-9515

Zohara, B.F., Azizunnesa, M.F. Islam, M.G.S. Alam and F.Y. Bari. (2014). Reproductive performances of indigenous ewes in Bangladesh. *IOSR Journal of Agriculture and Veterinary Science*, 7 (5), 64-72. https://www.iosrjournals.org/iosr-javs/papers/vol7-issue5/Version-1/L07516472.pdf

SAARC J. Agric., 22(2): 29-42 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.73858*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Recent Advancement and Future Prospects of Plasma Technology for The Quality and Quantity Enhancement Of Agricultural Production

H.K. Shastri[1], V.H. Trivedi[2] and M.T. Thakker[3*]

[1] Research Scholar, Gujarat Technological University, Ahmedabad, Gujarat, India
[2]Assistant Professor, Department of Instrumentation and Control Engineering, L. D. College of Engineering Ahmedabad, Gujarat, India.
[3]Professor, Department of Instrumentation and Control Engineering, L. D. College of Engineering Ahmedabad, Gujarat, India.

Abstract

Innovations in agriculture have greatly enhanced agricultural production, though the global community remains deeply worried about the disparity between food demand and supply. This places a significant burden on agriculture to produce and preserve enough food to feed everyone. Various technological advancements such as forecasting, drones, sensors, big data analytics, blockchain, IoT and plasma technology are playing a vital role in meeting future food demand. Extensive efforts are underway to explore the potential of plasma-based technology across agriculture applications. This includes seed germination, plant growth enhancement, shelf-life extension, preservation, detoxification, decontamination and many more. The transformative potential of plasma technology in agriculture, focusing on its application in enhancing seed germination and promoting plant growth through non-thermal plasma technologies such as, cold plasma treatment (CPT). Additionally, other plasma technologies, such as plasma-activated water (PAW), have shown significant decontamination of chemical and biological contaminants in agricultural produce. This work explores various findings, advancements and opportunities in the plasma technology for its potential application in agriculture for higher

* Corresponding author: dr.mtthakker@gmail.com

Received: 22. 08. 2024 *Accepted:22. 12. 2024*

productivity and better-quality yields to meet the ever-growing global food demand.

Keywords: Non-Thermal Plasma, Plasma Agriculture, Plasma Activated Water, Plant Growth, Shelf-life

Introduction

Food is the prime source for survival. No research, automation, skill, art or any kind of innovation can equate the Piece of bread. A report estimated that by 2050 world needs 70% more food, compare to what we produce today (De Clercq et al., 2018). However, looking at current scenario there are lots of hurdles to achieve this target. Degradation of land fertility, global warming and water crises are some of the biggest concerns for agriculture. Several factors affect agricultural production, including limited shelf life, contamination, natural disasters, war, pandemics, and the perception of farming as an unattractive profession. The World Government Summit 2018 focused to emphasize significant transformation agriculture sector by harnessing cutting-edge technologies This summit was emphasized on Unites Nation's Sustainable Development Goals (SDGs) and coined the term "Agriculture 4.0."

Agriculture 4.0 encompasses advancements for alternative means of food production and preservation like urban farming, vegan milk and cultured meat by applying novel cutting-edge technologies integrating recent scientific discoveries such as plasma technology.

Plasma known as the fourth state of matter is an ionized gas composed of ions, electrons and neutral particles. While industries have long reaped the benefits of plasma technology, recent research has turned its focus towards exploring its potential in agriculture domain. Plasma technology applications in agriculture offer benefits in seed treatment, plant growth promotion and produce preservation (Attri et al., 2020a; Desai et al., 2024). Both direct and indirect plasma treatments have shown significant improvements in agriculture, as evidenced by numerous studies highlighting enhanced seed germination, robust plant growth and extended shelf life for agricultural products.

Plasma

Solid substances, when heated or provided with energy, they transit into a liquid state. Further application of energy causes the substance to change from liquid to gas, and with even more energy, it can transform into plasma. Plasma can be categorized in various ways, based on its generation methodology, physical properties and behaviours, resulting in several classifications as shown in figure 1.

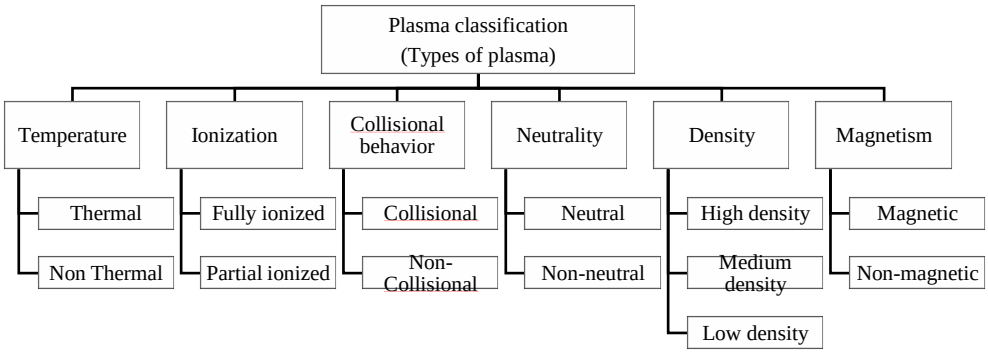


Fig. 1. Plasma Classification

Among all the types of plasma, non-thermal plasma (NTP) also known as cold plasma or atmospheric plasma, is mostly preferred in the field of agricultural research. Plasma is often generated by applying high voltage and high-frequency electricity to various gases through electrical electrodes. This process causes the gas to ionize, creating the plasma state. During this process various parameters like pressure, flow of gas and electrical supply need to be precisely controlled. Most common gases are, Normal air, He, O_2, N_2, Ar, NO and mixture of various gases with the pressure ranges from low, medium pressure or atmospheric pressure (from 10^{-2} to 101325 Pa) (Attri et al., 2022; Bormashenko et al., 2015). The power of the system (from watts to kilowatts) and frequency (from hertz to gigahertz) varies depending on the quality of plasma required for the treatment and the type of plasma to be generated. Barrier Discharge, Gliding arc, Arc Jet, Plasma Torch and some new technology like Microwave driven plasma (Refal Hussain, 2015) are used for the plasma generation.

Plasma technologies are used in the many industrial and medical sectors since many years as shown in figure 2. In last few years, researchers have also find some of the positive results of plasma treatment in the agriculture domain. Plasma and its byproducts have potential to induce alterations in the characteristics of agricultural products. By precisely control mechanism and techniques, some desired quality and quantity improvements of the agriculture products can be achieved.

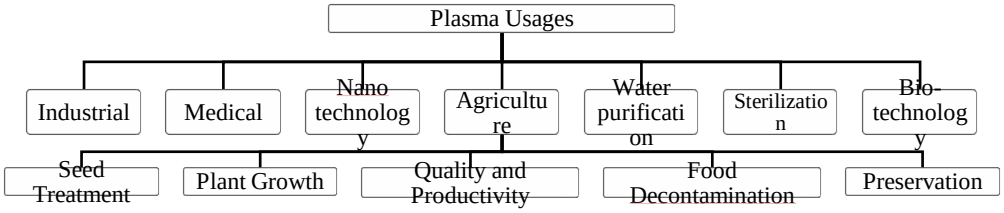


Fig. 2. Applications of Plasma

The NTP can generate the reactive charged species such as electrons, ions, neutral species, with emissions of ultraviolet radiation and electric fields (Attri et al., 2020b). Depending upon the usage of gases, plasma generates reactive oxygen and nitrogen species (RONS) and light. During the plasma treatment on the agriculture products, RONS change various properties like pH, electrical conductivity and oxidation-reduction potential of agriculture produces.

Plasma Treatment for the Seed Germination and Plant Growth

Germination is the natural process which converts seed to plant. This process needs significant amount of time however, by applying various treatments on the seed, germination time can be reduced to some extent. This treatment can be physical, chemical or biological. Physical therapy encompasses a range of interventions such as temperature, electromagnetic fields, ionization, ultrasound, plasma and more. Plasma treatment changes the physical and biological properties of the seed which gives significant amount of change in seed germination and plant growth (Mildaziene et al., 2022). The treatment on seed basically scratches the outer layer of seeds or deform its structure. This deformation increases the water absorption capacity of the seed, which decreases germination time. The dielectric barrier discharge (DBD) plasma technique is a popular method employed to improve seed germination rates. By subjecting seeds to controlled plasma conditions, this technology stimulates biological processes within the seeds, leading to more robust and vigorous germination.

Seed treatment using non thermal plasma

In this treatment, plasma chambers serve as containers where seeds are strategically positioned for targeted therapy. The schematic diagram of plasma chamber is shown in the figure 3. The gas supply system allows for different gas combinations to be introduced into the chamber, enabling versatile treatment options. The effects of plasma treatment on different seeds can vary depending on the specific combinations of gases utilized during the process. Most preferred gases are He, Ar, N_2, Air, O_2, NO, NO +10% N_2 etc. The flow of gas is carefully regulated by a precise controller, ensuring optimal conditions within the chamber. Pressure is controlled using a vacuum pump. Electrodes play a crucial role, and their placement within the chamber is significant for effective treatment. High-voltage and high-frequency electrical supply applied to the electrodes through variable power supply system. Additional technical functionalities that could be integrated into a plasma generator include mechanism to change distance between electrode and target, or temperature control mechanism. Numerous plasma generators are commercially available, although researchers often prefer customized plasma chambers for specific seed treatment.

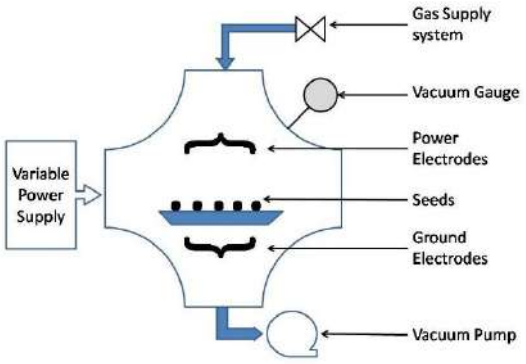


Figure 3. Schematic of NT Plasma Generator

Result analysis for NTP treated seed

After plasma treatment on the various seeds like radish sprouts, wheat, sunflower, pea, bean, maize, rice, pumpkin, cucumber, pepper, barley, spinach, basil, black pine etc., seed germination rate increased by 20% to 25%, details are shown in the Table. 1

Table 1. Results of various seed after Plasma treatment

Treated seeds	Plasma Technology	Result	Reference
Radish Sprouts carrot	Low pressure/ NTP/ O_2	Growth enhancement	(Matra, 2016) (Kitazaki et al., 2012) (Guragain et al., 2023)
Chili pepper	Plasma Jet	Enhancement in seed germination	(Ahmed et al., 2022)
Sunflower	DBD	Seed germination, phytohormone balance, and seedling growth	(Zukiene et al., 2019)
Wheat	Low pressure NTP	Growth and seed germination	(Lotfy et al., 2019) (Jiang et al., 2014)
Soybean	Cold argon plasma	Germination, root length	(Sayahi et al., 2024)
Basil	Radio-frequency (RF) room temperature plasma treatment	Germination increased	(Singh et al., 2022)
Ajwain	Low pressure radio frequency plasma	Improved germination index	(Gholami et al., 2016)

Treated seeds	Plasma Technology	Result	Reference
Tomato	Plasma treatment	Promote seed germination and seedling growth	(Mekarun&Watthanaphanit, 2022)
Barley	80 Watt DBD plasma	Improve seed germination, final germination percentage and vigor index	(Mazandarani et al., 2020)
Pea	Cold atmospheric pressure plasma	Affects Enzymes essential for the germination	(Svubova et al., 2020)
Altaic flax seeds	High-power UV-radiation plasma,	Increase of the germination velocity rate (more than twice).	(Dubinov et al., 2018)
Rice	LPGOD plasma and PAW	Enhanced seed germination percentage, enzymatic activities, yield contributing characters and yield of rice	(Rashid et al., 2022)
Cotton seed	Cold plasma treatment	Improvement in germination	(Groot et al., 2018)

By comparing the seed germination of plasma-treated seeds with untreated ones, an increased germination rate is observed after plasma treatment. In addition to the improvement in germination, researchers have also found increased seed weight and a shorter harvest time as a result of plasma treatment. Table. 1 illustrates that each type of seed treatment requires a specific setup. Plasma treatment that gives positive results for one seed may not work as effectively on other seed. The chemistry of the plasma varies based on gas composition, power levels, timing, positioning of electrodes and seed placement. The treatment process can also be influenced by certain chemicals. For instance, carbon tetrafluoride has been observed to delay germination, whereas cyclohexane can significantly accelerate the germination process. The changed plasma chemistry can also alter chlorophyll, photosynthesis, gibberellin (GA), abscisic acid (ABA) ratio, protein, thiol compound and various stress level of the plant (Volin et al., 2000).

Critical findings and research scope

Literature consistently supports the beneficial effects of plasma treatment on various seeds, although some cases have shown differing outcomes. Cell elongation, DNA damages and protein structure changes are observed by some researchers after plasma treatment (Svubova et al., 2020). In the case of hard-surfaced seeds like Mung beans, researchers have observed that plasma water treatment leads to an increase in the germination rate compare to direct plasma treatment (Zhou et al., 2019). In numerous instances, extending the treatment duration or supplying high power to the electrodes does not offer a cost-effective solution for improving germination rate.

Finding literature on the impact of consuming plasma-treated food on humans or other organisms was quite challenging. The majority of research is on the experimental stage, with limited literature available on real-time field surveys. Some studies also suggest that there is no significant difference in yield when comparing plasma-treated seeds to untreated ones (Ahn et al., 2019). Indeed, this field is relatively new, offering ample scope for further research and exploration.

Plasma Treatment for Enhancing the Quality of Agriculture Product

Each year worldwide, unsafe food causes 600 million cases of foodborne diseases and 420000 deaths. 30% of food born deaths occur among children under 5 years of age (Food Safety- WHO, 2022). Between one-third to half of all food produced worldwide goes to waste, even developed nations like America dumps around 40 percent of their food produced (Dana Gunders, 2012). In this context, the primary concern revolves around deficiency in technology for preservation and contamination of food either in form of biological contamination (viruses, parasites and bacteria like E coli etc.) or chemical contamination (naturally occurring toxins, heavy metals, organic pollutants, pesticides, fertilizers etc.).

Traditional methods for decontamination are washing, cleaning the product using water and chemicals like chlorine, acid, etc. Coating the outer surface using edible wax is preferred to improve shelf life of agricultural products. Temperature variations are widely used to combat biological contamination. Altering the temperature of food, either by extreme heat or cold, is a simple yet effective way to decontaminate biological substances. This technique affects the food quality like change in the color, fragrance, texture, hardness, crunchiness or degradation of antioxidant, vitamins etc. Overall, using traditional decontamination methods are effective but affect biological, chemical, physical and sensory properties of food. Noval methods for the decontamination of the food are ultra-high pressure, ionizing radiation, including gamma rays (Fatemi et al., 2012) X-ray or electron beam (Shin et al., 2011), ultrasound (Ajlouni et al., 2006), pulsed light, pulsed electric fields (Mañnas et al., 2001) plasma activated water (PAW) etc.

PAW can play vital role for the decontamination of food products having various texture and folds. These places are very difficult to reach and preferred by many micro-organisms to hide. PAW is product of NTP’s reaction with water containing a rich diversity of highly reactive oxygen species (ROS) and reactive nitrogen species (RNS), considered as the primary reactive chemical component in food decontamination. First successful study was conducted on the antibacterial activity of PAW in fresh strawberries (Ma et al., 2015). Also, various papers published recently claims that NTP treatment is a chemical-free and eco-friendly method to kill bacteria, bacterial spores, biofilms, viruses and fungi (Xiang et al., 2019; Zhou et al., 2019).

PAW generation method

For PAW generation most preferred plasma technique used by researchers are atmospheric pressure plasma jet (APPJ) and DBD, which are simple to use yet capable of producing richly RONS. The RONS plays key role for the decontamination of the food. The power of RONS depends on the effectiveness of the generated plasma which is influenced by factors such as the source of water, power supply, duration of activation, type of working gas, positioning of electrodes, as well as the techniques and equipment used for generating plasma. Even specialized RONS are produced to address explicit needs, such as targeting specific types of microorganisms or to enhance a particular quality aspect. PAW generation benefits by use of low TDS (low hardness) water, which enhances oxidation reduction potential (ORP) and reduces the pH of PAW, leading to effective antibacterial properties. Values of pH and ORP also depend upon the power and duration of treatment. Increasing these parameters gives lower pH and high electrical conductivity.

Typically, atmospheric air is used as a cost-effective gas source. However, in some cases, Argon gas is preferred as it produces higher levels of Hydrogen Peroxide (H_2O_2), known for its potent antiseptic properties. Additionally, combinations like He and Ar+O_2 are also utilized. The position of the electrode can also affect the PAW generation. Two most common positions of electrodes are, above water (PAW-A) and under water (PAW-B). Underwater electrodes produce more ROS, ORP and electrical conductivity. PAW can be also used with combination of other treatment like combine PAW with mild heat (Choi et al., 2019), ultrasound and blanching treatment (Gracy and Gupta, 2019) shows effective microbial inactivation of food.

Effectiveness of PAW treatment for decontamination

The latest uses of PAW for decontamination of food products or surfaces against biological substances are summarized in Table. 2.

In addition to biological decontamination, PAW can also degrade a wide range of pesticides, including parathion, paraoxon, omethoate, dichlorvos, malathion, azoxystrobin, cyprodinil, fludioxonil, cypermethrin and chlorpyrifos (Mousavi et al., 2016). Overall, this technique offers a potential environment friendly solution for pesticide residue management in agriculture, as it minimizes the need for harsh chemicals and reduces the risk of pesticide runoff into water bodies. However, the efficacy and feasibility of PAW for pesticide degradation may vary depending on factors such as the type of pesticide, crop characteristics and application methods.

Table 2. Biological decontamination of various food using Plasma treatment

Sample	Microorganisms	Technique	Result	Reference
Tofu	S. enterica, L.monocytogenes, and E. coli	PAW A, Plasma Jet, Air	Reduction 0.5-0.8 log CFU/g	(Frías et al., 2020)
Rice cake	S. Typhimurium, L.monocytogenes, and E. coli	PAW A, DBD, Air	Reduction 1.0-2.78 logCFU/g	(Han et al., 2020)
Lettuce	L. innocua and P. fluorescens	PAW B, DBD, Air	Reduction 2.4 logCFU/g	(Ajlouni et al., 2006)
Fresh cut Fruits	Natural microflora	PAW B, Micro plasma array, Air	Reduction ~1 logCFU/g	(Bagheri and Abbaszadeh, 2020; Liu et al., 2020; Zhao et al., 2019)
Mung bean sprouts	Natural microflora	PAW A, Plasma Jet, Air	Reduction ~2.5 logCFU/g	(Xiang et al., 2019)

Critical findings and research scope

PAW produced through NTP technology has shown effectiveness in reducing pesticide residues, as evidenced by various studies like Strawberries, grapes (Sarangapani et al., 2020) and tomatoes (Gracy and Gupta, 2019). However, most research outcomes are based on laboratory experiments, with limited literature on continuous process system development. For instance, DBD plasma can generate 520 L/hr. of PAW, which can be stored and utilized as needed, making it an economical and readily available option for potential commercial use. While PAW technology offers safe and efficient pesticide residue reduction, careful control is crucial to prevent undesirable outcomes like color changes, sensory deterioration, or increased toxicity levels. Although progress has been made in removing target pesticides to major extent, complete pesticide degradation is still area of research.

Thin walled Gram Negative bacteria (e.g., Salmonella and E. coli) are less resistant to Plasma treatment compared to thick membranes Gram Positive (e.g., L. monocytogenes). (Mai-Prochnow et al., 2014). There are various perspectives for the bacterial killing mechanism. One perspective is that, plasma radicals such as OH and NO are absorbed by the bacteria's surface, leading to the formation of volatile compounds like CO_2 and H_2O. This process may potentially inflict irreparable damage to the cell surface, ultimately causing cell death (Misra and Jo, 2017). While other perspective (Mai-Prochnow et al., 2014; Ryu et al., 2013), is that, the toxicity effect of Hydroxyl radicals (OH) within plasma is accountable for the bacteria

demise, attributing it to the damaging effects on lipids and proteins. The findings also states that reactive protein species interact with amino acid chains, resulting in changes to protein structure, harm to nucleic acids and damages the cell. Despite the differing perspectives for decontamination methods, all share a common conclusion that plasma treatment has the potential to prevent food from microbes which enhance the shelf life.

Conclusion

Plasma technology especially CPT and PAW is having potential to boost seed germination, seedling as well as plant growth and shelf life improvement. It is a modern approach that effectively eliminates both pathogenic and non-pathogenic microbes. Choosing the right plasma technology is critical. In seed germination, it depends on factors like seed type and physiology. Similarly, for decontamination, it varies based on the type of bacteria and chemicals that need to be removed. Plasma treatments have shown positive results for decontaminating agricultural products. However, the challenge of achieving 100% decontamination while preserving product quality remains to be addressed. Increased seed germination using plasma technology offers substantial potential for rapid plant growth, resulting in faster yield and increased profitability for farmers. Comparing the quality and quantity of yield between traditional farming and plasma-treated farming is also an area of research for various plants and treatments. The toxicity of plasma residuals and potential adverse effects resulting from interactions with food chemistry are also under investigation. Plasma technology is an emerging research area in agriculture, as most available research still in the experimental stage. Implementing it in real-time field applications could revolutionize agricultural practices, making them more sustainable and efficient to meet global food demand while minimizing environmental impact and resource usage.

References

Ahmed, N., Masood, A., Siow, K. S., Wee, M. F. M. R., Haron, F. F., Patra, A., Nayan, N., and Soon, C. F. (2022). Effects of Oxygen (O2) Plasma Treatment in Promoting the Germination and Growth of Chili. *Plasma Chemistry and Plasma Processing*, *42*(1), 91–108. https://doi.org/10.1007/s11090-021-10206-2

Ahn, C., Gill, J., and Ruzic, D. N. (2019). Growth of Plasma-Treated Corn Seeds under Realistic Conditions. *Scientific Reports*, *9*(1), 4355. https://doi.org/10.1038/s41598-019-40700-9

Ajlouni, S., Sibrani, H., Premier, R., and Tomkins, B. (2006). Ultrasonication and Fresh Produce (Cos lettuce) Preservation. *Journal of Food Science*, *71*(2). https://doi.org/10.1111/j.1365-2621.2006.tb08909.x

Attri, P., Ishikawa, K., Okumura, T., Koga, K., and Shiratani, M. (2020a). Plasma agriculture from laboratory to farm: A review. In *Processes* (Vol. 8, Issue 8). https://doi.org/10.3390/PR8081002

Attri, P., Ishikawa, K., Okumura, T., Koga, K., and Shiratani, M. (2020b). Plasma agriculture from laboratory to farm: A review. In *Processes* (Vol. 8, Issue 8). https://doi.org/10.3390/PR8081002

Attri, P., Okumura, T., Koga, K., Shiratani, M., Wang, D., Takahashi, K., and Takaki, K. (2022). Outcomes of Pulsed Electric Fields and Nonthermal Plasma Treatments on Seed Germination and Protein Functions. *Agronomy*, *12*(2), 482. https://doi.org/10.3390/agronomy12020482

Bagheri, H., and Abbaszadeh, S. (2020). Effect of Cold Plasma on Quality Retention of Fresh-Cut Produce. *Journal of Food Quality*, *2020*, 1–8. https://doi.org/10.1155/2020/8866369

Bormashenko, E., Shapira, Y., Grynyov, R., Whyman, G., Bormashenko, Y., and Drori, E. (2015). Interaction of cold radiofrequency plasma with seeds of beans (Phaseolus vulgaris). *Journal of Experimental Botany*, *66*(13), 4013–4021. https://doi.org/10.1093/jxb/erv206

Choi, E. J., Park, H. W., Kim, S. B., Ryu, S., Lim, J., Hong, E. J., Byeon, Y. S., and Chun, H. H. (2019). Sequential application of plasma-activated water and mild heating improves microbiological quality of ready-to-use shredded salted kimchi cabbage (Brassica pekinensis L.). *Food Control*, *98*, 501–509. https://doi.org/10.1016/j.foodcont.2018.12.007

Dana Gunders. (2012). *Acknowledgments About NrDC*. http://uliwestphal.com/mutates.html.

De Clercq, M., Vatz, A., and Biel, A. (2018). World Government Summit. In *World Government Summit* (pp. 4–25).

de Groot, G. J. J. B., Hundt, A., Murphy, A. B., Bange, M. P., and Mai-Prochnow, A. (2018). Cold plasma treatment for cotton seed germination improvement. *Scientific Reports*, *8*(1). https://doi.org/10.1038/s41598-018-32692-9

Desai, M., Chandel, A., Chauhan, O. P., and Semwal, A. D. (2024). Uses and future prospects of cold plasma in agriculture. *Food and Humanity*, *2*, 100262. https://doi.org/10.1016/j.foohum.2024.100262

Dubinov, A. E., Kozhayeva, J. P., and Zuimatch, E. A. (2018). Scarification of Altaic Flax Seeds With High-Power UV Radiation Generated by Plasma of Nanosecond Electric Discharges. *IEEE Transactions on Plasma Science*, *PP*, 1–7. https://doi.org/10.1109/TPS.2018.2844213

Fatemi, F., Asri, Y., Rasooli, I., Alipoor, Sh. D., and Shaterloo, M. (2012). Chemical composition and antioxidant properties of γ-irradiated Iranian *Zataria multiflora* extracts. *Pharmaceutical Biology*, *50*(2), 232–238. https://doi.org/10.3109/13880209.2011.596208

Food safety. (n.d.). Retrieved March 6, 2024, from https://www.who.int/news-room/fact-sheets/detail/food-safety

Frías, E., Iglesias, Y., Alvarez-Ordóñez, A., Prieto, M., González-Raurich, M., and López, M. (2020). Evaluation of Cold Atmospheric Pressure Plasma (CAPP) and plasma-activated water (PAW) as alternative non-thermal decontamination technologies for tofu: Impact on microbiological, sensorial and functional quality attributes. *Food Research International*, *129*, 108859. https://doi.org/10.1016/j.foodres.2019.108859

Gholami, A., Safa, N. N., Khoram, M., Hadian, J., and Ghomi, H. (2016). Effect of Low-Pressure Radio Frequency Plasma on Ajwain Seed Germination. *Plasma Medicine*, *6*(3–4), 389–396. https://doi.org/10.1615/PlasmaMed.2017019157

Gracy, R. T., and Gupta, V. (2019). Effect of plasma activated water (PAW) on chlorpyrifos reduction in tomatoes. *International Journal of Chemical Studies*, *5000*(3), 5000–5006.

Guragain, R. P., Baniya, H. B., Shrestha, B., Guragain, D. P., and Subedi, D. P. (2023). Non-Thermal Plasma: A Promising Technology for the Germination Enhancement of Radish (Raphanus sativus) and Carrot (Daucus carota sativus L.). *Journal of Food Quality*, *2023*, 1–15. https://doi.org/10.1155/2023/4131657

Han, J.-Y., Song, W.-J., Kang, J. H., Min, S. C., Eom, S., Hong, E. J., Ryu, S., Kim, S. bong, Cho, S., and Kang, D.-H. (2020). Effect of cold atmospheric pressure plasma-activated water on the microbial safety of Korean rice cake. *LWT*, *120*, 108918. https://doi.org/10.1016/j.lwt.2019.108918

Jiang, J., He, X., Li, L., Li, J., Shao, H., Xu, Q., Ye, R., and Dong, Y. (2014). Effect of Cold Plasma Treatment on Seed Germination and Growth of Wheat. *Plasma Science and Technology*, *16*(1), 54–58. https://doi.org/10.1088/1009-0630/16/1/12

Kitazaki, S., Koga, K., Shiratani, M., and Hayashi, N. (2012). Growth Enhancement of Radish Sprouts Induced by Low Pressure O_2 Radio Frequency Discharge Plasma Irradiation. *Japanese Journal of Applied Physics*, *51*(1S), 01AE01. https://doi.org/10.1143/JJAP.51.01AE01

Liu, C., Chen, C., Jiang, A., Sun, X., Guan, Q., and Hu, W. (2020). Effects of plasma-activated water on microbial growth and storage quality of fresh-cut apple. *Innovative Food Science and Emerging Technologies*, *59*, 102256. https://doi.org/10.1016/j.ifset.2019.102256

Lotfy, K., Al-Harbi, N. A., and Abd El-Raheem, H. (2019). Cold Atmospheric Pressure Nitrogen Plasma Jet for Enhancement Germination of Wheat Seeds. *Plasma Chemistry and Plasma Processing*, *39*(4), 897–912. https://doi.org/10.1007/s11090-019-09969-6

Ma, R., Wang, G., Tian, Y., Wang, K., Zhang, J., and Fang, J. (2015). Non-thermal plasma-activated water inactivation of food-borne pathogen on fresh produce. *Journal of Hazardous Materials*, *300*, 643–651. https://doi.org/10.1016/j.jhazmat.2015.07.061

Mai-Prochnow, A., Murphy, A. B., McLean, K. M., Kong, M. G., and Ostrikov, K. (Ken). (2014). Atmospheric pressure plasmas: Infection control and bacterial responses. *International Journal of Antimicrobial Agents*, *43*(6), 508–517. https://doi.org/10.1016/j.ijantimicag.2014.01.025

Mañas, P., Barsotti, L., and Cheftel, J. C. (2001). Microbial inactivation by pulsed electric fields in a batch treatment chamber: effects of some electrical parameters and food constituents. *Innovative Food Science and Emerging Technologies*, *2*(4), 239–249. https://doi.org/10.1016/S1466-8564(01)00041-8

Matra, K. (2016). Non-thermal Plasma for Germination Enhancement of Radish Seeds. *Procedia Computer Science*, *86*, 132–135. https://doi.org/10.1016/j.procs.2016.05.033

Mazandarani, A., Goudarzi, S., Ghafoorifard, H., and Eskandari, A. (2020). *Evaluation of DBD plasma effects on barley seed germination and seedling growth*. *August*. https://doi.org/10.1109/TPS.2020.3012909

Mekarun, J., and Watthanaphanit, A. (2022). In situ plasma treatment of tomato and rice seeds in- liquid to promote seed germination and seedling growth. *Plasma Processes and Polymers*, *19*(6). https://doi.org/10.1002/ppap.202100238

Mildaziene, V., Ivankov, A., Sera, B., and Baniulis, D. (2022). Biochemical and Physiological Plant Processes Affected by Seed Treatment with Non-Thermal Plasma. In *Plants* (Vol. 11, Issue 7). MDPI. https://doi.org/10.3390/plants11070856

Misra, N. N., and Jo, C. (2017). Applications of cold plasma technology for microbiological safety in meat industry. In *Trends in Food Science and Technology* (Vol. 64, pp. 74–86). Elsevier Ltd. https://doi.org/10.1016/j.tifs.2017.04.005

Mousavi, S. M., Imani, S., Dorranian, D., Larijani, K., and Shojaee, M. (2016). Original Article. Effect of cold plasma on degradation of organophosphorus pesticides used on some agricultural products. *Journal of Plant Protection Research*, *57*(1), 25–35. https://doi.org/10.1515/jppr-2017-0004

Rashid, M., Alam, M. S., and Talukder, M. R. (2022). *COLLECTIVE IMPACTS OF LPGOD PLASMA AND PLASMA ACTIVATED WATER TREATMENT IN RICE (Oryza sativa L.)*. *20*(2), 17–30. https://doi.org/10.3329/sja.v20i2

Refal Hussain, and S. N. (2015). Research Journal of A Review of Microwave-Induced Plasma for Production of High Value Products from Waste Glycerol. *A Review of Microwave-Induced Plasma for Production of High Value Products from Waste Glycerol*, *6*(1842), 1842–1848.

Ryu, Y.-H., Kim, Y.-H., Lee, J.-Y., Shim, G.-B., Uhm, H.-S., Park, G., and Choi, E. H. (2013). Effects of Background Fluid on the Efficiency of Inactivating Yeast with Non-Thermal Atmospheric Pressure Plasma. *PLoS ONE*, *8*(6), e66231. https://doi.org/10.1371/journal.pone.0066231

Sarangapani, C., Scally, L., Gulan, M., and Cullen, P. J. (2020). Dissipation of Pesticide Residues on Grapes and Strawberries Using Plasma-Activated Water. *Food and Bioprocess Technology*, *13*(10), 1728–1741. https://doi.org/10.1007/s11947-020-02515-9

Sayahi, K., Sari, A. H., Hamidi, A., Nowruzi, B., and Hassani, F. (2024). Application of cold argon plasma on germination, root length, and decontamination of soybean cultivars. *BMC Plant Biology*, *24*(1). https://doi.org/10.1186/s12870-024-04730-4

Shin, J., Harte, B., Harte, J., and Dolan, K. (2011). The Effect of Low-dose X-ray Irradiation on the Quality of Fresh-cut Asparagus in Microwaveable Vacuum Skin Packs. *HortScience*, *46*(1), 64–69. https://doi.org/10.21273/HORTSCI.46.1.64

Singh, R., Kishor, R., Singh, V., Singh, V., Prasad, P., Aulakh, N. S., Tiwari, U. K., and Kumar, B. (2022). Radio-frequency (RF) room temperature plasma treatment of sweet basil seeds (Ocimum basilicum L.) for germination potential enhancement by immaculation. *Journal of Applied Research on Medicinal and Aromatic Plants*, *26*, 100350. https://doi.org/10.1016/j.jarmap.2021.100350

Švubová, R., Kyzek, S., Medvecká, V., Slováková, Ľ., Gálová, E., and Zahoranová, A. (2020). Novel insight at the Effect of Cold Atmospheric Pressure Plasma on the Activity of Enzymes Essential for the Germination of Pea (Pisum sativum L. cv. Prophet) Seeds. *Plasma Chemistry and Plasma Processing*, *40*(5), 1221–1240. https://doi.org/10.1007/s11090-020-10089-9

Volin, J. C., Denes, F. S., Young, R. A., and Park, S. M. T. (2000). Modification of Seed Germination Performance through Cold Plasma Chemistry Technology. *Crop Science*, *40*(6), 1706–1718. https://doi.org/10.2135/cropsci2000.4061706x

Xiang, Q., Liu, X., Liu, S., Ma, Y., Xu, C., and Bai, Y. (2019). Effect of plasma-activated water on microbial quality and physicochemical characteristics of mung bean sprouts. *Innovative Food Science and Emerging Technologies*, *52*, 49–56. https://doi.org/10.1016/j.ifset.2018.11.012

Zhao, Y., Chen, R., Liu, D., Wang, W., Niu, J., Xia, Y., Qi, Z., Zhao, Z., and Song, Y. (2019). Effect of Nonthermal Plasma-Activated Water on Quality and Antioxidant Activity of Fresh-Cut Kiwifruit. *IEEE Transactions on Plasma Science*, *47*(11), 4811–4817. https://doi.org/10.1109/TPS.2019.2904298

Zhou, R., Li, J., Zhou, R., Zhang, X., and Yang, S. (2019). Atmospheric-pressure plasma treated water for seed germination and seedling growth of mung bean and its sterilization effect on mung bean sprouts. *Innovative Food Science and Emerging Technologies*, *53*, 36–44. https://doi.org/10.1016/j.ifset.2018.08.006

Zukiene, R., Nauciene, Z., Januskaitiene, I., Pauzaite, G., Mildaziene, V., Koga, K., and Shiratani, M. (2019). Dielectric barrier discharge plasma treatment-induced changes in sunflower seed germination, phytohormone balance, and seedling growth. *Applied Physics Express*, *12*(12), 126003. https://doi.org/10.7567/1882-0786/ab5491

SAARC J. Agric., 22(2): 43-53 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.73679*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Comparative Productivity and Profitability of Banana Intercropping with Vegetables

M.A.H. Khan[1*], M.M. Rahman[1], T. Tasmima[2] and M.A. Hossain[3]

[1]Principal Scientific Officer, On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail
[2]Scientific Officer, On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail and [3]Principal Scientific Officer, Horticulture Division, Regional Agricultural Research Station
Bangladesh Agricultural Research Institute, Jamalpur, Bangladesh

Abstract

Productivity and profitability of vegetables intercropping in banana-based cropping system was analyzed in farmer's field of MLT site, Madhupur, Tangail in two consecutive years during 2020-21 and 2021-22 to find out a suitable intercrop combination of vegetables with banana for higher productivity and profitability. There were three intercrop-based treatments i.e., Banana + Potato, Banana +Cabbage+ Potato and Banana + Cauliflower + Potato along with Sole banana. Banana (Amrit Sagar), Cabbage (Parel), Cauliflower (Thirty-three) and Potato (Granola) were used as test materials. The experiment was laid out in a randomized complete block design with six dispersed replications. The unit plot size was 400 m^2. The results revealed that all the intercrops' treatments produced higher banana equivalent yield over the sole banana. However, among the intercrop combinations, Banana + Cauliflower + Potato provided the highest equivalent yield (101.89 tha^{-1} followed by Banana + cabbage + potato. Sole banana produced the lowest equivalent yield in both the cropping seasons. Higher gross margin (Tk.6,66,898 ha^{-1}) was also obtained from Banana + cauliflower + Potato treatment as well as higher BCR (3.79) than other intercrop treatments. So, the farmers of Madhupur Tracts (AEZ-28) and similar areas of

* Corresponding author: helim1367@gmail.com

Received: 05. 06. 2024 *Accepted: 05. 11. 2024*

Bangladesh could be suggested to cultivated cauliflower and potato as intercrop with banana instead of sole banana.

Keyword: Banana equivalent yield, Crop index, Intercrop and monetary advantage.

Introduction

Bangladesh is an agricultural country and most of the inhabitants are involved in agriculture directly or indirectly for their livelihood. The country possesses very fertile land in which diversified crops grow very easily. Agriculture is the single largest producing sector and contributes about 11.38 % to the total Gross Domestic Product (GDP) in the economy of Bangladesh. The majority of the farmers are marginal and smallholders and their land size is on an average 0.05 to 2.49 acres and 1.50 to 2.49 acre, respectively (MOA, 2022). Demand for food has been increasing with the rapid population increase while land accessibility has been diminishing. Thus, the only way to increase agricultural production is to increase yield per unit area (Hirpa, 2014). Increasing food demand for the over population is creating challenge to the country for increasing productivity of the limited land. Now cultivation of long duration crops is discouraged and simultaneously short duration intercrops, relay crops and mixed crop are emphasized for cultivation to ensure food security for a large number of populations. Accordingly, intercropping is a time demanding technology for cultivation of long duration crops.

Banana (*Musa sapientum* L.) is a very popular fruit due to its low price and is used both as vegetable and as a dessert fruit. It is a rich source of carbohydrate and having plenty of vitamins particularly vitamin B. It is also a good source of potassium, phosphorus, calcium and magnesium. Banana powder is used as the first baby food. It helps in reducing risk of heart diseases when used regularly and is recommended for patients suffering from high blood pressure, arthritis, ulcer, gastroenteritis and kidney disorders.

It is one of the cheapest, most plenteous and nutritious of all fruits which are available throughout the year. Among more than 118 minor crops in Bangladesh, banana is one of the top listed fruit crops, which is available throughout the year and consumption rate is higher than any other fruits which comprise about 16% of the total fruit production (BBS, 2022). It has great economic importance as well as nutritional value.

Bananas are largely grown in well drained high land, which is also suitable for growing other cash crops. The inter row space of banana remains underutilized in the early growing period. During this period, short duration crops may be grown as intercrops with banana. Intercropping with banana is more profitable without much investment than sole crop. The success of intercropping systems depends mostly on selection of component crops as well as agronomic modification of resources used. It

is a wide spaced (1m × 1.25m) crop and life span ranges 390-395 days. It is a long duration crop grows slowly in first growth stage and establishment of full canopy takes several months. This privilege can be taken for growing potato, cabbage and cauliflower in between the rows as intercrops. These crops can easily be intercropped with banana at early growth stage for their short stature and quick growing habit. Intercropping has been considered advantageous in terms of economy of space, saving on tillage, as well as utilization of available nutrients and moisture in unused space. Presently, intercropping is gaining acceptance among small holder farmers as it provides a yield advantage compared to sole cropping through yield stability and helps achieve diversified domestic needs (Bhatti et al., 2013). Multiple cropping facilitates the farmers to cultivate two or three crops in a year especially in those areas where growing season is shrinking for sequential farming due to climate change (Jabbar et al., 2010). Inter cropping systems are more stable than sole cropping. It increases total productivity per unit area through maximum utilization of land labour and growth resources.

It is believed that, poverty cannot be reduced to a desired level without increasing productivity of agriculture sector and at the same time it has to be assured that farmers get fair price of the crops. Natural calamities like draught, flood, cyclone, tornado etc. are a very regular phenomenon which hinders the production of agriculture to a great extent. Cultivable land is being decreased due to the pressure of massive population. As a result, food security is being threatened. So, intercropping is an excellent technique to increase total productivity, monetary return and utilizes the available growth resources more efficiently and sustainably as well as to fulfill the diversified need of farmers (Akhteruzzaman et al., 2008). Moreover, it provides several major advantages namely; diversification reduces risk associated with crop failure, offers greater yield stability.

In Bangladesh small and marginal farmers constitute 79.4% of our farming community and their cultivated lands are decreasing day by day (MoA, 2022). Besides, multiple cropping may ensure proper utilization of resources towards increased production per unit area and time on a sustainable basis (Ahmad et al., 2013). Banana is an important fruit crop in Bangladesh. Potato, cabbage and cauliflower are also important vegetable crops in Bangladesh. Banana growers are used to grow vegetables as intercropping in some pocket areas of Bangladesh. For getting higher productivity and economic return, it is in need to find out the optimum combination of banana-vegetable intercropping system. However, various studies have been conducted in the past about vegetables intercropping system but results on banana-vegetable intercropping are very scanty. Therefore, this experiment was undertaken to optimize the productivity and economic return of banana-vegetable based intercropping system.

Materials and Methods

The field experiment was conducted at the farmers' field of Madhupur MLT site, under On-Farm Research Division, Bangladesh Agricultural Research Institute (BARI), Tangail in irrigated condition during two consecutive years of 2020-21 and 2021-22 to find out a suitable intercrop combination of vegetables with banana for higher productivity and profitability. The experimental site located at approximately $24^0 64^/$N latitude and $90^0 09^/$E longitude with the altitude of 19 m above sea level. The land was medium high and the soil of the study area was clay loam to clay in texture with well drainage system and almost acidic in reaction having pH range of 4.3 to 6.5. Mean annual precipitation was 2212 mm, most of which (90%) was received during May to September due to monsoon. The highest temperature (33.9^{o}C) in August and the lowest in December (10.1^{o}C). The relative humidity was the highest (84.5%) in August and the lowest (75.2 %) in March. Monthly mean maximum and minimum air temperature (31.9 and 19.3^{o}C), total rainfall (2018 mm) and relative humidity (82.7 %) were prevailing during the study period. The experiment consisted of four treatments viz. T_1= Sole banana, T_2= Banana + Potato, T_3=Banana +Cabbage +Potato and T_4=Banana + Cauliflower + Potato. The variety of banana (Amrit Sagar), cabbage (Parel), cauliflower (Thirty-three) and potato (Granola) were used as test materials.

The experiment was laid out in a randomized complete block design with six dispersed replications. The unit plot size was 400 m^2. Banana was the main crop, cabbage; cauliflower and potato were the intercrops in the study. Banana, cabbage, cauliflower and potato were transplanted in 1m×1.5m, 60cm×45cm and 45cm×15cm plant to plant and row to row distance, respectively. The recommended fertilizer doses at the rate of 230-80-300-36-2 kg NPKSZn ha^{-1} along with cowdung 5 t ha^{-1}, 180-45-60-24 kg NPKS ha^{-1} and 125-30-136-15kg NPKS respectively were applied in banana, cabbage, cauliflower and potato. In banana, all of cowdung, P, S and Zn were applied as basal during final land preparation 3 to 4 days prior to planting. The N and K were applied in four equal splits as side dressing first one at sucker establishment next two sides dressing at two months' interval and last one at after emergence of inflorescence and mixed thoroughly with the soil followed by irrigation. For cabbage and cauliflower all P and S fertilizer were applied as basal. N and K applied in three equal splits at 10-15, 30 and 45 days after transplanting as ring method. For potato all of P, S and half of N and K applied a basal and remaining half of N and K applied as side dressing at 30-35 days after planting during earthing up operation. Thirty to forty days old suckers of banana were transplanted on 15- 20 September 2020 and 17-21 September 2021.Cabbage and cauliflower were sown at five days after planting of banana. Forty to forty-five days old seedlings of cabbage and cauliflower were transplanted on 20-24 September 2020 and 22-26 April 2021 and potato were planted on 09-12 November 2020 and 06-11November 2021, respectively. First weeding was done at 15 days after cabbage and cauliflower

transplanting while the banana was 20 days old after planting. Second weeding was done at 40 DAT especially prior to head and card stage. Potato tubers were planted after harvest of cabbage and cauliflower as intercrop with banana. Weeding followed by earthing up was done at 35 days after planting of potato. Irrigation was done for banana 10 days (cabbage and cauliflower at 5 DAT) and 25 days (cabbage and cauliflower at 20 DAT) after sucker planting. The 3rd irrigation for cabbage and cauliflower was done at 40 DAT (before head initiation) while the banana plant was 45 days old. Potato was irrigated at 25, 50 and 65 days after planting (age of banana plant was 81, 106 and 121 DAT, respectively). Plant protection measures were done properly for normal growth and development of crops. Cabbage and cauliflower were harvested on 10-14 November 2020 and 11-15 November 2021. Potato was harvested on 12-16 January 2021 and 10-15 January 2022 in two consecutive years. Banana was also harvested on 15-20 October 2021 and 15-19 October 2022 in successive years. The yield contributing characters of banana was recorded from 10 randomly selected plants in both the years.

Yield of individual crop was converted into equivalent yield on the basis of the prevailing market price of individual crop (Prasad and Srivastava, 1991).

Banana equivalent yield (BEY)=

$$\text{Yield of inter crop banana} + \frac{\text{Yip} \times \text{Pp}}{\text{Pb}} + \frac{\text{Yic} \times \text{Pc}}{\text{Pb}} + \frac{\text{Yica} \times \text{Pca}}{\text{Pb}}$$

Where, Yi= Yield of intercrop potato, Pp= Price of potato, Yic= Yield of intercrop cabbage, Pc= Price of cabbage and Yica= Yield of intercrop cauliflower, Pca= Price of cauliflower and Pb= price of banana.

Production efficiency: Production efficiency value in terms of kg ha^{-1}day^{-1} was calculated by total main product divided by total duration of crops. (Tomar and Tiwari, 1990).

Production Efficiency (kg ha^{-1}day^{-1}) = $\frac{\sum Yi}{\sum di}$ Where, Yi= Yield (kg) of ith crop, di= Duration (day) of ith crop of the intercrop and i= 1, 2&3

Land utilization index (LUI): It was worked-out by taking total duration of crops in an individual intercropping system divided by 365 days (Rahman *et al.* 1989). It was calculated by the following formula:

$$\text{Land Utilization Index (\%)} = \frac{d_1 + d_2 + d_3}{365} \times 100$$

Where d_1, d_2 and d_3 the duration of 1st, 2nd and 3rd crop.

Pooled analysis was done as there was no significant difference in yield and yield contributing characters between two years. The collected data on different parameters were statistically analyzed using analysis of variance technique with the help of computer package MSTAT-C and mean comparison among the treatments was made by LSD test at 5% level of significance (Gomez and Gomez, 1984).

The gross economic return was calculated on the basis of prevailing market price of the commodities. The inputs used included seed, fertilizer, labour and insecticides. The two years' average results were analyzed for economic benefits using the methodology prescribed by CIMMYT (1988).

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return}}{\text{Total cost}}$$

Results and Discussion

Yield attributes of banana:

Yield attributes of banana are presented in Table 1. The result indicated that yield contributing characters of banana were not varied significantly among the treatments in two consecutive years. It was noticed that there was no significant adverse effect of the intercrops on the performances of banana regarding yield and yield contributing characters. This is probably due to the advantages came from root and canopy structures of the main crop banana and all intercrops grown at early stages of planting. These results are in agreement with the findings of (Hasan et al., 2017).

Table 1. Yield attributes of banana as influenced by different vegetables intercropping systems at Madhupur,Tangail during 2020-21 and 2021-22 (Pooled data).

Treatments	Length of hand (cm)	No. of hands/bunch	No. of Finger /Hand	Wt. of hands (kg)	Wt. of bunch (kg)
T_1	91.80	11.00	17.00	2.77	24.41
T_2	90. 41	10.00	16.00	2.54	22.91
T_3	89. 37	10.00	16.00	2.58	22. 38
T_4	89. 94	10.00	16.00	2.57	22.50
$LSD_{(0.05)}$	ns	ns	ns	ns	ns
CV (%)	4.68	5.79	4. 82	5.87	7. 21

T_1= Sole banana, T_2= Banana +Potato, T_3=Banana+ cabbage +Potato and T_4= Banana +Cauliflower +Potato

Yield of banana and component crops:

The sole banana cultivation produces slightly higher yield of banana as compared to intercrop situation. Banana grown in association with intercrops like cabbage, cauliflower and potato contributed to slightly lower yield (8-12%). This might be due to the competition by the intercrops for the same resources i.e. space, nutrition, water etc. grown in association with banana. However, banana yield ranged from 53.45 to 60.49 tha^{-1}. Cabbage and cauliflower yield was recorded as 35.19 and 34.82 tha^{-1}. Potato yield was recorded 13.97 to 15.64 tha^{-1}in different treatments which were far below the potential yield of potato but it contributed to the higher system

productivity with the same management practices. Similar reflection was noticed by (Rahman et al., 2006) and (Hasan et al., 2017). It was observed that potato grown after cabbage and cauliflower produced lower tuber yield than that of potato and banana grown only. The reason might be that, the preceding intercrops cabbage and cauliflower delayed the optimum sowing time for potato cultivation. Therefore, growing potato after cabbage and cauliflower as intercrop with banana might be involved in comparatively lower tuber yield as well as acted as a risk factor for exposing diseases to the next crop potato. When two crops (Banana + Potato) grown as intercrop showed 8% yield reduction while three crops (Banana+ Cabbage or Cauliflower +Potato) grown as intercrop resulted in 10.10-11.64% yield reduction than sole banana.

Table 2. Yield of banana and component crops as influenced by different intercropping systems at Madhupur, Tangail during 2020-21 and 2021-22 (pooled data).

Treatments	Banana yield ($t\ ha^{-1}$)	Cabbage yield ($t\ ha^{-1}$)	Cauliflower yield ($t\ ha^{-1}$)	Tuber yield ($t\ ha^{-1}$)	*Crop index (%)
T_1	60.49	-	-	-	-
T_2	55.94	-	-	15.64	92.48
T_3	54.38	35.19	-	13.97	89.90
T_4	53.45	-	34.82	14.82	88.36
$LSD_{(0.05)}$	5. 38	-	-	1. 29	-
CV(%)	7.83	-	-	8.23	-

T_1= Sole banana, T_2= Banana +Potato, T_3=Banana+ cabbage +Potato and T_4= Banana +Cauliflower +Potato and *Crop index (%) means percent reduction or increase of yield as compared to sole crop in intercrop situation.

System productivity:

System productivity was measured in terms of banana equivalent yield from different treatment combinations (Table 3). The yield of banana was not varied curiously but component crops yield played a significant role for increasing banana equivalent yield. Yield of intercrops i.e. cabbage, cauliflower as well as potato donated to higher system productivity over the sole banana cultivation. All the intercropping treatments showed better performance than sole banana cultivation. The highest equivalent yield (101.89 tha^{-1}) was obtained from Banana + Cauliflower + Potato (T_4) treatment which was statistically similar with Banana + Cabbage + Potato (T_3) treatment but differed from other treatments. The lowest yield (60.49 tha^{-1}) was obtained from sole banana cultivation. Higher productivity from the intercrop combinations indicated the consequences of higher production from the component crops under intensified land use systems. (Musa et al., 2013) reported that higher

system productivity obtained from the intercrop-based systems over the sole crop. (Nazrul et al., 2007) also showed higher system productivity in intercrop vegetables combinations with banana than sole banana. Banana + vegetables intercropping system increased total productivity by 18.33-68.44% over sole banana (Table 3). Among the treatments, BEY in banana + cauliflower + potato combination was 68.44% higher over the sole banana and lowest in banana + potato intercropping system. Similar results were reported by (Hasan et al., 2017).

Production efficiency:

Mean maximum production efficiency was measured for the treatments and presented in the Table 3. Production efficiency was found always higher from intercrop combinations than that of sole banana cultivation. The intercrops-based results supported the findings of (Rahman et al., 2006) and (Bantie, 2015). The maximum production efficiency (202 $kgha^{-1}$ day^{-1} was recorded from Banana + Cauliflower + Potato (T_4) followed by Banana+cabbage+Potato (T_3) and the minimum (154 $kgha^{-1}day^{-1}$) from sole banana. Higher production efficiency from the intercropping systems indicated the suitability, productivity as well as profitability of the systems over the sole banana farming.

Land utilization index (LUI):

Land use efficiency is the effective use of land in a cropping year which mostly depends on crop duration. The average land utilization index indicated that intercropping system used the land for 126-140 % period of the year whereas sole crop banana used the land for 108% period of the year (Table 3). Land utilization index was about 17-30 % higher in intercropping system than sole cropping due to intercropping system occupied the land for longer period than sole crop.

Table 3. Banana equivalent yield (BEY), production efficiency and land equivalent ratio of different intercropping systems of banana with vegetables at Madhupur, Tangail (Pooled 2020-21 and 2021-22)

Treatment	Banana equivalent yield (t ha^{-1})	% Increase BEY over sole banana	Production efficiency ($kg^{-1}ha^{-1}day^{-1}$)	Land equivalent ratio (LER)
T_1	60.49	-	154	108
T_2	71.58	18.33	156	126
T_3	97.68	69.52	203	140
T_4	101.89	70.42	200	140
$LSD_{(0.05)}$	8.12	-	-	-
CV (%)	9.15	-	-	-

T_1= Sole banana, T_2= Banana +Potato, T_3=Banana+ cabbage +Potato and T_4= Banana +Cauliflower +Potato

Economic advantage:

The cost and return analysis were done on the basis of prevailing market price during the crop season are shown in Table 4. On the basis of two years' average result, all intercrop combinations gave monetary advantages over sole crops. It was noticed that all the intercrop combinations resulted in higher gross return and gross margin over sole banana. Similar statement regarding higher yield from intercropping system was given by (Hasan et al., 2017). The higher gross margin (Tk. 6,66,898 ha^{-1}) was found in intercropping of banana with cauliflower + potato followed by cabbage +potato (Tk. 6,36,060 ha^{-1}) which gave an additional income of (Tk. 3,10,488 and 2,79,650 ha^{-1}) over sole banana. Total cultivation cost was lower in sole crop than intercropping treatments due to inclusion of component crops. Intercropping of cabbage, cauliflower and potato brought about an increase in return per unit investment. It was evident that intercropping was beneficial and recorded higher benefit cost ratio (BCR) than monoculture of banana. Among the intercropping systems the highest BCR (3.79) was obtained from Banana + cauliflower + Potato intercropping systemwhich further indicated the superiority of this treatment over other treatments (Table 4). These results are in agreement with the findings of Khan *et al*. (2023).

Table 4. Cost and return analysis of different intercropping systems of banana with vegetables at Madhupur, Tangail (average of 2020-21 and 2021-22)

Treatment	Gross return ($Tkha^{-1}$)	Total cost ($Tk\ ha^{-1}$)	Gross margin ($Tk\ ha^{-1}$)	BCR
T_1	4,79,960	1,33,550	3,56,410	3.59
T_2	5,69,120	1,66,252	4,02,868	3.42
T_3	8,65,320	2,29,260	6,36,060	3.77
T_4	9,06,160	2,39,262	6,66,898	3.79

Price of output: ($Tkkg^{-1}$): Banana=12.00, Cabbage=10.00, Potato= 12.00 and Cauliflower= 12.00 Input cost ($Tkkg^{-1}$): Urea= 16.00, TSP=22.00, MoP=15.00, Gypsum=12.00, Zinc sulphate=220, Boric acid=450.00

Conclusion

Two years average result indicated that intercropping banana with cauliflower/cabbage and potato gave higher productivity as well as monetary advantage than monoculture of banana. Thus, it could be concluded that a planting pattern comprising on banana + cabbage/cauliflower + potato in banana intercropping system should be adopted for better productivity and to get maximum profit. So, the farmers of Madhupur Tracts (AEZ-28) and similar areas of Bangladesh could be suggested to cultivated cauliflower, cabbage and potato as intercrop with banana as an alternative of sole banana.

References

Ahmad, F., Islam, M. N., Alom, M. S., Sarker, M. A. I. and Mannaf, M. A. (2013). Study on intercropping leafy vegetables with okra (*Abelmoschus esculentus* L.). *Bangladesh Journal of Agricultural Research*, 38(1): 137-143.

Akhetruzzaman, M., Islam, M.N., Nag, B.L. and Rahman, M.T. (2008). Productivity of potato-hybrid maize relay cropping under different fertilizer levels. *Eco-friendly Agricultural Journal*, 1(5): 300-303.

Bantie, Y. B. (2015). Determination of Effective Spatial Arrangement for Intercropping of Maize (*Zea mays* L.) and Potato (*Solanum tuberosum* L.) Using Competition Indices *Ethiopia Journal of Horticulture*, 2**:**137.

BBS (Bangladesh Bureau of Statistics). (2022). Year Book of Agricultural Statistics of Bangladesh. Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. Pp. 1-659.

Bhatti, I. H., Ahmad, R., Jabbar, A., Nadeem, M., Khan, M. M and Vains, S.N. (2013). Agronomic performance of mash bean as an intercrop in sesame under different planting patterns. *Emirates Journal of Food and Agriculture*, 25: 52-57.

Bose, T. K. (1990). Fruits: Tropical and Sub-tropical Calcutta, India: Naya Prokash. Pp132-185.

Gomez, K. A and Gomez, A. A. (1984). Statistical procedures for Agricultural Research, International Rice Research Institute. John Willy and Sons, New York, Chickester, Brisbane, Torento, Singapore, Pp.1- 643.

Grimes, A., Quasem, A. M., Uddin, M. S., Jahiruddin, N. and. Malik, R. N. (1983). Performance of Different Cropping Patterns in 1992-93 at the Cropping System Research Site, Hathazari, Chittagong.

Haque. M. A. (1984). Intercropping of Banana and its economic return, *Bangladesh Journal of Agriculture*, 3**:**53-55.

Hirpa, T. (2014). Response of maize crop to spatial arrangement and staggered inter seeding of haricot bean. *International Journal of Environment*, 3: 126-138.

Jabbar, A., Ahmad, R., Bhatti, I. H., Rehman, A., Virk, Z. A. and Vains, S. N. (2010). Effect of different rice-based intercropping systems on rice grain yield and residual soil fertility. *Pakistan. Journal of Botany*, 42: 2339–2348.

Khan, M. A. H., Rahman, M. M., and Sultana, N. (2023). Intercropping of mukhikachu and papaya with pineapple. *SAARC Journal of Agriculture*, 21 (1):25-38.

Kurata, T. (1986). A Study on Farming System inUSA. *Quarterly Journal of Agriculture and Ecology*, 26:179-205.

MOA (Ministry of Agriculture). (2022). Hand Book of Agricultural Statistics. Government of the People's Republic of Bangladesh. http://www.moa.gov.bd/statistics/ statistics.htm.

Musa, M., Azad, A. K. and Gurung, T. R. (Eds.). (2013). Popularizing multiple cropping innovation as a means to raise crop productivity and farm income in SAARC countries.

Nazrul, M. I., Rahman, M. A. and Quayyum, M. A. (2007). Performance of intercropping Banana with vegetables. *SAARC Journal of Agriculture*, 5 (1): 53-57.

Rahman, M. M., Khan, M. H., Mallick, R. N. and Hudgens, R. E. (1989). Guidelines for Farming Systems Research Methodology. Bangladesh Agricultural Research Council, Farmgate, Dhaka-1215.

Rahman, M. Z., Rahman, M. H., Haque, M. E., Kabir, M. H., Naher, S. L., Ferdaus, K. M. K. B., Huda, A. K. M. N., Imran, M. S. and Khalekuzzaman, M. (2006). Banana Based Intercropping System in North-west Part of Bangladesh, *Bangladesh Journal of Agronomy*, 5(2): 228-231.

Tomer, S. S. and Tiwari, A. S. (1990). Production potential and economics of different crop sequences. *Indian Journal of Agronomy*, 35 (1&2): 30-35. ISSN (Electronic): 0974-4460 CABI Record Number: 19910745378

SAARC J. Agric., 22(2): 55-66 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.74341*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Cucumis Sativus L. Foamy Extract Induces Apoptosis in MDA-MB-231 Cells

L. Kumaraswamy[1*] and P.N. Tallur[2]

Associate Professor of Biotechnology[1]. Associate Professor of Chemistry[2] Maharanis Science College for women (Autonomous) JLB Road Mysore 570005. Karnataka, India.

Abstract

Cucumis sativus L. is considered as an important salad fruit as well as vegetable, fruits. It is consumed as herbal medicines. We have investigated the effects of foamy extract on the viability of the MDA-MB-231 human cells. Results revealed that extract significantly (P < 0:05) inhibited the proliferation of cells in comparatively lower toxic effects. The IC50 was found to be 116.11 µg/mL against MDA-MB-231 cells, Annexin V/PI staining assays indicated that it stimulates apoptosis in MDA-MB-231. Treated cells were observed for greater incidence of apoptotic cells, when compared to the untreated cells. Thus, it is efficient enough to induce apoptosis, in MDA-MB-231 cells. Cucumber foamy extract may prove to be an important source of natural anticancer agents.

Keywords: Apoptosis, *Cucumis sativus* L, Foamy extract, HR-LCMS, MDA-MB-231cells.

Introduction

Cucumber originated in India, where it appears to have been cultivated for more than 3,000 years ago. *C. sativus* L.is noticeable inexpensive crop cultivated globally. It endures fruit of a cylindrical shape with a light aroma and a crisp texture with high water content and an essential component in salad and raita. They are widely grown and consumed in either raw or preserved pickled form all over the world. China produces 61.9 million tonnes, followed by European Union, Russia, Turkey. India is the leading exporter of cucumber and gherkins in 2023-2024 with the production of

[*] Corresponding author: latha.gsch@gmail.com

Received: 25. 08. 2024 *Accepted: 25. 12. 2024*

54,015.97 metric ton. It has earned 58.71 million US $ by export. India's major export destinations are USA, Germany, France, Spain and Russia as per APEDA statistics (Agricultural and Processed Food Products Export Development Authority). Cucumber is divided into pickling and slicing varieties (Grumet et al., 2022). Different types of Cucurbitacin are identified in cucumbers, they are cytotoxic in nature which inhibit proliferation of tumours. The Indian thali is incomplete without a slice of Cucumber. It is consumed all over the world majorly as salad fruit as well as vegetable. It is listed as naturally low caloric and ancient food. It is an important income earning crop. Literature survey indicates that India possesses heterogeneous germplasm collection. It is a site of large genetic diversity, only small part of it exists in different parts of the world (Pal and Saha 2019).

The study of Globocon, 2020 every four minutes woman is diagnosed with breast cancer, about 1,78,000 new cases being diagnosed every year and mortality 12.7 per 100,000 women and 685000 deaths globally (Kharat et al., 2022). Numerous studies have demonstrated that the chance of developing breast cancer rises with age cancer dealing still has many unmet requests and needs new beneficial representatives' drugs. New and competent bioactive compounds against cancer should be developed for public health, for this purpose identification of new substances with anticancer activity is critical and crucial in the development of anticancer drugs (Inthi et al.,2023). Anticancer chemical research has advanced during the past few years. Many scholars have scrutinized plant-obtained bioactive complexes' possible as preventive agents to decrease cancer. *C. sativus* is considered as an important medicinal plant (Latha, 2022). It is one of the supreme members of the *Cucurbitaceae* family. It is believed to originate in Indian subcontinent and is recognized as a hub of diversity Sharma et al. (2022). Phytochemicals present in this family are often used as diuretic and cardiotonic managers. They also demonstrate good anti-inflammatory, antitussive, cytotoxic and expectorant effects. Apart from the biological profile, the *Cucurbitaceae* family has several therapeutically important chemical compounds Since ancient time (Habib et al., 2023). It is consumed as traditional food and used to treat constipation, headache for soothing effects and for reducing swelling in the skin. Its fruit juice has refreshing effective and fruits were used as cooling vegetable. Many chemo preventive chemicals have been discovered based on their ability to regulate one or more specific chemical processes (Bakam et al., 2023). In the current study showed that foamy extract of *C. sativus* L. is rich in tetracyclic compounds among them gitoxigenin is abounded in foamy extract of local green cultivar of *Cucumis sativus* L. of Hassan District, Karnataka, is examined on MDA-MB-231 cells human breast cancer cell lines. This study suggests that bioactive compounds found in foamy extract is the potential candidate to hit the growth of MDA-MB-231 cells.

Materials and Methods

Collection of Cucumber Fruits:

The native local variety of C. *sativus* L.*green (nati southe)* was harvested from a farm in the Karnataka, India. Katte Belaguli,village which is 5km from Holenarasipura taluk, Hassan district. White frothy substance was extracted from fresh fruits. Cutting a thin slice of cucumber at end, placing it back on the flat surface, and rubbing it between the blossom and stem ends of the cucumber in a circular motion produced the white foamy substance. For the experiment,100 gm of fresh frothy stuff was collected and used for the experiment showed in Figure -1.

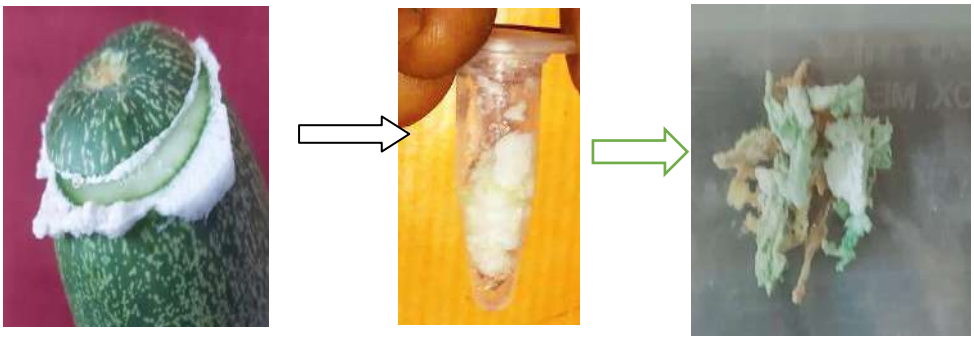


Fig. 1. C. *sativus* L. fruit foamy extract and dried powder

Extraction and Separation

Soxhlet extraction of foamy extract was done with 70 methanol. Distillation was performed to isolate the solvent; the concentrate was evaporated to desiccation and the remainder was dissolved in 5ml of 70% methanol. Preliminary Phytochemical Analysis was done according to Rai et al. (2023).

HR-LCMS Q-TOF/MS study of foamy extract

The extract that was subsequently analysed by HR-LCMS. HR-LCMS analysis was carried out at the IIT Bombay, Pawai, Mumbai, Sophisticated Analytical Instrument Facility (SAIF). Agilent Technologies, USA was able to obtain the metabolite fingerprint of the foamy substance *C. sativus* L. ZORBAX Eclipse Plus-C18, 5micron (Agilent) Mode, 150x2.2 mm. Model G6550A, a high-resolution liquid chromatography and mass spectrometry system with a mass resolution of 0.010%, was employed. The MS acquisition method, with a scanning rate of one spectrum per second, was configured with a minimum range of 60 (m/z) and a maximum range of 1000 Dalton (m/z). By comparing the retention time (RT) and masses of the compounds, Agilent Mass Hunter Qualitative Analysis B.06 was able to identify the bioactive chemicals. With a gas flow rate of 13psi/minute, gas chromatography has been sustained at 250^0C. Using a hip sampler model G4226A, the auxiliary speed and ejection speed were both set at 100 µl/minute. The injection volume utilized for HR-

LCMS was 8 µl, and the flush out factor was 5 µl. In the first minute of the 30-minute acquisition period, the solvent composition flow A: Milli-Q water containing 0.1% formic acid B: Acetonitrile and TOF/6500 series. By comparing retention times and mass spectra with the respective reference standards, metabolites were found. A composite pattern of major and minor peaks were seen in the chromatogram that was produced. The analysis was completed at the advanced analytical instrument facility located in Mumbai, India, at the Indian Institute of Technology.

MTT Assay

Briefly, around 1×10^4 MDA-MB-231 cells human breast cancer cell lines purchased from NCCS Pune. Cells were seeded into each well of 96 well plate which were placed for incubation at 37 °C and 5% CO_2 in a CO_2 incubator. After 24 hr the cells were treated with foamy extract at various concentrations (0, 20, 40, 80, 100, 200 µg/mL). All the mentioned concentrations were tested in triplicates and the results were given as an average of each combination. The cells were again incubated in the CO_2 incubator for 24 hr under the same incubation condition. After the incubation 20µL of MTT(3-(4,5-Dimethylthiazol-2yl)-2,5-Diphenyltetrazolium Bromide reagent) 5mg/ml was added to each well and further incubated for another 4hr in Co_2 incubator, After the incubation time, the 96 well plates were removed and MTT media in each well are replaced with 100µl of DMSO (Dimethyl Sulfoxide), were placed for 30 min at RT dark. Followed by this the plates were subjected to spectrophotometric reading at the λ570nm using microplate reader.

Apoptosis Assay

Briefly, around 1×10^6 cells were seeded into each well of 6 well plate which were incubated at 37°C and 5% CO_2 in a CO_2 incubator. After 24hr, the cells were treated with the specific concentration of the compound (0% to 30%) to induce apoptosis in cells. The well plate was incubated at 37°C and 5% CO_2 in a CO_2incubator. After 24 hr, the cells were harvested and washed with 1mL cold phosphate-buffered saline (PBS). The washed cells were centrifuged, the supernatant was discarded, and the pellet was resuspended in 1mL of 1X annexin-binding buffer. A volume of 2.5 µL Annexin V stain and 2.5 µL 100 µg/mL Propidium iodide (PI) working solution was added to each 100µL of cell suspension. The cells were incubated at room temperature for 15 minutes. After the incubation period, 400 µL(1X) annexin-binding buffer was added, and mixed gently. As soon as possible, the stained cells were analysed by flow cytometry, measuring the fluorescence emission at 530nm and 575nm (or equivalent) using 488-nm excitation. Apoptotic activity by flow cytometry was studied by FITC V Kit (no. 51-65874X), Propidium Iodide (PI) (no. 51-66211E) Annexin V binding buffer (no. 51-66121E).

Statistical Analysis

Entirely experiments were completed in triplicate at three independent times. The calculations were executed in Excel, and the statistical significance was analysed one-way or two-way ANOVA depending on the experiment. The results were

reported as mean ± SD (the standard error of the mean). The statistical difference was set at * $p < 0.5$, ** $p < 0.05$, *** $p < 0.001$.

Results and Discursion

In this study we collected 100gm of fresh frothy substances, followed by Soxhlet extraction with 70% methanol. Approximately 2mg of residue was obtained. It was dissolved in 2ml 70% methanol and 1ml of this extract was analysed for preliminary phytochemical analysis it indicated the presence triterpenes (Latha and Raja Naika 2020). It was sent to Sophisticated Analytical Instrument Facility (SAIF), IIT Bombay, Pawai, Mumbai, for HR-LCMS analysis. Result showed in Table-1: Gitoxigenin 8.33ppm in 10µL sample loaded is significant result. The local green cultivar of C. *sativus* L is the rich source of bioactive compounds *C. sativus* L. (Latha and Raja Naika, 2020).

Table 1. Prominent Compounds of Foamy Extract of *C. sativus* L data by SAIF IIT Bombay

Mass	m/z	Name	Formula	ppm
574.314	597.3039	Cucurbitacin A	$C_{32}H_{46}O_9$	0.35
390.2374	413.2267	Gitoxigenin	$C_{23}H_{34}O_5$	8.33
560.3346	583.3238	Cucurbitacin-C	$C_{32}H_{48}O_8$	0.65
558.3226	581.3109	Cucurbitacin B	$C_{32}H_{46}O_8$	5.93
404.2195	407.2338	Strophanthidin	$C_{23}H_{32}O_6$	0.96
556.2996	579.2885	Cucurbitacin E	$C_{32}H_{44}O_8$	7.17
374.2479	397.2368	Digitoxigenin	$C_{23}H_{34}O_4$	5.95

MTT Assay:

The cytotoxic effect of methanolic foamy extract was subjected evaluation by means of 3-(4,5 dimethyl-2-yl)-2,5 diphenyl tetrazolium bromide (MTT) assay. Cells have been exposed to different concentration The IC50 value of the given compound was found to be at 116.11 µg/mL concertation. Table-2 and Figure -2

Table 2. MTT Assay

Concentration(µg /mL)	OD	Cell inhibition (%)	Average	SD
Control	0.778	-	-	-
	0.7839	-	-	-
	0.7956	-	-	-
20	0.7737	1.543966721	3.76666119	1.99773135

Concentration(µg /mL)	OD	Cell inhibition (%)	Average	SD
	0.7517	4.34354373		
	0.7433	5.412473134		
40	0.6047	23.04980829	20.6701678	2.52388961
	0.6442	18.02329503		
	0.6213	20.93740019		
80	0.4864	38.10389739	34.3244684	3.77308238
	0.5162	34.31174308		
	0.5457	30.55776482		
100	0.4666	40.6235167	43.0625421	2.75915209
	0.4518	42.50686851		
	0.4239	46.05724117		
200	0.1226	84.39872085	83.4146271	1.99789347
	0.1484	81.11558054		
	0.12	84.72957995		

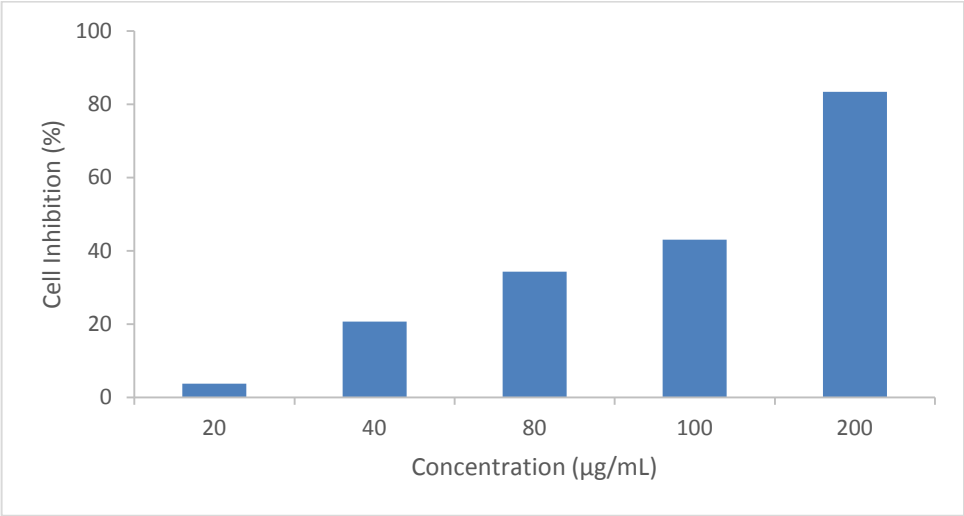


Fig. 2. Cell Inhibition (%)

Apoptosis Assay

After being exposed to foamy extract for 24 hours, MDA-MB-231 cells were driven to undergo apoptosis. The study in the graphical representation of apoptosis assay, the conjugation of 10^3-10^4field on both X-axis and Y-axis represents the appearance of apoptotic cells. The field beyond 10^4 range represents cells in late apoptotic phase and death phase, whereas field below 10^3 range represents live cells. FIGURE -3 and FIGURE 4. results indicate that gitoxigenin induces cell death via the apoptotic pathway in Human MDA-MB-231 cancer cells, so that this compound can be developed as an anticancer agent in the future from C. *sativus* foamy extract.

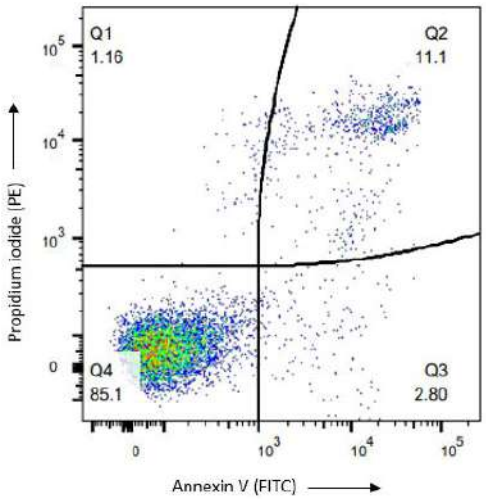


Fig. 3. Appearance of Apoptotic Cells

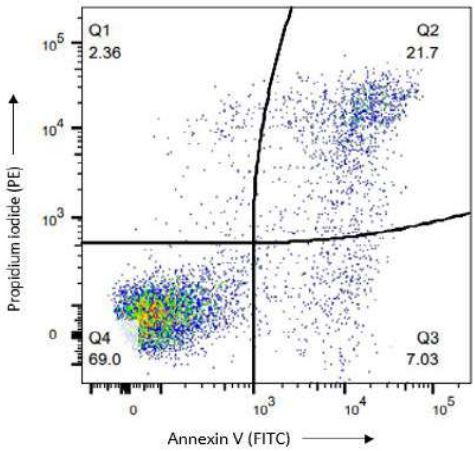


Fig. 4. FACS graph representing cells in the 30% concentration sample

Phosphatidyl (PS) can be bound by annexin V an anticoagulant, when calcium is present. PS will go to the surface of the cell during the early phases of apoptosis. Due to its conjugation with fluorescein isothiocyanate (FITC), annexin V can be identified via flow cytometry.

Propidium iodide was utilised to distinguish between surviving, early apoptotic cells and necrotic, late apoptotic cells. Necrotic cells would bind to Annexin V-FITC and exhibit membrane permeabilization. Both early apoptotic and living cells released propidium iodide. Because of the delayed necrotic-like cell disintegration, late apoptotic cells will be stained with propidium iodide and FITC together. When Human MDA-MB-231 cells were exposed to gitoxigenin for 24 hours, the therapy induced apoptosis. Figure-5 and Figure- 6.

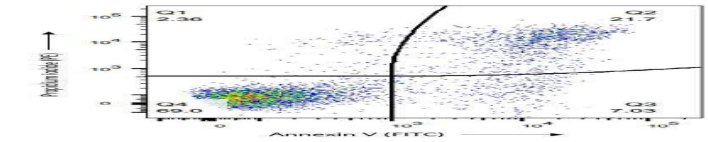


Fig. 5. Morphology of Human MDA-MB-231 cancer cells control and Human MDA-MB-231 cell lines

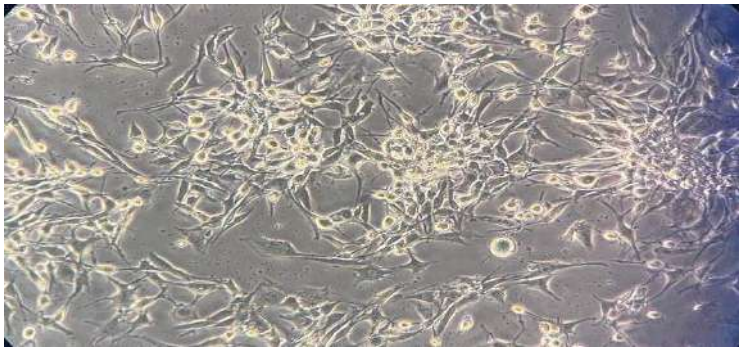


Fig. 6-34.8 µg/mL treated cells Human MDA-MB-231

In the present study we recorded the therapeutic application, of *C. sativus*. We have explored the phytochemical and pharmacological profile foamy substance *C. sativus*. The HRLCMS study of substance revealed different bioactive compounds. Among the prominent compounds in the foamy extract Gitoxigenin (8.33 ppm) was found in uppermost concentration. The cells treated with the foamy extract are observed to show better incidence of apoptotic cells, when compared to the untreated cells (control). Thus, the bioactive compounds in foamy extract is efficient enough to induce apoptosis, in MDA-MB-231 cells.

In the preliminary study, we carried out quantitative estimation of cardiac glycosides. Total glycosides of the sample quantitatively determined according to Raymond reaction (Latha. 2023). The IC50 value of the given compound was found to be at 116.11 µg/mL concentration. In the presence of calcium, annexin V functions as an anticoagulant and has the ability to bind phosphatidyl (PS) The translocation of PS to the cell surface occurs early in apoptosis. Because annexin V is coupled with fluorescein isothiocyanate (FITC), it can be identified using flow cytometry. While necrotic cells exhibited membrane permeabilization and would bind to Annexin V-FITC, surviving, early apoptotic cells could be distinguished from necrotic, late apoptotic cells using propidium iodide (Mazzio et al., 2021). Excreta of propidium iodide was observed in both early apoptotic and living cells. Because late necrotic-like cell disintegration occurs, late apoptotic cells will be stained with propidium iodide and FITC (Akhil et al., 2023). In the apoptosis assay we found field beyond 10^4 range represents cells in late apoptotic phase and death phase, whereas field below 10^3 range represents live cells. The cells treated with the compound are observed to show greater incidence of apoptotic cells. Phosphatidyl serine (PS) is a key biomarker of early apoptosis. So, it is necessary to perform further investigation to elucidate pathway which induce apoptosis MDA-MB-231 cell lines.

The recent data available on the study of cytotoxic activity using the MTT assay, the cytotoxic effect of A. indicum-mediated synthesized CuO NPs was assessed against human lung A549 and breast MDA-MB-231 cancer cell lines. The results of the investigation showed that ZnO-PB-NPs might, in a dose-dependent way, cause considerable cytotoxicity in human breast cancer cells. Treatment with ZnO-PB-NPs reduced the breast cancer cells capacity to proliferate (Nagarajaiah et al., 2023). The research demonstrated the green synthesized CuO Nanoparticles has potential biological activity, including good dye degradation in malachite green, effective anticancer activity against the MDA-MB-231 cancer cell line, and antibacterial action against gram positive bacteria. (Nafeh et al., 2023).

The MDA-MB-231 cells treated with MLPD underwent morphological examination, which revealed cytotoxic alterations such as vacuole formation, changed shape, and a decrease in the number of cells forming apoptotic bodies. The study was done fraction of the A. muricata leaf extract might stop the proliferation of the human MDA-MB-231 cell line, which is used as a model for triple negative breast cancer in

the culture media used RPMI 1640 (Sathiyavimal et al., 2022): After 72 hours of incubation, RNAs were extracted using TriPure isolation reagent from both treated and untreated MDA-MB-231 cell lines using A. muricata DMSO extract. The expression of P53 and Bcl2 was measured by qRT-PCR, with the β-actin gene serving as an internal control. ELISA was used to analyse the protein expression of the BRCA1, BRCA2, EGFR, p53, Bcl2, Cytochrome C, and Caspase 3 genes (Pal et al., 2023). The A. muricata DMSO extract-treated cell line exhibited overexpressed levels of pro-apoptotic P53 gene expression, suggesting that the extract may be effective in driving cancer cells towards programmed death (Grumet et al., 2022) The crude extract from the Southeast Asian medicinal herb Houttuynia cordata Thunb (HCT) significantly reduced the growth of MDA-MB-231 and MCF-7 cells (Chekuri et al., 2023). The purpose of the study was to determine how cytotoxic this plant extract and its fractions were to MDA-MB-231 and MCF-7 human breast cancer cells (Rai et al., 2023) The phytoactive components of HCT are identified. The 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay was used to assess the vitality of the cells. Using a flow cytometry approach, the manner of cell death was determined by labelling with annexin V-FITC and propidium iodide (PI). Using fluorescence microplate readers and fluorescent probes labelled 2',7'-dihydrodichlorofluorescein diacetate (DCFH-DA) and dihydroethidium (DHE+), the oxidative stress was quantified. High performance liquid chromatography was used to characterise HCT phytochemicals (HPLC) (Ella et al., 2021) and (Menchikov et al., 2023). Plants are the prime source of folk medicine, homoeopathy and aromatherapy. Cucumber is a popular vegetable and also fruit, which has been widely used in folk medicine to reduce heat and inflammation. It is a rich source of vitamin C, and can be used externally to cool, cleanse and healthy. It is climber of several promising aspect (Sauter and Edward, 2020). This implies that ethnobotanical information of plant resources can be studied by its phytochemical analysis.

Conclusion

Very popular vegetable as well as fruit *Cucumis sativus* L. has many bioactive compounds found in foamy extract expressed the of activity of inhibiting proliferation and inducing apoptosis in MDA-MB-231 cells of breast cancer. Further investigation to be done to elucidate pathway which induce apoptosis MDA-MB-231 cell lines.

Acknowledgement

The authors were grateful for the Sophisticated Analytical Instrument Facility (SAIF), by IIT Bombay, Pawai, and Mumbai to carry out the HR-LCMS of *Cucumis sativus* L.

References

Akil, A. S. 2023. The Effects of Wild Yam Root (Dioscoreavillosa) Extract in Human Triple Negative MDA-MB-231 Breast Cancer Cells. *Florida Agricultural and Mechanical University*., 22(4):12-24.

Bakam, B.Y. Pambe, J. C,.Grey, T.Maxeiner, S. Rutz, J. Njamen, D. Blaheta, R.A, and Zingue, S. 2023. Cucumis sativus (Cucurbitaceae) seed oil prevents benzo (a) pyrene- induced prostate cancer in vitro and in vivo. *Environmental Toxicology*.,38(9):2069-2083.

Chekuri, S. Vyshnava, S. S. Somisetti, S. L. Cheniya, S. B. K.Gandu, C. and Anupalli, R. R. 2023. Isolation and anticancer activity of quercetin from Acalypha indica L. against breast cancer cell lines MCF-7 and MDA-MB-231. *3 Biotech.*,13(8): 289-295.

Ella R, Reddy S, Blackwelder W, Potdar V, Yadav P, and Sarangi V, 2021. Efficacy, safety, and lot-to-lot immunogenicity of an inactivated SARS-CoV-2 vaccine (BBV152): Interim results of a randomised, double-blind, controlled, phase 3 trial. *Lancet.*, 398(2173):1-5.

Grumet, Kariyil, B. J. Desai, A. G. John, R.and SV, V. B. 2022. Methanol extract of Pergularia daemia (Forssk.) Chiov. leaves induce apoptosis in triple-negative breast cancer through intrinsic pathway., 61(1):329-338.

Habib, T. N., Abu Amra, E. S., Ahmed, A. R., and Mokhtar, G. S. 2023. Antitumor Potential Effect of Graviola Leaves Extracts on the MDA-MB-231 Cell Line. *Sohag Journal of Sciences.*,8(1): 47-52.

Inthi, P. Pandith, H. Kongtawelert, P. and Banjerdpongchai, R. 2023. Anti-cancer Effect and Active Phytochemicals of Houttuynia cordata Thunb. against Human Breast Cancer Cells. *Asian Pacific Journal of Cancer Prevention.*, 24(4):1265-1274.

Kharat, K. Jawale, S.Kharat, A. R. Achary, P. and Ragade, V. R. 2022. Moringa oleifera Methanolic Extract Induces Apoptosis in Human Breast Cancer Cells. International *Journal of Pharmaceutical Investigation.,12(1):28-32.*

Latha, K. and Raja Naika, H.2020. MS Q- TOF Analysis of *Cucumis sativus* L. and Evaluation of its Antiproliferative, Antioxidant and Na^+/K^+-ATPase activity: *Journal of Annuals of Agri Bio Research.,*25(2):185-190.

Latha, K. 2022. Phytochemical Analysis in Foamy Extract of Cucumber (*Cucumis Sativus* L.): *SAARC Journal of Agriculture*, 20(2):145-155.

Mazzio, E. Almalki, A. Darling-Reed, S. F. and Soliman, K. F. 2021. Effects of wild yam root (Dioscoreavillosa) extract on the gene expression profile of triple-negative breast cancer cells. *Cancer Genomics and Proteomics.*,18(6): 735-755.

Menchikov, L.G. and Popov, A.V. 2023. Physiological Activity of Trace Element Germanium Including Anticancer Properties. *Biomedicines.*,11(6):15-25.

Nafeh, G. Abi Akl,M. Samarani,J.Bahous,R. Al Kari, G. Younes, M. Sarkis, R. and Rizk, S. 2023. Urtica dioica Leaf Infusion Enhances the Sensitivity of Triple-Negative Breast Cancer Cells to Cisplatin Treatment. *Pharmaceuticals.*,16(6):780-791.

Nagarajaiah, S. Nanda, N. Manjappa, P. Nagabhushana, B. M. Gadewar, M. Rao, S. and Krishna, P. G. 2023. Evaluation of apoptosis in human breast cancer cell (MDA-MB-231) induced by ZnO nanoparticles synthesized using Piper beetle leaf extract as bio-fuel. *Applied Physic* .,129(6):461-468.

Pal, A. Sanyal, S. Das,S. Sengupta TK. 2023. Effect of Lantana camara ethanolic leaf extract on survival and migration of MDA-MB-231 triple negative breast cancer cell line. *bioRxiv.*, 20(2):1-21.

Pal, D. and Saha, S. 2019. Chondroitin: a natural biomarker with immense biomedical applications. *RSC advances*.,9(48):28061-28077.

Rai, N. Gupta, P.Verma, A. Tiwari, R. K..Madhukar, P. Kamble, S. C.. ... and Gautam, V. 2023. Ethyl Acetate Extract of Colletotrichum gloeosporioides Promotes Cytotoxicity and Apoptosis in Human Breast Cancer Cells. *ACS omega*., *8*(4):3768-3784.

Sathiyavimal, S. Durán-Lara, E. F. Vasantharaj, S.Saravanan, M.Sabour, A.. Alshiekheid, M., and Pugazhendhi, A. 2022. Green synthesis of copper oxide nanoparticles using Abutilon indicum leaves extract and their evaluation of antibacterial, anticancer in human A549 lung and MDA-MB-231 breast cancer cells. *Food and Chemical Toxicology*., 168, (113);330-342.

Sauter, and Edward, R. 2020. Cancer prevention and treatment using combination therapy with natural compounds. *Expert review of clinical pharmacolog*y.,13(3): 265-285.

Sharma, D. Shree, B. Kumar, S. Kumar, V. Sharma, S. and Sharma,S. 2022. Stress induced production of plant secondary metabolites in vegetables: Functional approach for designing next generation super foods. *Plant Physiology and Biochemistry*., 192(1):252-272

SAARC J. Agric., 22(2): 67-79 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.76073*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Productivity of Zero-Tilled Dibbled Sunflower Under Different Planting Densities in Salt Affected Soils of Bangladesh

M.H. Rashid[1*], P.C. Goswami[2] and T.T. Raisa[3]

[1]Crops Division, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka-1215
[2]International Rice Research Institute (IRRI), IRRI Bangladesh Office, House-103, Road-1, Block-F, Banani, Dhaka-1213, Bangladesh
[3]Department of Botany, University of Dhaka, Dhaka-1000, Banagladesh

Abstract

Planting density is an important factor for enhancing the productivity and profitability of sunflower in saline ecosystems which has not been sufficiently evaluated in farmers' fields of diverse saline soils. An on-farm experiment was conducted to identify the suitable planting density for better growth and higher yield and profit in the saline soil. The experiment was conducted in three salt affected sites with three planting densities, 29630, 37037 and 74074 ha^{-1} through the planting arrangement of 75 cm × 45 cm, 60 cm × 45 cm and 45 cm × 30 cm, respectively, under zero tilled condition with four replications. Results revealed that seed yield obtained in planting arrangement, 60 cm × 45 cm and 45 cm × 30 cm were 31.3 % and 22.2 % higher than 75 cm × 45 cm, respectively. The locations with salinity of 6.02 and 7.71 dS m^{-1} decreased seed yield by 6.5 % and 17.4 %, respectively, compared to 4.93 dS m^{-1}. The planting arrangement, 60 cm × 45 cm increased the gross margin by 35-50 % due to higher seed yield against slightly higher cost for seed and more number of labor required for different operations but decreased by 24-49 % in 45 cm × 30 cm where seed and labor requirement was the highest among treatments. The adoption of planting arrangement, 60 cm × 45 cm can increase the productivity of zero-tilled dibbled sunflower and thus increase the income of coastal saline farmers.

Keywords: Plant population, saline soil, sunflower, yield and profitability.

[*] Corresponding author: hrashid67@yahoo.com

Received: 06. 09. 2024 *Accepted: 06. 12. 2024*

Introduction

Over 800 million hectares of land globally affected by salt contamination, including 77 million hectares of irrigated land (FAO, 2008; Eynard et al., 2005). In Bangladesh coastal saline areas have expanded from 0.83 million to 1.09 million hectares due to climate change, leaving large areas uncultivable (Karim et al., 1990; SRDI, 2012). Across South and Southeast Asia, millions of hectares lie fallow due to salinity, with about 0.33 million hectares left uncultivated in Bangladesh during the winter season (Rashid et al., 2018; Ibrahim et al., 2018; Shahidullah et al., 2018). Cultivating salt-tolerant oilseed crops during these fallow periods could significantly improve land productivity (Rashid et al., 2015).

Bangladesh currently experiences a per capita oil consumption deficit, with domestic intake at only 10 grams per day compared to the recommended 22 grams (Rahman and Khan, 2005). Closing this gap requires enhancing domestic oilseed production, either through technological advancements or the introduction of high-yielding oilseed crops. Sunflower presents a viable solution due to its high-quality edible oil, adaptability to diverse environments, low labor demands, and compatibility with mechanization, establishing it as a major oilseed crop worldwide (Ali et al., 2013; Ozer et al., 2004; Kazemeini et al., 2009). Research indicates that rice-sunflower cropping systems are well suited for coastal saline regions, which could contribute to increase national oil consumption (Rashid et al., 2013).

Single wet season rice is the predominant cropping system in the saline coastal area of Bangladesh. The slow drying process of excessive moist soil after the harvest of wet season rice delays the field to come in field condition to plough land for dry season winter (rabi) and pre-monsoon crops. Again, the delayed planting of winter crops such as sunflowers decreases yield due to warmer temperatures at the early growth period, which promotes excessive early stem growth and reduces time to flowering. Moreover, the delayed-planted crop is often affected by the storm surges and rainfall at reproductive and maturity stages. The zero-till dibbled sunflower in residual moist soil can overcome this worse situation and harvest a higher seed yield and boost income through minimizing cost for land preparation and irrigation (Rashid et al., 2014).

Salinity is a major environmental constraint that hampers plant growth and yield, including that of sunflower (Majeed et al., 2010; Khan et al., 2014; Abd_Allah et al., 2015; Munns and Tester, 2008; Rozema and Flowers, 2008; Kronzucker and Britto, 2011; Zhang and Shi, 2013). Sunflower exhibits moderate sensitivity to salinity (Hafeez et al., 2017; Katarji et al., 2003), with high salinity levels markedly reducing seed yield (Zeng et al., 2015). However, agronomic strategies such as early sowing, selection of hybrid varieties, and optimization of planting density can help alleviate the negative impacts of salinity on sunflower productivity (Rashid et al., 2014; Ishfaq et al., 2009; Ali et al., 2011).

Planting density, managed by adjusting row and plant spacing, is essential for optimizing sunflower yield, as sunflower cannot compensate for interspace gaps through branching or tillering (Pereira and Hall, 2019). Achieving the ideal plant density maximizes resource efficiency and promotes balanced crop growth (Pereira and Hall, 2019). Studies indicates that adjustments in row and plant spacing affect root distribution and soil moisture levels (Cucci et al., 2017). Higher plant densities, however, increase competition for light, reducing both vegetative and reproductive adaptability (Soleymani, 2017) while lower densities limit light absorption and decrease yield per unit area (Kemanian et al., 2004; Ali et al., 2013).

The influence of plant density on grain yield and profitability can vary across salinity gradients in zero-till dibbled planting systems. Therefore, an on-farm experiment was conducted in a tidal saline ecosystem to evaluate the effects of plant density on sunflower yield and profitability under zero-till dibbled conditions.

Materials and Methods

Experimental Site and Seasons

The on-farm trial was conducted during the dry season in the villages of Shadpur and Bharasimla in Kaligonj Upazila, and Shreefalkathi in Shamnagar Upazila, Satkhira district, Bangladesh. These locations lie within the Ganges Tidal Flood Plain agro-ecological zone (UNDP and FAO, 1988). The climate is subtropical, with an average annual rainfall of 1710 mm, peaking in July and August. Mean temperatures range from a minimum of is 12.5°C in January to a maximum of 35.5°C in April and May. The soil in the experimental fields, up to 15 cm depth, is clay loam with a pH of 7.4 to 7.7 (1:2.5 with water). Organic carbon content is 9.5 - 10.8 g kg^{-1} (Walkley and Black method; Allison, 1965), total nitrogen 0.9- 1.1 g kg^{-1} (Yoshida et al., 1976), available phosphorus 26.7- 29.7 mg kg^{-1} (Olsen et al., 1982), exchangeable potassium 0.4 -0.6 m mol kg^{-1} (Page et al., 1982), available sulphur 25.7- 26.3 mg kg^{-1} (Fox et al., 1964), and extractable zinc 0.9 -1.0 mg kg^{-1} (Page et al., 1982).

Experimental Design and Treatments

The field experiment employed a randomized complete block design with four replications with each plot covering an area of 40 m^2. The experimental fields had similar soil types and crop management histories. Three planting densities were tested: (a) 74074 plants ha^{-1} with 45 cm row spacing and 30 cm plant spacing, (b) 37037 plants ha^{-1} with 60 cm row spacing and 45 cm plant spacing, and (c) 29630 plants ha^{-1} with 75 cm row spacing and 45 cm plant spacing. The third density reflects the current standard practice (Rashid et al., 2012), while the other two densities were selected in consultation with experienced farmers who adopted zero-till dibbled sunflower after the monsoon rice harvest.

Crop Establishment

Sunflower was grown during the dry season (November to March). After harvesting the monsoon rice, sunflower seeds were manually dibbled under zero-till conditions. The hybrid cultivar Hysun33 was used, with two seeds per hill dibbled according to the designated treatments between November 22 and 24. Plant emergence occurred within five days of sowing, and thinning to one plant per hill was carried out 15 days after sowing. The crop reached maturity by March 7, and harvesting took place between March 7 and 10. Fertilizers were applied at the following rates of 90 kg N, 40 kg P, 97 kg K, 30 kg S, 5 kg Zn, and 1.4 kg B per hectare as per recommendation of the fertilizer recommendation guide (Ahmmed et al., 2018). Phosphorus was applied as triple superphosphate, potassium as KCl, sulphur as gypsum, zinc as zinc sulphate, and boron as boric acid. Half of the nitrogen was applied as urea at 15 days after plant emergence, while the remaining nitrogen applied in two equal splits at 40-42 and 62-64 days after sowing. Irrigation was provided three times at early vegetative, bud formation and seed development stages (24-25, 40-42, and 62-64 days after sowing, respectively) with irrigation water electrical conductivities of 1.05-1.20, 1.21-1.71, and 1.67-2.78 dS m^{-1} at the Shadpur, Bharasimla, and Shreefalkathi sites, respectively. The zero-till crop was established with the residual soil moisture and this early sown crop. The other two irrigation was applied at two critical stages of sunflower.

Monitoring and Measurement

Soil Salinity: Electrical conductivity (EC) of the topsoil (0-15 cm) in the unit plots of all experimental sites was measured using a 1:5 soil: water suspension (EC 1:5). The EC values were then converted to soil saturation extract EC (ECe) following the method outlined by Watling (2007).

Seed Yield: Seed yields were measured from a 20.25 m^2 area in the central part of each plot. The seeds were manually threshed from the heads using a metallic stick, and the moisture content was determined immediately after weighing. Sunflower seed yield was reported on a dry weight basis, with a moisture content of 90 g per kg.

Profitability Analysis: Labour used for various operations, including sowing, thinning, irrigation, fertilizer and pesticide application, harvesting, threshing, and seed cleaning, was recorded. The time (in hours) required for each operation in each treatment plot was recorded using a stopwatch and expressed as person-days ha^{-1}, with 8 hours equating to 1 person-day. The variations in seed and labour requirements across different treatments are presented in Table 1. Costs differed among treatments, and profitability was assessed based on total variable cost, gross return, gross margin, and benefit-cost ratio (BCR). Total variable costs encompassed input costs (seeds,

fertilizers, and pesticides), labor costs, and irrigation pump rental fees. Gross return was calculated based on grain and stalk prices prevailing in the community.

Table 1. Labour and input that varied among plant densities (spacing).

Input/labour	Treatments (Spacing)		
	75 cm × 45 cm	60 cm × 45 cm	45 cm × 30 cm
Seed (kg ha^{-1})	7.5	9.5	19.0
Labour (person ha^{-1})			
Sowing	15	19	30
Thinning	4	5	7
Fertilizer application	11	15	25
Harvesting	14	18	22
Threshing	15	19	23
Drying and cleaning	4	5	4

Statistical Analyses: Data analysis was performed using CROPSTAT 7.2.3.3 version (IRRI, 2007). The least significant difference (LSD) test at $P < 0.05$ was employed to test differences among treatment means. Differences were considered significant at $P \leq 0.05$ unless otherwise indicated.

Results and Discussion

Soil Moisture

The interaction between plant density and salt-affected location had no significant on soil moisture from the day of sowing to 60 days after sowing (DAS). Soil moisture remained similar across all treatment plots on these dates (Table 2). Across different sowing densities, soil moisture was consistent at all observation points. However, soil moisture varied among locations from sowing to 60 DAS. Sreefalkathi had higher soil moisture at all points compared to the Bharasimla and Shadpur sites, with moisture levels at the latter two sites being largely similar. Despite the higher soil moisture in Sreefalkathi the site also exhibited higher soil salinity, indicating the site's inherently higher salinity due to its higher sub-soil water salinity levels. The increasing salinity of irrigation water in different sites increased the salinity of the soils and decreased the soil moisture depletion (Pearson, 2003; Salehin et al., 2018).

Table 2. Soil moisture at different dates in various plant densities and locations.

Factor	Soil moisture (%)				
	DS	15 DAS	30 DAS	45 DAS	60 DAS
Spacing (T)					
75 cm × 45 cm	34.1	26.1	17.8	14.8	11.5
60 cm × 45 cm	34.7	25.5	20.4	14.8	11.3
45 cm × 30 cm	34.6	26.4	20.5	15.0	10.9
$LSD_{0.05}$ (T)	ns	ns	ns	ns	ns
Location (L)					
Shadpur	27.7	22.2	17.5	13.3	8.4
Bharasimla	37.3	23.6	16.8	13.0	10.5
Shreefalkathi	38.3	32.2	26.4	18.3	14.9
$LSD_{0.05}$ (L)	1.2	1.5	1.0	0.8	0.8
$LSD_{0.05}$ (T×L)	ns	ns	ns	ns	ns

Soil Salinity

The interaction between plant density and salt-affected location did not significantly affect the electrical conductivity (ECe) of the soil from sowing to 90 DAS (Table 3). The ECe values of the soil in the treatment plots remained consistent from sowing to 90 DAS, indicating that the treatment effects were not influenced by soil salinity at the different locations. However, ECe varied significantly across locations throughout the study period, with soil salinity following the trend of Sreefalkathi > Bharasimla > Shadpur from sowing to 90 DAS.

Table 3. Soil electrical conductivity at different dates in various plant densities and locations.

Factor	Electrical conductivity (dS m^{-1})						
	DS	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Spacing (T)							
75 cm × 45 cm	3.83	4.26	4.83	5.45	5.72	6.22	6.22
60 cm × 45 cm	3.79	4.26	4.84	5.43	5.72	6.26	6.12
45 cm × 30 cm	3.84	4.29	4.83	5.43	5.69	6.22	6.13
$LSD_{0.05}$ (T)	ns	ns	ns	ns	ns	ns	ns
Location (L)							
Shadpur	3.42	3.77	4.53	4.93	5.15	5.58	4.93
Bharasimla	3.76	4.33	4.69	4.95	5.19	5.77	6.02
Shreefalkathi	4.28	4.70	5.28	6.43	6.79	7.34	7.71
$LSD_{0.05}$ (L)	0.09	0.04	0.05	0.05	0.04	0.06	0.06
$LSD_{0.05}$ (T×L)	ns	ns	ns	ns	ns	ns	ns

Seed Yield

The seed yield produced with plant populations of 37037 plants ha^{-1} (60 cm × 45 cm) and 74074 plants ha^{-1} (45 cm × 30) cm was similar and significantly higher than the yield from 29630 plants ha^{-1} (75 cm × 45 cm). Specifically, seed yields from the 60 cm × 45 cm and 45 cm × 30 cm plant spacing were 31.3 % and 22.2 % higher, respectively, than the 75 cm × 45 cm spacing (Figure 1). These findings align with the studies of Li *et al*., (2019) and Mojiri and Arzani (2003). Malik *et al*. (2001) also found higher seed yields with a 60 cm × 30 cm arrangement, while Kaya et al. (2015) reported that a of 60 cm × 35 cm planting pattern was effective for increasing grain yield. Seed yields in Shadpur and Bharasimla were statistically similar but significantly higher than in Sreefalkathi. Yield reductions of 6.5 % and 17.4 % were observed at Bharasimla and Sreefalkathi, respectively, compared to the lowest saline site, Shadpur. This decrease in yield corresponded with an increase in soil salinity, which ranged from 4.93 dS m^{-1} at Shadpur to 6.02 dS m^{-1} at Bharasimla and 7.71 dS m^{-1} at Sreefalkathi (Figure 1). Similar results have been reported by other researchers, who have highlighted the negative impact of salinity on sunflower productivity (Kronzucker and Britto, 2011; Zhang and Shi, 2013). Zeng *et al*. (2015) also found that high salinity (ECe 9.03 to 18.06 dS m^{-1}) reduced seed yield by 31 %.

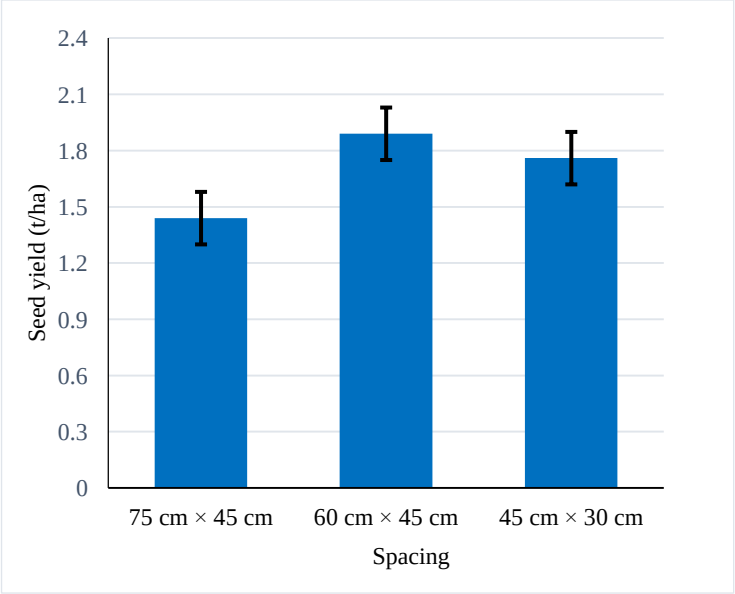


Fig. 1. Seed yield of sunflower as influenced by different spacing. Bars indicate $LSD_{0.05}$.

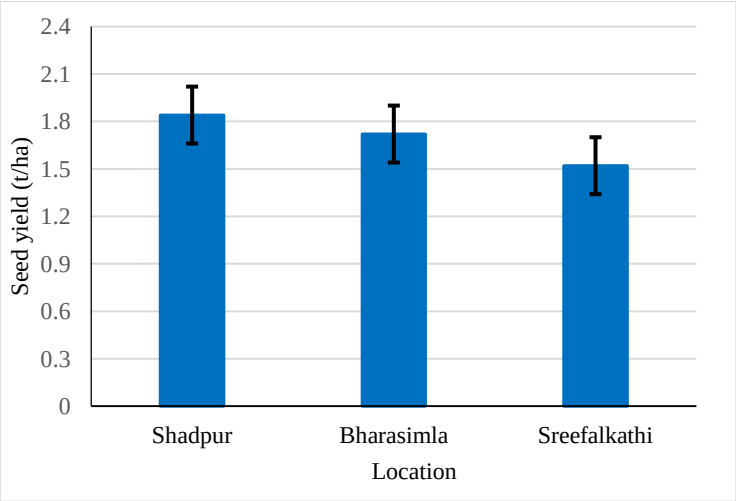


Fig. 2. Seed yield of sunflower as affected by salt affected locations. Bars indicate $LSD_{0.05}$.

Profitability

On average, the seed requirements were 7.5, 9.5, and 19 kg ha^{-1} for planting densities of 75 cm × 45 cm (29630 plants ha^{-1}), 60 cm × 45 cm (37037 plants ha^{-1}), and 45 cm × 30 cm (74074 plant ha^{-1}), respectively. Correspondingly, a total of 18 and 38 person-days ha^{-1} were needed for activities such as sowing, thinning, fertilizer application, harvesting, threshing, drying and cleaning in the 60 cm × 45 cm and 45 cm × 30 cm planting densities, respectively. All other costs remained consistent across treatments. The total variable cost was 15.9 and 56.4 % higher in the 60 cm × 45 cm and 45 cm × 30 cm densities, respectively, compared to the 75 cm × 45 cm density. Increasing the planting density from 29630 to 37037 plants ha^{-1}resulted in a 24-28 % increase in gross return, while a decrease of 16-22 % was observed in the 45 cm × 30 cm density (74074 plant ha^{-1}). The gross margin was highest in the 60 cm × 45 cm density, followed by the 75 cm × 45 cm density, with the lowest in the 45 cm × 30 cm density. Increasing the planting density from 75 cm × 45 cm to 60 cm × 45 cm boosted the gross margin by 35-50 %, but decreased it by 24-49 % in the 45 cm × 30 cm density. The gain in gross return at the 45 cm × 30 cm density was offset by higher total variable cost. The gross margin decreased by 5.5% to 27.1 % in Bharasimla and 28.0% to 53.8 % in Sreefalkathi, compared to the lowest saline site, Shadpur. The benefit cost ratio (BCR) over total variable cost was highest in the 60 cm × 45 cm density, followed by 75 cm × 45 cm, with the lowest in the 45 cm × 30 cm density. The BCR slightly decreased in Bharasimla but significantly in Sreefalkathi (Table 4). The gross margin and BCR were mainly influenced by seed yield, variable seed costs, and labor wages, which varied depending on planting density.

Table 4. Profitability of three plant densities of sunflower at different locations.

Density	Location	TVC* (BDT ha^{-1})	Gross return** (BDT ha^{-1})	Gross Margin (BDT ha^{-1})	BCR
75 cm × 45 cm	Shadpur	57120	99448	42328	1.74
	Bharasimla	57120	97135	40015	1.70
	Shreefalkathi	57120	86391	29271	1.51
60 cm × 45 cm	Shadpur	66200	127299	61098	1.92
	Bharasimla	66200	120369	54169	1.82
	Shreefalkathi	66200	110219	44019	1.66
45 cm × 30 cm	Shadpur	89350	121709	32358	1.36
	Bharasimla	89350	112942	23592	1.26
	Shreefalkathi	89350	104286	14936	1.17

*TVC = Total variable cost, BDT = Bangladeshi Taka; **Price of seed plus stalk; farm gate seed price t^{-1} BDT 50000, stalk = BDT 22500 t^{-1} for spacing 75 cm × 45 cm and BDT 25000 for spacing 60 cm × 45 cm and 45 cm × 30 cm.

Conclusions

Our results showed that increasing the planting density from 29,630 to 37,037 and 74,074 plants ha^{-1} significantly increased seed yield in zero-tilled dibbled sunflower, although it also led to higher total variable costs. Seed yield was not significantly affected by salinity levels up to 6.02 dS m^{-1} but declined significantly at 7.71 dS m^{-1}. The gain in total return from the highest density of 74074 plants ha^{-1} (45 cm × 30 cm) was nullified by the increased total variable costs. The planting density of 37037 plants ha^{-1} (60 cm × 45 cm) resulted in higher profitability across all salt-affected locations compared to both the lowest density of 29630 plants ha^{-1} (75 cm × 45 cm) and the highest density of 74074 plants ha^{-1} (45 cm × 30 cm), indicating its superior performance. Given the yield advantage and higher profitability, the planting density of 37037 plants ha^{-1} with a spacing of 60 cm × 45 cm is recommended for zero-tilled dibbled sunflower in saline ecosystems. Further validation of this density in different establishment methods within saline environments is also needed. Moreover, studies are required for confirming the potential implications of these findings on long-term sustainability and soil health in saline environments.

Acknowledgement

The authors highly acknowledge the financial support from the Bangladesh Agricultural Research Council for this piece of research.

References

Abd_Allah, E.F., Hashem, A., Alqarawi, A. A. and Hend, A. A. (2015). Alleviation of adverse impact of cadmium stress in sunflower (*Helianthus annuus* L.) by arbuscular mycorrhizal fungi. *Pakistan Journal of Botany,* 47(2): 785-795.

Ahmmed, S., Jahiruddin, M., Razia, S., Gegum, R. A. Biswas, J. C., Rahman, A. S. M. M., Ali, M. M., Islam, K. M. S., Hossain, M. M., Gani, M. N., Hossain, G. M. A., Sattar, M. A. 2018. Fertilizer Recommendation Guide-2018. Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka-1215.

Ali, A., Ahmad, A., Khaliq, T., Ali, A. and Ahmad, M. (2013). Nitrogen nutrition and planting density effects on sunflower growth and yield: a review. *Pakistan Journal of Nutrition 12* (12): 1024-1035.

Ali, H., Riaz, M., Zahoor, A. and Ahmad, S. (2011). Response of sunflower hybrids to management practices under irrigated arid-environment. *African Journal of Biotechnology,* 10 (12: 2666-2675.

Allison, L. E. (1965). Organic carbon, In: Methods of Soil Analysis, *Agronomy Series No*. *9*. Ed. Black, C.A., 1367-76. ASA, Madison, WI.

Cucci, G., Lacolla, G. and Caranfa, G. (2017). Spatial distribution of roots and cracks in soils cultivated with sunflower. *Archives of Agronomy and Soil Science,* 64 (1): 13-24. DOI:

Eynard, A., Lal, R. and Wiebe, K. (2005). Crop response in salt-affected soils. *Journal of Sustainable Agriculture, 27* (1): 5-50.

FAO (Food and Agriculture Organization). (2008). Land and Plant Nutrition Management Service. http://www.fao.org/ag/agl/agll/spush/intro.htm.

Fox, R. L., Olson, R. A. and Rhoades H. F. (1964). Evaluating the sulphur status of soil by plant and soil tests. *Soil Science Society of America Proceeding*, 28: 243-246.

Hafeez, A., Arshadullah, M., Rasheed, M., Mahmood, I. A., Hyder, S.I., Aamir, S.S., Shaaban, M. and Mahmood, T. (2017). Effect of soil salinity on germination and growth of sunflower (*Helianthus annuus* L). *Journal of Innovative Bio-Research*, 1 (1): 46-51.

Ibrahim, M., Zaman, M., Mostafizur, A. and Shahidullah, S. (2018). Diversity of crops and land use pattern in Barisal Region. *Bangladesh Rice Journal*, 21(2): 57-72.

IRRI (2007). CropStat Stat for Windows. Version 7.2. 3, 3, IRRI, Metro Manila.

Ishfaq, M., Ali, A., Khaliq, A. and Yaseen, M. (2009). Allometry, agronomic traits and yield of autumn planted sunflower hybrids under varying row spacing. *Pakistan Journal of Agricultural Science*, 46: 248-257.

Karim, Z., Hussain, S. G. and Ahmed, M. (1990). Salinity problems and crop intensification in the coastal regions of Bangladesh. *Soils publication* No. 33. BARC, p.17.

Katarji, N., Van Hoorn, J. W., Hamdy, A. and Mastrorilli, M. (2003). Salinity effect on crop development and yield, analysis of salt tolerance according to several classification methods. *Agricultural Water Management*, 62 (1): 37–66.

Kaya, M. D., Bayramin, S. and Kaya, G. (2015). The effect of planting geometry and seed priming on sunflower yield under rainfed conditions. *Fresenius Environmental Bulletin, 24* (11c): 4095-4101.

Kazemeini, S.A., Edalat, M. and Avat, S. (2009). Interaction effects of deficit irrigation and row spacing on sunflower (*Helianthus annuus* L.) growth, seed yield and oil yield. *African Journal of Agricultural Research*, 4: 1165-1170.

Kemanian, A.R., Stöckle, C.O. and Huggins, D.R. (2004). Variability of barley radiation-use efficiency. *Crop Science*, 44: 1662–1672.

Khan, A., Iqbal, I., Ahmad, I., Nawaz, H. and Nawaz, M. (2014). Role of proline to induce salinity tolerance in sunflower (Helianthus annus L.). *Science Technology and Development*, 33(2): 88-93.

Kronzucker, H. J. and Britto, D. T. (2011). Sodium transport in plants: A critical review. *New Phytologist*, 189: 54–81.

Li, J., Zhongyi Qu, Jin Chen, Bo Yang and Huang, Y. (2019). Effect of planting density on the growth and yield of sunflower under mulched drip irrigation. Water, 11 (4): 752.

Majeed, A., Nisar, M. F. and Hussain, K. (2010). Effect of saline culture on the concentration of Na+, K+ and Cl- in Agro stistolonifera. *Current Research Journal of Biological Science*, 2(1): 76-82.

Malik, M. A., Shah, S. H., Mahmood, S. and Cheema, M. A. (2001). Effect of various planting geometries on the growth, seed yield and oil content of new sunflower hybrid (SF-187). *International Journal of Agriculture and Biology*, 3(1): 55-56.

Mojiri, A. and Arzani, A. (2003). Effects of nitrogen rate and plant density on yield and yield components of sunflower. *Journal of Science and Technology of Agriculture and Natural Resources*, 7:115-125.

Munns, R. and Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, 59 (1): 651–681.

Olsen, S. R., Cole, C. V., Watanable, F. S. and Dean, L. A. (1982). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *U. S. Department of Agriculture Circular* No. 939.

Ozer, H., Polat, T. and Ozturk, E. (2004). Response of irrigated sunflower (*Helianthus annuus* L.) hybrids to nitrogen fertilization: growth, yield and yield components. *Plant Soil and Environment*, 5: 205-211.

Page, A. L., Miller, R. H. and Keeny, D. R. (1982). Methods of soil analysis part 2: chemical and microbiological properties. *Agronomy Monogaph* No. *9*. ASA Inc., Madison, WI.

Pearson, K. E. (2003). Basic of salinity and sodicity effects on soil physical properties. https://waterquality.montana.edu/energy/cbm/background/soil-prop.html

Pereira, M.L. and Hall, A. J. (2019). Sunflower oil yield responses to plant population and row spacing: vegetative and reproductive plasticity. *Field Crops Research*, 230: 17–30.

Rahman, M. M. and Khan, S. I. (2005). Food security in Bangladesh: food availability. In: ed. *Government of the People's Repubpic of Bangladesh and World Food Programme-Bangladesh*, P. 9. 19-20 October, 2005, IDB Bhavan, Agargaon, Dhaka, Bangladesh,

Rashid, M. H., Hossain, F., Nath, D. K., Sarker, P. C., Ferdous, A. K. M. and Russell, T. (2015). Oilseed crops in rice-based cropping systems in southern Bangladesh. In: Humphreys, E., T.P. Tuong, M.C. Buisson, I. Pukinskis and M. Phillips. Revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices Conference Proceedings. pp. 405-420. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF).

Rashid, M. H., Nasrin, S., Rony, M. K. I., Mahalder, D., Begum, S. (2012). Sunflower cultivation after harvesting of t. aman rice in saline area (In *Bangla*). Folded brochure. International Rice Research Institute, 2/2 Banani, Dhaka 1213, Bangladesh.

Rashid, M. H., Nasrin, S. and Mahalder, D. (2014). Zero tilled dibbled sunflower enables planting earlier and harvest more in the coastal saline area of Bangladesh. *International Journal of Environmental Science and Development.* 5 (3): 260-264.

Rashid, M. H., Rony, M. K. I, Nasrin, S., Mahalder, D. and M. A. Saleque. (2013). System productivity of rice-sunflower sequence in rainfed coastal saline area. *Bangladesh Agronomy Journal*, 16 (2):17-20.

Rashid, M. H., Shirazy, B., Ibrahim, M. and Shahidullah, S. (2018). Cropping Systems and their Diversity in Khulna Region. *Bangladesh Rice Journal*, 21(2): 203-215.

Rozema, J. and Flowers, T. (2008). Crops for a salinized world. Science, 322: 1478–1480. Retrieved April 30, 2024. https://www.jstor.org/stable/20176943?seq=1

Salehin, M., Chowdhury, M., Arefin, M, Clarke, D., Mondal, S., Nowreen, S., Jahiruddin, M., Haque, A. (2018). Mechanisms and drivers of soil salinity in coastal Bangladesh. In Ecosystem services for well-being in deltas (pp. 333-347). Palgrave Macmillan, Cham. 10.1007/978-3-319-71093-8_30.

Shahidullah, S., Nasim, M., Quais, M., and Saha, A. (2018). Diversity of Cropping Systems in Chittagong Region. *Bangladesh Rice Journal*, 21(2): 109-122.

Soleymani, A. (2017). Light response of sunflower and canola as affected by plant density, plant genotype and N fertilization. *Journal of Photochemistry and Photobiology. B Biology*, 173: 580–588.

SRDI (Soil Resources and Development Institute). 2012. Saline soils of Bangladesh. PP. 6-7. Soil Resources and Development Institute, Mrittika Bhaban, Krishi Khamar Sarak, Dhaka-1215.

UNDP (United Nations Development Programme) and FAO (Food and Agriculture Organization). (1988). Land Resources Appraisal of Bangladesh for Agricultural Development, Report 2, Agricultural Regions of Bangladesh. p. 275.

Watling, K. (2007). Measuring salinity. Fact Sheet, Department of Natural Resources and Water. Queensland Government, Australia. L 137. Retrieved April 30, 2024.

http://joomla.speedweb.com.au/soil2015/images/sampledata/publications_tab/schoolresources/factsheets/07_measuring-salinity.pdf

Yoshida, S., Forno, D. A., Cock, J. H. and Gomez, K. A. (1976). Laboratory manual for physiological studies of rice, 3rd edition. International Rice Research Institute, Philippines.

Zeng, W., Chi Xu, Jiesheng Huang, Jingwei Wu and Tao Ma. (2015). Emergence rate, yield, and nitrogen use efficiency of sunflowers (*Helianthus annuus*) vary with soil salinity and amount of nitrogen applied. *Communications in Soil Science and Plant Analysis*, 46 (8):1006-1023.

Zhang J.L. and Shi H.Z. (2013). Physiological and molecular mechanisms of plant salt tolerance. *Photosynthesis Research*, 115: 1–22.

SAARC J. Agric., 22(2): 81-98 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.75734*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Physico-Chemical Properties and Fertility Status of Forest Soils Under AEZ-29 (Northern and Eastern Hills) of Bangladesh

M.J. Tania [1], N.J. Mim[1], A.Z.M. Moslehuddin[1] and T.S. Hoque[1*]

[1]Department of Soil Science, Bangladesh Agricultural University
Mymensingh-2202, Bangladesh

Abstract

Soil properties influence land management practices and differ in regions with diverse topography and ecological variations. An experiment was conducted at the Department of Soil Science, Bangladesh Agricultural University, Mymensingh, Bangladesh with 16 soil samples collected at 0-15 cm depth from various hilly forest locations of three districts of AEZ-29 (Northern and Eastern Hills) covering 12 series to assess their physical, chemical and fertility properties. Most of the soils were sandy loam in texture, strongly acidic to very strongly acidic (pH 4.23-5.46) and non-saline. The cation exchange capacity (CEC) was very low to medium with an average of 7.31 $cmol_c\ kg^{-1}$ and organic matter (OM) status was medium with mean of 2.62%. The soils had very low to low levels (0.07-0.16%) of total nitrogen (N) and available phosphorus (P) content (1.29-10.9 mg kg^{-1}) but low to medium level (10.33-22.51 mg kg^{-1}) of available sulphur (S). Besides, very low to very high levels of exchangeable potassium (K), calcium (Ca) and magnesium (Mg) with averages of 0.34, 3.10 and 1.64 $cmol_c\ kg^{-1}$, respectively, were observed. The status of available iron (Fe) and manganese (Mn) in all the soils were very high ranging from 20-108 and 24-217 mg kg^{-1}, respectively. The soils showed medium or low to very high levels of available zinc (Zn), copper (Cu) and boron (B) with averages of 2.64, 0.74 and 0.61 mg kg^{-1}, respectively. The variations in physico-chemical and fertility properties of these soils might be due to variation in parent material, land uses and soil erosion. Among different soil series, Sitakundu showed the maximum values of pH, CEC, OM, total N, exchangeable K, Ca and Mg and available B. Although some of the hill soils seemed to be inherently fertile,

* Corresponding author: tahsinasharmin@bau.edu.bd

Received: 27. 08. 2024 *Accepted: 27. 12. 2024*

proper fertilizer management especially for macronutrients, liming and erosion control practices are crucial for agricultural crop production.

Keywords: Physico-chemical properties, Dupi tila, Tipam, Available nutrients

Introduction

Bangladesh is the largest deltaic plain having a unique geographic position. Its landscape is remarkably diverse, formed by sediments ranging in age from recent to tertiary. The soils of Bangladesh derive from various parent materials, distributed across three main physiographic units: Northern and Eastern hills (12% of the area), Pleistocene terraces (8% of the area), and Recent floodplains (80% of the area) (Islam et al., 2017; Huq and Shoaib, 2013). Depending on their formation and appearance, these soils are categorized into 21 general classes (Moslehuddin et al., 1997), where fourteen soil types are found in floodplain areas, six in terraces, and one in hilly areas. Based on physiography, soils, inundation regimes and agro-climatology, thirty agro-ecological zones (AEZs) have been recognized in Bangladesh (FRG, 2018). Each AEZ refers to an area characterized by identical agricultural and ecological properties; these similarities are more pronounced at the sub-region and subunit levels. The present study area namely Northern and Eastern Hills in Bangladesh represents the 29th among 30 agroecological zones, encompassing the hilly areas. It spans about 12% of the land area and occupies about 18,171 km² (FRG, 2018). This region includes Chittagong Hill Tracts, Khagrachhari, Bandarban, Cox's Bazar, and small areas along the northern border of the Sherpur, Sunamganj, Mymensingh, and Sylhet districts. The Northern and Eastern Hills of Bangladesh feature a complex relief with steep slopes and rolling terrain in some areas. The landscape consists of high hills above 150-1,000 m mean sea level (MSL) with steep slopes and low hills below 150 m with steep to rolling topography (FRG, 2018). High hills are prone to landslides during heavy monsoon rains. Both high and low hills have strongly acidic and sandy soils.

Soil formation in Bangladesh varies due to its geological position which is at the junction of Indian, Burmese, and Eurasian plates (Chowdhury et al., 2021). The country is predominantly covered in alluvium, with Tertiary deposits found in the north, east, and southeastern parts of the Sylhet district, as well as the folded side of Chittagong and Chittagong hill tracts (Roy et al., 2012). The geology of Bangladesh is an integral part of the geology of the Bengal Basin. Tertiary hill sediments in the northern and eastern hills are one of the major geological formations in Bangladesh soils (Brammer, 1996) which comprise mainly the unconsolidated and little consolidated beds of sandstones, siltstones, shales, and some conglomerates. In the higher ranges of the Chittagong and Sylhet hill areas, the rocks are mainly formed from the Surma and Tipam formations in the late Oligocene to mid-Miocene period, and the lower hill ranges predominantly contain rocks from the Dupi Tila formation between the mid-Miocene to Pliocene periods (Huq and Shoaib, 2013). Tipam Formation is a lithostratigraphic unit in the Bengal Basin consisting of shales and siltstones, varying in consolidation, with some regions containing calcareous

materials and Dupi Tila is the primary aquifer of this Bengal Basin consisting of sandstones, siltstones, and shale layers (Huq and Shoaib, 2013).

The predominant soil type found in the Northern and Eastern Hills is brown hill soil. This soil typically exhibits a yellow-brown to dark brown coloration and is characterized by its permeability, loamy texture, and high acidity levels. Brown hill soil also tends to have low moisture retention capacity, limited organic matter content, and relatively low fertility levels (Hossain et al., 2014). Soil properties of hills (physical, chemical and biological) are influenced by factors like altitude, water availability, temperature (Huq and Shoaib, 2013), topography (Akhtaruzzaman et al., 2014) and land use systems (García-Oliva et al., 1994). Land use systems cause losses in Soil Organic Carbon (SOC), nutrients, groundwater reduction, soil structure changes, and reduction in biological elements (Al Mamun et al., 2021). In hilly regions (especially in the Chittagong Hill Tracts) and undulated areas of Bangladesh, land degradation is common due to heavy rainfall, soil erosion, and deforestation (Nath et al., 2005). This causes sedimentation, flooding, and interruptions in water storage, which are increased by the hydrological regime (NN, 2001). Hill soils are acidic due to increased topography, which facilitates basic cations removal through leaching and runoff processes, resulting in gradual acidification in forest hills (Brammer, 1971). Soil acidification decreases pH and increases micronutrient concentrations. The bioavailability and toxicity of excess amounts of micronutrients are significantly influenced by their forms (Gauthier, 2002). Acid forest soils often have high levels of soluble iron, manganese and aluminum, leading to increased plant uptake and root damage (Akhtaruzzaman et al., 2014). Land physiography and slope gradients also influence surface runoff and soil erosion in these areas (Akhtaruzzaman et al., 2014) leading to macronutrient loss, including phosphorus, nitrogen, potassium, and trace elements, which impact soil fertility (Biswas et al., 2010; Rasul and Thapa, 2007; Gafur et al., 2003). Besides, river-borne sediment from hills reduces the fertility of cultivable land (Islam et al., 2006). Deforestation, land degradation and soil erosion hamper sustainable hill farming in Bangladesh (Biswas et al., 2012). Jhum cultivation and other practices also have significantly degraded the soil in the Chittagong Hill Tracts (Biswas et al., 2012) which impacts both agricultural lands and natural forests, and results in rapid depletion of resources. Therefore, urgent action is needed from planners and policymakers to protect hill soil based on its use and properties.

In Bangladesh, agriculture accounts for approximately 11.38% of Gross Domestic Product (GDP) (BBS, 2023) which is not sufficient for the increasing population that grows at 2.5% annually. Limited land resources in the country have led to land conversion for agriculture, horticulture, and other uses (Hassan, 1994). Over time, vegetation and soil properties have changed due to climate fluctuations, soil erosion, and human activities including deforestation, land degradation, and pollution. Soil quality for agriculture depends on elements like nutrient content, proper fertilizer use, and management practices. People working with soil must understand the physical, chemical, and nutritional aspects of a soil and assess its suitability for agricultural or

structural purposes (Foth, 1990). Previous studies have focused on the growth performance of planted species and planting techniques in hilly areas, neglecting the importance of soil characteristics in improving and maintaining soil resources (Akhtaruzzaman et al., 2014). Studies on soil characteristics particularly physicochemical properties and fertility status will provide basic information for better resource management in hilly forest regions. Therefore, the present study was conducted to evaluate the physical and chemical properties of soils in the Northern and Eastern Hill regions (AEZ 29) and to assess the fertility status for offering recommendations for improved agricultural practices at the farmer level.

Materials and Methods

Site selection

The sites were selected that covered hill soils from Northern and Eastern Hills (AEZ 29) comprising 12 series *viz*. Rangamati, Salbon, Barkal, Khadimnagar, Nolua, Sitakundu, Dhum, Ghagra, Tamabil, Bijipur, Suvolong and Datmara. The sites covered three districts namely Chattogram, Bandarban and Cox's Bazar, four upazilas *viz.* Lohagora, Chokoria, Satkania and Bandarban Sadar and seven villages i.e. Borohatia, Chunti, Mekhla, Sualok, Badarkhali, Nilachal and Bajalia. The selected sites are shown in Figure 1. The experimental sites comprised of high lands, medium high lands, high hills, medium high hills, low hills and valleys. There were some constraints for crop production in these forest areas such as steeply slope, acidity, soil erosion and wild animal attack etc. The basic information regarding soil series, administrative units, geographical locations, land types, land uses and soil formation of the studied areas are enlisted in Table 1.

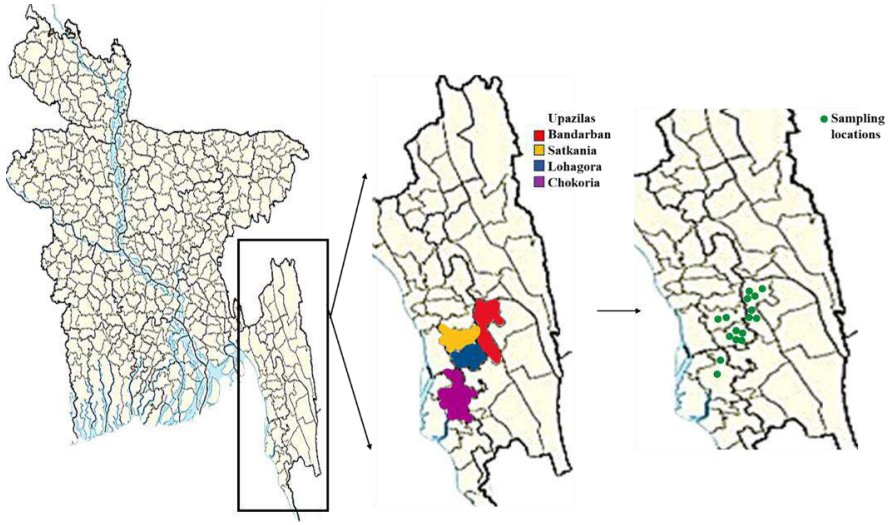


Fig. 1. Map showing the soil sampling locations

Table 1. Some basic information of soil samples collected from AEZ 29 under study

Soil series	Administrative units	Geographical locations	Land types (Topography)	Land uses	Soil formation
Rangamati	Village: Borohatia Upazila: Lohagora District: Chattogram	21° 59' 21" 92° 02' 52"	HL	Natural forest	Dupi-Tila
Salbon-1	Village: Borohatia Upazila: Lohagora District: Chattogram	21° 58' 45" 92° 02' 10"	HL (Terrace)	Plantation Forest	Dupi-Tila
Salbon-2	Village: Chunti Upazila: Chokoria District: Cox's Bazar	21° 55' 53" 92° 03' 38"	LH	Natural forest	Dupi-Tila
Barkal	Village: Mekhla Upazila: Bandarban Sadar District: Bandarban	22° 11' 43" 92° 11' 48"	HH	Natural forest	Tipam
Khadimnagar-1	Village: Borohatia Upazila: Lohagora District: Chattogram	22° 01' 96" 92° 05' 37"	LH	Plantation Forest	Dupi-Tila
Khadimnagar -2	Village: Sualok Upazila: Bandarban Sadar District: Bandarban	22° 40' 47" 92° 16' 11"	LH	Teak forest elevation: 190 Ft	Dupi-Tila
Nolua-1	Village: Badarkhali Upazila: Chokoria, District: Cox's Bazar	21° 56' 15" 92° 03' 50"	LH	Natural forest	Dupi-Tila
Nolua-2	Village: Sualok Upazila: Bandarban Sadar District: Bandarban	22° 09' 39" 92° 10' 34"	LH	Teak forest elevation: 170 ft	Dupi-Tila
Sitakundu	Village: Nilachal Upazila: Bandarban Sadar District: Bandarban	22°17' 13" 92° 21' 63"	MHH	Natural forest	Tipam
Dhum	Village: Mekhla Upazila: Bandarban Sadar District: Bandarban	22° 10' 55" 92° 11' 49"	MHH	Plantation Forest	Tipum
Ghagra	Village: Mekhla Upazila: Bandarban Sadar District: Bandarban	22° 10' 43" 92° 11' 46"	MHH	Natural forest	Tipam
Tamabil-1	Village: Borohatia Upazila: Lohagora District: Chattogram	21° 58' 51" 92° 01' 56"	MHH	Natural forest	Tipam

Soil series	Administrative units	Geographical locations	Land types (Topography)	Land uses	Soil formation
Tamabil-2	Village: Sualok Upazila: Bandarban Sadar District: Bandarban	22° 09' 44" 92° 10' 38"	MHH	Natural forest	Tipam
Bijipur	Village: Bajalia Upazila: Satkania District: Chattogram	22° 08' 05" 92° 09' 42"	Valley	Boro-Fallow-T. Aman	Piedmont
Suvolong	Village: Borohatia Upazila: Lohagora District: Chattogram	21° 58' 46" 92° 02' 06"	LH	Plantation Forest	Dupi-Tila
Datmara	Village: Bajalia Upazila: Satkania District: Chattogram	22° 12' 96" 92° 16' 46"	LH	Unestablished Farm	Dupi-Tila (Very shallow soil)

MHL: Medium High Land; LH: Low Hill; MHH: Medium High Hill; HH: High Hill; HL: High Land

Soil sample collection and preparation

A total of sixteen composite samples were collected from AEZ 29 to represent hill forest soils with multiple uses. Ten of the sixteen samples were collected from natural forest areas and four samples were taken from plantation forest areas and forest tree species like teak, garjan, acacia, mahogany, gamhar etc. occupy the lands. On the other hand, one sample was collected from a valley where rice cultivation is recently practiced (yield is very low) in a small area, and the remaining one sample was taken from an unestablished farm (used for nursery purpose to grow fruit crops) in a forest area. Two composite samples were collected from each of the four series *viz.* Salbon, Khadimnagar, Nolua, and Tamabil. For each of the remaining series, one composite sample was collected as representative. For all the cases, the sampling depth ranged from 0 to 15 cm. The soil samples were brought to the laboratory of the Department of Soil Science, Bangladesh Agricultural University for physical and chemical analysis. At first the samples were air-dried at room temperature, crushed, thoroughly mixed, sieved through a 20-mesh sieve, and then stored in plastic bags for subsequent analysis.

Physical and chemical properties determination

The particle size of the soils was analyzed by hydrometer method (Bouyoucos, 1962) using 10 mL of 5% Calgon solution as a dispersing agent. The hydrometer readings were taken at 40 seconds and 2 hours of sedimentation. The pH of the soils was determined electrochemically with a glass-electrode pH meter in a soil suspension with a soil-water ratio of 1:2.5 after 30 minutes of shaking (Jackson, 1973). The electrical conductivity (EC) of soil samples was measured with a conductivity meter (Hardie and Doyle, 2012) by maintaining a soil-water ratio of 1:5 after 30 min of

shaking followed by resting for 1 hour. Cation exchange capacity of the studied soils was determined by sodium saturation method (Chapman, 1965) where Na^+ ions were replaced by 1 N NH_4OAc using a centrifuge machine and then the concentration of Na^+ ions in the solution was measured by a flame photometer.

Fertility properties determination

Organic matter (OM)

Soil organic carbon (SOC) content was assessed by wet oxidation method (Walkley and Black, 1934) using an excess amount of 1 N $K_2Cr_2O_7$. The remaining $K_2Cr_2O_7$ solution was titrated with 1 N $FeSO_4$ to determine SOC. The organic matter content was calculated by multiplying % organic carbon with the van Bemmelen factor, 1.73.

Macronutrients

The semi-Micro-Kjeldhal method was used to determine the total N content of soil (Bremner and Mulvaney, 1982). Available phosphorus (P) was extracted from the soils using Bray No 1 solution as an extractant (Bray and Kurtz, 1945) and then the concentration was colorimetrically measured. Available S was determined by using $CaC1_2$ solution (0.15%) as an extractant (Williams and Steinbergs, 1959) and the S content was estimated turbidimetrically with a spectrophotometer. Exchangeable potassium (K), calcium (Ca) and magnesium (Mg) were determined by ammonium acetate extraction method using a flame photometer (Knudsen et al., 1982; Kooch et al., 2017).

Micronutrients

Available Fe, Mn, Zn and Cu were determined by DTPA extraction followed by determination by an atomic absorption spectrophotometer as described by Lindsay and Norvell (1978). Available B was extracted by hot water 0.02 M $CaCl_2$ solution (1:2 ratio) followed by determination by a spectrophotometer using azomethine-H method (Keren, 1996).

Statistical analysis

The soil analysis data were statistically evaluated using mean and standard error employing the Statistix 10 package program and Pearson's correlation coefficient matrix was estimated with statistical package R.

Results and Discussion

Physical and chemical properties

Soil is a heterogeneous system and many characteristics differentiate one soil from another. The study of physico-chemical properties of soils aids in management of resources while working with a certain type of soil (Balasubramanian, 2017). The soil texture plays an important role in the development of vegetation and nutrient cycling. It influences the supply of air, water, and essential nutrients required for root growth (Robertson, and Vituosik, 1981). Among the 16 soil samples, 11 were categorized as

sandy loam, 2 as silt loam, and 3 as loam in texture (Table 2). Most locations had sandy loam as the predominant texture including Rangamati, Salbon (1 and 2), Khadimnagar (1 and 2), Nolua-1, Sitakundu, Tamabil-1, Bijipur, Suvolong, and Datmara. Meanwhile, Barkal and Dhum soils were identified as silt loam, and Nolua-2, Ghagra, and Tamabil-2 soils were characterized as loam in texture. That means, the soil texture of the hill soils varied among sandy loam, loam, and silt loam, with the majority (68%) of soil samples exhibiting a sandy loam texture. A significant portion of these soils contained higher sand content compared to silt and clay. According to Brammer (1971), sand is the dominant particle in hill soils and they are developed from sandstone parent materials. Sandy loam soils typically have good drainage and aeration, which can benefit root development. However, water runoff and erosion are major concerns in these soils.

In AEZ 29, The pH values of the studied soils ranged from 4.23 to 5.46, indicating that all the soils were acidic (Table 2). The highest pH value (5.46) was observed in the Sitakundu soil, while the lowest pH (4.23) was recorded in the Ghagra soil. On average, the pH of the sixteen soils was 4.73. Most of the soils were strongly acidic in reaction except Khadimnagar-1 and Ghagra soils which were very strongly acidic in reaction. Hassan et al. (2017) stated that the mean pH of high and medium hill soils is strongly acidic, while the mean pH of low hill soils is very strongly acidic. The source of this acidity is attributed to both the inherent acidity of the parent rocks like granite and granite gneiss (silica-saturated igneous and metamorphic rocks) (Dhumgond et al., 2012) and intensive leaching of basic elements like Ca and Mg. Generally, hill soils are unfavorable for crop production (BARC, 2012). To improve crop production in these acidic soils, amendment of liming materials in soil is essential for farmers. Liming materials change the pH, correct the negative effects of acid cations, and improve soil fertility (Reddy and Subramanian, 2016). The EC of the AEZ 29 soils ranged from 0.04 to 0.21 dS m^{-1} (Table 2). Ghagra soil had the highest EC (0.21 dS m^{-1}) and Salbon-1 had the lowest EC (0.04 dS m^{-1}). The average EC of the selected soils was 0.07 dS m^{-1}. The soils analyzed in this study were non-saline because the soluble salts were leached out from the soil (Rao, 1992). The CEC of the soils studied ranged between 3.85 and 12.60 $cmol_c$ kg^{-1} (Table 2). Sitakundu had the highest CEC (12.60 $cmol_c$ kg^{-1}), while Tamabil-2 had the lowest (3.85 $cmol_c$ kg^{-1}). On average, the CEC of the soils was 7.31 $cmol_c$ kg^{-1}. Some soils showed medium CEC (Tamabil-1, Dhum, Sitakundu, Nolua 1 and 2, Barkal and Salbon-2), while others had low (Rangamati, Salbon-1, Khadimnagar-2, Ghagra, Bijipur, Suvolong and Datmara) or very low (Tamabil-2 and Khadimnagar-1) CEC. The variation in CEC may be linked to factors such as soil texture, clay mineral composition, organic matter accumulation, and erosion levels (Shoji et al., 1982). In this study, the relatively low CEC values can be attributed to the sandy texture of the soils, primarily composed of kaolinite (Akhtaruzzaman et al., 2014; Alam et al., 1993).

Fertility properties

Bangladesh soils typically have low organic matter content, with most soils having less than 1.5% at 0-15 cm depth (BARC, 2005). Based on organic matter content, agricultural soils are classified into very low, low, medium, high, and very high categories (Osman, 2013). In Northern and Eastern Hill soils, organic matter content ranged from 1.71 to 5.10% (Table 2). The highest organic matter content (5.10%) was found in Sitakundu, and the lowest content (1.71%) was recorded in Rangamati, Salbon-1, and Suvolong series. The average organic matter content was 2.62%. Sitakundu and Dhum had high organic matter status, while the rest of the soils showed medium level of organic matter (FRG, 2018). Sitakundu soils had the highest status of organic matter, followed by Dhum soils, which could be due to natural forest and forest plantation in areas where the soils have a higher cation exchange capacity than other soils. Most hill soils in developing countries are not fertilized, and the nutrient demands of trees are met primarily through nutrient recycling (Hassan et al., 2017).

Table 2. Particle size distribution, textural classes, pH, EC, CEC and organic matter status of the soils under study

Soil series	Particle size			Textural class	pH	EC ($dS\ m^{-1}$)	CEC ($cmol_c\ kg^{-1}$)	OM (%)
	Sand (%)	Silt (%)	Clay (%)					
Rangamati	58.96	27.28	13.76	Sandy Loam	4.60	0.06	7.12	1.71
Salbon-1	72.96	17.28	9.76	Sandy Loam	4.73	0.04	5.51	1.71
Salban-2	58.96	31.28	9.76	Sandy Loam	4.63	0.07	6.79	3.39
Barkal	30.24	53.28	16.48	Silt Loam	4.54	0.07	8.72	3.44
Khadimnagar-1	72.96	15.28	11.76	Sandy Loam	4.45	0.05	1.99	1.87
Khadimnagar-2	72.24	19.28	8.48	Sandy Loam	4.63	0.05	7.44	2.40
Nolua-1	66.96	23.28	9.76	Sandy Loam	4.90	0.08	8.39	2.97
Nolua-2	34.24	49.28	16.48	Loam	4.74	0.04	4.23	2.49
Sitakundu	60.24	31.28	8.48	Sandy Loam	5.46	0.11	12.6	5.10
Dhum	32.24	51.28	16.48	Silt Loam	4.72	0.09	11.6	3.79
Ghagra	36.24	41.28	22.48	Loam	4.23	0.21	6.47	3.09
Tamabil-1	58.96	31.28	9.76	Sandy Loam	4.98	0.07	8.72	2.28
Tamabil-2	44.24	43.28	12.48	Loam	4.99	0.07	3.85	1.79
Bijipur	62.24	31.28	6.48	Sandy Loam	4.81	0.05	8.72	2.35
Suvolong	54.96	35.28	9.76	Sandy Loam	4.67	0.08	8.39	1.71
Datmara	60.24	25.28	14.48	Sandy Loam	4.66	0.06	6.47	1.87
Average	-	-	-	-	4.73	0.07	7.31	2.62
SE (±)	-	-	-	-	0.06	0.01	0.09	0.04

Data are means of three replicates

In AEZ 29, the total N ranged from 0.07 to 0.16% with an average of 0.11% (Figure 2a). The lowest total N (0.07%) was found in Rangamati and Khadimnagar-1 soils, while the highest N content (0.16%) was observed in Sitakundu, Nolua-1, Ghagra, and Dhum soils. In terms of soil test interpretation, Rangamati, Salbon-1, Khadimnagar (1 and 2), Tamabil-2, Suvolong, and Datmara series had very low levels of total N. On the other hand, Salbon-2, Barkal, Nolua (1 and 2), Sitakundu, Dhum, Ghagra, Tamabil-1, and Bijipur soils had low levels of total N (FRG, 2018). Normally soils with low organic matter contain low N. The amount of available P in the studied soils varied from 1.29 to 10.9 mg kg^{-1} (Figure 2b). The lowest P (1.29 mg kg^{-1}) was recorded in Tamabil-1 soil, and the highest P (10.9 mg kg^{-1}) was noted in Dhum soil. On average, there was 5.39 mg kg^{-1} of available P in AEZ 29. Based on soil test value interpretation, the soil available P status was grouped as very low (Salbon 1 and 2, Nolua-1, Tamabil-1, and Suvolong), low (Rangamati, Barkal, Khadimnagar 1 and 2, Nolua-2, Tamabil-2, Bijipur, and Ghagra), and medium (Sitakundu, Dhum, and Datmara) (FRG, 2018). In the terrace and hilly areas of Bangladesh, acidic soils lack available P. This is because P easily binds with Fe and Al in acidic soils, despite applying additional P (Moslehuddin et al., 1997). Notably, lower pH levels can enhance the availability of metallic ions, particularly Mn, Fe and Al, which can combine with soluble P to form insoluble compounds (Lalljee, 1997). Moreover, the limited microbiological activities in strongly acidic soils can further reduce the availability of soil P (Havlin et al., 1999). Exchangeable K content ranged from 0.16 to 0.99 $cmol_c$ kg^{-1} (Figure 2c). The highest exchangeable K (0.99 $cmol_c$ kg^{-1}) was found in Sitakundu soil, while the lowest exchangeable K content (0.16 $cmol_c$ kg^{-1}) was observed in Nolua-2, Bijipur, and Suvolong soils. The average exchangeable K content for AEZ 29 was 0.34 $cmol_c$ kg^{-1}. Sitakundu and Ghagra soils had a very high level of exchangeable K, while Dhum and Tamabil-2 soils exhibited a high level. Khadimnagar-2, Barkal, Tamabil-1, and Salbon-2 soils had an optimum level of exchangeable K, and Nolua-1 and Datmara soils had a medium level. The remaining soil samples in AEZ 29 showed a low level of exchangeable K. Soil available S content ranged from 10.33 to 22.51 mg kg^{-1} (Figure 2d), with Rangamati having the highest (22.51 mg kg^{-1}) and Ghagra the lowest (10.28 mg kg^{-1}). The average S content was 16.28 mg kg^{-1}. Rangamati, Khadimnagar-1, and Sitakundu soils had a medium S level, while others had low S levels. Low availability of S in the hill soils might be attributed to the sandy texture and leaching loss of sulphate ions from the soils. Exchangeable Ca in the soils ranged from 0.78 to 9.42 $cmol_c$ kg^{-1} (Figure 2e). Sitakundu soil had the highest (9.42 $cmol_c$ kg^{-1}), and Rangamati had the lowest (0.78 $cmol_c$ kg^{-1}) exchangeable Ca. The average was 3.10 $cmol_c$ kg^{-1}. Sitakundu soil showed very high Ca levels, Barkal, Nolua (1 and 2), Tamabil (1 and 2), and Salban-2 had medium Ca levels, while Salbon-1, Dhum, Ghagra, Suvolong, Datmara, and Khadimnagar-2 had low Ca levels. Rangamati, Bijipur, and Khadimnagar-1 had very low Ca levels. The exchangeable Mg content in the

collected soils ranged from 0.58 to 3.83 $cmol_c\ kg^{-1}$ (Figure 2f). Sitakundu soil had the highest exchangeable Mg, while Khadimnagar-1 soil had the lowest. The average exchangeable Mg content was 1.64 $cmol_c\ kg^{-1}$. In terms of soil test value interpretation, Sitakundu, Salbon-2, Barkal, Nolua-2, and Tamabil (1 and 2) soils showed a very high level of exchangeable Mg. Nolua-1, Dhum, Ghagra, Datmara, and Suvolong had a high status, while Salbon-1 had an optimum status of exchangeable Mg. Rangamati, Bijipur, and Khadimnagar (1 and 2) soil series exhibited low exchangeable Mg content. According to Akhtaruzzaman et al. (2014), higher topography enhances the removal of base cations (K, Ca, Mg) through leaching and runoff processes that cause forest hill soils to become gradually acidified.

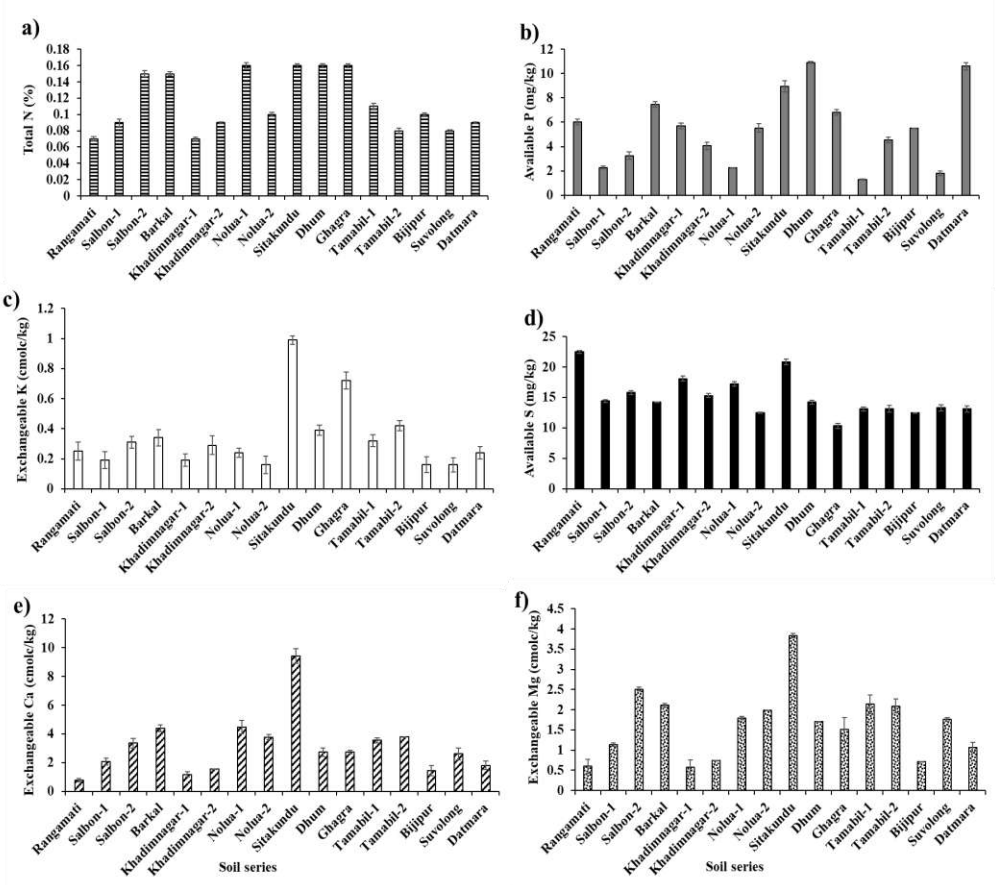


Fig. 2. Macronutrient contents in selected soils of AEZ 29. The status of total N (a), available P (b), exchangeable K (c), available S (d), exchangeable Ca (e), and Mg (f) of 16 soil series at 0-15 cm depth.

The hill soils of Bangladesh are slight to very strongly acid, rich in Fe and Mn and deficient in some macro and micronutrients (Gafur, 2014). The available Fe content of the collected soils varied from 20 to 108 mg kg^{-1} (Figure 3a), with Dhum soil having the highest (108 mg kg^{-1}) and Barkal soil having the lowest (20 mg kg^{-1}) status. The average available Fe content was 67.19 mg kg^{-1} in the hill soils. Based on soil test value interpretation, all the soil samples showed very high level of available Fe. The available Mn content in the studied soils ranged from 24 to 217 mg kg^{-1} (Figure 3b). Barkal soil had the highest (217 mg kg^{-1}) available Mn, while Rangamati and Bijipur soils had the lowest (24 mg kg^{-1}) available Mn. In AEZ 29, the average available Mn content was 79.56 mg kg^{-1}. In terms of soil test value interpretation, all the soil samples exhibited a very high level of available Mn. The higher concentrations of Fe and Mn, are possibly due to parent materials and predominant soil-forming processes prevailing under existing environmental conditions (He, 1990). The available Zn content in the collected soils ranged from 1.09 to 5.07 mg kg^{-1} (Figure 3c). Tamabil-2 soil had the highest (5.07 mg kg^{-1}) available Zn, while Nolua-2 soil had the lowest (1.09 mg kg^{-1}) available Zn. The average available Zn content was 2.64 mg kg^{-1}. Based on soil test value interpretation, Khadimnagar-1, Salbon-2, Nolua-1, Bijipur, Sitakundu, Ghagra, Dhum, Barkal, and Tamabil-2 soils exhibited a very high level of available Zn. Suvolong, Khadimnagar-2, and Datmara had a high Zn level. Rangamati and Tamabil-1 soils showed an optimum Zn level, while Salbon-1 and Nolua-2 had a low level of available Zn. Again, the available Cu content in the collected soils ranged from 0.22 to 1.22 mg kg^{-1} (Figure 3d). Salbon-2 soil had the highest (1.22 mg kg^{-1}) available Cu, while Rangamati soil had the lowest (0.22 mg kg^{-1}) available Cu. The average available Cu content was 0.74 mg kg^{-1}. In terms of soil test value interpretation, Suvolong, Salbon-2, Nolua (1 and 2), Bijipur, Ghagra, Barkal, and Tamabil-2 soils displayed a very high level of available Cu. Khadimnagar-1 had high level, and Sitakundu, Dhum, Tamabil-1, and Datmara had optimum level of available Cu. Rangamati, Salbon-1, and Khadimnagar-2 soils had low status of available Cu. Hassan et al. (2017) reported that mean Zn content is very low for high and medium hill soils and low for low hill soils, while mean Cu content is low for both high and low hill soils but very low for medium hill soils. Cu is scavenged most efficiently by Fe-Mn oxide minerals, clay minerals, and coatings, and it is less mobile than other microelements (Sanaullah and Akhtaruzzaman, 2020). The amount of Zn in soil is mainly determined by the type of rocks and minerals in the parent material of soil (Lindsay, 1979). Research by Kabata-Pendias and Pendias (1952) noted that sandy soils tend to have lower Zn content. The available B status of the collected soils varied from 0.28 to 0.99 mg kg^{-1} (Figure 3e). The highest available B (0.99 mg kg^{-1}) was recorded in Sitakundu soil and the lowest (0.28 mg kg^{-1}) was found in Nolua-2. The mean value of available B in the studied soils was 0.61 mg kg^{-1}. Kadimnagar-1, Salbon-2, Nolua-1, Bijipur, Sitakundu, and Datmara soils showed very high B level whereas Rangamati, Barkal, and Khadimnagar-2 had high B content. Again, Salbon-1, Tamabil-1, and Dhum had optimum B level, while Ghagra,

Suvolong, and Tamabil-2 had medium B content. Nolua-2 soil showed low status of available B (FRG, 2018). Here more than 80% soil samples showed a very high level of B which might be due to the low soil pH.

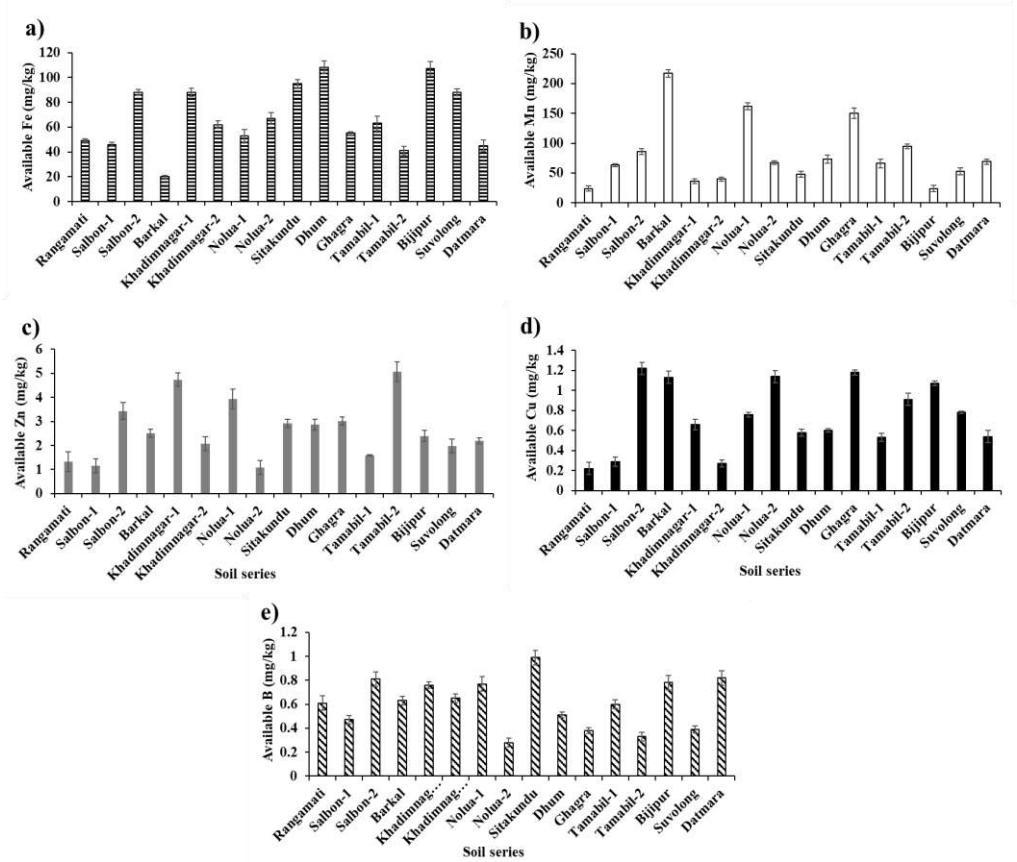


Fig. 3. Micronutrient contents in selected soils of AEZ 29. The status of available Fe (a), Mn (b), Zn (c), Cu (d), and B (e) of 16 soil series at 0-15 cm depth.

Correlation among different properties of soils

Pearson's correlation coefficient revealed positive and negative correlations among different physical, chemical and fertility properties of soils (Figure 4). There was positive significant correlation among 24 associations and negative significant correlation among 7 associations. Organic matter had positive significant correlation with total N, exchangeable K, Ca, Mg and CEC. CEC was significantly correlated with Ca and Total N. Clay content (%) showed a significant positive correlation with EC and silt (%) but had a negative significant relation with pH and sand (%). Soil pH showed significant positive association with exchangeable Ca and Mg. Total N had a

significant positive association with exchangeable K, Ca, Mg, Mn and EC. Exchangeable Ca and Mg both showed significant positive relationship with exchangeable K. Exchangeable K had significant positive relation with EC. Available B showed significant positive relation with available S and sand%. Available Mn showed significant positive relation with Cu but significant negative relation with available Fe. Sand (%) showed significant negative association with silt (%), clay (%) as well as available Mn and Cu.

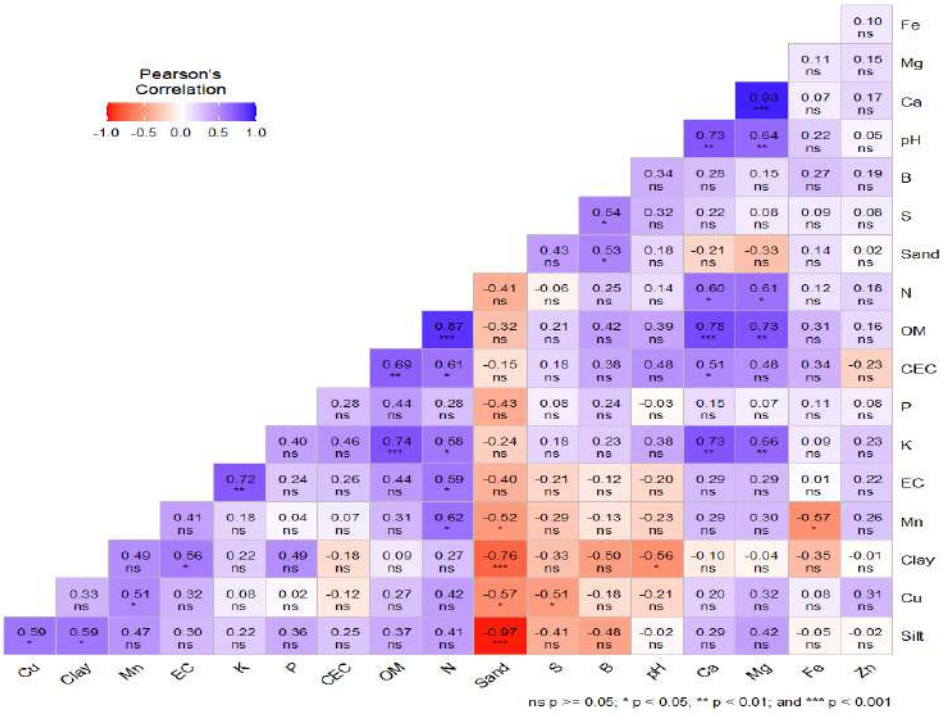


Fig. 4. Estimation of Pearson's correlation coefficients among different properties of hill soils

These findings shed light on the complex relationships among various physicochemical and fertility properties of the studied soils. Sitakundu and Dhum series have the most fertile soils in this region, with higher organic matter content and better nutrient retention. Proper fertilization and management can make this region suitable for crop production. The overall poor status of essential macronutrient elements in all series, such as total N, available P, exchangeable K, and available S, can be attributed to several factors including the low soil pH, sandy texture, soil erosion, run off and leaching of nutrient elements from soil as well as land degradation. A long-term fertility management program by using both organic sources of nutrients such as poultry manure, cow dung, green manure, household

wastes, rice straw and other crop residues and inorganic fertilizers may improve soil health and ensure the sustainability of crop production in the studied areas to some extent.

Conclusion

The soils of AEZ 29 were generally poor in physico-chemical properties such as texture, pH, organic matter, CEC, as well as fertility status, making crop production difficult in this region. The use of lime is mandatory for better crop production and combat soil acidity in the hilly areas of AEZ 29. The soils of this region had low to medium CEC and OM, low levels of total N and available P, and low to medium levels of available S. Exchangeable K, Ca and Mg levels of this soil varied widely from very low to very high. These hill forest soils showed high levels of Fe and Mn, and moderate to high levels of Zn, Cu and B. Overall, some management practices are crucial for agricultural productivity such as erosion control, organic matter addition and precise fertilization for macronutrients etc. Besides, soil test values must be confirmed with crop response studies, and soils should be tested regularly to assess their suitability for crop production. Furthermore, new agricultural technologies and policies should be established with information on resource management in hilly areas that might be useful in facing the challenges of crop production and in preventing soil degradation.

Acknowledgments

The authors gratefully acknowledge the financial support from BAURES (Bangladesh Agricultural University Research System) for research funding and the logistic support from the Department of Soil Science, Bangladesh Agricultural University in conducting the research.

Competing Interest

The authors declare no competing interest

References

Akhtaruzzaman, M., Haque, M., and Osman, K. (2014). Morphological, physical, and chemical characteristics of hill forest soils at Chittagong University, Bangladesh. *Open Journal of Soil Science*, 4(1): 26-35.

Al Mamun, M.M.A., Emon, S.B.T.A., and Alam, M.S. (2021). Soil properties under eight different land uses in Bandarban hill district of Bangladesh. *International Journal*, 5(1): 202-214.

Alam, L., Miyauchi, N., and Shinagawa, A. (1993). Study on clay mineralogical characteristics of hill and terrace soils of Bangladesh. *Clay Science*, 9(2): 109-121.

Balasubramanian, A. (2017). Physical properties of soils. doi: 10.13140/RG.2.2.24150.24648

BARC. (2005). Fertilizer recommendation guide. Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

BARC. (2012). Fertilizer recommendation guide. Bangladesh Agricultural Research Council, Farmgate, Dhaka, Bangladesh.

BBS (Bangladesh Bureau of Statistics). (2023*). Statistical Pocketbook of Bangladesh. BBS*, Dhaka.

Biswas, S., Swanson, M.E., Shoaib, J.U., and Haque, S.M. (2010). Changes in soil chemical properties under modern and traditional farming systems at Khagrachari, Chittagong Hill Tracts, Bangladesh. *Journal of Forestry Research*, 21(4): 451-456.

Biswas, S., Swanson, M.E., and Vacik, H. (2012). Natural resources depletion in hill areas of Bangladesh: A review. *Journal of Mountain Science*, 9(2): 147-156.

Bouyoucos, G.J. (1962). Hydrometer method improved for making particle size analysis of soil. *Agronomy Journal*, 54(5): 465-466.

Brammer, H. (1971). Bangladesh land resources. Technical Report-3 (AGL: SF, Pak-6). FAO, Rome.

Brammer, H. (1996). The geography of the soils of Bangladesh. *University Press Limited*, Dhaka, 1–263.

Bray, R.H., and Kurtz, L.T. (1945). Determination of total organic and available forms of phosphorus in soils. *Soil Science*, 59(1): 39-46.

Bremner, J.M., and Mulvaney, C.S. (1982). Nitrogen-total. In: Page, A.L., Miller, R.H., and Keeney, D.R. (Editors), Methods of Soil Analysis, Part 2, American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, Pp. 595-624.

Chapman, H.D. (1965). Cation exchange capacity. In: Black, C.A. (Editor), Methods of Soil Analysis, American Society of Agronomy, Madison, Pp. 891-901.

Chowdhury, K., Hossain, M.S., and Khan, M.S.H. (2021). Introduction to Bangladesh geosciences and resources potential, Pp. 1-12.

Dhumgond, P., Prakash, S.S., Raj, T.P., Reddy, S.B., and Shivakumar, K.M. (2012). Dynamics of soil organic carbon and their fractions under different cropping systems in Hill Zone Acid Soils of Karnataka. *Madras Agricultural Journal*, 99: 762-768.

Foth, H.D. (1990). Fundamentals of Soil Science, John Wiley and Sons, New York, 8th edition.

FRG (Fertilizer Recommendation Guide). (2018). Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

Gafur, A. (2014). Traditional land use and environmental degradation in the Chittagong Hill Tracts of Bangladesh.

Gafur, A., Jensen, J.R., Borggaard, O.K., and Petersen, L. (2003). Runoff and losses of soil and nutrients from small watersheds under shifting cultivation (Jhum) in the Chittagong Hill Tracts of Bangladesh. *Journal of Hydrology*, 279(1-4): 293-309.

García-Oliva, F., Casar, I., Morales, P., and Maass, J.M. (1994). Forest-to-pasture conversion influences on soil organic carbon dynamics in a tropical deciduous forest. *Oecologia*, 99(3-4): 392-396.

Gauthier, C. (2002). Contribution to the study of fractionation of free aluminium in solutions of forest soils. Influence of quality and nature of organic matter (Doctoral dissertation, Faculté des Sciences et Techniques, Université de Limoges).

Hardie, M., and Doyle, R.B. (2012). Measuring soil salinity. *Methods in Molecular Biology (Clifton NJ)*, 913: 415–425.

Hassan, M., Hassan, R., Pia, H., Hassan, M., Ratna, S., and Aktar, M. (2017). Variation of soil fertility with diverse hill soils of Chittagong Hill Tracts, Bangladesh. *International Journal of Plant and Soil Science*, 18(1): 1–9.

Hassan, M.M. (1994). Forest soils of Bangladesh. *Bangladesh Journal of Forest Science*, 23(2): 1-11.

Havlin, J.L., Beaton, J.D., Tisdale, S.L., and Nelson, W.L. (1999). Soil Fertility and Fertilizers: An Introduction to Nutrient Management, 6th edition, Upper Saddle River, Prentice Hall.

He, Y.C. (1990). The study on geologic environment of Hai Luogou. *Journal of Geology*, 10: 43–48.

Hossain, M.I., Kashem, M.A., and Osman, K.T. (2014). Fertility status of some forested soils of Chittagong Hill Tracts, Bangladesh. *International Journal of Latest Research in Science and Technology*, 3(1), 82-87.

Huq, S.M.I., and Shoaib, J.U.M. (2013). The soils of Bangladesh. In: World Soils Book Series (Vol. 1). Dordrecht: Springer.

Islam, M.A., Hasan, M.A., and Farukh, M.A. (2017). Application of GIS in general soil mapping of Bangladesh. *Journal of Geographical Systems*, 9(5): 604-621.

Islam, M.S., Hasan, G.M.J., and Chowdhury, M.A.I. (2006). Destroying hills in the north-eastern part of Bangladesh: A qualitative assessment of extent of the problem and its probable impact. *International Journal of Environmental Science and Technology*, 2(4): 301-308.

Jackson, M.L. (1973). Soil Chemical Analysis-Advanced Course: A Manual of Methods Useful for Instruction and Research in Soil Chemistry, Physical Chemistry of Soils, Soil Fertility, and Soil Genesis, 2nd edition.

Kabata-Pendias, A., and Pendias, H. (1992). Trace Elements in Soils and Plants, 2nd edition, CRC Press, Boca Raton, Pp. 365.

Keren, R. (1996). Boron. In: Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T., and Sumner, M.E. (Editors), Methods of Soil Analysis: Part 3, Chemical Methods, American Society of Agronomy, Madison, Wisconsin, USA, Pp. 603-626.

Knudsen, D., Peterson, G.A., and Pratt, P.F. (1982). Lithium, sodium and potassium. In: Page, A.L., Miller, R.H., and Keeney, D.R. (Editors), Methods of Soil Analysis: Part 2, American Society of Agronomy, Madison, Pp. 225-247.

Kooch, Y., Samadzadeh, B., and Hosseini, S.M. (2017). The effects of broad-leaved tree species on litter quality and soil properties in a plain forest stand. *Catena*, 150: 223–229.

Lalljee, B. (1997). Phosphorus fixation as influenced by soil characteristics of some Mauritian soils. Food and Agricultural Research Council, University of Mauritius, Réduit.

Lindsay, W.L. (1979). Chemical Equilibria in Soils, John Wiley and Sons Ltd., Pp. 449.

Lindsay, W.L., and Norvell, W.A. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Science Society of America Journal*, 42(3), 421-428.

Moslehuddin, A.Z.M., Laizoo, S., and Egashira, K. (1997). Fertility status of Bangladesh soils- A review. *Journal Faculty Agriculture, Kyushu University*, 41: 257-267.

Nath, T.K., Inoue, M., and Chakma, S. (2005). Shifting cultivation (jhum) in the Chittagong Hill Tracts, Bangladesh: Examining its sustainability, rural livelihood and policy implications. *International Journal of Agricultural Sustainability*, 3(2): 130-142.

Osman, K.T. (2013). Soils: Principles, Properties and Management. Springer, Dodrecht, the Netherlands.

Rao, K.V. (1992). Dynamics of aluminium in base unsaturated soils of Karnataka. Ph.D. Thesis, University Agricultural Science, Bangalore, India.

Rasul, G., and Thapa, G.B. (2007). The impact of policy and institutional environment on costs and benefits of sustainable agricultural land uses: The case of the Chittagong Hill Tracts, Bangladesh. *Environmental Management*, 40(2): 272-283.

Reddy, C.H.B.R., and Subramanian, K.S. (2016). Synthesis and characterization of nano-amendment for effective remediation of soil acidity. *Asian Journal of Soil Science*, 11(1): 51-57.

Robertson, G.P., and Vitousek, P.M. (1981). Nitrification potentials in primary and secondary succession. *Ecology*, 62(2): 376-386.

Roy, M.K., Ahmed, S.S., Bhattacharjee, T.K., Mahmud, S., Moniruzzaman, M., Haque, M.M., Saha, S., Molla, M.I., and Roy, P.C. (2012). Paleoenvironment of deposition of the Dupi Tila Formation, Lalmai Hills, Comilla, Bangladesh. *Journal Geological Society of India*, 80(4): 409-419.

Sanaullah, A.F.M., and Akhtaruzzaman, M. (2020). Studies on some micronutrient status of soils of two South Eastern Forest and agricultural areas of Bangladesh. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 14(6): 40-45.

Shoji, S., Fujiwara, Y., Yamada, I., and Saigusa, M. (1982). Chemistry and clay mineralogy of Ando soils, brown forest soils, and podzole soils formed from recent Towada ashes, Northeastern Japan. *Soil Science*, 133(2): 69-86.

Walkey, A.J., and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1): 29-38.

Williams, C.H., and Steinbergs, A. (1959). Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research*, 10(3): 340-352.

SAARC J. Agric., 22(2): 99-113 (2024) *DOI: DOI:https://doi.org/10.3329/sja.v22i2.75222*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Nitrogen Application Alters Growth and Yield of Brri DHAN28

M. Biswas, K.G. Quddus and M.S. Jahan*
Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh

Abstract

Nitrogen is not only a major nutrient but the most limiting nutrient element for rice production. The present study was conducted to examine the effect of different doses of nitrogen on growth and yield of BRRI dhan28. The experiment was conducted in a Randomized Complete Block Design (RCBD) with four replications. The treatments include six doses of nitrogen, 0 - 175 kg N ha^{-1} with an interval of 35 kg N ha^{-1} as urea. Data on growth and yield contributing characters of rice were collected and analyzed statistically. The optimum dose for BRRI dhan28 was estimated 140 kg N ha^{-1}. Results showed that plant height (cm), tillers m^{-2} and dry matter (kg ha^{-1}) yield increased significantly with increasing levels of N. However, at 60 DAT, plant height (cm), tillers m^{-2} and dry matter (kg ha^{-1}) production with 140 kg N ha^{-1} were statistically similar to that displayed by other nitrogen doses. The yield contributing parameters especially the panicle m^{-2} and test weight (g) were found superior with the treatment of 140 kg N ha^{-1}. Application of 140 kg N ha^{-1} showed AE and PFP for N as 14.5 kg kg^{-1} and 23.31, respectively. Application of N fertilizer @ 140 kg ha^{-1} increased grain yield by about 62% compared to N-control treatment in BRRI dhan28.

Keywords: Boro rice, BRRI dhan28, Growth, Nitrogen, Yield

Introduction

Rice is the most dominant cereal food in Bangladesh and provides two-third of total calorie requirement and about one-half of the total protein consumption of an average person in the country (BRRI, 2023). In Bangladesh rice is cultivated in three seasons

* Corresponding author: mjahan70@at.ku.ac.bd

Received: 30. 07. 2024 *Accepted: 30. 11. 2024*

namely Aus (March-September), Aman (July-December) and Boro (November-May) (Shelley *et al*., 2016, Al Mamun *et al*., 2021). Boro is the principal rice crop here regarding amount of production. But, the national mean yield of boro rice is lesser (4.193 t ha^{-1}) than that of other rice-producing nations (BRRI, 2022). It is mentionable that for rice production application of fertilizer and water are two important management practices. Though nitrogen fertilizer plays a major role in rice production, all fertilizers should be applied judiciously for increasing crop productivity (Islam *et al*., 2018).

Nitrogen (N) is one of the supreme yield-controlling nutrient elements in rice cultivation worldwide, especially in tropical Asia (Saleque *et al*., 2004). It is an essential constituent of chlorophyll and increases leaf photosynthesis which promotes growth of the crop. Rice plants need N during vegetative stage to stimulate growth and tillering, which ultimately governs the number of panicles. Nitrogen contributes to spikelet production and sink size formation throughout the panicle formation stage. It also helps in grain filling, taming the photosynthetic capacity, and stimulating carbohydrate buildup in culms and leaf sheaths (Mae, 1997). Bufogle *et al.,* (1997) reported that nitrogen absorbed by rice during the vegetative growth stages contributed in growth during reproduction and grain-filling through translocation. This could support minimize pressures posed by break down of structural protein in stem and leaves, thus prolonging the life-period of green leaves by preserving high photosynthetic rate (Juan *et al.,* 2006). Plant growth is seriously hampered when lower dose of nitrogen is applied, which drastically reduces the yield. It is a concern that inadequate usage of nitrogen, instead of providing yield benefit, may decrease the same (Adhikari *et al.,* 2018). A number of studies have indicated that an optimum dose of nitrogen is essential for good rice yield. Jahan *et al*., (2014) demonstrated that grain yield of three local aromatic rice varieties increased progressively up to 60 kg ha^{-1} and then declined with higher doses. Khatun *et al*., (2014) indicated that the highest yield of rice varieties, BRRI dhan28 and BRRI dhan29 was obtained with 150 kg N ha^{-1}. However, both excess and insufficient supply of N may decrease grain yield of rice to a great extent (Awan *et al*., 2011). An adequate N supply can increase as much as 60% rice production over control (Mikkelsen *et al.,* 1995).

A number of studies have been conducted in Bangladesh to examine the effect of nitrogen levels on rice yield on the yield of BRRI dhan28 (Diba *et al*., 2005, Khatun *et al*., 2014, Hoque *et al*., 2021, Mollik, 2022). Determination of the optimum dose nitrogen for rice in coastal soils received scanty attention. Islam *et al*., (2015) reported 145 kg N ha^{-1} in one year and 200 kg ha^{-1} in the following year in BRRI dhan29 in a coastal non-saline soil. Although BRRI dhan28 is a salt-sensitive rice variety, many coastal farmers prefer to grow BRRI dhan28 in low to moderately saline soils with non-saline irrigation water. Under these situations, the present study was undertaken to determine the optimum dose of N on growth and yield of BRRI dhan28 in a coastal saline soil of Bangladesh.

Material and Methods

Experimental site

The experiment was accomplished during Boro season (January to May) at the Professor Dr. Purnendu Gain Field Laboratory, Agrotechnology Discipline, Khulna University, Khulna. The experimental site is under the agro-ecological zone Gangas Tidal Flood Plain (AEZ-13, Bajoa silty clay loam). The climate of the experimental site enjoys low temperature and humidity during the *Rabi* season and relatively high temperature, humidity, and heavy rainfall during the *Kharif* season. The experimental field soil (0-15 cm) had pH 7.90, organic matter 3.66%, total N 0.17%, available P 12 (µg/g soil), exchangeable K 0.47 (cmol/kg) and available Zn 0.76 (µg/g soil). The field soil was rich in sulphur 96 (µg/g soil) and B 0.63 (µg/g soil). The experimental field soil was moderately saline (EC 5.04 dS m^{-1}).

Treatments and experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with 4 replications and 6 treatments 0, 35, 70, 105, 140 and 175 kg N ha^{-1}.

Seed collection and raising of seedlings

BRRI dhan28, a high yielding rice variety was used as a test crop in this experiment. Seeds were immersed in water in a bucket for 24 hrs. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs. The nursery bed was prepared by puddling with repeated plowing followed by laddering. The sprouted seeds were sown in the seed bed uniformly as possible on December 12.

Preparation of main field

The experimental land was ploughed on with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings followed by laddering to have a good puddled field. All kinds of weeds and crop residues were removed from the field. Individual plots were cleaned and finally leveled with the help of a wooden plank.

Crop management

The experimental field was fertilized with 60 kg TSP, 90 kg MOP, 6 kg zinc sulfate and 52 kg gypsum ha^{-1}, respectively as suggested by BRRI. Full doses of fertilizers except urea were applied during final land preparation and thoroughly incorporated into the soil. Urea was top dressed in three equal installments at 20, 35, and 50 days after transplanting (DAT). Forty-day-old seedlings were uprooted carefully and were transplanted as per experimental treatment on January 21. Three seedlings were given in each hill, and spacing between plant to plant and row to row of (20 x 20) cm was maintained properly. Two hand weeding were done to check weed infestation in the crop at 30 and 50 DAT. In the field 2-4 cm of standing water was maintained throughout the growing period until the grain filling stage. Furadan 5G was applied at 21 DAT to control ufra and malathion @ 1.00 l ha^{-1} was applied to control insects.

The crop was harvested at full maturity when 80% of the grain turns golden yellow. Before harvesting five hills were uprooted randomly from each plot for taking yield components data. Grain and straw yields were adjusted at 14% moisture and recorded as a whole plot (10 m^2) basis.

Data collection and analysis

Data were recorded for different growth parameters (plant height, tillers $hill^{-1}$and dry matter $hill^{-1}$) starting from 45 DAT and continue till maturity. Data on yield and yield attributes (effective tiller m^{-2}, grains $panicle^{-1}$, 1000-grains weight, grain yield, biological yield and harvest index) were gathered after harvest. Before harvesting five hills were uprooted randomly from the center rows of each plot for obtaining effective tiller m^{-2}, grains $panicle^{-1}$and 1000-grain weight data. Grain and straw yields were adjusted at 14% moisture and recorded as a whole plot (10 m^2) basis, and then converted to per hectare basis. Biological yield was calculated with the following formula:

Biological yield (t/ha) = Grain yield (t/ha) + Straw yield (t/ha)

The harvest index (%) was estimated by the formula given by Donald and Humblin (1976):

Harvest Index (%) = (Grain yield/Biological yield) x 100

The recorded data were analyzed following the analysis of variance (ANOVA) technique by using a computer package Statistical Tools for Agricultural Research (STAR). Regression analysis (linear and polynomial) was used to examine the relationships between various nitrogen levels and growth parameters as well as between different nitrogen levels and yield parameters and yield. Student's'*t*' statistic was employed to test the significance level of various constants (a, b and c) and '*F*' test for the coefficient of determination (R^2).

Optimum dose of N

Functional relationship between grain yield and nitrogen doses was established using regression analysis. Optimum nitrogen dose was determined by differentiating the quadratic N response equation (Colwell, 1994). The form of the quadratic equation was given by,

$\bar{Y} = a + bN + cN^2$

Where is estimated output (e. g. yield), N is applied rate of nitrogen application, a is intercept, b and c are regression coefficients.

Differentiating the above equation we get,

$d\bar{Y}/dN = b + 2cN$

The optimum rate of N at the point where,

$d\bar{Y}/dN = 0$

$0 = b + 2cN$

$N = -b/2c$

The economic optimum dose of N was

Where, P_f is Price of fertilizer and P_y is price of product.

Nutrient use efficiency

Agronomic use efficiency and partial factor productivity of applied nitrogen was calculated by the following equation (Khatun, 2013):

Agronomic use efficiency (kg kg $^{-1}$) was expressed as the difference in grain yield between N fertilized and N-control plot divided by the quantity of N applied, as

$AE = (Y_f - Y_0)/N_a$

Where, AE is agronomic use efficiency ((kg kg $^{-1}$), Y_f *i*s the grain yield (kg ha^{-1}) with N, Y_0 is the yield (kg ha^{-1}) in N-control plot and N_a is the amount of applied N (kg).

Partial factor productivity (PFP) is the grain yield per quantity of nitrogen applied. PFP is unit less and can be calculated as

$PFP = Y_f/N_a$

Results and Discussion

Crop growth characters

Plant height, tiller m $^{-2}$ and dry matter yield at panicle initiation stage (60 DAT)

Nitrogen (N) is the key element in the production of rice and gives by far the largest response in plant height which promotes entire growth and development of plant. Different N levels showed significant effects on plant height for all growth stages (data not shown). Regardless of treatment differences, plant height increased progressively up to maturity (data not shown). In all growth stages the highest plant height was observed with N_5 (175 kg N ha^{-1}) and the lowest plant height was recorded from control treatment, N_0. Plant height at the panicle initiation (PI) stage ranged from 71 cm in the N-control plot to 85 cm in the plot receiving the highest dose of N (Table 1).

A linear regression equation explained the relationship between plant height and the applied N (Table 1). Intercept, regression coefficient and R^2 were significant for the linear relationship (p value the parameters were 0.00, 0.01 and 0.01, respectively). Shorter plant at 140 kg N ha^{-1} compared to both 105 and 175 kg N ha^{-1}, was an observation in the plant height data. Taller plant usually bears more leaves, produces more photosynthesis and eventually contributes to yield of rice. However, excessive plant height may contribute to plant lodging and tolls yield.

Table 1. Response of plant height, tiller m^{-2} and dry matter yield m^{-2} at the panicle initiation stage (60 DAT) to the applied nitrogen in BRRI dhan28

Applied N (kg ha^{-1})	Plant height (cm)	Tiller m^{-2}	Dry matter (kg ha^{-1})
0	71	266	9905
35	76	345	10970
70	80	429	12437
105	83	452	12650
140	80	519	13827
175	85	521	13900
a	73 ± 2 (p = 0.00)	292 ± 20 (p = 0.00)	10227 ± 307 (p = 0.00)
b	0.07 ± 0.02 (p = 0.01)	1.48 ± 0.19 (p = 0.01)	23.48 ± 2.90 (p = 0.01)
R^2	0.81 (p = 0.01)	0.93 (p = 0.01)	0.94 (p = 0.01)

Previous report showed the highest plant height of 86 cm with 200 kg N ha^{-1} application in BRRI dhan28 (Chameley *et al.* (2015). Paramanik *et al.* (2015) and Sarker *et al.* (2018) also found that the plant height considerably increases with the higher doses of nitrogen.

Number of tillers m^{-2}

Tiller number m^{-2} was significantly influenced by the nitrogen levels at all growth stages (data not shown). Irrespective of nitrogen rates, tiller production increased progressively up to 75 DAT and declined slightly at maturity (data not shown). Earlier studies also showed reduction in tillers m^{-2} in boro rice after 50% flowering that continued to harvest (Ahmed *et al.*, 2018). The results indicates that the number of tillers per unit area was the highest at the 75 DAT and after that began to decline owing to the mortality of tertiary tillers under plant competition for growth resources (Bhuyan *et al*., 2014, Haque and Haque, 2016). Except 45 DAT, in other growth stages the maximum number of tillers was obtained with N_5 (175 kg N ha^{-1}) and the minimum number was found in control treatment, N_0. Tillers number at the PI stage varied from 266 in the N-control plot to 521 in the plot getting 175 kg N (Table 1). A linear regression equation clarified the association between tillers number and the N dose (Table 1). Intercept, regression coefficient and R^2 were significant for the linear relationship (p value the parameters were 0.00, 0.01 and 0.01, respectively). Our findings corroborate with findings of Adhikari *et al.* (2018) who reported that tillers m^{-2} increase with the increased dose of nitrogen. Chamely *et al.* (2015) also recorded the higher number of tillers per unit area with the application of 200 kg N ha^{-1}.

Dry matter (kg ha^{-1})

Total dry matter (TDM) production denotes the production potential of a crop and high TDM production is the prerequisite for high yield. TDM of rice plants were measured at 45, 60, and 75 DAT and at harvest (data not shown). Accumulation of dry matter was very slow at early stage (45 to 60 DAT) and increased progressively over time attaining the highest at harvest (data not shown). Dry matter m^{-2} was significantly influenced by the nitrogen levels at all growth stages except 45 DAT (data not shown). A linear regression equation described the correlation between dry matter m^{-2} and the N rates (Table 1). Intercept, regression coefficient and R^2 were significant for the linear relationship (p value the parameters were 0.00, 0.01 and 0.01, respectively). At 60 DAT (PI stage) the highest dry matter (13,900 kg ha^{-1}) was obtained with the treatment N_5 (175 kg ha^{-1}) and the lowest (9905 kg ha^{-1}) was obtained from $N_{0,}$ the control treatment. Application of nitrogen causes significant difference in the pattern of partitioning of dry matter of rice at all the growth stages where low nitrogen levels triggers allocation of lowest dry matter to all plant parts (Haque and Haque, 2016).

Yield contributing characters

Number of panicle m^{-2}, field grain per panicle and 1000-grain weight

The variation of panicle m^{-2} due to nitrogen rates is shown in Table 2. It was observed that in BRRI dhan28 the number of panicles increased with the increasing level of nitrogen. In plots getting the control treatment, BRRI dhan28 produced 315 panicles m^{-2}. Receiving 35 kg N ha^{-1}, panicles m^{-2} in BRRI dhan28 reached 320. At 70 kg N ha^{-1}, BRRI dhan28 produced 358 panicles m^{-2} which increased to 392 with 105 kg N application. Application of 140 kg N ha^{-1} increased panicles m^{-2} sharply to 417 in BRRI dhan28. However, there was slight reduction in panicles m^{-2} in plots receiving 175 kg N ha^{-1}. Previous studies also reported more number of panicles m^{-2} in BRRI dhan28 with higher rates of N (Khatun *et al*., 2014). According to their findings, application of 250 kg N ha^{-1} (314) produced 109 more panicle m^{-2} compared to N-control treatment (205). The polynomial function ($Y = 305 + 0.930N – 0.0016N^2$, $R^2 = 0.93^*$) elucidated the relationship between applied N and panicles m^{-2} (Table 2). Adequacy of nitrogen probably favored the cellular activity during tiller formation and development, which led to increased number of panicles. This finding commensurate with the statement made by Pramanik *et al.* (2015) that number of panicles m^{-2} increases with the increment of nitrogen level up to 75 kg N ha^{-1} and thereafter decreases in 100 kg N ha^{-1}. Miah *et al.* (2012) found that panicles m^{-2} was affected by the doses of nitrogen as USG 240 kg N ha^{-1}.

Table 2. Effect of various nitrogen doses on yield and yield attributes of BRRI dhan28 rice

Nitrogen dose (kg ha^{-1})	Panicles m^{-2}	Filled grains panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
0	315	76	21.03	1.22	3.24	37.59
35	320	84	21.36	2.46	5.11	47.85
70	358	98	22.08	3.11	6.26	49.66
105	392	99	21.92	3.92	7.29	53.76
140	417	105	22.17	3.25	6.17	52.73
175	411	108	22.07	3.8	6.98	53.61
a	304.96**	76*	20.99*	1.29*	3.35*	38.67**
b	0.9301^{ns}	0.328*	0.0163*	0.0353*	0.055*	0.229*
c	-0.0016^{ns}	-0.00083^{ns}	-0.000058^{ns}	0.00013^{ns}	0.00021**	-0.00085*
R^2	0.93*	0.97**	0.91*	0.92*	0.91*	0.95*
Optimum N (kg ha^{-1})	290	197	139	140	132	135

Filled grains panicle^{-1}

The application of nitrogen increased filled grains panicle^{-1} (Table 2). The lowest filled grains panicle^{-1} (76) was observed from the control plot, which increased to 84 with 35 kg N ha^{-1}. Increasing the N rates increased grain per panicle progressively up to 108 with 175 kg N ha^{-1}. A quadratic equation ($Y = 76 + 0.328^{*}N - 0.00083^{ns}N^2$, $R^2 = 0.97^{**}$) explained the relationship between applied N and filled grain per panicle (Table 2). This result agrees to the observation made by Ahmed *et al.* (2005) that N fertilizer management significantly affects the number of grains panicle^{-1}. Khatun *et al*., (2014) obtained the higher number of grains panicle^{-1}with 50 kg N ha^{-1}, while the inferior number from plots receiving no nitrogen in BRRI dhan28 during boro season. Their study further disclosed that in BRRI dhan28 the growth in number of grains per panicle was 31% at 50 kg N ha^{-1} (114) compared to control-N treatment (87).

1000-grain weight (g)

Weight of 1000 grains is one of the most important parameters among the yield contributing characters. The application of N changed in the 1000-grain weight by about 5.42%, the lowest (21.03 g) in the control plots and the highest (22.17 g) with 140 N kg ha^{-1} applications (Table 2). The quadratic equation $Y = 21 + 0.016N - 0.000058N^2$, $R^2 = 0.91^{*}$, explained the relationship between applied N and the1000-grain weight of BRRI dhan28 in the coastal soil. The estimated optimum level of N

for the 1000-grain weight of BRRI dhan28 was 139.5 kg ha^{-1}. Mohaddesi *et al.* (2011) reported that the 1000-grain weight was significantly influenced by increasing nitrogen levels in the rice line 843 in Iran. They recorded an increase in 1000-grain weight of 5.2% at 250 kg N ha^{-1} application compared to 300 kg N ha^{-1} application in the year 2006. However, the 1000-grain weight of rice usually varies with variety. Management practices poorly influence 1000-grain weight of a given variety. Under most conditions, the 1000-grain weight for a given variety varies only slightly (Yoshida, 1981).

Grain yield (t ha^{-1})

The lowest grain yield (1.22 t ha^{-1}) was obtained with the native N, which increased to 2.46 t ha^{-1} with the application of 35 kg N ha $^{-1}$. Increasing the level of N application, increased grain yield progressively up to 105 kg N ha^{-1}, and then there was noticeable decrease with 140 kg N ha^{-1}. Increasing the rate of N application to the highest level (175 kg N ha^{-1}) increased grain yield but that was lower than the yield obtained with 140 kg N ha^{-1}. Increased doses of nitrogen helps increase panicle length, effective tillers per hill, and filled grains panicle^{-1} which ultimately enhances the grain yield (Miah *et al.* 2012). This results consonance with the findings of Haque and Haque (2016) who found the highest grain yield (5.36 t ha^{-1}) in BUDhan 1 during aman season when the crop was fertilized with 60 kg N ha^{-1} followed by 80 kg N ha^{-1} (4.99 t ha^{-1}).

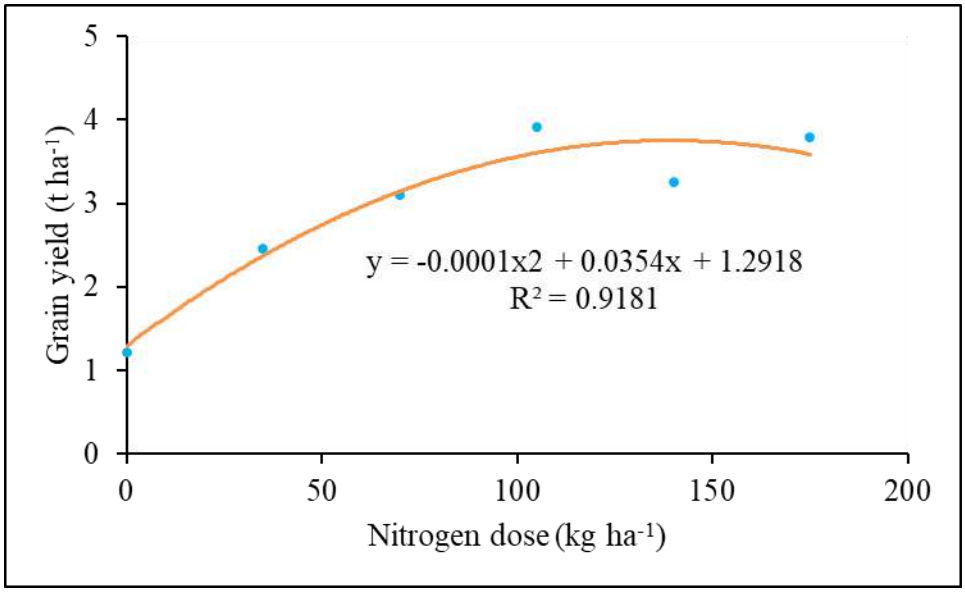


Fig. 1. Functional relationship between grain yield and different doses of nitrogen

Plotting grain yield (t ha^{-1}) against N doses produced a polynomial line (Figure 1). From Figure 1 it is clear that the responses of rice yield to nitrogen was usually rapid at low levels, slower at intermediate levels and could become negative at high levels. The relationship between the variables under consideration produced was explained by a polynomial regression equation $Y = 1.29 + 0.03531N – 0.00013N^2$. ($R^2$= 0.92*). The equation explained that about 92% the variation in yield was explained by various nitrogen applications. Differentiating the polynomial equation, the optimum level of N for rice was 140 kg N ha^{-1} in the experimental field. Khatun *et al*. (2016) also found a quadratic relationship between grain yield and nitrogen doses in BRRI dhan28. Singh *et al*., (1998) also demonstrated that increased grain yield of 20 lowland rice genotypes was gained at 150–200 kg N ha^{-1} at IRRI, Philippines. In fertilizer experiments, 90% of the maximum yield is frequently considered as an economical dose (Fageria *et al*., 2003). The 90% of the maximum grain yield was attained at 136 kg N ha^{-1} (Fageria *et al*., 2008). Likewise, Dobermann *et al*., (2000) received the highest mean grain yield during the dry season at IRRI, Philippines with 120 to 150 kg N ha^{-1}. Singh *et al*., (2007) detected 120 kg N ha^{-1} as an optimum rate for a yield level of 7.45 and 6.80 t ha^{-1} in Indo-Gangetic plain of Ludhiana, India.

It is worth to mention that the rice yield was lower than the expected in experimental field soil. The experimental field soil had 0.17% N, which is sufficient to produce 4.25 t grain ha^{-1} according to the equation derived from (IRRI, 1980),

Where, is estimated yield t ha^{-1}, N_f is N applied through fertilizer, S_N is total N content in soil. The soil had capacity to produce about 6.88 t ha^{-1} with the application of 105 kg N ha^{-1}, which is about 75% higher than the obtained yield of 3.92 t ha^{-1}.

The reason for the lower yield in the experimental field may be attributed to (i) delay transplanting, (ii) aged seedlings, (iii) salinity stress at panicle initiation stage, (iv) mild insect (stem borer) and disease (blast) infection in the ripening phase, and/or (v) tendency to lodge during maturity (Islam *et al*., 2015, Ahmed *et al*., 2022).

Biological yield (t ha^{-1})

Table 2 shows the effects of different N treatments on biological yield. Biological yield was significantly influenced by different doses of nitrogen. The highest biological yield (7.29 t ha^{-1}) was obtained from N_3 which was statistically different from N_{35} (5.11 t ha^{-1}) and N_0 (3.24 t ha^{-1}). The lowest yield (3.24 t ha^{-1}) was recorded from the control. The quadratic equation $Y = 3.35 + 0.05539N – 0.00021N^2$, R^2 = 0.91* explained the relationship between N application and biological yield. The optimum N was estimated as 132 kg ha^{-1} for the biological yield. These results are in agreement with the findings of Singh and Lallu (2005) who reported that each increment doses of nitrogen significantly increased biological yield over its preceding dose.

Harvest index (%)

Harvest index is the ratio of grain yield and biomass yield and is expressed in percentages (%). Results revealed that harvest index was significantly affected by

different level of N application (Table 2). The highest harvest index (53.76%) was resulted from N_{175} that was statistically similar to harvest index noticed from N_{105} and N_{140}. The lowest harvest index (37.59%) was resulted from N_0. Polynomial equation $Y = 38.67 + 0.229N - 0.00085N^2$, $R^2 = 0.95^*$ explained the relationship between the rate of N application and HI of BRRI dhan28 (Table 2). However, Pramanik and Bera (2013) reported substantial influence of nitrogen on harvest index, maximum harvest index (47.07%) was detected when nitrogen was applied @ 150 kg ha^{-1} while minimum (42.60%) was achieved in control treatment.

Nitrogen use efficiency

Agronomic use efficiency (AE) of N in BRRI dhan28 varied from 14.50 to 35.43 kg kg^{-1} (Table 3). The AE was the highest at 35 kg N ha^{-1} and then decreased progressively with the increase of N rates up to 140 kg N ha^{-1}. There was a little reduction in AE when application was 175 kg N ha^{-1}. The 140 kg N ha^{-1}, which was the desired level of N application for coastal soils, had AE of 14.50 kg kg^{-1} (Table 3). Prior studies disclosed AE of BRRI dhan29 ranging from 6.0 to 35.7 kg kg^{-1} in 2009 but from 12.36 to 24.40 kg kg^{-1} during 2010 in a tidal flooded non-saline soil of Barisal, Bangladesh (Islam *et al.*, 2015). Khatun *et al.*, (2015) obtained significant variation in AE in BRRI dhan28 for urea deep placement in two locations of Gazipur, Bangladesh. They documented an AE of 22.0 to 42.0 kg kg^{-1} in BRRI dhan28 at BRRI farm, Gazipur, while 18.0 to 31.0 at Dhirasshram village, Gazipur Sadar Upazila, Gazipur, Bangladesh. Fageria and Baligar (2001) reported that AE was 23 kg grain produced per kg of N applied across N rates. Yoshida (1981) reported AE in lowland rice in the tropics in the range of 15 to 25 kg grain produced per kg of applied N.

Table 3. Agronomic use efficiency and partial factor productivity of N by BRRI dhan28

Applied N (kg ha^{-1})	Agronomic Use Efficiency (AE) (kg kg^{-1})	Partial Factor Productivity (PFP)
0	-	-
35	35.43	70.28
70	27.00	44.43
105	25.71	37.33
140	14.50	23.31
175	14.74	21.71

Partial Factor Productivity (PFP) of N in BRRI dhan28 differed from 21.71 to 70.28 (Table 3). The PFP was the highest at 35 kg N ha^{-1} and then declined gradually with the increase of N rates. The 140 kg N ha^{-1}, which was the anticipated level of N

application for coastal soils, had PFP of 23.31 (Table 3). Former studies reported that PFP of N ranged from 18 to 83 in BRRI dhan28 (Khatun, 2013). Khatun *et al*., (2015) described significant variation in PFP in BRRI dhan28 for urea deep placement in two locations of Gazipur, Bangladesh. They reported PFP of 57.20 to 81.87 in BRRI dhan28 at BRRI farm, Gazipur, while 59.90 to 84.73 at Dhirasshram village under Gazipur Sadar Upazila, Gazipur, Bangladesh.

Conclusion

Results revealed that grain yield, yield components and biological yield of rice grown in Bajoa silty clay loam soil were significantly influenced by N rates. Hence, proper nitrogen management is vital for improving N use efficiency and obtaining more rice yield. The optimum N dose for coastal soils in Boro season might be 140 kg ha^{-1} for rice. The application of 140 kg N ha^{-1} offered taller plants (80 cm), 519 tillers m^{-2} and a biomass of 13,827 kg ha^{-1}. Similarly, panicles m^{-2} as well as 1000-grain weight (g) was found maximum with 140 kg N ha^{-1}. The application of 140 kg N ha^{-1} exhibited AE and PFP for N as 14.5 kg kg^{-1}, and 23.31, respectively in BRRI dhan28. Application of N fertilizer increased grain yield by about 1.2-2.6 t ha^{-1} compared to control in BRRI dhan28. Thus, adequate N application is one of the approaches to increase straw yield and subsequently grain yield in coastal soil.

References

Adhikari, A., Sarkar, M.A.R., Paul, S.K. and Saha, K.K. (2018). Impact of nutrient management on the yield performance of some aromatic fine rice (*Oryza sativa* L.) varieties in Boro season. *Archives of Agriculture and Environmental Science*, 3(3): 245-251.

Ahmed, M., Islam, M. and Paul, S.K. (2005). Effect of nitrogen on yield and other plant characters of local T. Aman rice variety Jatai. *Research Journal of Agriculture and Biological Sciences*, 1(2): 158- 161.

Ahmad, R. (2022). Mega rice varieties becoming less productive, pest susceptive. The Dhaka Tribune. https://www.dhakatribune.com/bangladesh/2022/04/22/mega-rice varieties-becoming-less-productive

Ahmed, A., Rashid, M.M., Rahman, M.J. and Islam, M.S. (2018). Performance of boro rice in response to different application methods of urea fertilizer. *Turkish Journal of Agriculture - Food Science and Technology*, 6(7): 869-876. doi: https://doi.org/10.24925/turjaf.v6i7.869-876.1826

Al Mamun, M.A., Nihad, S.A.I., Sarkar M.A.R., Aziz, M.A., Qayum, M.A., Ahmed, R., Rahman, N.F.A., Hossain, M.I. and Kabir, M.S. (2021). Growth and trend analysis of area, production and yield of rice: A scenario of rice security in Bangladesh. *PLoS ONE*, 16, 12: e0261128.

Awan, T.H., Ali, R.I., Manzoor, Z., Ahmad, M. and Akhtar, M. (2011). Effect of different nitrogen levels and row spacing on the performance of newly evolved medium grain rice variety, KSK-133. *Journal of Animal and Plant Sciences*, 21(2): 231-234.

BBS. (2023). Yearbook of Agricultural Statistics-2022. Bangladesh Bureau of Statistics (BBS), Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh. Pp. 673.

Bhuyan, M.H.A., Ferdousi, M.R. and Iqbal, M.T. (2014). Increasing yield and agronomic efficiency of boro rice (*Oryza sativa*) by fertigation with bed planting compared with conventional planting. *International Journal of Agriculture and Biological Engineering*, 7(5): 34-47. doi: 10.3965/j.ijabe.20140705.004

BRRI. (2022). *Adhunic Dhaner Chash (24th edition)* (in Bengali). Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. Pp. 114.

BRRI. (2023). Bangladesh Rice Knowledge Bank. Training Division, Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh.

Bufogle, A., Bollich, P.K., Norman, R.J., Kovar, J.L., Lindau, C.W. and Macchiavelli, R.E. (1997). Rice plant growth-and nitrogen accumulation in drill-seeded and water-seeded culture. *Soil Science Society of America Journal*, 61: 832-839.

Chamely, S.G., Islam, N., Hoshain, S., Rabbani, M.G., Kader, M.A. and Salam, M.A. (2015). Effect of variety and nitrogen rate on the yield performance of boro rice. *Progressive Agriculture*, 26 (1): 6-14.

Colwell, J.D. (1994). Estimating fertilizer requirements: A quantitative approach. CAB International, Wallingford, Oxon OX 10SDE, UK.

Diba, F., Farukh, M.A., Islam, N. and Bhuiya, N.S.U. (2005). Effect of nitrogen and potassic fertilizers on the performance of BRRI dhan28 and BRRI dhan29 in *boro* season. *Bangladesh Journal of Agriculture and Environment*, 1(1): 57-64.

Dobermann, A., Dawe, D., Roetter, R.P. and Cassman, K.G. (2000). Reversal of rice yields decline in a long term continuous cropping experiment. *Agronomy Journal*, 92: 633-643.

Donald, C.M. and Hamblin, J. (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Advances in Agronomy*, 28: 361-405. http://dx.doi.org/10.1016/S0065-2113(08)60559-3

Fageria, N.K. and Baligar, V.C. (2001). Lowland rice response to nitrogen fertilization. *Communications in Soil Science and Plant Analysis*, 32: 405-1429.

Fageria, N.K., Stalon, N.A. and Baligar, V.C. (2003). Nutrient management for improving lowland rice productivity and sustainability. *Advances in Agronomy*, 80: 63-152.

Fageria, N.K., Stalon, N.A. and Cutrim, V.A. (2008). Dry matter and yield of lowland rice genotypes as influenced by nitrogen fertilization. *Journal of Plant Nutrition*, 31: 788-795.

Hoque, M.M., Hossen, M.S., Akter, S.E., Alim, S.M.A., Nadim, M.K.A. and Zhuma, M.A.A. (2021). Nitrogen use efficiency, growth and yield performance of BRRI dhan28 under different doses of nitrogenous fertilizer application. *Journal of the Bangladesh Agricultural University*, 19(3): 318-324. https://doi.org/10.5455/JBAU.70839

Islam, S.M.M., Gaihre, Y.K., Biswas, J.C., Jahan, M.S., Singh, U., Adhikary, S.K., Satter, M.A. and Saleque, M.A. (2018). Different nitrogen rates and methods of application

for dry season rice cultivation with alternate wetting and drying irrigation: Fate of nitrogen and grain yield. *Agricultural Water Management*, 196: 144-153.

Islam, S.M.M., Khatun, A., Rahman, F., Hossain, A.T.M.S., Naher, U.A. and Saleque, M.A. (2015). Rice response to nitrogen in tidal flooded non-saline soil. *Bangladesh Rice Journal*, 19: 62-67.

IRRI (International Rice Research Institute). (1980). Nitrogen fertilizer needs for rice. In International Rice Research Institute Annual report for 1980. Pp. 254.

Jahan, M.S., Sultana, S. and Ali, M.Y. (2014). Effect of different nitrogen levels on the yield performance of aromatic rice varieties. *Bulletin Institute of Tropical Agriculture, Kyushu University*, 37: 47-56.

Juan., C, Zhong, W., Gang, C. and Yi-wei, M. (2006). Effects of nitrogen fertilizer treatments on filling and respiratory rate of caryopsis in rice. *Rice Science*, 13: 199-204.

Khatun, A. (2013). Effect of nitrogen from organic and inorganic sources on plant nutrient composition, yield and seed quality of boro rice. PhD thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh.

Khatun, A., Bhuiya, M.S.U. and Saleque, M.A. (2014). Response of nitrogen on yield and seed quality of boro rice. *Bangladesh Rice Journal*, 18 (1&2): 24-32.

Khatun, A., Quais, M.K., Begum, A.A., Saleque, M.A. and Bhuiya, M.S.U. (2016). Response of medium and long duration boro rice variety (*Oryza sativa* L.) to nitrogen fertilizer. *The Agriculturists*, 14(2): 48-60.

Khatun, M., Quais, M.K., Sultana, H., Bhuiyan, M.K.A. and Saleque, M.A. (2015). Nitrogen fertilizer optimization and its response to the growth and yield of lowland rice. *Research on Crop Ecophysiology*, 102: 1-16.

Khatun, A., Sultana, H., Zaman, M.A.U., Pramanik, S. and Rahman, M.A. (2015). Urea deep placement in rice as an option for increasing nitrogen use efficiency. *Open Access Library Journal*, 2: e1480. http://dx.doi.org/10.4236/oalib.1101480

Mollik, M.A.H. (2022). Effect of organic and inorganic fertilizer application on rice production (BRRI dhan28). MS thesis, Department of Soil Science, Shere-Bangla Agricultural University, Dhaka.

Haque, M.A. and Haque, M.M. (2016). Growth, yield and nitrogen use efficiency of new rice variety under variable nitrogen rates. *American Journal of Plant Sciences*, 7: 612-622.

Mae, T. (1997). Physiological nitrogen efficiency in rice: Nitrogen utilization, photosynthesis, and yield potential. *Plant and Soil*, 196: 201-210.

Miah, I., Chowdhury, M.A.H., Sultana, R., Ahmed, I. and Saha, B.K. (2012). Effects of prilled urea and urea super granule on growth, yield and quality of BRRI dhan28. *Journal of Agroforestry and Environment*, 6(1): 57-62.

Mikkelsen, D.S., Jayaweera, G.R. and Rolston, D.E. (1995). Nitrogen fertilizer practices of lowland rice culture. In: Bacon, P.E. (Editor). Nitrogen fertilization and the environment. Marcel Dekker, New York. Pp. 171-223.

Mohaddesi, A., Abbasian, A., Bakhshipour, S. and Aminpanah, H. (2011). Effect of different levels of nitrogen and plant spacing on yield, yield components and physiological

indices in high-yield rice (Number 843). *American-Eurasian Journal of Agricultural and Environmental Sciences*, 10(5): 893-900.

Pramanik, K. and Bera, A.K. (2013). Effect of seedling age and nitrogen fertilizer on growth, chlorophyll content, yield and economics of hybrid rice (*Oryza sativa* L.). *International Journal of Agronomy and Plant Production*, 4: 3489-3499.

Pramanik, A.H.M.M., Hasan, M.A., Hossain, M.G. and Islam, M.R. (2015). Foliar fertilization on BRRI dhan28 to reduce soil application of nitrogenous fertilizer. *Journal of Science and Technology*, 13: 64-74.

Saleque, M.A., Abedin, M.J., Bhuiyan, N.I., Zaman, S.K. and Panaullah, G.M. (2004). Long-term effects of inorganic and organic fertilizer sources on yield and nutrient accumulation of lowland rice. *Field Crops Research*, 86: 53-65.

Sarker, U.K., Uddin, M.R., Sarkar, M.A.R., Salam, M.A., Hasan, A.H. and Park, S.U. (2018). Physiological responses of high-yielding rice cultivars to elevated nitrogen levels. *Bioscience Research*, 15(1): 229-249.

Shelley, I.J., Takahashi-Nosaka, M., Kano-Nakata, M., Haque, M.S. and Inukai, Y. (2016). Rice cultivation in Bangladesh: present scenario, problems, and prospects. *Journal of International Cooperation for Agricultural Development*, 14: 20-29.

Singh, S.N. and Lallu. (2005). Influence of different levels of nitrogen on its uptake and productive efficiency of paddy varieties. *Indian Journal of Plant Physiology*, 10(1): 94-96.

Singh, Y., Gupta, R.K., Singh, B. and Gupta, S. (2007). Efficient management of fertilizer nitrogen in wet direct-seeded rice (*Oryza sativa*) in northwest India. *Indian Journal of Agricultural Sciences*, 77: 561- 564.

Singh, U., Ladha, J.K., Castillo, E.G., Punjalan, G., Tirol-Padre, A. and Duqueza, M. (1998). Genotypic variation in nitrogen use efficiency in medium and long duration rice. *Field Crops Research*, 58: 35-53.

Yoshida, S. (1981). Fundamental of rice crop science. The International Rice Research Institute, Los Baños, Laguna, Philippines.

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Wheat Crop Productivity in Berseem- Rice - Wheat Cropping System in Comparison with the Conventional Wheat- Rice- Wheat Cropping System Planted in Rice-Wheat Area of Punjab Pakistan

S.K. Tanveer[1*], I. Hussain[2], M. Hussain[4], M. Sohail[2], S.H. Abbas[3], M. Qamar[3], M.F. Iqbal[4], Z. Mahmood[3] and S. Waqar[3]

[1] SAARC Agriculture Centre, BARC Complex, Dhaka Bangladesh
[2]Plant Sciences Division (PSD), Pakistan Agricultural Research Council (PARC), Islamabad, Pakistan
[3]Wheat Program, Crop Science Institute, National Agricultural Research Center, Islamabad, Pakistan
[4] Adaptive Research Farm Gujranwala, Pakistan

Abstract

Rice-wheat cropping system has an important role in ensuring the food security of Pakistan. Inclusion of a leguminous crop like Berseem (Egyptian clover) in this cropping system can have positive effects on the yields of subsequent crops. To find out the effects of different cropping systems on the productivity of wheat crop, during crop season 2014-15, wheat crop adaptation plots were planted on 10 different farmers' fields in five major rice crop growing districts of Punjab province including Sheikhupura, Hafizabad, Mandi Bahaouddin, Gujranwala and Sialkot in two different cropping systems i.e., wheat-rice-wheat and berseem-rice-wheat. Although there were variations in grain yields of wheat crop planted under both cropping systems on different sites, but on overall basis 5.4 % more grain yield was recorded in case of berseem-rice-wheat cropping system as compared to the crop planted in conventional wheat-rice-wheat cropping system. In case of some sites less wheat crop grain yields were recorded in case of berseem-rice-wheat cropping system as compared to the crop planted in wheat-rice-wheat cropping system and it ranged from 7.5% to 16.7%

[*] Corresponding author: Sikander73@ Hotmail.Com

Received: 12. 08. 2024 *Accepted: 12. 12. 2024*

but in case of maximum number of sites, more wheat crop grain yields were recorded in case of berseem-rice-wheat cropping system as compared to the crop planted in wheat-rice-wheat cropping system and these differences ranged from 5.47% to 30.76% respectively. This shows that planting of berseem crop instead of wheat after two to three years can be helpful in getting the more yields of subsequent crops, and it is also soil health and environment friendly.

Keywords: Rice, Wheat, Berseem, Cropping System, Wheat Yield.

Introduction

Rice-wheat cropping system (RWCS) is one of the world's largest agricultural production systems, which covers an area of about 26 M ha and extends over the Indo-Gangetic Plains (IGP) in South Asia (Chauhan et al., 2012 and Shweta and Malik, 2017). Both rice and wheat crops have been cultivated in South Asia (Bangladesh, Bhutan, India, Nepal & Pakistan) and China for over 1000 years and more than 85% of the RWCS practiced in South Asia is located in the Indo-Gangetic Plains. The I GP is a fertile area of 225 M ha, which includes most of eastern and northern India, whole of Bangladesh, Nepal and Pakistan. The rice-wheat cropping system occupies 32% and 42 % of the total rice and wheat area respectively (Saharawat et al., 2012). In Pakistan, Rice – Wheat cropping system is being practiced on an area of about 2.2 M ha (Nawaz and Farooq., 2016).

Wheat (*Triticum aestivum* L.) and Rice (*Oryza sativa* L.) are the two main cereal crops of Pakistan. During 2023-24 wheat crop was planted on an area of 9.6 million ha and its total production was 31.4 million tonnes, while the total area under rice crop was 3.6 million ha with the total production of 9.9 million tonnes. Wheat crop is cultivated under the different cropping systems like cotton-wheat, rice-wheat, maize-wheat and fallow-wheat etc. Rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) cropping system is one of major cropping system of the Punjab province.

According to Nawaz et al., (2019), rice-wheat cropping system (RWCS), due to different factors like declining soil fertility, depletion of ground water, rising problem of salinity and alkalinity, increasing problems of weeds, insects, pests and diseases, is showing yield stagnation. Sweta and Malik, (2017) have also reported same kinds of issues from India. According to them it might be because, both rice and wheat are heavy feeders and nutrient - exhaustive crops and the amount of external nutrients applied to rice and wheat can not keep pace with the amount of nutrients removed from the soil, which leads to soil and production exhaustion (Ladha et al., 2003 and Singh et al., 2005). It has also been reported that the well-fertilized crops of rice and wheat meet about 50.8% of their nitrogen (N) requirements from the soil (Ravisankar et al., 2014), which may result in poor factor productivity of RWCS (Singh et al., 2019). It has been also reported that the continuous use of chemical fertilizers without nutrient recycling has led to a great loss of soil fertility and productivity

(Ram N., 1995). It is the fact that cereal-cereal sequences are more exhaustive, unsustainable and put a heavy demand on soil resources as compared to the cereal-legume and cereal-oilseed sequences.

It has been reported that inclusion of legume crops in the system not only fixes atmospheric N but also enriches soil fertility, increases nutrient availability, improves soil structure, reduces disease incidence, promotes mycorrhizal colonization (Wani et al., 1995), and ultimately helps to sustain the long-term productivity of cereal – based cropping systems. The substitution of wheat with berseem (*Trifolium alexandrinum* L.) only once or twice in a three – year cycle of the rice-wheat cropping system has also been recommended (Banjara TR et al., 2021).

Berseem (*Trifolium alexandrinum* L.) is one of the most important leguminous fast-growing, high-quality forages that is mainly cut and fed as a green chopped forage and it can also be used as a green manure crop. It is an annual, sparsely hairy, erect forage legume, 30 to 80 cm high, with the shallow taproot system. It is a N-fixing legume, which is not only used by the Berseem (*Trifolium alexandrinum* L.) itself but also by succeeding crops. It regrows after cutting and helps in weed control. It gives 4-6 cutting yielding from 40-50 tha^{-1} contains calcium and other vitamins which increases milk production (Ali., 2012). Legume crops enhance 0.9% organic matter, 0.12% nitrogen, 2.8 ppm available phosphorous, 52 ppm available potassium, reduce pH of soil up to 0.4 and increase 0.5% organic carbon after its harvest compared to rice-wheat cropping system (Ali et al., 2012). According to a study of Rai et al., (2013), the cowpea and Egyptian clover also complement the cropping system's soil SOC pools and productivity because of spatial and temporal annidation and different rooting behaviors.

The purpose of these adaptation plots was to promote leguminous based rice –wheat cropping system i.e., Berseem – Rice - Wheat cropping system in comparison with the conventional Wheat – Rice - Wheat cropping system on the farmer's fields in the different rice producing districts of Punjab province.

Materials and Methods

The adaptation plots of wheat crop were planted on different farmer's fields in the 5 different main rice crop producing districts of Punjab province including Sheikhupura, Hafizabad, Mandi Mandi Bahaouddin, Gujranwala and Sialkot, the detail of which is given in Table 1. Those farmers were selected who had planted berseem (Egyptian clover) crop as a fodder on some area of their land during rabi season 2013-14. So, on those farmers' fields wheat crop was planted in two different cropping systems (treatments) i.e., 1. Wheat cop planted in conventional (i.e., Wheat-Rice-Wheat) cropping system and 2. Wheat crop planted in legume-based (i.e., Berseem-Rice-Wheat) cropping system. Before planting of crop on all sites, soil samples were collected from the 0-40 cm soil depth and analyzed for various soil factors by using the standard procedures (Table 1). Wheat variety Borlaug-2016 was

planted by keeping the seed rate of 50 kg/acre and nutrients i.e., N & P were applied @ 120: 90 kg/ha in the form of Urea and Diammonium Phosphate (DAP) at the time of land preparation for planting of wheat crop. On all sites weeds were controlled with the application of appropriate herbicides and similarly water was applied to the crop according to its requirements. Data was recorded regarding crop germination, grain yields and different yields components. Crop germination data was recorded by using the one square meter quadrate, randomly from three different points and similarly for grain yields and different yield components crop samples were randomly harvested from all sites and from both treatments by using the one square meter quadrate. Tillers were counted and data was recorded regarding plants heights, spike lengths (cm) and number of spikelets per spike. Samples were weighed for biological yields and after drying, these samples were thrashed for grain yields. Data was analyzed by using Randomized Complete Block Design (RCBD) with Factorial arrangement having two factors i.e., planting sites and cropping systems with three replications by using the Statistix 8.1 software at 5% alpha level, while Tukey test was applied for comparison of means.

Table 1. Soil analysis of 0-40 (cm) top soil depth of the different sites of the rice-wheat area of Punjab before the sowing of wheat crop in different rotations i.e., Wheat-Rice-Wheat (W-R-W) and Berseem-Rice-Wheat (B-R-W) during the cropping year 2014-15.

Site. No	Site Name	Crop rotation	Soil Texture	Saturation%	Soil pH	E.C. dsm^{-1}	Organic matter%	Available-P mg kg^{-1}	Available-K mg kg^{-1}	Total Nitrogen (%)	TOC (%)/ SOC
1.	Munir Farm Mureedkay, District Sheikhupra	W-R-W	Loam	38	7.77	1.27	0.69	8.2	120	0.035	0.40
		B-R-W	Loam	39	7.28	2.91	0.62	7.9	120	0.031	0.36
2.	Liaqat Bhatti Farm, Mureedkay District Sheikhupra	W-R-W	Loam	39	7.31	3.1	0.53	5.2	160	0.027	0.31
		B-R-W	Loam	35	7.39	2.7	0.49	4.3	120	0.025	0.29
3.	Village Jalhar Bhattian, Feroze Pur Watwan, District Sheikhupra	W-R-W	Loam	36	7.81	1.56	0.69	7.3	100	0.035	0.40
		B-R-W	Loam	38	7.79	1.20	0.50	7.1	100	0.025	0.29
4.	Village Nakay Wal Bosal Bosal, District Mandi Bahaouddin	W-R-W	Loam	38	7.89	1.05	0.60	6.3	140	0.030	0.35
		B-R-W	Loam	37	7.83	1.29	0.67	8.1	120	0.034	0.39
5.	Bhatti Chack, District Hafizabad	W-R-W	Loam	41	8.06	1.42	0.59	5.2	100	0.030	0.34
		B-R-W	Loam	36	8.01	1.21	0.61	5.2	100	0.031	0.35

Site. No	Site Name	Crop rotation	Soil Texture	Saturation%	Soil pH	E.C. dsm^{-1}	Organic matter%	Available-P mg kg^{-1}	Available -K mg kg^{-1}	Total Nitrogen (%)	TOC (%)/ SOC
6.	Village Gagay Wali, District Gujranwala	W-R-W	Clay	47	7.53	1.91	0.57	4.3	80	0.029	0.33
		B-R-W	Loam	39	7.51	2.40	0.53	5.1	80	0.027	0.31
7.	Mushtaq Cheema farm village Begowala, District Sialkot	W-R-W	Clay	48	7.71	0.75	0.63	5.3	100	0.032	0.37
		B-R-W	Loam	40	7.69	1.07	0.55	5.7	100	0.028	0.32
8.	Ch. Farooq farm, village Begowala, District Sialkot	W-R-W	Loam	40	7.79	0.75	0.62	6.4	120	0.031	0.36
		B-R-W	Loam	39	7.62	1.20	0.60	6.2	100	0.030	0.35
9.	Village Langay, District Sialkot	W-R-W	Loam	38	8.06	2.18	0.63	7.6	100	0.032	0.37
		B-R-W	Loam	40	8.01	1.23	0.60	8.8	120	0.030	0.35
10.	Village Porab, District Sialkot	W-R-W	Loam	36	7.61	0.88	0.53	6.9	120	0.027	0.31
		B-R-W	Loam	36	7.71	0.87	0.60	5.2	100	0.030	0.35

Results and Discussion

Significant differences in crop germination, plant height, and different yield components like spike length, spike lets per spike, biological yields and grain yields were recorded in case of wheat crop which was planted on different sites under the different cropping systems (Table. 2 & Fig. 1). In case of different sites, maximum grain yield (4.01 t/ha) was recorded in case of Site-3 (village Jalhar Bhattian, Feroze Pur Watwan, District Sheikhupra), followed by Site-5 (Bhatti Chack, District Hafizabad) having grain yield of 3.75 t/ha, while minimum grain yield (1.95 t/ha) was recorded in case of Site-10 (village Porab, District Sialkot) (Fig.1). Differences in grain yields of different sites might be mainly due to differences in soil and other different crop management practices. Similarly, variations in the grain yields under different cropping systems, except in case of Site-3 (village Jalhar Bhattian, Feroze Pur Watwan, District Sheikhupra), were recorded in case of both cropping systems (Fig. 2). In case of 5 different sites i.e., Sites 2 (Liaqat Bhatti Farm, Mureedkay District Sheikhupra), 4 (Village Nakay Wal Bosal Bosal, District Mandi Bahaouddin), 6 (Village Gagay Wali, District Gujranwala), 8 (Ch. Farooq farm, village Begowala, District Sialkot) and 9 (Village Langay, District Sialkot) more grain yields were recorded in case of berseem-rice-wheat rotation as compared with the wheat-rice-wheat rotation, having differences of 29.5%, 33.2%, 5.47%, 7.66% and 30.76%

respectively, while in case of 4 different sites i.e., Site 1(Munir Farm Mureedkay, District Sheikhupra), 5(Bhatti Chack, District Hafizabad), 7(Mushtaq Cheema farm village Begowala, District Sialkot) and 10 (Village Porab , District Sialkot) more grain yields were recorded in case of rice-wheat rotation in comparison with the berseem - rice - wheat rotation having differences of 9.8%, 7.5%, 16.7% and 16.7% respectively (Fig.2).

Table 2. Wheat crop germination and different yield components as affected by the different crop rotations (i.e., Wheat-Rice-Wheat and Berseem-Rice-Wheat) planted on 10 different sites in rice – wheat area of Punjab during cropping season 2014-15.

Site No.	Crop rotation	Ger/m^2	P.H (cm)	S. length (cm)	No of S. let's/spike	Tillers/m^2	B.Y (t/ha)
1.	Wheat-Rice-Wheat	187.0abcde	93.0efdh	10.2cdef	18.1abc	334.0a	11.1abcd
	Berseem-Rice-Wheat	179.3cdef	95.1defg	9.9defg	18.8abc	257.7bcde	11.7abc
2.	Wheat-Rice-Wheat	184.7bcde	97.8bcde	10.9abc	18.8abc	253.3cdefg	9.4efg
	Berseem-Rice-Wheat	178.7cdef	104.9a	11.0ab	19.2ab	317.3a	11.9ab
3.	Wheat-Rice-Wheat	204.3a	97.1cdef	11.4a	19.4a	281.0bc	10.5bcde
	Berseem-Rice-Wheat	179.0 cdef	102.4ab	10.9abc	19.0abc	327.7a	11.5ab
4.	Wheat-Rice-Wheat	161.7fg	100.0abcd	10.3bcdef	18.1abc	221.7h	10.0cdef
	Berseem-Rice-Wheat	177.7cdef	100.2abc	10.4bcde	18.1abc	254.3cdef	10.7bcde
5.	Wheat-Rice-Wheat	175.0ef	100.8abc	10.6bcd	17.7c	281.3bc	12.3a
	Berseem-Rice-Wheat	176.0def	103.4a	11.0ab	18.6abc	252.7cdefg	11.0abcd
6.	Wheat-Rice-Wheat	152.7g	90.7ghi	10.4bcde	18.3abc	270.3bcd	9.7def
	Berseem-Rice-Wheat	195.7abc	89.8hij	10.2cdef	18.3abc	262.7bcde	9.5ef
7.	Wheat-Rice-Wheat	191.7abcde	92.6fgh	10.6bcd	18.8abc	242.7defgh	8.9fgh
	Berseem-Rice-Wheat	188.7abcde	92.3fgh	10.3bcdef	18.8abc	238.7efgh	8.8fgh
8.	Wheat-Rice-Wheat	184.0bcde	87.2ijk	9.4g	18.6abc	224.7fgh	7.1ij
	Berseem-Rice-Wheat	202.3ab	93.7efgh	9.8efg	17.9bc	252.3cdefg	8.0ghi
9.	Wheat-Rice-Wheat	183.0cde	82.9k	9.7fg	17.9bc	262.0bcde	7.9hi
	Berseem-Rice-Wheat	187.3abcde	85.8ijk	9.7fg	17.7c	223.7gh	8.0ghi
10.	Wheat-Rice-Wheat	178.0cdef	86.9ijk	9.9defg	18.3abc	242.3defgh	5.6k

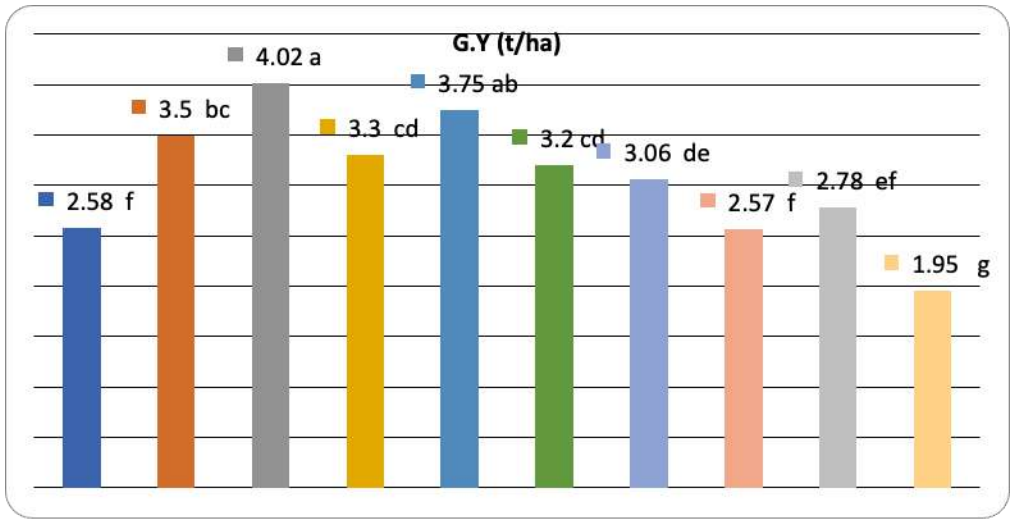


Fig. 1. Overall variations in grain yields of wheat crop (t/ha) planted 10 different sites under different cropping systems (i.e., Wheat-Rice-Wheat and Berseem-Rice-Wheat) in the rice-wheat area of Punjab during crop season 2014-15.

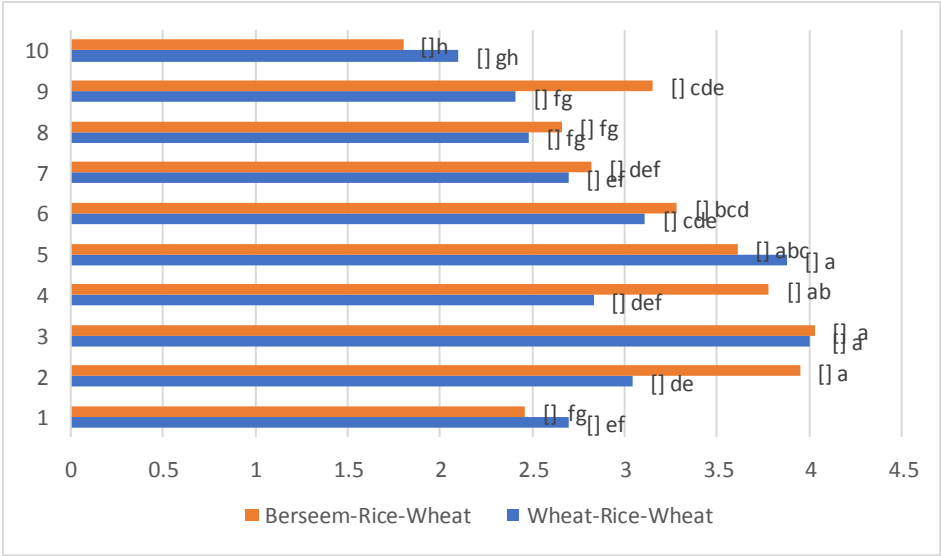


Fig. 2. Variations in grain yields of wheat crop (t/ha) as affected by the different cropping systems (i.e., Wheat-Rice-Wheat (W-R-W) and Berseem-Rice-Wheat (B-R-W) planted on 10 different sites in the rice-wheat area of Punjab.

Overall results of all sites show that there was 5.4 % more grain yield and 4.5% more biological yield in case of wheat crop planted in berseem-rice-wheat rotation as compared with the wheat - rice - wheat rotation (Fig.3). This shows that inclusion of leguminous crop in the rice-wheat cropping system increased wheat crop productivity, which might be mainly due to the increase of soil fertility. Similar results have also been reported by a field survey study of Sher et al., (2016), which was conducted to evaluate the impact of berseem (*Trifolium alexandrium* L) cultivation on productivity of subsequent crops in wheat - rice cropping system. For this purpose, one hundred and twenty farmers were interviewed through random selection procedure in agro-ecological zone of Gujranwala Punjab during rabi season 2013-14. The study concluded that in berseem-rice-wheat cropping system, the yield of rice and wheat crop was increased by 11% and 8% respectively. It has also been reported that, it also decreased the input cost of these crops by 5% and 3% respectively, due to atmospheric nitrogen fixation and also by reducing the weed population in subsequent crops. Singh et al., (2015), also reported that crop sequence having grain and fodder legume gave more grain yield of wheat as compared to the conventional rice-wheat cropping system. It is because, as legumes fix atmospheric nitrogen, which ultimately contributes for the better development of plant and biomass production. Similarly, according to Singh et al. (1997), inclusion of berseem in rice-wheat cropping system fulfills fodder requirements, increases the yields of subsequent crops, improves soil fertility and water holding capacity, reduces the nitrogen fertilizer requirement and similarly reduces the weed population in wheat crop. Rangaswami et al., (1990) also reported that legume crop assists in nutrient recycling within the system to economize and sustain the system and similarly it reduces the dependence on chemical fertilizers for crop production. Singh et al., (2007) also reported that it assists in habitat conservation rather than destruction. Soni and Kaur, (1984), reported that cultivation of a legume crop as a third crop during the summer season in the rice-wheat sequence proved better in enhancing the system rice equivalent yield. Wani et al., (1995), reported that inclusion of legumes in rotation hastened the N and P transformation. Parsad et al. (2011) and Anwar et al. (2010) reported that legumes had direct benefit of nitrogen fixation through root nodules to enhance soil fertility which could be used as companion as well as subsequent crop.

Similar types of issues have been reported from India, and according to Panwar et al., (2019), the sustainability of rice and wheat production is under threat due to the monotonous husbandry of RWCS and similarly it has been reported that the situation of nutrient mining is more alarming in the highly productive areas of IGP of India, where widely cultivated RWCS is supported with inadequate and unbalanced nutrient management practices (Singh et al., 2008).

Reduced cost of inputs of wheat sown in berseem-rice-wheat rotation as compared to the wheat-rice-wheat rotation has also been reported by Sher et al. (2016). This might be due to less usage of weedicides because weeds germinated in berseem were cut off

along with fodder crop, so that there was less need of herbicide application. Likewise crop requires less nitrogenous fertilizer when sown after berseem. Similar findings have been reported by Singh et al. (1997) who reported that inclusion of legumes in multiple cropping systems offered many advantages to farmers. Legume-based cropping system also improves the yields of rice crop and according to Banjara TR et al., (2021), the grain yield of rice increased (4.7- 13.9%) in sequences that involved legume crops during winter and summer season as compared to rice-wheat sequence.

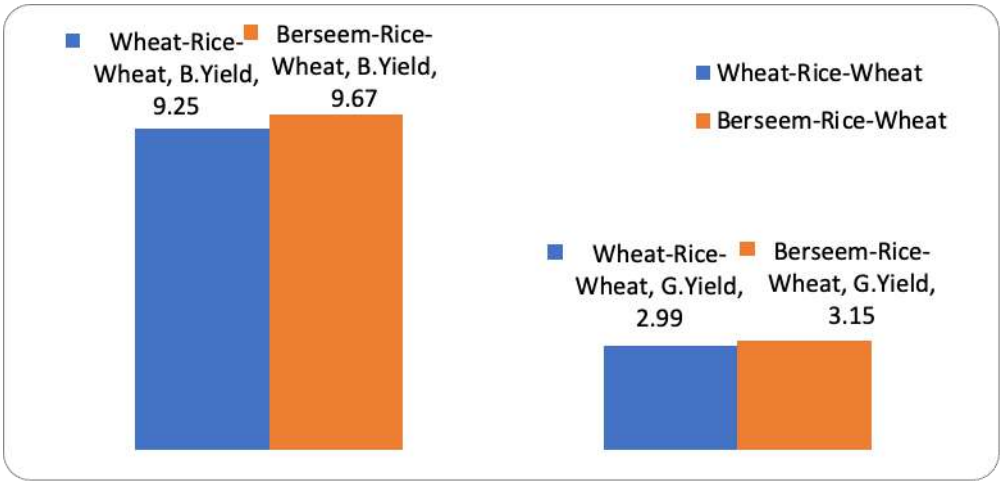


Fig. 3. Variations in Biological yields (t/ha) and Grain yields (t/ha) of wheat crop as affected by the different cropping systems (i.e., Wheat-Rice-Wheat (W-R-W) and Berseem-Rice-Wheat (B-R-W) planted on 10 different sites in the rice-wheat area of Punjab.

A suitable crop diversification assists in increasing farm income by better withstanding weather conditions, controls price fluctuations, ensures a balanced food supply, conserve natural resources, reduces use of chemical fertilizers and pesticides, ensures environmental betterment and also creates employment opportunities (Gill MS & Ahlawat IP, 2006). An integrated farming system (IFS) provides an opportunity to improve the economic yield per unit area and per unit time by intensification and diversification of crops and integration of allied enterprises. Similarly, according to Ali RI et al., (2012), leguminous based rice - wheat cropping system also gives better income mainly due to the production of higher grain and straw yield. Bohra et al., (2007); Mall et al., (2014) and Parsad, (2016) also reported that intensification of crop sequences with legumes increases yield and profitability.

As berseem improves soil fertility through N fixation from the atmosphere, and helps in reducing the weed population, so it is not only good for the soil health and environment due to the less use fertilizers and herbicides but is also economically beneficial for the farmers. So, there is a dire need of promotion of planting of berseem in the rice-wheat cropping system.

Conclusion

It can be concluded that inclusion of berseem in the existing conventional rice-wheat cropping system can improve the yields of subsequent crops. Thus, the diversification of rice-wheat cropping system with berseem - rice - wheat can give better productivity and profitability in the rice-wheat areas of Punjab Pakistan. So, substitution of wheat with berseem only once or twice in a three – year cycle of the rice-wheat cropping system of Pakistan is not only economically favorable but it is also beneficial in terms of nitrogen fixation, reduces inputs requirement, good for soil health and environment. It can be beneficial for the livestock and dairy industry by supplying the ample quantity of fodder for this sector.

References

Nawaz, A., Farooq, M., Nadeem, F., H.M. kadambot., Siddique., Lal, R. Faisal Nadeem, kadambot, H.M.; Siddique and Rattan L. (2019). Rice-wheat cropping systemin South Asia: Issues, options and opportunities. *Crop and Pasture Science.* 70 (5) 395-327. https://doi.org/10.1071/CP18383.

Nawaz, A. and Farooq, M. (2016). Weed management in resource conservation production systems in Pakistan. *Crop Protection*. 85: 89-103

Ali, M.A. (2012). Rahnuma-i-Rabi Faslat baraye Zari Karkonan.*Hand Book*. pp. 61

Ali, R.I., Awan, T.H., Ahmad, M., Saleem, M.U., Akhtar, M. (2012). Diversification of rice based cropping systems to improve soil fertility, sustainable productivity and economics. *Journal of Animal & Plant Sciences*. 22 (1): 108-112.

Anwar, A., Ansar M., Nadeem, M., Ahmad, G., Khan, S., and Hussain, A. (2010). Performance of non- traditional winter legumes with oats for forage yield under rainfed conditions. *Journal of Agriculture Research*. 48(2):171-180.

Banjara, Tej Ram., Bohra, J.S., Kumar, Sushil., Ram, Asha., Pal, Vijay. (2021). Diversification of rice-wheat cropping system improves growth, productivity and energetic of rice in the Indo-Gangetic Plains of India. *Agricultural Research*. https://doi.org/10.1007/s 40003-020-005533-9

Bohra, J. S., Singh, R. K., Singh, U.N., Singh, K., Singh, R.P. (2007). Effect of crop diversification in rice-wheat cropping system on productivity, economics land use and energy use efficiency under irrigated ecosystem of Varansi. *Oryza*.(44) :320-324.

Chauhan, B.S., Mahajan, G., Sardana, V., Tim Sina, J., Jat, M.L. (2012). Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, Opportunities, and Strategies. *Advances in Agronomy*. (117):315-369.

Gill, M.S., Ahlawat, I.P. (2006). Crop diversification – its role towards sustainability and profitability. *Indian Journal of Fertilizer*. (2): 125-131.

Ladha, J.K., Dawe, D., Pathak, H., Padre, A.T., Yadav, R.L., Bijay, S., Yadvinder, Singh, Singh, Y., Singh, P., Kundu, A.L., Sakal, R., Ram, N., Regmi, A.P., Gami, S.K., Bhandari, A.L., Amin, R., Yadav, C.R., Bhattari, E.M., Das, S., Aggarwal, H.P.,

Gupta, R.K. and Hobbs, P.R. (2003). How extensive are yield declines in long-term rice-wheat experiments in Asia?. *Field Crops Research*. (81), 159-180.

Mall, U.S., Manjhi, R.P., Thakur, R. (2014). Intensification and diversification of rice (*Oryza sativa*) based cropping systems for productivity, profitability and water expense efficiency on Jharkhand. *International Journal of Agricultural Sciences*. (10):124-129.

Pakistan Economic Survey, 2023-24. Economic Adviser's Wing Finance Division Government of Pakistan.

Parsad, D. (2016). Diversification of existing rice-based cropping system for sustainable productivity under assured irrigation condition for Chhattisgarh plains. *International Journal of Multidisciplinary Education and Research*. (1): 85-88.

Parsad, D., Urkurkar J.S., Bhoi, S.K. and Nag, N. (2011). Production potential and economic analysis of different rice based cropping systems in Chhattisgarh plains. . *Research Journal of Agricultural Sci*ences. 2(1): 36-39.

Panwar, A.S., Shamim, M., Babu, S., Ravishankar, N., Prusty, A.K., Alam, N.M., Singh, D.K., Bindhu, J.S., Kaur, J., Dashora, L. N, et al. (2019). Enhancement in productivity, nutrient use efficiency, and economics of rice-wheat cropping systems in India through farmer's participatory approach. *Sustainability*. 11 (1):122. Doi: 10.3390/su11010122.

Rai, A.K., Ghosh, P.K., Ram, S.N., Singh, S., Kumar, S., Manhanta, S.K., et al., (2013). Carbon sequestration in Forage based land use systems. Jhansi, Uttar Praddesh, India: Indian Grassland and Fodder Research Institute.

Ram, N. (1995). Long-term effects of fertilizers on crop production and soil properties in Mollisol Technical Research Bulletin.Govind Ballabh Plant University of Agriculture and Technology, Pantnagar.

Rangaswami, A., Manicksundaram, P.V., Vidhya, G. (1990). Integrated farming system: a variable approach. *Farming System News Letter*. (1):11-13.

Ravisankar, N., Gangwar, B., Prasad, K. (2014). Influence of balanced fertilization on productivity and nutrient use efficiency of cereal based cropping systems. *Indian Journal of Agricultural Sciences*, (84): 248-254.

Saharawat, Y.S., Ladha, J.K., Pathak, H., Gathala, M., Chaudhary Neelem and Jat, M.L. (2012). Simulation of resource conserving technologies on productivity, income and greenhouse gas GHG emission in rice-wheat system. *Journal of Soil Science and Environmental Management*. 3(1): 9-22.

Sher, F., Latif, M. T., Hussain, M.., Iqbal, M. F., Basher, A., Baig, M. M. Q., Waqar, M. Q. and Ali, M. A. (2016). Impact of berseem (*Trifolium alexandrinum*) cultivation on productivity of subsequent crops in wheat - rice system. *International Journal of Advanced Research on Biological Sciences.* 3(5):16-20.

Shweta, Malik. M. (2017). Improving wheat productivity in rice - wheat cropping system through crop establishment methods. *International Journal of Pure & Applied Biosciences*. 5(3): 575-578. Doi: 10.18782/2320-7051.2751.

Singh, D.N., Bohra, J.S., Banjara, T.R. (2019). Diversification of rice - wheat cropping system for sustainability and livelihood security. In: Crop diversification for resilience in agriculture and doubling farmer's income. ICAR-Indian Agricultural Research Institute (IARI) Pusa, New Delhi, pp 78-91.

Singh, G., Singh V. P., Singh, O.P. and Singh, R.K. (1997). Production potential of various cropping systems in flood prone areas of eastern Uttar Pradesh. *Indian Journal of Agronomy.* 42(1): 9-12.

Singh, R.K., Bohra, J.S., Singh, T.K., Singh, J.P., Singh, Y., Singh, C.S. (2007). Productivity and economics of integrated farming system in irrigated ecosystem of eastern Uttar Pradesh. *Indian Journal of Agronomy.* (52):11-15.

Singh, S., Bawa, S.S., Singh, S., Sharma, S.C., Sheoran, P. (2015). Productivity, profitability and sustainability of rainfed chickpea under inorganic and biofertilization in foothills of north-west Himalayas. *Archives of Agronomy and Soil Science*. 61(8):1151-1163. Doi: 10.1080/03650340.2014.988147.

Singh, V.K., Dwivedi, B.S., Shukla, A.K., Chauhan, Y.S., Yadav, R.L. (2005). Diversification of rice with pigeon pea in a rice-wheat cropping system on Typic Ustochrept: effect on soil fertility, yield and nutrient use efficiency. *Field Crops Research.* 92 (1): 85-105. doi:10.1016/j.fcr.2004.09.011.

Singh, V.K., Tiwari, R., Gill, M.S., Sharma, S.K., Tiwari, K.N., Dwivedi, B.S., Shukla, A.K., Mishra, P.P. (2008). Economic viability of site-specific nutrient management in rice - wheat cropping. *Better crops-India.* (2):16-19.

Soni, P.N., Kaur, M. (1984). Studies on production potential of different cropping system in Chhattisgarh. AICRP- Cropping System Research, Development of Agronomy, Directorate of research, published IGKV, Raipur (C.G.).

Wani, S.P., Rupela, O.P., Lee, K.K. (1995). Sustainable agriculture in the semi - arid tropics through biological nitrogen fixation in grain legumes. Plant Soil. 174 (1-2): 29-49. doi: 10.1007/BF00032240.

SAARC J. Agric., 22(2): 127-138 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.75562*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Efficacy and Cost Economics of Bio-Pesticides and Botanical Extracts Against Cabbage Butterly *Pieris brassicae nepalensis* Doubleday in Cauliflower Crop in ILAM, Nepal

A. Subedi[1*], S. Tiwari [2] and N. Mishra[3]

[1]Department of Agriculture, Ministry of Agriculture and Livestock Development (MOALD), Kathmandu, Nepal.
[2]Department of Entomology, Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal.
[3]Himalayan College of Agricultural Sciences and Technology (HICAST) Kirtipur, Kathmandu, Nepal.

Abstract

A field experiment was conducted to compare the efficacy and profitability of using bio-pesticides and locally available botanical extracts for the management of cabbage butterfly *Pieris brassicae nepalensis* Doubleday for cauliflower production. The management study was established in farmer's field in Barhabasti, Ilam, Nepal. Eight different types of management treatments were deployed in a randomized complete block design (RCBD) with three replications. The treatments were i) *Bacillus thuringensis* var *kurstaki* (2 gm /lt) ii) *Metarhizium anisopliae* (2.5 ml /lit) iii) *Beauveria bassiana* (3 ml /lit) iv) *Acorus calamus* (1:5) v) *Lantana camara* (1:5) vi) Neem oil (1.5 ml /lt) vii) Cow urine (1:4) viii) Control. Results showed that bio-pesticides and botanical extracts were significantly superior over control. *L. camara* treated plots contained the lowest larval population compared to all other treatments. The order of effectiveness of the treatments based on the population reduction was *L. camara* > *A. indica* > *A. calamus* > Cow urine > *M. anisopliae* > *B. thuringiensis* > *B. bassiana* > control. The above treatments were also safe to natural enemies since there was non-significant mortality effect of bio-pesticides on natural enemies. The highest benefit cost ratio (2.36) was recorded in neem

[*] Corresponding author: anupasubedi55@gmail.com

Received: 20. 08. 2024 *Accepted: 20. 12. 2024*

oil treated plots that was superior to all other treatments. To summarise, this study can help to develop an IPM protocol for the sustain able management of cabbage butterfly in crucifer field.

Keywords: *Pieris brassicae nepalensis* Doubleday, Botanicals, Bio-pesticides, Efficacy, Management

Introduction

Cauliflower (*Brassica oleracea* L. var. *botrytis)* is a popular winter season vegetable widely grown throughout the world. It is also one of the most important vegetable crops grown in terms of area in Nepal. While 35,974 ha of the total area is occupied by cauliflower cultivation, it also has one of the highest shares in terms of productivity which is 14.8 mt /ha (MOALMC, 2018). Although the Terai region produces and sells more vegetables, the vegetables grown in the hilly region have better value as they produce during rainy reasons when prices are relatively higher (Prasain, 20ll). In most of the mid-hills, cauliflower is planted almost all round the year but there are some limiting factors to its qualitative and quantitative production.

One of the major constraints behind the low yield of crucifers is the damage caused by insect pests commonly attacking at various stages of the crop growth (Bondada et al., 2009). Prasad (1963) revealed that the combined infestation brought about by the pest complex arrives at the degree of 14 to 100 percent with the consequent decrease in the yield from 42 to 97 percent. Cabbage butterfly *Pieris brassicae nepalensis* Doubleday alone causes more than 40% yield loss in vegetable crops (Ali & Rizvi, 2007). It is the most destructive pest found wherever the crucifer vegetables are grown (Younas & Naeem et al., 2004). The larvae feeds on the leaves by biting and chewing them and causes loss of foliage which ultimately causes retardation of growth resulting in undersized cauliflower head. It is responsible for causing serious damages at all the growing stages of the plant from seedling to vegetative and flowering stages (Bhandari et al., 2009).

In Nepal, the use of chemicals is in increasing but the loss induced by pests is on the rise despite the increasing usage of pesticides. The realization of the negative effects of these chemicals has forced to shift to other safer alternatives that can fit into the cropping systems (Ansari et al., 2013). This has developed an interest in the pest control agents that are bio-active and ecologically safe. The recent advancements in science are deliberately providing a breakthrough in pest management by providing bio-pesticides. These have high target selectivity, environmental compatibility, economic viability, a novel mode of action, and are considered much safer to the environment and other beneficial organisms as well as a rational approach in the long run. To overcome the negative effect of pesticides and to deliver non-pesticidal management practices, it is essential to manage the pests through ecologically safe, environmentally sound, and economically viable methods.

Materials and Methods

Experimental site

The experiment was conducted in Rabi season (from September to January 2021) in the farmer's field in Ilam. Ilam is a hilly district situated at 26.9094° N latitude and 87.9282° E longitude and an altitude of 1020 m from the mean sea level. The weather of the research site was warm temperate. The place received a rainfall of 6.3 cm and recorded the maximum temperature of 21.8°c and a minimum temperature of 3.8°c during the research period. The topography of the field was uniform with a gentle slope.

Design & layout of the experiment

The experiment was established in randomized complete block design (RCBD) with eight treatments and three replications. There were altogether twenty-four plots with 24 plants in each plot. The area of a single plot was 3m* 1.8 m with a spacing of 0.5 m between each plot and 1.0 m between each block. Crop Geometry was 60 cm row to row and 45 cm plant to plant. The cauliflower seedlings (7 leaves and 45 days old) cv. Super White Top grown in nursery were transplanted in a main research field. The seedlings were not treated by any chemicals before transplantation. The sample plants were five in number selected following a standard "W" transect pattern for each plot. The details of the treatment are given in Table 1.

Table 1. Treatment details

Treatment	Treatment name	Trade name	Dose	Group of insecticides
T1	*Bacillus thuringiensis* var *kurstaki*	Maha-astra	2 gm / lit water	Bio-pesticide
T2	*Metarhizium anisopliae*	Kalichakra	2.5 ml /lit water	Bio-pesticide
T3	*Beauveria bassiana*	Daman	3 ml /lit water	Bio-pesticide
T4	*Acorus calamus*	Home made	1:5(1part *Acorus* extract and 5-part water)	Botanical
T5	*Lantana camara*	Home made	1:5(1part *Lantana* extract and 5-part water)	Botanical
T6	*Azadirachta indica* (oil)	Nimbecidine	1.5ml /lit water	Botanical
T7	Cow urine	Collected locally and mixed with water during spray	1:4(1part cow urine and 4-part water)	Animal waste
T8	Control		Water	

Preparation of botanical extract

Fresh rhizomes of *A. calamus* and leaves & flowers of *L. camara* were brought to the laboratory. They were pulverized and crushed. 200 gm of the crushed products were added in one-liter water and left overnight (about 14 hours). The extract was filtered and applied as a treatment. Some other treatment materials were also collected from the periphery of research sites. The doses of the treatments were applied as foliar spray within the research plots with the help of a hand sprayer during evening hours. These treatments were applied 3 times in the plot at an interval of 10 days. Care was taken to properly clean the sprayer after the application of one treatment and before applying another.

Sampling and Data observation

Sampling was done as follows:

- Before the first spray of treatments and three samplings after its spray in 3 days interval.
- Before the second spray of treatments and three samplings after its spray in 3 days interval.
- Before the third spray of treatments and three samplings after its spray in 3 days interval.

The weather parameters of the research site were taken from the Department of Hydrology and Meteorology, Dhankuta. Weather parameters include temperature (minimum and maximum), relative humidity, and rainfall. Considering *P. brassicae nepalensis* as the target pest, the number of *P. brassicae nepalensis* larvae associated with the plant in the field was counted from 5 selected sample plants. Data was recorded at - 1 day before spray and 3, 6, and 9 days after application of treatments. Assessment of natural enemies was done where the number of ladybird beetle and spiders associated with the plant in the field were counted from 5 selected sample plants at all sampling times.

The fresh weight of the curd was also recorded immediately after the harvest using a weighing balance and the average yield per plot was recorded after harvesting the experimental plot plants and converted them into per hectare.

Efficacy of treatments in yield

All the harvestable yields from each plot were kept separately leaving the affected plants. Cauliflower yield was recorded from all treatment plots. The yield per plot was extrapolated into yield per hectare.

While comparing the efficacy of treatments in terms of yield, an increase in yield over control was calculated using the formula (Pradhan, 1969).

Increase in yield over control (%) = $\left(\frac{T-C}{C}\right) * 100$

Where,

T= yield from the treated plot

C= yield from the control plot

Economic analysis

The research goal was to find out the suitable management strategy with the most favorable benefit: cost ratio. The additional yield obtained in treated plots over control was recorded and total returns from each treatment were worked out. Benefit: cost ratio for all treatments were calculated considering the prevailing market price of necessary inputs, the market rate of the curd, etc.

Statistical analysis

Abnormal data on insect population count were transformed into square root value to get normal data. The data were subjected to analysis using analysis of variance (ANOVA) and pair of means were separated by using Duncan's Multiple Range Test (DMRT) at 5% and 1% level of significance (Gomez & Gomez, 1984). Data were analyzed using Microsoft Excel and Minitab statistical packages.

Results and Discussion

Effect on *P. brassicae nepalensis* larvae

The pre-count of larvae was non-significant showing uniform distribution of population in all plots. After the first spray of the treatments on the sixth DAS, *A. indica* oil and *A. calamus* treated plot showed a significant reduction in the control of larval population over control. Ninth day after the spray, *A. indica* proved efficacy against the *P. brassicae nepalensis* larva as it caused a significant reduction in the population. The antifeedant and toxic effects of *A. indica* on *P. brassicae nepalensis* caused the population reduction (Sharma & Gupta, 2009). However, considering the mean reduction over 9 days of the first spray, a significant reduction of the larval population was observed in the *A. calamus* treated plot (Figure 1). The findings were similar with the study conducted by Bajpai and Chandel (2009) who reported that the plant extract of *A. calamus* gave the maximum larval mortality killing 80.87% of *P. brassicae nepalensis* compared to ten other indigenous plant extracts considering its insecticidal effects. *A. indica* oil-treated plot was at par with the *A calamus* treated plot on the sixth DAS of treatments. On a ninth day, *A. indica* oil-treated plot showed high effectiveness over control with a subsequent reduction in the larval population.

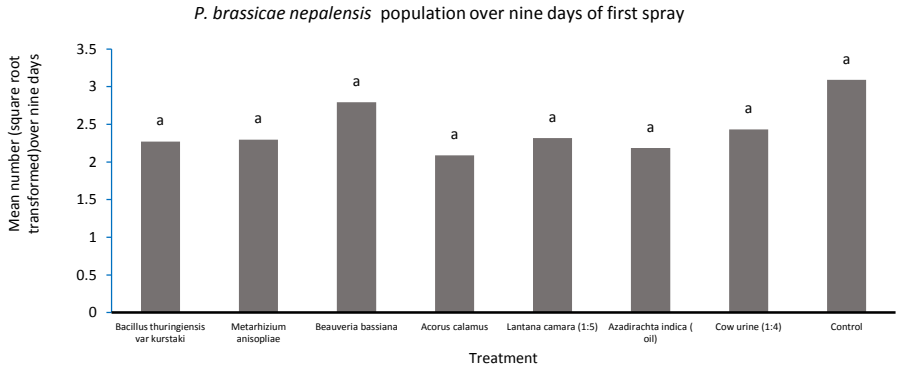


Fig. 1. Mean larval population (square root transformed) in various treatments over nine days after the first spray.

Similar was the result of the second spray (Figure 2). The mean over nine days of the second spray showed the lowest larval population in the *A. indica* oil-treated plot. This is due to the oviposition deterrence, antifeedant and toxic effects of *A. indica* based products among which the oil-based formulations reduced the survival of larvae by 51%. Direct contact with the eggs also reduced their survival (Hasan et al. 2010). The key insecticidal element responsible for its antifeedant and toxic effects in insects is azadirachtin, a steroid-like tetranortriterpenoid (Mordue (Luntz) & Nisbet, 2000).

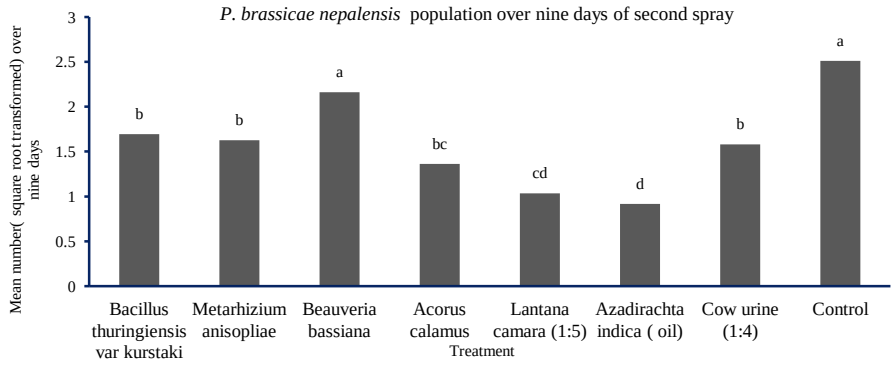


Fig. 2. Mean *P. brassicae nepalensis* population (square root transformed) in various treatments over nine days after the second spray.

On the sixth day after the third spray of the treatments, *L. camara* showed significant control of the larvae in comparison to other plots. The data recorded nine days after the spray also showed a similar result (Figure 3). *L camara* was superior compared to other treatment plots. This finding agrees with Sharma (2016) who evaluated some plant derivatives for the management of *P. brassicae nepalensis*. The result revealed

that among other plant derivatives. *L. camara* resulted in significantly higher toxicity to the caterpillars. The study conducted by Bhattarai et al. (2016) reported a Percentage Reduction Over Control (PROC) of 27.50% and a mortality percentage of 33.37 of the larval population of *P. brassicae nepalensis on* the application of *L.camara*. The mean population over nine days of the third spray recorded the lowest population presence in *L. camara* (1:5) treated plot followed by *A. indica* oil and then by *A. calamus* treated plots.

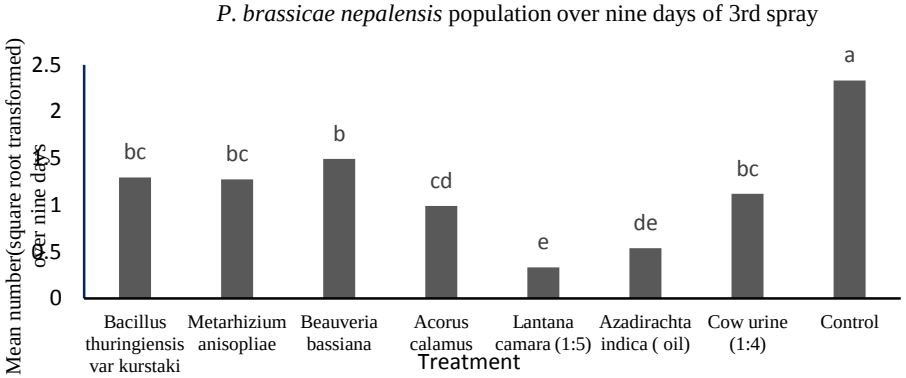


Fig. 3. Square root transformed mean *P. brassicae nepalensis* population in various treatments over nine days after the third spray.

B. thuringiensis and *B. bassiana* and were less effective in controlling the larval population as compared to *A. indica* and *L. camara* though they were significantly better over control. This could be due to the decrease in toxicity with time (Chaterjee & Chowdhary, 2003). The poor performance of the microbial insecticides could also be related to the concentration since the efficacy of the microbial pesticides is concentration dependent (Dhawan & Joshi, 2017; Hussain et al., 2003). Garcia-Gutierrez et al. (2010) also reported that the native isolate of *B. bassiana* recorded higher mortality of *P. brassicae nepalensis* than the commercial formulations of *B. bassiana* and *M anisopliae.*

Effect on natural enemies

The number of natural enemies was slightly increased in number as compared to the pre-spray of the treatments for Ladybird beetle and spider. This could be because the botanicals are effective against a limited number of target species, they degrade rapidly, are therefore highly eco-friendly and are also less likely to kill the beneficial insects in nature (Guleria & Tiku, 2009). There was no significant difference between the treatments even after all three sprays. However, there was a significant difference between the population of spiders in *B. thuringiensis* var *kurstaki* and *M. anisopliae* treated plot which were statistically similar and showed an increment in the number

of spider population after the third spray. The population was highest in the untreated control. The findings agree with Vanlaldiki et al. (2013) who, on the study of the effect of eco-friendly insecticides on the predatory coccinellid reported that *A. indica* products and *B thuringiensis* proved to be the safest to the predatory beetle. Dutta et al. (2016) reported that *A. indica* is the safest to Coccinellid beetles and foraging honeybees, recording 7.50 beetles/ plant, and 9.64 honeybees/plot/five minute. Similarly, Maxwell & Fadamiro (2006) reported that *B thuringiensis* had no significant effects on the number of spiders and ladybird beetles.

Effect on yield

The yield was comparatively higher in all sprayed treatments than unsprayed ones (Table 2). Among sprayed, *A. indica* oil-treated plot produced the highest yield which was significantly higher than all the other treatments. This was followed by *L. camara* (1:5). Baidoo and Adam (2012) also reported that the use of *A. indica* and *L. camara* increased the yield by 37.05% and 25.80% respectively. The effect of *L. camara* on cauliflower yield was statistically like *A. calamus* and cow urine. Among the treatments sprayed, *B. thuringiensis* treated plot gave the lowest yield, but it was significantly higher than the control plot. The reason for the low yield could be the damaged plants showing stunted growth because of the destruction of leaves by the larval feeding (Wawrzyniak, 1996). The cultivar selected and the proper balance of fertilizers along with the recommended cultivation practices followed timely could also be the supporting factors in the yield increase besides the effective control of pests by the treatments resulting in less destruction of plant foliages.

Table 2. Mean number (square root transformed) value of yield.

Treatment details	Mean
Bacillus thuringiensis var *kurstaki*	25.6 ± 1.54^{bc} (655.36)
Metarhizium anisopliae	25.79 ± 2.01^{bc} (665.12)
Beauveria bassiana	27.172 ± 0.91^{bc} (738.21)
Acorus calamus	27.792 ± 0.68^{ab} (772.40)
Lantana camara (1:5)	31.188 ± 0.56^{ab} (972.69)
Azadirachta indica (oil)	33.92 ± 1.11^{a} (1150.57)
Cow urine (1:4)	28.8 ± 1.42^{ab} (829.44)
Control	20.95 ± 1.74^{c} (438.90)
Mean	27.65
SEM (±)	0.861
CV (%)	15.25
p value	0.00

SEM = Standard Error of Mean, CV = Coefficient of Variance

Cost Economics

The maximum increase in yield over control was recorded in *A. indica* oil-treated plot giving the highest net profit and benefit-cost ratio of 2.36. The next best cost-effective treatment was *L. camara* with the benefit-cost ratio of 1.94 which showed a significant increase in yield over control. This was followed by cow urine (1.64), *A. calamus* (1.53), and *B. bassiana* (1.41) with the increase in yield over control of 66.6%, 61.11%, and 52.78% respectively. *B. thuringiensis* and *M. anisopliae* recorded the low benefit-cost ratio of 1.31 and 1.32 which was also significantly higher as compared to the control plot which was 1.01 (Table 3). The higher benefit-cost ratio obtained because of higher yield could also be influenced by the cultivar selected, balanced fertilizers and cultivation practices followed timely besides the proper pest control in treated plots. Ghanasambandhan et al. (2000) reported that botanicals are eco-friendly and have a higher benefit-cost ratio along with being safer to mammals and no risk of developing pest resistance.

Table 3. Economics of different insecticides applications against *P. brassicae nepalensis* Doubleday

Treatment details	Head weight (mt/ha)	Increase in yield over control. (%)	Total return (Rs/ha)	Cost of cultivation (Rs/ha)	Net profit (Rs/ha)	B:C ratio
Bacillus thuringiensis var *kurstaki*	28.74	34.71	2011644.44	1534814.81	476829.63	1.31
Metarhizium anisopliae	29.93	40.28	2094804.44	1592592.59	502211.85	1.32
Beauveria bassiana	32.59	52.78	2281471.11	1614814.81	666656.30	1.41
Acorus calamus (1:5)	34.37	61.11	2405915.56	1570370.37	835545.19	1.53
Lantana camara (1:5)	43.56	104.16	3048888.89	1570370.37	1478518.52	1.94
Azadirachta indica (oil)	51.26	140.28	3588137.78	1521481.48	2066656.30	2.36
Cow urine (1:4)	35.56	66.66	2488888.89	1514814.81	974074.08	1.64
Control	21.33	0.00	1493333.33	1481481.48	11851.85	1.01

Conclusion

On the evaluation of the various bio-pesticides and locally available botanical extracts, based on their efficacy in terms of control and cost effectiveness, *Azadirachta indica* oil and *Lantana camara (*1:5) showed the best result with decrease in the pest population and increased yield over control. However, all the

treatments were significantly better over control. Furthermore, excellent repellency showed by the azadirachtin present in oil formulation could be tested at different concentrations and different formulations for the increased efficacy. The locally available materials like *Lantana camara, Acorus calamus* or cow urine and different bio-pesticides like *Bacillus thuringiensis, Beauveria bassiana, Metarhizium anisopliae* could be encouraged among farmers as well as further researched at different formulations and different concentrations for their improved efficacies.

References

Ali, A and Rizvi, P. (2007). Developmental Response of Cabbage Butterfly, *Pieris brassicae* L. (Lepidoptera: Pieridae) on Different Cole Crops under laboratory and field Condition. Asian Journal of Plant Sciences, 6, Pp 1241.1245.

Ansari, A., Aryal, S. and Dangi, N. (2013). Extent and potential use of bio-pesticides for crop protection in Nepal. SAARC Agriculture Centre.

Baidoo, P. and Adam, J. (2012). The Effects of Extracts of *Lantana camara* (L.) and *Azadirachta indica* (A. Juss) on the Population Dynamics of *Plutella xylostella, Brevicoryne brassicae* and *Hellula undalis* on Cabbage. Sustainable Agriculture Research, 1, 229. 10.5539/sar. v1n2p229.

Bajpai, R and Chandel, B.S. (2009). Evaluation of *Adhatoda vasica, Acorus calamus* and *Vitex nugendo* as a source of phago-antifeedant against cabbage butterfly, *Pieris brassicae* Doubleday (Lepidoptera: Pieridae) on mustard, Brassica campestris. International Journal of Biotechnology and Biochemistry, 5(4), Pp 451-458.

Bhandari, K., Sood, P., Mehta, H., Choudhary, A. and Prabhakar, C.S. (2009). Effect of botanical extracts on the biological activity of granulosis virus against *Pieris brassicae*. Phytoparasitica, 37(4), Pp 317–322.

Bhattarai, S., Soti, A., Dubey, D. and Timilsina, D., Sapkota, P.& Panthi, S. (2016). Field mortality response of cabbage butterfly (*Pieris brassicae* (Linn.) Doubleday) against ecofriendly measures at Paklihawa, Rupandehi, Nepal. International Journal of Agricultural and Environmental Research, 2, Pp 270-275.

Bondada, B., Rao, N. and Rao, Ch.V.(2009). Evaluation of different I.P.M. modules for the management of insect pests of cabbage. Pestology. 33. Pp 9-13.

Chaterjee, H. and Chowdhury, A K. (2003). Persistent toxicity of some bio-pesticides against *Pieris brassicae* infesting cauliflower. Annals of Plant protection sciences, 11(2), Pp 215-219.

Dhawan, M. and Joshi, N. (2017). Enzymatic comparison and mortality of *Beauveria bassiana* against cabbage caterpillar *Pieris brassicae* Linn. Brazilian Journal of Microbiology, 48, Pp 522–529.

Dutta, N.K., Aslam, S.N., Mahmudunnabi, M., Khatun, M.F. and Kwon, Y.J. (2016). Efficacy of some new generation insecticides and botanicals against mustard aphid and their toxicity to coccinellid predators and foraging honeybees. Bangladesh Journal of Agricultural Research, 41, Pp 725-734.

García-Gutiérrez, C., Rosas-García, N.F., Norzagaray-Campos, M and Chaírez-Hernández, I. (2010). Efficacy of *Beauveria bassiana* and *Metarhizium anisopliae* to Control *Pieris rapae* on Cabbage in the Field. Southwestern Entomologist, 35(1), Pp 75-83.

Ghanasambandhan, S., Balakrishna, M.P. and Pillai, KS. (2000). Integrated Pest Management in twenty first century. Pestology, 24, Pp 9-11.

Gomej, K.A. and Gomej, A.A. (1984). Statistical procedures for agricultural research. 2nd Edition, John Wiley and Sons, New York, Pp 680.

Guleria, S. and Tiku, A. (2009). Botanicals in Pest Management: Current Status and Future Perspectives. In: Peshin R., Dhawan A.K. (eds). Integrated Pest Management: Innovation-Development Process. Springer, Dordrecht.

Hasan, F. and Ansari, M.S.(2010). Effect of different cole crops on the biological parameters of *Pieris brassicae* (L.) (Lepidoptera: Pieridae) under Laboratory Conditions. Journal of Crop Science and Biotechnology, 13, Pp 195-202.

Hussain, M.A., Pachori, R., and Choudhary, B.S. (2003). Management of *Spodoptera litura* Fab on cabbage with special reference to microbial pesticides. Research on crops, 4(2), Pp 263-267.

Maxwell, E.M. and Fadamiro, H.Y. (2006). Evaluation of several reduced risk insecticides in combination with an action threshold for managing lepidopteran pests of cole crops in Alabama. Florida Entomologist, 89(2), Pp 117-126.

MOALMC. 2018. Statistical Information on Nepalese Agriculture 2073/2074 (2016/2017). Kathmandu, Nepal: Government of Nepal, Ministry of Agriculture Land Management and Cooperatives, Monitoring, Evaluation and Statistics Division, Agriculture Statistics Section.

Mordue (Luntz), A.J. and Nisbet, A.J. (2000). Azadirachtin from neem tree *Azadirachta indica*: its action against insects. Neotropical Entomology, 29(4), Pp 615–632.

Pradhan, S. (1969). Insect Pests of Crops. National Book Trust, New Delhi, India, Pp 80.

Prasad, S.K. (1963). Quantitative estimation of damage to cruciferous crops caused by cabbage worm, cabbage looper, diamond back moth and cabbage aphid. Indian Journal of Entomology, 25 (3), Pp 242-259.

Prasain, S. (2011). Nepal produces veggies worth Rs 45 billion annually: Report. http://www.ekantipur.com/the-kathmandu-postl20lll02l15lmoney/nepal-produces-veggies-worth-rs-45-billion-annually-report/218494.htm1. Downloaded on 10th October 2022.

Sharma, A. and Gupta, R. (2009). Biological activity of some plant extracts against *Pieris brassicae* (Linn.). Journal of Bio-pesticides, 2 (1), Pp 26-31.

Sharma, S. (2016). Evaluation of some Plant derivatives for management of cabbage butterfly (*Pieris brassicae).* International Journal of Science, Environment and Technology, 5, Pp 395-400.

Vanlaldiki, H., Singh, M.P. and Sarkar, P.K. (2013). Efficacy of eco-friendly insecticides on the management of Diamond Back Moth (Plutella *xylostella* Linn.) on cabbage. The Bioscan 8(4), Pp 1225-1230.

Wawrzyniak, M. (1996). Assessment of the effect of selected plant extracts on *Pieris brassicae* Linn. (Lepidoptera) and its endoparasite *Apanteles glomeratus* L. (Hymenoptera). Polish Journal of Entomology, 5(3-4), Pp 327-335.

Younas, M., Naeem, M., Raqib, A. and Masud, S. (2004). Population dynamics of cabbage butterfly (*Pieris brassicae*) and cabbage aphids (*Brevivoryne brassicae*) on five cultivars of cauliflower at Peshawar. Asian Journal of Plant Science, 3, Pp 391-393.

SAARC J. Agric., 22(2): 139-151 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.75611*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Evaluation of Tomato Seed Health and Sustainable Management Practices using Biological and Chemical Approaches

M.S. Naznin[1*], M.H. Kabir[2], M.M.H. Chowdhury[3] and M.L. Hasan[4]

[1]Agronomy Division, Bangladesh Agricultural Research Insitute; [2]Dept. of Seed Science & Technology, Bangladesh Agricultural University (BAU), Mymensingh; [3]Professor Golam Ali Fakir Seed Pathology Centre, BAU, Mymensingh; [4]Soil Resource Development Institute, Dhaka.

Abstract

An experiment evaluated the seed health status of eight tomato varieties viz. Binatomato-6 (V1), Binatomato-7 (V2), Binatomato-10 (V3), Binatomato-11 (V4), Binatomato-12 (V5), Binatomato-13 (V6), Ratan (V7) and Roma VF (V8) alongside sixteen bio-agents and fungicide treatments, including controls and various concentrations of garlic, neem, Allamanda, *Trichoderma* spp., and Sinkar. The results indicated that Binatomato-13 had the highest percentage of healthy seeds (84.42%), lowest discoloration (3.32%) and highest germination rate (93.0%). Six seed-borne fungi were identified, with Ratan showing high susceptibility (20.0%) while Binatomato-12 effectively reduced fungal incidence (7.64%). Neem extract at a 1:1 concentration achieved the highest vigor index (1433.20) and significantly improved normal seedling development (79.67%). Neem also reduced the incidence of *A. flavus*, *F. oxysporum*, and other fungi. Consequently, Binatomato-13 was the best-performing variety and Neem at 1:1 was the most effective plant extract for reducing seed-borne infections.

Keywords: Health, Management, Quality, Seed, Tomato

Introduction

Bangladesh, an agro-based country, has 45% of its labor force engaged in agriculture (BBS, 2016). Among vegetables, tomato (*Solanum Lycopersicum L.*) is significant in consumption, production, and commercial use, especially for canning (Chowdhury,

[*] Corresponding author: sadianaznin6959@gmail.com

Received: 17. 09. 2024 *Accepted: 17. 12. 2024*

1979). Rich in vitamins A, B, and C, along with minerals like calcium and iron, tomatoes contain lycopene, an antioxidant that may reduce prostate cancer risk (Naika *et al*., 2005). However, tomato production faces constraints such as pests, diseases, weeds, and postharvest losses. Seedborne diseases are critical, with over 200 reported globally (Jones *et al*., 1991). Pathogenic fungi impact seed quality and germination, transmitting diseases from seeds to seedlings (Islam and Borthakur, 2012). Common seedborne diseases in Bangladesh include early blight (*Alternaria solani*), germination reduction (*Aspergillus flavus*), and Fusarium wilt (*Fusarium oxysporum*), leading to yield losses of 60% to 70% (Kirankumar *et al*., 2008). Effective management of these diseases is essential for producing high-quality seeds. While chemical treatments are common (Braga *et al*., 2010), biological agents like *Trichoderma* spp. show promise in crop protection (Howell, 2003). This research aims to identify seed-borne fungi in nine tomato varieties and assess biological control agents against chemical fungicides.

Materials and Methods

The experiment was conducted at the Seed Pathology Centre (SPC) and the Department of Seed Science and Technology, Bangladesh Agricultural University (BAU), Mymensingh, from July to November 2020. Eight tomato varieties viz. Binatomato-6, Binatomato-7, Binatomato-10, Binatomato-11, Binatomato-12, Binatomato-13, Ratan, and Roma VF were evaluated against fungal pathogens and sixteen treatments viz. control (T0), Garlic (w/v) @ 1:1 (T1), 1:2 (T2), 1:3 (T3), Neem (w/v) @ 1:1 (T4), 1:2 (T5), 1:3 (T6), *Allamonda* (w/v) @ 1:1 (T7), 1:2 (T8), 1:3 (T9), *Trichoderma* sp. (w/v) @ 1:1 (T10), 1:2 (T11), 1:3 (T12), Sinkar (w/v) @ 1:1 (T13), 1:2 (T14) and 1:3 (T15) were used for the study, including bio-agents and fungicides. Seed quality assessment included purity analysis, where seeds were separated based on morphology and size, with purity percentage calculated using ISTA (2022) methods. A

representative seed sample was taken. The seeds were separated into components based on morphology, size, and other characteristics. Each component was weighed and purity Percentage were calculated by this formula [(Weight of Pure Seed/Total Sample Weight) ×100] (ISTA, 2022). Moisture test was calculated by oven-dry method. A representative seed sample of tomatoes were taken for the test. The initial mass of the tomato seeds was recorded. The sample were placed in an oven at temperature of 105°C for 24 hours, until a constant mass was achieved. After drying, the sample were allowed to cool in a desiccator and the final mass was recorded. The moisture content was calculated as a percentage [Moisture Content (%) = (wet weight - dry weight) x dry weight / 100]. Germination test and determination of vigor index were also done following plastic pot method (Warham, 1990). Vigor index was calculated by following formula [Vigor index (VI) = Germination (%) × {Root length (cm) + shoot length (cm)}]. Soil was sourced from the Plant Pathology Field Laboratory, BAU. Seed inspection for seedborne mycoflora was conducted using naked-eye and microscopic methods, focusing on uniformity and discoloration (Peksen and Peksen, 2003).

Identification of seed-borne fungi followed the methods of Ellis (1976) and Neergaard (1979), with surface sterilization of seeds using sodium hypochlorite. Fungal growth was examined after incubation at 20-25°C. Bacterial isolation involved sterilization, maceration of seeds, and serial dilution onto nutrient agar, with biochemical tests for identification (Srinivasan, 2017) (Plate 1-4).

Morphological and biochemical characteristics were assessed, and seeds were treated with biological and chemical fungicides before germination testing The experiment employed a completely randomized design (CRD) with three replications, and data analysis was conducted using MSTAT statistical software

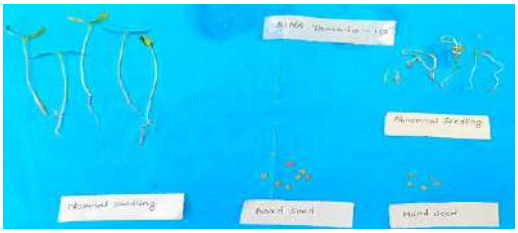


Plate 1. Categories of germinated seedlings (Binatomato-10)

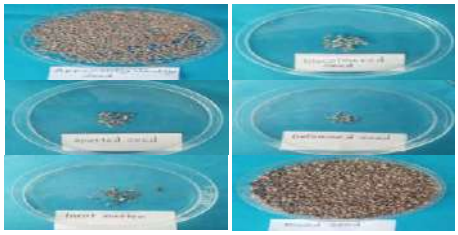


Plate 2. Different categories of inspected dry seeds

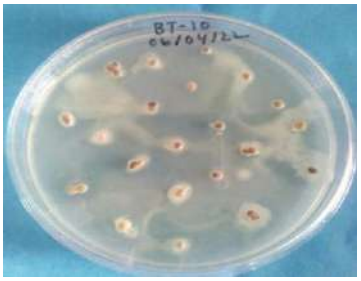


Plate 3. Isolation of bacteria from tomato seeds (incubated method)

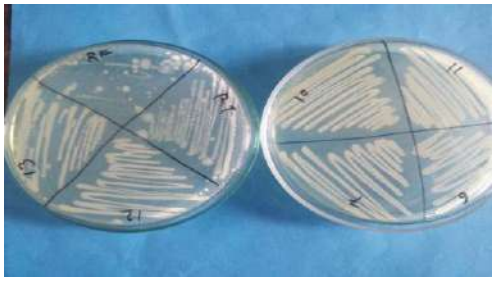


Plate 4. Pure culture of bacteria on NA medium

Results and Discussion

Purity and moisture test: The study found that Binatomato-13 had the highest seed purity (98.8%), while Ratan had the lowest (96.2%). All varieties had ideal moisture levels (7-8%), minimizing fungal and bacterial risks (Table1).

Table 1. Purity test and moisture content of different varieties of tomatoes

Variety	Pure seed (g)	Other seed (g)	Inert matter (g)	% Purity	Moisture content (%)
Binatomato-6	9.83 ab	0.11 cd	0.06 c	98.30 abc	7.80 ab
Binatomato-7	9.73 d	0.12 c	0.15 a	97.30 c	7.60 bc
Binatomato-10	9.84 ab	0.12 c	0.04 d	98.40 abc	7.30 cde
Binatomato-11	9.76 cd	0.16 a	0.08 b	97.60 bc	7.20 de
Binatomato-12	9.80 bc	0.12 c	0.08 b	98.00 abc	7.10 e
Binatomato-13	9.88 a	0.10 d	0.02 e	98.80 a	7.30 cde
Roma VF	9.85 ab	0.12 c	0.03 de	98.50 ab	8.00 a
Ratan	9.62 e	0.14 b	0.15 a	96.20 d	7.50 bcd
Level of sig.	0.01	0.01	0.01	0.01	0.01
$LSD_{(0.05)}$	0.06	0.02	0.02	1.03	0.29
CV (%)	0.3	3.2	4.32	0.6	2.19

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

Binatomato-13 showed the highest seed purity due to fewer contaminants. Efficient seed cleaning and 7-8% moisture reduce fungal and bacterial infection risks (Ellis, 1992; Jayaraman and Kalyanasundaram, 2009).

Seed dry inspection test: Binatomato-13 also had the highest proportion of apparently healthy seeds (84.42%), whereas Ratan showed the lowest (54.33%), with a notable amount of discolored and deformed seeds (Table 2). (Table 2 and Plate 2).

Table 2. Seed health evaluation by dry seed examination

Variety	Apparently healthy seed (%)	Discolored seed (%)	Spotted seed (%)	Deformed seed (%)	Inert matter (%)
Binatomato-6	82.83 ab	6.33 c	4.67 d	4.92 e	1.25 e
Binatomato-7	81.42 b	5.5 cd	7.83 c	3.5 fg	1.5 e
Binatomato-10	81.90 b	3.92 e	5.32 d	6.46 d	2.77 c
Binatomato-11	75 c	6.08 cd	7.00 c	8.75 b	2.67 c
Binatomato-12	83.5 ab	5.27 d	4.63 d	4 f	2.6 cd
Binatomato-13	84.42 a	3.32 e	7.50 c	3.02 g	2.08 d
Roma VF	54.33 e	12.25 a	13.43 a	13.27 a	6.42 a
Ratan	72 d	8.67 b	9.77 b	6.95 cd	2.47 cd
$LSD_{(0.05)}$	2.26	0.88	1.06	0.73	0.54
Level of sig.	0.05	0.05	0.05	0.05	0.05
CV (%)	1.72	8.10	8.17	6.56	11.41

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

From this study, the variety Binatomato-13 also attain maximum quality like purity and healthy seeds with highest significant reduction in inert matter included discolored, spotted and deformed seeds in the present study might be due to perfect moisture content and qualitative seeds. Similarly, (Tekrony *et al*., 1980) reported that the maximum qualitative seeds may influence the dry matter accumulation. This finding is fully agreed the present findings.

Seed health test: Fungal infection was most prevalent in Ratan (20%), with Binatomato-11 (11.4%) and the lowest in Binatomato-12 (7.64%). Six seed-borne fungi were identified, with *Aspergillus flavus* and *Rhizopus stolonifer* being the most common pathogens, corroborating previous findings on tomato seed pathogens (Nishikawa et al., 2006; Mehrotra and Agarwal, 2003). Germination rates varied significantly, with Binatomato-13 achieving 98% germination, while Ratan recorded only 76% (Fig. 2).

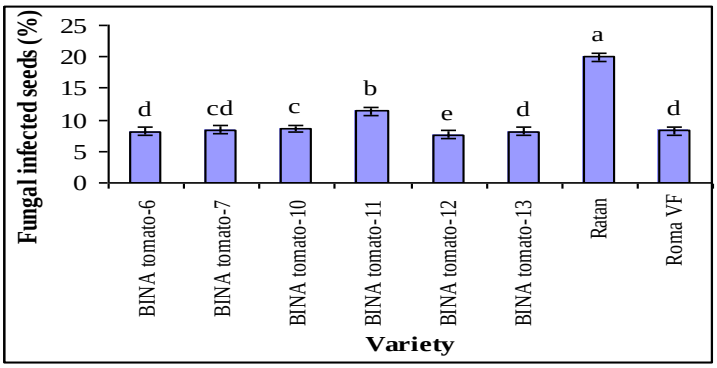


Fig. 1. Percentage of seed infection in different varieties of tomato

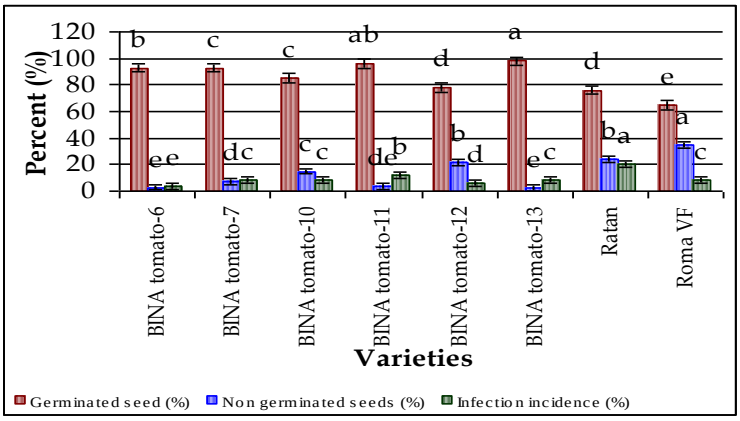


Fig. 2. Germination test of different varieties of tomato using blotter method

Table 3. Percent incidence of seed–borne fungi in eight different varieties of tomato

Seed-borne fungi	Incidence of seed –borne fungi (%)						Total
	A. flavus	*A. niger*	*F. oxysporum*	*C. lunata*	*Rhizopus spp.*	*Penicillium spp.*	
Binatomato-6	3.53 c	4.67 a	0.00 d	0.00 f	0.00 f	0.00 b	8.20 c
Binatomato-7	0.00 e	0.00 c	2.58 b	3.40 b	2.47 d	0.00 b	8.45 c
Binatomato-10	2.30 d	0.00 c	3.12 a	2.36 c	0.00 f	0.83 a	8.61 c
Binatomato-11	0.00 e	0.00 c	0.00 d	6.00 a	5.40 a	0.00 b	11.4 b
Binatomato-12	4.30 b	0.00 c	0.00 d	0.00 f	3.34 b	0.00 b	7.64 c
Binatomato-13	2.57 d	4.60 a	0.00 d	0.67 e	0.34 e	0.00 b	8.18 c
Ratan	11.0 a	3.00 b	2.33 c	1.33 d	2.34 d	0.00 b	20.0 a
Roma VF	4.00 bc	0.00 c	0.00 d	1.34 d	2.87 c	0.00 b	8.21 c
Level of sig.	0.01	0.01	0.01	0.01	0.01	0.01	0.01
$LSD_{(0.05)}$	0.65	0.36	0.21	0.25	0.32	0.01	1.03
CV (%)	10.69	13.26	11.73	7.64	8.74	3.41	5.81

column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differs significantly as per 0.05 level of significance.

In this study, seed-borne fungi such as *Fusarium oxysporum*, *Rhizopus stolonifera*, *Curvularia lunata*, *Aspergillus flavus*, *A. niger* and *Penicillium* spp. were isolated from tomato seeds. Previous studies (Nishikawa *et al*., 2006; Mehrotra and Agarwal, 2003; Telang, 2010; Hamim *et al*., 2014) similarly found these fungi in tomato seeds ().

Biochemical criteria of pathogenic bacteria on tomato seeds: In evaluating seedborne bacterial pathogens, *Erwinia carotovora* subsp. *carotovora* was found on the seed surface, confirming its seed-borne nature, with disease incidence at 12% (Table 4). Physical and chemical seed treatments showed efficacy in controlling *E. carotovora*, with sodium hypochlorite sterilization proving effective (Plate 6).

Table 4. Characterization of *Erwinia carotovora* subsp. *carotovora* isolates obtained from different varieties of tomato seeds

Isolated variety	Anaerobic growth	Gram staining	KOH solubility test	Yellow pigment on YDC	Pathogenecity test
Binatomato-6	+	-	+	+	+
Binatomato-7	+	-	+	+	+
Binatomato-10	+	-	++	+	++
Binatomato-11	+	-	+	+	+

Isolated variety	Anaerobic growth	Gram staining	KOH solubility test	Yellow pigment on YDC	Pathogenecity test
Binatomato-12	+	-	+	+	+
Binatomato-13	+	-	+	+	+
Ratan	+	-	++	+	+
Roma VF	+	-	+	+	+

+ = positive, - = negative, ++= strongly positive

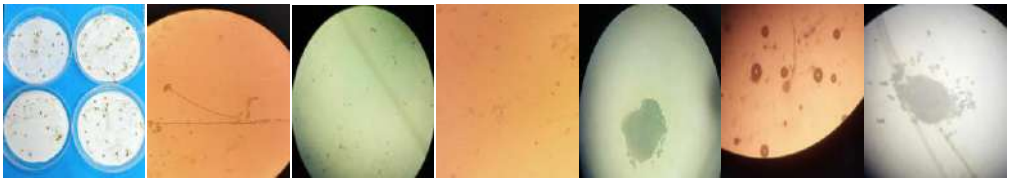
This study found that physical chemical seed treatments were effective against *E. carotovora* subsp. *carotovora.* Sodium hypochlorite (1% for 3 minutes) effectively sterilized seeds. The bacterium's characteristics suggest seed-borne transmission, supported by studies (Mathur and Manandhar, 2003; Singh and Mathur, 2004).

Germination rate and determination of vigor index: In this study, Binatomato-13 showed the highest germination (93%) and vigor index (1239.31), while Ratan had the lowest germination (75.67%) and vigor index (573.33). Pathogenic fungi like *C. lunata*, *F. oxysporum* and *A. solani* significantly reduced germination rates in tomato seeds (Table 5).

Table 5. Percentage of seed germination, seedling vigor and percent germination category of eight varieties of tomato in sand method

Tomato varieties	Germination (%)	Required days for germination	Mean shoot length (cm)	Mean root length (cm)	Vigor index	Normal seedling	Abnormal seedling	Dead seed	Hard seed
Binatomato-6	89 c	5 f	6.87 a	4.6 c	988.83 bc	83.66 ab	6.00 ab	4.000 e	4.666 cd
Binatomato-7	91 b	7 e	6.5 a	6.13 bc	1117.33 ab	86.33 a	5.50 abc	4.333 e	3.666 d
Binatomato-10	82 e	8 d	6.76 a	5.85 c	1,002.02 bc	70.33 de	7.50 a	10.00 bcd	12.66 ab
Binatomato-11	86 d	8 d	7.13 a	7.3 a	1208.98 a	77.33 bcd	3.00 d	9.666 bcd	9.666 abc
Binatomato-12	87 c	9 c	6.5 a	7 ab	1142.5 a	64.00 e	5.00 bcd	16.66 a	14.66 a
Binatomato-13	93 a	9 c	6.3 a	7.37 ab	1239.31 a	84.00 ab	5.00 bcd	6.33 de	4.000 d
Ratan	75.67 f	10 b	5 b	3 d	573.33 d	74.33 cd	3.50 cd	11.00 bc	11.33 ab
Roma VF	85 d	12 a	7.4 a	5 cd	1022 c	72.33 d	5.50 abc	13.33 ab	8.000 bcd
$LSD_{(0.05)}$	1.37	0.81	0.99	1.12	107.10	7.72	2.49	4.24	5.61
Level of sig.	0.05	0.01	0.05	0.05	0.05	0.05	0.01	0.05	0.05
CV	0.92	3.15	9.06	10.35	6.08	5.85	29.72	26.81	38.74

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

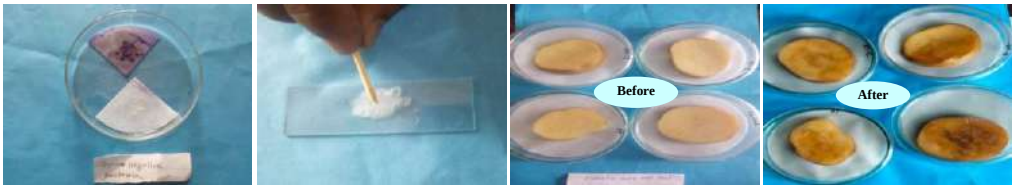


Seed health test by blotter method | *R. stolonifera* under microscope | *R. stolonifera* on infected seed | *Penicillium spp*. under microscope | *Penicillium sp*. on infected seed | *Aspergillus flavus* under microscope | *A. flavus* on infected seed

Curvularia lunata under microscope | *C. lunata* on infected seed | *Aspergillus niger* under microscope | *A. niger* on infected seed | *Fusarium oxysporum* under microscope | *Fusarium oxysporum* on infected seed

Plate 5. Six seed–borne pathogen detected on tomato seeds

Evaluation of Tomato Seed Health and Sustainable Management Practices



Gram staining of *Erwinia carotovora* subsp. *carotovora* | KOH solubility test | Pathogenesity test | *Erwinia carotovora* subsp. *carotovora*

Plate 6. Biochemical test results of different bacterial isolates

Impact of seed treatments on germination, vigor index and seedlings: In this study, seed treatments with plant extracts, bio-agents, and fungicides significantly improved Ratan tomato seed quality. Garlic (1:1 w/v) resulted in the highest germination (93.33%) and Neem (1:1 w/v) had the highest vigor index (1433.2). Untreated seeds showed the lowest germination (75.67%) and vigor index (573.33). The longest shoot (8.20 cm) was from *Allamonda* (1:3 w/v), and the longest root (7.97 cm) from *Trichoderma* (1:2 w/v) treatments. Neem-treated seeds had the lowest abnormal seedlings (9.67%) and lowest percentages of dead (4.33%) and hard seeds (2.33%), while untreated seeds had the highest abnormal seedlings (21.33%) (Table 6).

Table 6. Effect of seed treatment with plant extracts, bio–agents and fungicide on percent germination and vigor index (Variety Ratan)

Treatment	Germination (%)	Shoot length (cm)	Root length (cm)	Vigor index	Normal seedling (%)	Abnormal seedling (%)	Dead seed (%)	Hard seed (%)
Control	75.67 c	5.0 c	3.0 d	573.33 f	57.00 c	21.33 a	14.33 a	10.00 a
Garlic @ (1:1) w/v	93.33 a	6.5 b	5. 17 c	1088.8 e	79.67 a	11.00 b	5.00 cd	4.33 bcd
Garlic @ (1:2) w/v	91.33 ab	7.17 ab	8.00 a	1384.3 ab	79.33 ab	10.33 b	7.00 bcd	3.33 cd
Garlic @ (1:3) w/v	89.00 ab	7.17 ab	5.87 bc	1163.8 de	73.00 b	13. 33 b	7.33 bcd	6.00 b
Neem @ (1:1) w/v	92.oo ab	7.67 ab	7.97 a	1433.2 a	79.67 a	9.67 b	4.33 d	2.33 d
Neem @ (1:2) w/v	87.00 b	6.87 ab	7.37 ab	1241.4 abcde	75.67 ab	13.67 b	8.00 bcd	4.33 bcd
Neem @ (1:3) w/v	88.33 ab	7.77 ab	7.13 ab	1315.0 abcd	78.00 ab	12.00 b	7.67 bcd	4.67 bcd
Allamonda @ (1:1) w/v	90.00 ab	6.5 b	7.00 ab	1218.2 bcde	75.00 ab	12.67 b	7.33 bcd	5.67 bc
Allamonda @ (1:2) w/v	91.00 ab	6.93 ab	7.10 ab	1277.1 abcde	75.67 ab	10.67 b	9.33bcd	4.33 bcd
Allamonda @ (1:3) w/v	86.67 b	8.2 a	6.03 bc	1234.3 abcd	77.00 ab	12.00 b	7.33bcd	4.00 bcd
Trichoderma spp.@ (1:1) w/v	87.67 ab	6.70 b	5.83 bc	1097.1 e	76.00 ab	15.00 b	5.00 cd	4.00 bcd
Trichoderma spp.@ (1:2) w/v	88.33 ab	7.67 ab	7.97 a	1371.3 abc	75.67 ab	12.33 b	10.33 ab	4.33 bcd
Trichoderma spp.@ (1:3) w/v	86.33 b	6.76 b	6.77 abc	1186.0 cde	73.33 ab	11.67 b	10.33 ab	4.67 bcd
Sinkar @ (1:1) w/v	90.33 ab	7.10 ab	7.33 ab	1163.8 abcd	73.00 b	12.00 b	7.00 bcd	4.67 bcd
Sinkar @ (1:2) w/v	87.00 b	7.57 ab	6.23 abc	1201.0 bcde	76.00 ab	11.67 b	7.00 bcd	5.33 bc
Sinkar @ (1:3) w/v	89.00 ab	7.90 ab	7.13 ab	1337.9 abcd	74.67 ab	11.00 b	10.33 ab	4.00 bcd
$LSD_{(0.05)}$	5.95	1.4	1.8213	197.20	6.59	5. 88	4.67	2.58
Level of Significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CV	4.05	11.89	16.56	9.77	5.28	28.26	35.22	32.73

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

Control | Neem treated seed | Garlic treated seed | *Trichoderma spp.* | *Allamonda* | Sinkar 80WP

Plate 7. Seed treated with plant extracts, bio–agents and fungicides

Impact of seed treatments on germination and fungal infection: The study found *Allamonda* @ (1:1) w/v treated seeds had the highest standard germination (93.0%), with *Trichoderma* spp. @ (1:1) w/v also performing well (89.33%). All treatments improved germination over the control (76.33%), which had the highest fungal incidence. Garlic @ (1:3) w/v significantly reduced *A. niger* (1.06%), while Neem @ (1:1) w/v was most effective against *A. flavus*, *F.*

Evaluation of Tomato Seed Health and Sustainable Management Practices

oxysporum, *C. lunata*, *R. stolonifer*, and *Penicillium* spp. Garlic @ (1:2) and @ (1:3) w/v also effectively reduced *Penicillium* spp., with other treatments showing similar effectiveness against fungi (Table 7).

Table 7. Effect of seed treatment with plant extracts, bio–agents and fungicide on incidence of seed–borne pathogens (Variety Ratan)

Treatments	Standard germination (%)	Frequency of occurrence (%)					
		A. flavus	*A. niger*	*F. oxysporum*	*C. lunata*	*R. stolonifer*	*Penicillium spp.*
Control	76.33 c	11.33 a	10.33 a	5 a	11 a	12 a	3.27 a
Garlic @ (1:1) w/v	85.67 b	2.00 b	1.2 cde	1.13bc	1.67 b	1 f	0.76bc
Garlic @ (1:2) w/v	89 ab	2.67 b	1.78 cde	1.27 bc	2 b	2.67 bcde	0.23 c
Garlic @ (1:3) w/v	87 ab	3.67 b	1.06 e	1.13 bc	2 b	2.67 bcde	0.3 c
Neem @ (1:1) w/v	88 ab	1.67 b	2.17 cde	0.6 c	1.33 b	1 f	0.1 c
Neem @ (1:2) w/v	88.33 ab	2.00 b	2.67 bcde	0.71 c	2 b	3 bcd	0.87 bc
Neem @ (1:3) w/v	86.33 ab	2.00 b	2 cde	1.35 bc	1.67 b	1 f	1.4 b
Allamonda @ (1:1) w/v	93 a	2.00 b	2.9 bc	1.57 bc	2.67 b	2.67 bcde	1.06 bc
Allamonda @ (1:2) w/v	9 2.33 ab	2.33 b	2.43 cde	1.2 bc	2.67 b	2.33 cdef	0.7 bc
Allamonda @ (1:3) w/v	87.67 ab	2.00 b	2.83 bcd	0.75 c	3.0 b	2 cdef	0.83 bc
Trichoderma sp.@ (1:1) w/v	89.33 a	3.33 b	4.3 b	2.03 b	1.67 b	3.33 bc	0.65bc

Treatments	Standard germination (%)	Frequency of occurrence (%)					
		A. flavus	*A. niger*	*F. oxysporum*	*C. lunata*	*R. stolonifer*	*Penicillium spp.*
Trichoderma sp.@ (1:2) w/v	88 ab	3.00 b	1.5 cde	1.25 bc	1.33 b	4 bc	0.56bc
Trichoderma sp.@ (1:3) w/v	89 ab	2.33 b	1.5 cde	1.01 bc	1.67 b	1. 33 ef	0.93 bc
Sinkar @ (1:1) w/v	86.33 ab	2.00 b	2.83 bcd	1.43 bc	1.33 b	2. 33 cdef	0.6 bc
Sinkar @ (1:2) w/v	88 ab	2.67 b	2.33 cde	1.7 bc	1.67 b	3.33 bc	0.83bc
Sinkar @ (1:3) w/v	8 7.67	2.67 b	1.17 de	1.68 bc	2 b	1.67 def	0.76bc
$LSD_{(0.05)}$	7. 01	2.35	1.73	1.22	1.82	1.56	1.03
Level of sig.	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CV	4.82	47.47	38.65	49.34	42.21	32.30	71.37

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance.

This study assessed the impact of plant extracts, bio-agents, and fungicides on tomato seed germination, vigor index, and seedling growth. *Allamonda* and *Trichoderma* treated seeds showed the highest shoot and root length, while Neem-treated seeds exhibited the best vigor index and normal seedling percentage. Neem also recorded the lowest percentage of abnormal, dead, and hard seeds. Plant extracts were more effective than bio-agents and fungicides, aligning with findings from Ismael (2010) and Telang (2010) on seed germination and seedling vigor improvement.

Allamanda (1:1 w/v) and *Trichoderma* sp. (1:1 w/v) showed significant responses in standard germination. Garlic (1:3) effectively controlled *A. niger* and *Penicillium* spp., while Neem (1:1) was effective against *A. flavus*, *F. oxysporum*, *C. lunata*, *R. stolonifer*, and *Penicillium* sp. Plant extracts, including *Allium sativum* and *Azadirachta indica*, demonstrated greater antifungal activity than bio-agents and fungicides (Leite *et al*., 2012; Venturoso *et al*., 2011; Islam and Faruq, 2012).

Conclusion

All parameters significantly influenced seed quality and fungal incidence in tomato varieties. Binatomato-13 exhibited the best performance, while Ratan showed the poorest seed quality and was highly susceptible to fungal attack. To address Ratan's vulnerability, treatments with neem (1:1 w/v) yielded the highest vigor and disease reduction, followed closely by *Trichoderma* spp. (1:1 w/v) and garlic (1:2 w/v). This study suggests that using neem, *Trichoderma* spp. powder and garlic can effectively maintain seed quality and promote seedling growth by reducing fungal incidence, indicating that a combined treatment approach is more effective than single treatments.

Acknowledgments

The author thanks to Professor Golam Ali Fakir Seed Pathology Centre, BAU, Mymensingh for lab and MoST, Bangladesh for financial support.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this manuscript.

References

BBS (Bangladesh Bureau of Statistics). (2016). Yearbook of Agricultural Statistics of Bangladesh. Planning Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh, Dhaka.

Braga, M.P., Olinda, R.A., Homma, S.K., Dias, C.T. (2010). Relações entre tratamento térmico, germinação, vigor e sanidade de sementes de tomate. Revista Brasileira de Sementes, 32(1): 101-110.

Chowdhury, B. (1979). Vegetables. 6th Edition, the Director, National Book Trust, New Delhi, India, pp. 46.

Ellis, M.B. (1976). Dematiaceous Hyphomycetes. Kew, England: Commonwealth Mycological Institute. Available at: www.growtomatoes.com.

Ellis, R.H., Pieta Filho, C. (1992). Seed development and cereal seed longevity. Seed Science Research, 2: 9-15.

Hamim, I., Mohanto, D.C., Sarker, M.A., Ali, M.A. (2014). Effect of seed borne pathogens on germination of some vegetable seeds. Journal of Phytopathology and Pest Management, 1: 34-51.

Howell, C.R. (2003). Mechanisms employed by Trichoderma species in the biological control of plant diseases: The history and evolution of current concepts. Plant Disease, 87: 4-10.

Islam, M.T., Faruq, A.N. (2012). Effect of some medicinal plant extracts on damping-off disease of winter vegetable. World Applied Sciences Journal, 17(11): 1498-1503.

Islam, N.F., Borthakur, S.K. (2012). Screening of mycota associated with Aijung rice seed and their effects on seed germination and seedling vigour. Plant Pathology and Quarantine Journal, 2: 75-85.

Ismael, J.H.S. (2010). Isolation and identification of some fungi from certain solanaceous seeds in Sulaimania and Germian regions and their exudate effects on germination rate. Agriculture and Biology Journal of North America, 1: 615-619.

ISTA (International Seed Testing Association), "International Rules for Seed Testing," 2022 Edition.

Jayaraman, P., Kalyanasundaram, I. (2009). Natural occurrence of aflatoxins and toxigenic fungi in rice bran oil and deoiled bran. Indian Journal of Science and Technology, 2(10): 35-37.

Jones, J.B., Jones, J.P., Stall, R.E., Zitter, T.A. (1991). Compendium of tomato diseases. AP, Minnesota, USA.

Kirankumar, R., Jagadeesh, K.S., Krishnaraj, P.U., Patil, M.S. (2008). Enhanced growth promotion of tomato and nutrient uptake by plant growth promoting rhizobacterial isolates in presence of tobacco mosaic virus pathogen. Karnataka Journal of Agricultural Science, 21(2): 309-311.

Leite, C.D., Maia, A.J., Botelho, R.V., Faria, C.M.D.R., Machado, D. (2012). Extrato de alho no controle in vitro e in vivo da antracnose da videira. Revista Brasileira de Plantas Medicinais, 14: 556-562.

Mathur, S.B., Manandhar, H.K. (2003). Fungi in Seeds: recorded at the Danish government institute of seed pathology for developing countries. Copenhagen, Denmark.

Mehrotra, R.S., & Agarwal, A. (2003). Tomato Health and Disease Management. Plant Pathology and Crop Diseases, 4th edition, McGraw-Hill Publishing, pp. 235-250.

Naika, S., de Jeude, V.L., de Goffau, M., Hilmi, M., van Dam, B. (2005). Cultivation of tomato. 4th edition. Digigrafi Publishing, Wageningen, Netherlands: Agromisa, ISBN Agromisa 9085730392.

Neergaard, P. (1979). Introduction to methods of seed-health testing. Seed Science and Technology, 7: 601-635.

Nishikawa, J., Kobayashi, T., Shirata, K., Chibana, T., Natsuaki, K.T. (2006). Seedborne fungi detected on stored solanaceous berry seeds and their biological activities. Journal of General Plant Pathology, 72: 305–313.

Peksen, E., & Peksen, A. (2003). Dry inspection test of tomato seeds: An indicator of germination and seedling vigor. Seed Science and Technology, 31(2), 455-462.

Singh, D., Mathur, S.B. (2004). Location of fungal hyphae in seeds. In Histopathology of Seed-Borne Infections. Singh, D., Mathur, S.B. (eds). Boca Raton, FL, USA: CRC Press, pp. 101-168.

Srinivasan, S. (2017). Bacterial endophytes: Isolation, characterization, and applications. Methods in Molecular Biology, 1627, 227-233. https://doi.org/10.1007/978-1-4939-7110-9_18.

Tekrony, D.M., Egli, D.B., Philips, A.D. (1980). Effect of field weathering on the viability and vigour of soybean seed. Agronomy Journal, 72: 749-753.

Telang, S.M. (2010). Effect of extracts of various plant parts on seed mycoflora and seed germination of tomato. Asian Science Hind Institute of Science and Technology, 5(1): 15-18.

Venturoso, L.R., Bacchi, L.M.A., Gavassoni, W.L., Conus, L.A., Pontim, B.C.A., Bergamin, A.C. (2011). Atividade antifúngica de extratos vegetais sobre o desenvolvimento de fitopatógenos. Summa Phytopathologia, 37(1): 18-33.

Warham, E.J. (1990). Effect of Telletia indica infection on viability, germination and vigor of wheat seed. Plant Disease, 74: 130-135.

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Resource Utilization and Profitability of Rice Production in the Terai Region of Nepal

L.K. Shrestha[1*], Y.B. Thapa[1], S.C. Dhakal[1] and D. Gauchan[2]

[1]Agriculture and Forestry University, Chitwan, Nepal
[2]Tribhuvan University, Kathmandu, Nepal

Abstract

Rice is the most important staple food crops in Nepal; however, the national yield of rice is low which has led in insufficient supply and heavy annual import. So, this study assessed the profitability and resource utilization of main and spring season rice production. A Semi-structured interview schedule was administered in 2022 among 360 randomly selected main-season rice-producing farmers across three major rice producing districts of Terai region of Nepal. Similarly, it conducted four Focus Group Discussions (FGDs) to collect necessary data for spring season rice from two Terai districts within similar agro-ecological regions. Cobb-Douglas production function was used to assess the resource utilization in main season rice production. Result revealed that per hectare total cost and revenue of spring season rice production was higher with benefit-cost ratio of 1.63 as compared to main season. It is found that major resources such as the cost of seed, farm yard manure (FYM), chemical fertilizer, micronutrient and pesticides were found underused. On the other hand, the cost of labor, tillage and harvesting were found overused in the main season rice production. The proportion of the increase in rice income to the increase in costs of inputs for main season rice production was less, as indicated by the return to scale being less than unity. Hence, the study recommends to focus on addressing on prioritization to increase the cropping area under spring season rice and optimization in the use of resources supported by improved technologies to improve profitability and increase farmers' income from rice this can eases the constraints in the domestic supply of rice and thereby contribute to lowering the annual volume of rice import.

Keywords: Benefit-cost ratio, Main season rice, Profitability, Resource utilization, Spring season rice.

[*] Corresponding author: shresthalk2014@gmail.com

Received: 31. 08. 2024 *Accepted: 30. 11. 2024*

Introduction

Rice (*Oryza sativa* L.) is the most widely grown crop with annual production of 513.68 million Metric Tons (MT) in the World in 2022/23 (FAO, 2023). So, it is a staple food crop for more than 50% of the world's population (Birla et al., 2017). However, the growth in the yield of rice is low to meet the increase in its global market demands These calls for a higher increment in the yield of rice to meet future food requirements or demands (Hashim et al., 2024). In Nepal, rice is the most important staple food crop contributing significantly to the national food and nutritional security. It is grown in all the three agro-ecological zones viz. Terai, Hill and Mountain. Rice was found cultivated in 1.47 million hectares (ha) with production of 5.48 million MT and a yield of 3.79 MT/ha in 2022/23 (MoALD, 2023). The contribution of rice to the national Gross Domestic Product (GDP) is 3.25% and 13.6% to the Agricultural GDP in 2022/23 (MoALD, 2023). The Terai region is termed as the 'granary of Nepal' as it accounts for over two-third of the country's rice production. The main rice is cultivated from June-November and the spring season rice March - June in Nepal. The Ministry of Agriculture and Livestock Development (MoALD) / Prime Minister Agriculture Modernization Project (PMAMP) has prioritized the production of rice by creating its superzone and zone. The study selected three Terai districts viz. Jhapa, Rupandehi and Kailali where the area under rice as 92,915 ha; 63,873 ha and 72,377 ha along with production of 406,738 MT; 249,151 MT and 181,859 MT in 2021/22, respectively (MoALD, 2024). Districts are purposively selected based on their highest importance in rice production. The yield of rice in Nepal is low (3.79 MT/ha) as compared to the world's average yield (4 MT/ha) and neighboring countries Bangladesh (4.4 MT/ha) and China (6.7 MT/ha) and similar to the yield of India (3.7 MT/ha) and Pakistan (3.5 MT/ha). The low yield of rice is mainly due to the lack of adoption of high yielding and hybrid rice varieties. Nepal is ranked at 17th in production and 64th in terms of yield in the world (Choudhary et al., 2022). The current rice production level is insufficient to fulfill the growing demand for rice for ensuring the food security (Gairhe et al., 2021). It has been argued that by integrating the population growth rate of the last decade (0.57% per annum) with two productivity growth rate scenarios, the country can be self- sufficient by 2040 (Timsina et al., 2023). From the period 1960 to 2017, the annual growth rate of rice yield of Nepal was low (1.14%) as compared to the neighboring countries India (2.5%), Bangladesh (3%) and China (4.2%), and the World (4.5%) (FAO, 2019). Nepal exported rice till 1982 (equivalent of US$ 16.54 million in 1982) but after that it has been importing huge amount of rice annually. Nepal's imported of rice was US$ 625.68 million in 2022 (FAO, 2023).

The cost of production of rice in Nepal is high because of high labor-intensive nature of production and higher cost of inputs. The low profitability and lack of knowledge on using the resources optimally are the major hindrances for its wider expansion which has threatened the food security situation of the country. There is potentiality

of production of rice twice in a year as main and spring season specially in lower hills and Terai region of Nepal. The yield of spring season rice is high as compared to main season due to its high photosynthetic efficiency, disease and pest free condition and cultivation in fully irrigated condition. Thus, double cropping of rice will help in increasing the annual production of rice for easing in the supply constraints to meet its the domestic demand. The optimum used of resources would help in decreasing the cost of production and increasing profitability. In this context, this study aimed to assess the resource utilization and profitability of rice production in major rice producing districts of Terai region of Nepal; the latter being the granary of Nepal.

Materials and Methods

Research Design

Study employed multistage sampling, where provinces, districts and selected major growing municipality were selected purposively, while rice growing households were selected randomly from each of the selected major rice growing municipality in the selected districts. We selected three major rice producing provinces namely Koshi, Lumbini and Sudurpaschim out of seven provinces in Nepal (Figure 1). One largest rice producing district from each of these three provinces namely, Jhapa, Rupandehi and Kailali were further purposively selected Those districts are also MoALD priority rice promotion program where PMAMP have implemented rice zone and superzone programs to increase the production and productivity. Furthermore, for primary data collection, one major rice growing municipality from each district was selected viz, Kachanakawal rural municipality of Jhapa, Suddhodhan rural municipality from Rupandehi and Joshipur rural municipality from Kailali district consultation with the agricultural officials of PMAMP, Agriculture Knowledge Center (AKC) representing provincial governments and the local government. The pretested semi-structured interview schedule was administered to 120 randomly selected main season rice producing farmers in each district due to similar population size to represent. The three study districts (Jhapa in East, Rupandehi in Central and Kailali in West) of Terai region which is considered as the repository of Nepal for rice production. Altogether, the total of 360 samples were selected from three districts for the collection of primary data during the period of February - May 2022 through face-face interview. It employed a pre-tested semi-structure interview schedule to collect the primary data for main season rice production. The two key informant interview (KII) per district were conducted to validate information obtained from the respondents during primary data collection. Likewise, four FGD in Chitwan and Bardiya districts (2 in each district), with the participation of government officers, committee members, lead farmers including small, medium and large size farmers, women farmers in 2022. Two districts were selected because of the larger cultivated area under spring season rice and similar agro-ecological regions for primary data collection. The data were analyzed using the software Statistical

Packages for Social Sciences (SPSS) for coding, then Stata for regression analysis and Microsoft Excel for benefit-cost analysis and tabulations.

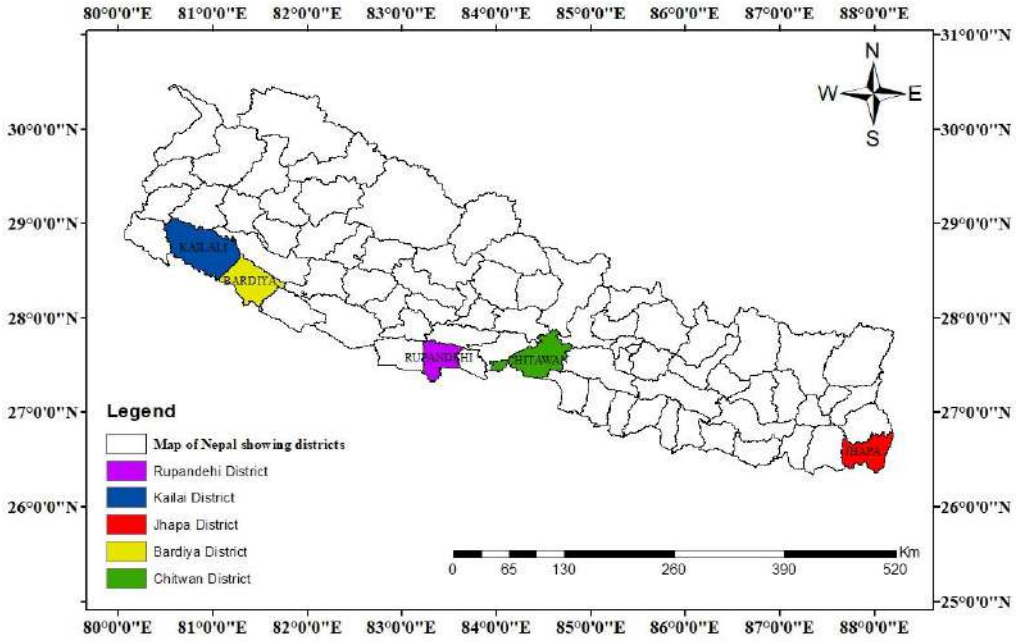


Fig. 1. Map of Nepal showing study sites

Profitability assessment

The Benefit-Cost Analysis (BCA) is a widely used tool in the economic analysis of agricultural projects internationally (Gittinger, 1982), and rice production in Nepal (Acharya et al. 2020). Accordingly, the study employs the BCA to assess the profitability of rice production in Nepal.

Profitability assessment is done by the benefit-cost ratio (BCR) as follows:

$$Benefit - Cost\ Ratio = \frac{Gross\ Return}{Total\ Variable\ Cost}$$

Where,

Total Variable Cost (NPR) = sum of variable costs of tillage, seed, labor, FYM, chemical fertilizer and micronutrient and pesticide.

The above formula to calculate the BCR was also used in the studies by Subedi et al. 2019 and Sapkota et al. 2021.

Gross Return (NPR) = Quantity of rice produced*Price + Quantity of by-products*Price

Production function analysis

Cobb–Douglas (C-D) production function is one the most common and frequently used (Dhakal, 2015) technique in economics to represent the technological relationship between the various inputs used and output produced. In the CD function the coefficients represent the elasticity of respective inputs, and the summation of these coefficients provides the return to scale. The CD production function model was used to compute the efficiency ratios of inputs used in main season rice production. Natural logarithm transformation of the equation of Cobb-Douglas production function is represented as follows:

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7$$

Where, the values are in NPR on per hectare basis.

Y = Gross income from rice production

X_1 = Tillage cost

X_2 = Seed cost

X_3 = Labor cost

X_4 = FYM cost

X_5 = Chemical Fertilizer cost

X_6 = Micronutrient and pesticide cost

X_7 = Harvesting cost and

a = Intercept

The efficiency of a resource used was determined by the ratio of the Marginal Value Product (MVP) of variable input and the Marginal Factor Cost (MFC) for the input and tested for its equality to one i.e. (MVP/MFC) =1. Taking reference of Goni et al. (2007), the resource use efficiency was calculated using the formula;

r = MVP/MFC

Where,

r = Efficiency ratio,

MVP = Marginal Value Product of a variable input; MFC = Marginal Factor Cost

$MVP_i = b_i * Y/X_i$

b_i – regression coefficients

Y = Geometric mean of gross revenue of rice production

X_i = Geometric mean of i^{th} inputs

Efficiency ratio is analyzed as:

r = 1, efficient use of resource

r>1, underused of the resource

r<1, overused of the resource

Again, following (Mijindadi, 1980), the relative percentage change in MVP of each resource required to obtain optimal resource allocation, i.e. r = 1 was estimated using the equation below;

$D = (1\text{-}MFC/MVP) \times 100$

Or $D = (1\text{-}1/r) \times 100$

Where,

D is the absolute value of percentage change in MVP of each resource

Return to scale analysis

The return to scale measures the proportional response of output due to overall changes in the inputs. The sum of the coefficients (b_i) estimated from the Cobb-Douglas production function regression model provides the value of return to scale.

Return to scale (RTS) = Sum of the coefficients ($b_1 + b_2 + \cdots + b_7$)

Decision rule:

RTS > 1: Increasing return to scale

RTS = 1: Constant return to scale

RTS < 1: Decreasing return to scale.

Results and Discussion

Profitability assessment of spring season rice

Table 1 shows that the total cost of spring season improved variety as chaite 5 of rice production of two districts (Chitwan and Bardiya) was NPR 106,037 and revenue was NPR 172,500 per hectare with benefit-cost ratio 1.63. In Bardiya, the per hectare cost of spring season rice production (NPR 90,244) was found low as compared to Chitwan (NPR 121,830) district which resulted in the higher profit in Chitwan (NPR. 67,170) in comparison to Bardiya (NPR 65,755) district due to premium price of rice. The benefit-cost ratio of spring season rice production of Bardiya and Chitwan was 1.73 and 1.55 respectively. The benefit-cost ratio is a measure of the profitability of rice production, indicating that for every unit of cost incurred, there is a certain multiple of benefit (revenue).

Table 1. Cost and revenue associated with spring season rice production (NPR/ha)

Variables	Overall	Location 1	Location 2
		Bardiya	Chitwan
A. Fixed costs (FC)			
Cost on land rent, water, electricity	17,680	10,900	24,460
Depreciation cost of assets	4,390	4,150	4,630
Sub-total (A)	22,070	15,050	29,090
B. Variable costs (VC)			
Seed	2,145	2,925	1,365
Labor	16,750	12,600	20,900
Tillage	20,325	19,200	21,450
Fertilizer (FYM & Chemical Fertilizer)	25,778	19,027	32,529
Plant protection (micronutrients, pesticides)	2,175	2,300	2,050
Harvesting cost	12,773	14,900	10,646
Interest on the amount invested to cover VC	4,021	4,243	3,800
Sub-total (B)	83,968	75,195	92,740
Total Costs (A+B)	106,037	90,245	121,830
Rice production (kg)	6,125	5,500	6,750
Revenue (NPR)	172,500	156,000	189,000
Profit (NPR)	66,462	65,755	67,170
B/C ratio	1.63	1.73	1.55

Source: FGDs, 2022

Profitability assessment of main season rice production

Table 2 presents information on the cost of main season improved variety (like sawa mansuli, ranjit, sarju 52) of rice production across three districts (n=360). The per hectare cost of tillage, seed, labor, FYM, chemical fertilizer, micronutrients and harvesting cost incurred in rice were found to be NPR 11466, 5232, 27977, 5364 10837, 1790 and 17393 respectively and the difference across district was found statistically significant at 1% level. The per hectare average total cost incurred in rice production was NPR 80,059 per hectare (Table 3). The total per hectare cost of production in Jhapa was significantly low (NPR 73,891) as compared to Kailali (NPR 76,957) and Rupandehi districts (NPR 89,330), and the difference across the district was found statistically significant at 1% level.

Table 2. The costs of main season rice production in Jhapa, Rupandehi, Kailaki Districts (NPR/ ha)

Variables	Overall (n=360)	District			f-value
		Jhapa (n=120)	Rupandehi (n=120)	Kailali (n=120)	
Tillage cost	11466 (3847.15)	12557 (3025.19)	11783 (3542.76)	10060 (4433.06)	14.224***
Seed cost	5232 (3203.75)	5414 (2020.81)	6623 (3803.67)	3660 (2817.17)	30.167***
Labor cost	27977 (5872.85)	25321 (4209.49)	28971 (5284.86)	29639 (6892.46)	20.876***
FYM cost	5364 (6531.49)	6512 (6295.17)	6772 (6837.02)	2807 (5692.06)	14.915***
Chemical fertilizer	10837 (4832.32)	7960 (3160.87)	12819 (6073.56)	11732 (3233.47)	40.821***
Micronutrient and pesticide cost	1790 (1940.31)	803 (1325.44)	2010 (2115.36)	2557 (1871.21)	29.796***
Harvesting cost	17393 (6531.63)	15324 (4909.10)	20352 (7397.12)	16503 (5994.93)	21.696***
Total Cost	80059 (15596)	73891 (11244)	89330 (16643)	76957 (13987)	40.15***

Notes: Figures in parentheses indicate standard deviation. *** indicate significant at 1 percent level.

On the relative shares of different inputs in the production of main season rice as shown in Fig.2, the total cost of labor used was maximum (35%), which is followed by harvesting (22%) and tillage cost (14%). Custom hiring centers and use of machineries were promoted in the study areas through rice superzone and zone for the reduction of labor cost. These findings were found in line with Subedi et al. (2020), who reported that the share of the cost of human labor (63.44 %) was highest in rice production in the Jhapa district. Sapkota et al. (2021) also reported high cost of labor (NPR 56,827) in rice production in the Rautahat district. Ghimire et al. (2024) reported agriculture production cost in Nepal is highly shared by labor and need to be optimized.

In line with this finding, Basnet et al. (2022) revealed that the labor cost of paddy has contributed most to the variable cost with 45.48% share in Morang, Nepal. Here, independent variables such as seed, labor and mechanical power had contributed significantly to the yield.

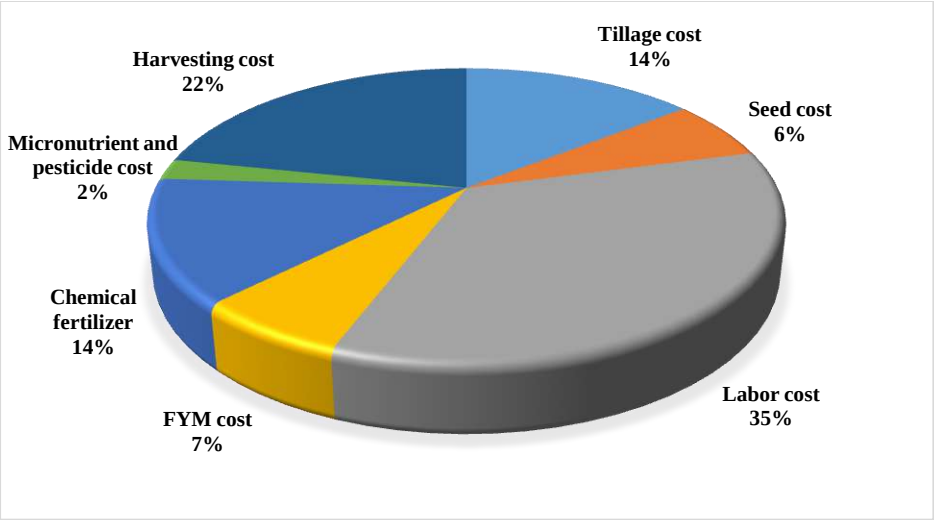


Fig. 2. Percentage share of various inputs to total cost of main season rice production

Cost, revenue and profitability of main season rice

Table 3 provides information on the per hectare cost, revenue, and profitability of main season rice production, across three different districts. The average production of rice was 4.09 MT per hectare in the study area. The average production of rice per hectare was found low in Kailali (4.02 MT) as compared to Jhapa (4.04 MT) and Rupandehi (4.21 MT).

The total revenue of rice production was found NPR 106,660 per hectare in the study area. Rice straw were used in mushroom farming as well as animals feed in the study areas. The revenue of rice production per hectare was found low in Jhapa (NPR 96,016) as compared to Kailali (NPR 108,503) and Rupandehi (NPR 115,459). Higher revenue in Rupandehi was due to the adoption of high yielding varieties and more price received by the farmers. Adhikari (2011) reported that the average total gross returns from rice production in Chitwan was NPR 66,597 per ha. Similarly, Subedi et al. (2020) reported that the average total returns from rice production per hectare as NPR 1,04,432 in Jhapa.

The per hectare profit from rice production was NPR 26,600 in the study area, which was found higher in Kailali (NPR 31,546) as compared to Jhapa and Rupandehi. Subedi et al. (2020) also revealed that the rice production was profitable in the Jhapa.

Table 3. Assessment of profitability of main season rice production (NPR, hectare)

Variables	Overall	District			F-value
		Jhapa	Rupandehi	Kailali	
Total cost	80059 (15596)	73891 (11244)	89330 (16643)	76957 (13987)	40.15***
Paddy production (MT)	4.09 (0.58)	4.04 (0.59)	4.21 (0.56)	4.02 (0.56)	4.34**
Straw production (kg)	5897 (5264)	6341 (4026)	4599 (3681)	6750 (7155)	5.81***
Total revenue (NPR)	106660 (18024)	96016 (13664)	115459 (17494)	108503 (17073)	44.56***
Profit (NPR)	26600 (15005)	22126 (11034)	26129 (13855)	31546 (17902)	12.69***
BC ratio	1.36 (0.23)	1.31 (0.17)	1.32 (0.20)	1.44 (0.28)	13.54***

Notes: Figures in parentheses indicate standard deviation. *** and ** indicate significant at 1 and 5 percent level of significance respectively.

The per kg cost of rice production was found NPR 19.57 and the price was NPR 24.63 which resulted in the B/C ratio of 1.36 in the study area (Table 3). This indicated that one rupee spent on rice production yields 36 paisa as net-benefits from rice production and, thus, the rice production has been profitable in the study area. The B/C ratio in Kailali district is higher (1.44) than Jhapa (1.31) and Rupandehi district (1.32). It is also found that the B/C ratio of main season rice (1.36) is very low as compared to the spring season (1.62) rice in the study areas. The reason for the lower B/C ratio are due to increase in costs of labor, lack of high-yielding varieties and improved technologies. In line with this finding, the benefit-cost ratio of rice production has been reported as 1.9 in the eastern region and as 1.8 in the country (Joshi et al., 2011). Sapkota et al. (2021) further reported the benefit-cost ratio 1.11 in rice production at Rautahat district of Nepal.

Production function analysis

The calculation F value (36.21) was statistically significant at 1% level which showed that the model has good explanatory power. The value of the coefficient of determination (R^2) indicated that about 40.7% of the variations in the dependent variables were elucidated by the explanatory variables in the model (Table 4). Keeping all other factor constant, it is found that an 1% increase in the cost of seed and tillage would increase the total income by 0.072 and 0.032% respectively; these are significant at 1 and 10% level of significance respectively. Similarly, an increase in expenditure on FYM by 1% would increase the total income by 0.003% which was statistically significant at 1% level. Likewise, increase in expenditure on chemical

fertilizer by 1% would increase the total income by 0.14% which was statistically significant at 1% level. Similarly, an 1% increase in the cost of human labor would increase the income from rice production by 0.071%; the increment was found statistically significant at 5% level. Further an 1% increase in the expenditure on micronutrient and pesticides increase the total income by 0.005% from rice production. Likewise, the result revealed that an 1% increase in the cost of harvesting increase the total income by 0.067% which was significant at 1% level.

Similar to this finding, Sapkota et al. (2021) revealed that human labor, tillage, FYM, chemical and pesticides and irrigation positively correlate with income while the other cost (mainly transportation costs) negatively affect the total income from rice production in Rautahat, Nepal. Subedi et al. (2020) reported that rice production was profitable in Jhapa, Nepal. Likewise, Rahaman et al. (2022) shows that rice is a profitable enterprise in the haor areas of Bhangladesh. Bwala and John (2018) reported that rice production in Bida Agricultural Zone of Niger State, Nigeria is profitable. Basnet et al. (2022) reported that the BC ratio of paddy as 1.66 indicates that it is a profitable enterprise.

Estimation of resources use Efficiency

The estimated Marginal Value Product (MVP) and efficiency ratios of different inputs used in rice production are presented in Table 4. The efficiency ratio of the inputs such as the seed (3.82), FYM (85.14), chemical fertilizers (1.50) and micronutrient cum pesticides (180.26) are found as greater than unity, which indicate the underused of these resources. On the other hand, the efficiency ratios of tillage (0.31), human labor (0.27) and harvesting (0.03) are less than unity, which indicate the overused of these resources. Thus, this implies that the resources used in the rice production are not optimally used.

For the optimal allocation of resources, the cost of seed, FYM, chemical fertilizers, and micronutrient cum pesticides need to be increased by 40.64, 98.83, 33.40 and 99.45 percent, respectively. On the other hand, the costs of tillage, human labor and harvesting should be decreased by 218.77, 266.60 and 2963.68 percent, respectively (Table 4). This shows the opportunity for re-adjustment such as use of more seeds by buying improved seeds for high productivity. Likewise, the farmers should increase the dose, quantity and quality of chemical fertilizers, micronutrient cum pesticides as per the estimates of resource use efficiency.

Likewise, the cost of human labor and harvesting can be decreased by introducing low-cost technologies. This is because the mechanization for the tillage can be decreased by adopting minimum tillage technologies, and other low-cost technologies. Ghimire and Dhakal (2014) and Danso-Abbeam et al. (2015) found that human labor was overused in their studies, which was in consistent with the results of this study.

Table 4. Estimation of efficiency ratios of inputs used in main season rice production

Variables	Coefficient	Std. error	t-value	MVP	MFC	r	D	Status
Ln tillage cost	0.032*	0.019	1.69	0.314	1	0.314	218.77	OU
Ln seed cost	0.072***	0.013	5.60	1.685	1	1.685	40.64	UU
Ln FYM cost	0.003***	0.001	3.59	85.141	1	85.141	98.83	UU
Ln Chemical fertilizer cost	0.140***	0.016	8.58	1.501	1	1.501	33.40	UU
Ln Labor cost	0.071**	0.034	2.05	0.273	1	0.273	266.60	OU
Ln Micronutrient and pesticide cost	0.005***	0.001	4.45	180.259	1	180.259	99.45	UU
Ln Harvesting cost	0.067***	0.018	3.76	0.033	1	0.033	2963.68	OU
Constant	7.980***	0.436	18.29					
Observations	360							
F-value (7, 352)	36.21***							
Prob>F	0.001							
R-square	0.419							
Adj. R-squared	0.407							
Return to scale	0.390							

Notes: ***, ** and * indicate significant at 1, 5 and 10 percent level of significance respectively. OU = Overused; UU = Underused

Return to scale analysis

The return to scale (sum of the regression coefficients of all the inputs) of main season rice production was found as 0.39. This indicates the decreasing return to scale in the production of paddy-rice. The additional proportion of output is smaller than the additional input employed. Subedi et al. (2020) reported that the coefficient for return to scale in rice production was 0.86 in Jhapa district. Likewise, Daniel et al. (2019) reported that the decreasing return to scale in rice production with a coefficient of 0.51 in Nigeria. The implication of decreasing-returns-scale in this study implies that the farmers can still increase the level of output at the current level of resources if they re-allocate the uses of resources in optimal combinations. Poudel et al. (2021) reported that the coefficient for the return to scale for of rice was 0.56 which means decreasing return to scale in Gorkha Nepal.

Conclusion

Study has found that inputs used such as the seeds, FYM, chemical fertilizer, micronutrients and pesticides are found underused in the main season rice production, on the other hand, inputs such as labor, tillage and harvesting were found overused. It means that the resources among different inputs were far from being optimally allocated in main season rice. For the optimum allocation of resources in main season rice production, the cost of seed, FYM, chemical fertilizers and micronutrient cum pesticides need to be increased whereas the cost of tillage, human labor and harvesting should be decreased. Thus, if one can ensure a balanced use of resources, the main season rice production could be increased economically, and it can be commercially more viable and also augment the food supply in the economy. It is found that main season rice production has decreasing returns to scale, which implies that the proportional increase in rice income would be lesser than the proportional increase in costs of all inputs taken together. Profitability of spring season rice are much better than the main season rice. Thus, the policymakers and farmers should focus on increasing the cropping area for spring season rice production; it offers huge scope to augment the supply of rice to meet the high domestic demand for rice in Nepal. To increase the profitability and raise the income of farmers from rice production, the major priority areas could be farmers' knowledge about optimum utilization of resources and adoption of improved technologies including increased use of inputs. With such measures, Nepal can still boost domestic supply of rice towards self-reliance in the food market.

Acknowledgements

Paddy farmers and related stakeholders involved during the study purpose are highly acknowledged for their cooperation, support, time, and valuable information. We would also like to convey our sincere gratitude to the Agriculture and Forestry University All those efforts from kind hearts involved directly and indirectly in this study were also appreciated.

References

Acharya, P., Regmi, P. P., Gauchan, D., Bahadur, D., & Bahadur, G. (2020). Benefit cost analysis of adoption of small farm machineries for rice cultivation in Nepal. *International Journal of Applied Sciences and Biotechnology.*

Adhikari, R.K. (2011). Economics of organic rice production. *The Journal of Agriculture and Environment*, 12: 97-103.

Basnet, B., Luitel, G., Sah, A., Baral, S. and Ghimire, M. (2022). Analysis of profitability and effect of factors of production in paddy cultivation in Morang, Nepal. *Archives of Agriculture and Environmental Science*, *7*(3): 425-431. https://doi.org/10.26832/24566632.2022.0703017

Birla, D. S., Malik, K., Sainger, M., Chaudhary, D., Jaiwal, R., & Jaiwal, P. K. (2017). Progress and challenges in improving the nutritional quality of rice (Oryza sativa L.). *Critical Reviews in Food Science and Nutrition*, 57(11), 2455-2481.

Bwala, M.A. and John, A.U. (2018). Profitability analysis of paddy production: A case of agricultural zone 1, Niger State Nigeria. *Journal of the Bangladesh Agricultural University*, 16(1): 88–92, doi: 10.3329/jbau.v16i1.36486.

Choudhary, D., Banskota, K., Khanal, N. P., McDonald, A. J., Krupnik, T. J., & Erenstein, O. (2022). Rice subsector development and farmer efficiency in Nepal: implications for further transformation and food security. *Frontiers in Sustainable Food Systems*, 5, 740546.

Danso-Abbeam, G., Dahamani, A.M. and Bawa, G.A. (2015). Resource-use-efficiency among smallholder groundnut farmers in Northern Region, Ghana. *American Journal of Experimental Agriculture*, 6(5): 290-304.

Daniel, E.J., Afofum, A.A. and Zakee, S.S. (2019). Econometric Analysis of Efficiency of Rice Inputs-Output Relationship in Yobe State *International Journal Innovative Finance and Economics Research, 7(4):101-109.*

Dhakal, S. (2015). Assessment of climate smart sustainable soil management practices and their impacts on farmer's livelihood in Khotang, Nepal.Master thesis submitted to Agriculture and Forestry University for the partial fulfillment of the requirements for the degree of Master of Science in Agriculture (Agricultural Economics), Rampur, Chitwan Nepal.

FAO. (2019). Food and Agriculture Organization of the United Nation. Information sheet on rice.

FAO. (2023). Food and Agriculture Organization Statistics Division 2022/23. Food and Agriculture Organization Statistics Division. https://www.fao.org/faostat/en/#data/TCL

Gairhe. S., Gauchan, D. and Timsina, K.P. (2021). Temporal dynamics of rice produc-tion and import in Nepal. *Journal of Nepal Agricultural Research Council*, 97-108, https://doi.org/10.3126/jnarc.v7i1.36932

Ghimire, B. and Dhakal, S.C. (2014). Production Economics of Sustainable Soil Management based Cauliflower (*Brassicae oleracea*. L. var. *botrytis*) in Dhading district of Nepal. *American* Journal of Agriculture and Forestry, 2(4):199–205.

Ghimire, B., Dhakal, S.C., Marahatta, S. and Bastakoti, R.C. (2024). Are Lentil (Lens culinaris) Farms Productive, Profitable, and Efficient in Resource Allocation? A Cross-Sectional Study from Nepal. Legume Science, 6: e217. https://doi.org/10.1002/leg3.217

Gittinger, J. P. (1982). Economic analysis of agricultural projects (completely revised and expanded) (No. Ed. 2, pp. xxi+-505pp).

Goni, M., Mohammed, S. and Baba, B.A. (2007). Analysis of resource use efficiency in rice production in the Lake Chad area of Borno State, Nigeria. *Journal of Sustainable Development in Agriculture and Environment,* 3(2): 31-37.

Hashim, N., Ali, M. M., Mahadi, M. R., Abdullah, A. F., Wayayok, A., Kassim, M. S. M., & Jamaluddin, A. (2024). Smart Farming for Sustainable Rice Production: An Insight into Application, Challenge, and Future Prospect. *Rice Science*, 31(1), 47-61.

Joshi, N.P., Maharjan, K.L. and Piya, L. (2011). Production Economics of Rice in Different Development Regions of Nepal. *Journal of International Development and Cooperation*, 17(1): 103-112.

Mijindadi, N. B. (1980). Production efficiency on farms in northern Nigeria. PhD dissertation. Cornell University, USA.

Ministry of Agriculture and Livestock Development (2023). Statistical Information on Nepalese Agriculture 2021/2022. Minsitry of Agriculture and Livestock Development. Governement of Nepal, Kathmandu, Nepal.

MoALD. (2024). Statistical Information on Nepalese Agriculture 2021/2022. Minsitry of Agriculture and Livestock Development. Governement of Nepal, Kathmandu, Nepal.

Poudel, U., Kattel, R. R., Gurung, B., Shrestha, S., Paudel, A., & Paudel, A. (2021). Economic analysis of rice (Oryza sativa L.) cultivation in Gorkha district of Nepal. *Archives of Agriculture and Environmental Science*, *6*(4): 489-497. https://doi.org/10.26832/24566632.2021.0604011

Rahaman, M.S., Sarkar, M.A.R., Rahman, M.C., Deb, L., Rashid, M.M., Reza, M.S., Siddique, M.A.B. (2022). Profitability analysis of paddy production in different seasons in Bangladesh: Insights from the *Haor. International Journal of Agriculture, Environment and Food Sciences*, 6 (3), 327-339. Doi**:** https://doi.org/10.31015/ jaefs.2022.3.1

Sapkota, N., Yadav, P.K. and Sapkota, S. (2021). An Economic Analysis of Rice Production in Rautahat District of Nepal. *Food and Agri Economics Review, 1(1): 01-09*.

Subedi, S., Ghimire, Y. N., Gautam, S., Poudel, H. K., & Shrestha, J. (2019). Economics of potato (*Solanum tuberosum* L.) production in terai region of Nepal. *Archives of Agriculture and Environmental Science*, 4(1), 57-62.

Subedi, S., Ghimire, Y.N., Kharel, M., Sharma, B., Shrestha, J. and Sapkota, B.K. (2020). Profitability and resources use efficiency of rice production in Jhapa District of Nepal. *International Journal of Social Science and Management, 7(4): 242-247. DOI: 10.3126/ijssm.v7i4.32487*

Timsina, K. P., Gauchan, D., Gairhe, S., Subedi, S. R., Pokhrel, B. B., Upadhyay, S., ... & Shrestha, J. (2023). Rice demand and production projections for 2050: Opportunities for achieving self-sufficiency in Nepal. *Nepal Agriculture Research Journal*, 15(1), 163-180. DOI : https://doi.org/10.3126/narj.v15i1.51926

SAARC J. Agric., 22(2): 169-180 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.75962*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Selection of the Best Time Series Arima Model to Forecast Onion Production in Bangladesh

M.R. Hasan[1*] and N. Khatun[2]

[1]Assistant Professor (Statistics), Department of Public Health
Leading University, Sylhet-3112, Bangladesh
[2]Lecturer, Department of Sociology, Tejgaon Mohila College, Dhaka-1215, Bangladesh

Abstract

Onion is one of the most commonly used spices in Bangladesh for preparing food and illness treatment. Since the demand for onions is rising daily, accurate projections must be made to implement policies based on that need. Hence, this study attempts to select the best Auto-Regressive Integrated Moving Average (ARIMA) model to forecast onion production in Bangladesh. Initially, this study considers Bangladesh's yearly onion production (in hg/ha) data set from 1971 to 2017. This study then applied the Box-Jenkins approach to build the model and forecast the onion production in Bangladesh. The data from 2018 to 2022 were utilized to compare the forecasted values. The AIC, AIC_C, and BIC values, error metrics, and residuals of the fitted model were assessed using onion production data. The comparative analysis shows that ARIMA (0, 2, 1) is the best model for precise forecasts of onion production in Bangladesh. The proposed model may help policymakers forecast accurately and know the future trend of onion production in Bangladesh.

Keywords: ARIMA model, Bangladesh, Box-Jenkins approach, Forecast, Onion

Introduction

Bangladesh is considered an agricultural country because of its monsoon climate and proximity to rivers. Of all the minor crops, onion (*Allium cepa* L.) is the most important seasonal crop for the human diet. Onion is essential in the human diet for its nutritional, aromatic, and medicinal qualities (Huda et al., 2008; Mishra et al.,

[*] Corresponding author: rashidulhasan067@gmail.com

Received: 03. 09. 2024 *Accepted:03. 12. 2024*

2013; Sharma et al., 2017). One of the primary objectives of Sustainable Development Goals (SDGs) is to achieve food security and ensure better nutrition, and onions are crucial to maintaining the people's proper nutritional status. Onion production is considered more profitable than competing spices and is a highly commercial, income-generating, and employment-generating activity (Anjum & Barman, 2017). It occupies the highest position among all other spice goods in Bangladesh in production (BBS, 2018). Due to its favorable agro-climatic conditions, onions are produced, processed, and marketed in Bangladesh. Onion is produced throughout Bangladesh, with the most extensive cultivation occurring in the following regions: Faridpur, Dhaka, Rajshahi, Cumilla, Jessore, Dinajpur, Mymensingh, Rangpur, and Pabna. Due to the rapid population growth, evolving consumption patterns, and the diverse applications of spices in various food items, the demand for onion in Bangladesh is consistently increasing.

Bangladesh's economy heavily depends on onions because they are widely consumed and have many applications and financial advantages. However, the Bangladeshi market faces difficulties such as odd price swings, intricate dynamics between supply and demand, and dishonest intermediary operations that hurt customers and growers by negatively impacting onion prices. However, insufficient government incentives make many farmers hesitant to grow onions. Bangladesh produced over 1866 thousand tons of onions on 459 thousand acres of land between 2016 and 2017, according to BBS (2018). However, the country must import 700–800 thousand tons of onions annually to meet the 2400 thousand tons of demand, primarily from India, the world's second-largest producer (Hossain, 2019). Such a large amount suggests that Indian onions greatly influence the domestic market price. Additionally, consumers' real incomes are directly impacted by the regular fluctuations in onion prices, which pushes them to adjust their consumption budgets. In this sense, boosting domestic production is crucial for helping consumers balance their food baskets on the one hand and decreasing reliance on imports on the other.

It is difficult for Bangladesh to produce even 15% of the country's yearly onion needs domestically, according to Hossain et al. (2017). The author further reported that the yield level is relatively low (about 370–500 kg/ha) compared to the larger yield (1000–1200 kg/ha) of onions grown in other countries. Lack of high-quality seed, improved varieties, and incorrect irrigation of onion production are all linked to reduced yield levels, which in turn cause an imbalance between supply and demand. Furthermore, such an imbalance frequently drives up the price of onions, directly affecting consumers' real incomes and causing them to adjust their consumption budget (Kondal, 2011). Therefore, increasing domestic production in the upcoming years will be crucial to help consumers balance their food basket and lessen their reliance on imports. Furthermore, it can only be accomplished with a precise forecast of onion production. Consequently, this study attempts to determine which Auto-Regressive Integrated Moving Average (ARIM) model is most suitable for predicting Bangladesh's onion production. Such an attempt may enable the government to design appropriate production schedules and trade policies to balance demand and supply in the domestic market through self-production rather than resorting to import.

The Box-Jenkins ARIMA model has been widely used in the field of forecasting econometric time series, inventory, and price modeling. Furthermore, this method is frequently used in the agricultural crop production process to foresee the yield of important crops including soybean, rice, wheat, jute, tea, palm oil, and so on. However, very limited use of ARIMA was found in forecasting onion production in Bangladesh. Several comparable studies (Kondal, 2011; Mishra et al., 2013; Sharma et al., 2017; Warade, 2016) that were carried out in India may be found in the literature. India leads the global onion market as an exporting nation. Thus, the policy-making in importing nations like Bangladesh may not be appropriate for the forecast based on the Indian context. Similar research was done nationally by Hossain et al. (2017); however, this study's shortcoming was that it only looked at onion production data from 1971 to 2013. Considering this limitation, an attempt has also been made in our work to forecast onion production spanning a large data set over 47 years using the most popular ARIMA model. However, several studies have been conducted in Bangladesh and abroad to analyze the forecast behavior of time series data by applying the ARIMA model. For instance, Mila and Parvin (2019) used the ARIMA model to forecast the area, production, and yield of onions in Bangladesh. Time series analysis, more specifically the ARIMA technique, was used by Kumar et al. (2024) to forecast onion prices in Gujarat, India's central wholesale market. Finally, this paper is organized under the following sections: Introduction, Materials and Methods, Results and Discussions, Conclusions and Policy Implications.

Materials and Methods

The Data

This study used data on yearly onion production (in hg/ha) in Bangladesh from 1971 to 2017, collected from the Food and Agricultural Organization (FAO) website (https://www.fao.org/faostat). The forecasting was made for 2018 to 2027. The data from 2018 to 2022 were used to validate the forecasting.

Box-Jenkins Approach

The Box-Jenkins approach is applied to univariate time series modeling and is particularly well suited to short-term forecasting (Ray & Bhattacharyya, 2020). The steps for the Box-Jenkins approach are identification, estimation, diagnostic checking, and forecasting. Before constructing the Box-Jenkins technique, it is essential to examine the stationarity of the time series. In this work, several well-known statistical tests, such as the Augmented Dickey-Fuller (1979) test and the Phillips-Perron (1988) test, were employed to examine the stationarity of time series. The identification step estimated the model's order using the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). Parameters were estimated using the Maximum Likelihood (ML) method after determining the model's order. The best model has been chosen using model selection criteria such as

Akaike Information Criteria (AIC), Akaike Information Corrected Criteria (AIC_C), and Bayesian Information Criteria (BIC). The standardized residuals plot, ACF plot of residuals, and histogram with a normal curve of residuals were used to perform diagnostic checking. The Ljung-Box test (Ljung and Box, 1978) was also used to test the residuals' autocorrelation. In this case, the null hypothesis is $H_o : \rho_1 = \rho_2 = ... = \rho_k = 0$ that is the autocorrelation among the residuals is zero is tested with the Ljung-Box statistic $Q^* = n(n+2)\sum_{k=1}^{m}(n-k)^{-1}\rho_k{}^2 \sim \chi^2(m)$. Where *n* is the number of observations used to estimate the model, ρ_k is the sample autocorrelation at lag *k*, and *m* is the number of lags being tested.

The accuracy of the selected model was measured using the Mean Absolute Percentage Error (MAPE). The MAPE is perhaps the most commonly used indicator of forecasting accuracy (Armstrong & Collopy, 1992; Goodwin & Lawton, 1999) and is defined by the following formula $MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{\hat{y}_t - y_t}{y_t}\right| \times 100$. Where *n* is the number of observations, y_t is the observed value at time *t*, and $\hat{y}_t$ is the predicted value by the model for time *t*. Finally, the forecasted and actual values were compared to check the validity of the chosen model (Ray et al., 2016).

The ARIMA Model

A generalization of an auto-regressive moving average model in time series analysis is called an auto-regressive integrated moving average (ARIMA) model. The study took a non-seasonal ARIMA (*p, d, q*) model into consideration because the data show no seasonal variation. The model can be derived as follows:

A time series process $\{Y_t\}$ is called an auto-regressive process of order *p* denoted by AR (*p*) and is defined by $Y_t = \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + ... + \alpha_p Y_{t-p} + \varepsilon_t$

If $\{\varepsilon_t\}$ is a white noise with mean zero and variance σ^2 then $\{Y_t\}$ is called a moving average process of order *q* denoted by MA (*q*) and is defined by $Y_t = \varepsilon_t + \beta_1\varepsilon_{t-1} + \beta_2\varepsilon_{t-2} + ... + \beta_q\varepsilon_{t-q}$. The combination of AR and MA models are known as autoregressive moving average (ARMA) model. An ARMA (*p, q*) model is defined as

$Y_t = \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + ... + \alpha_p Y_{t-p} + \varepsilon_t + \beta_1\varepsilon_{t-1} + \beta_2\varepsilon_{t-2} + ... + \beta_q\varepsilon_{t-q}$; Where, Y_t is the original series. For every *t* we assume that ε_t is independent of $Y_{t-1}, Y_{t-2}, \ldots, Y_{t-p}$.

Again, a time series $\{Y_t\}$ is said to follow an ARIMA model if the *d* th difference $W_t = \nabla^d Y_t$ is a stationary ARMA process. If $\{W_t\}$ follows an ARMA (*p, q*) model, $\{Y_t\}$ is said to be an ARIMA (*p, d, q*) process. Thus an ARIMA (*p, 1, q*) process is defined by:

$$W_t = \alpha_1 W_{t-1} + \alpha_2 W_{t-2} + ... + \alpha_p W_{t-p} + \varepsilon_t + \beta_1 \varepsilon_{t-1} + \beta_2 \varepsilon_{t-2} + ... + \beta_q \varepsilon_{t-q};$$

Where, $W_t = Y_t - Y_{t-1}$

Statistical Software and Packages Used

The study's analysis was carried out entirely using the open-source statistical programming software R Studio (version 4. 3. 0) for Windows. Several library packages are utilized for analysis, including **TSA, forecast, MASS,** and **t series**.

Results and Discussions

Plot of the Original and Differenced Time Series

The original and differenced onion production data are shown graphically in Figures 1 and 2.

It is clear from Figure 1 that the yearly onion production in Bangladesh fluctuated over the study period of 1971 to 2017. It started in 1971 and fell till 1977, then reached a short peak in 1978 and 1980, and after that, the production again fell dramatically. So there is a decreasing trend up to the year 1981. Between 1982 and 2000, onion production was almost equal, and then it fell again for a short time. After 2003, there was a dramatic increase in onion production, which led to an increasing trend; that is, the variation of onion production was unstable, leading to the data series not being stationary. One of the main causes of this increase is the revolution in the agricultural sector in Bangladesh.

The first step in building an ARIMA model is to identify whether the variable being forecasted is stationary in a time series. To obtain a stationary series, we take the difference 'd' of the original time series. The first and second differenced onion production series are presented below. Figure 2(b) shows that the second differenced onion production data is stationary in its mean and variance. Thus, to stabilize the variance and to make the series stationary, the second difference is enough that the difference order is 2, and it is said that integrated order d=2. But before moving further, we first test the stationarity (unit root problem) of the second differenced data series using the Augmented Dickey-Fuller and Phillips-Perron tests.

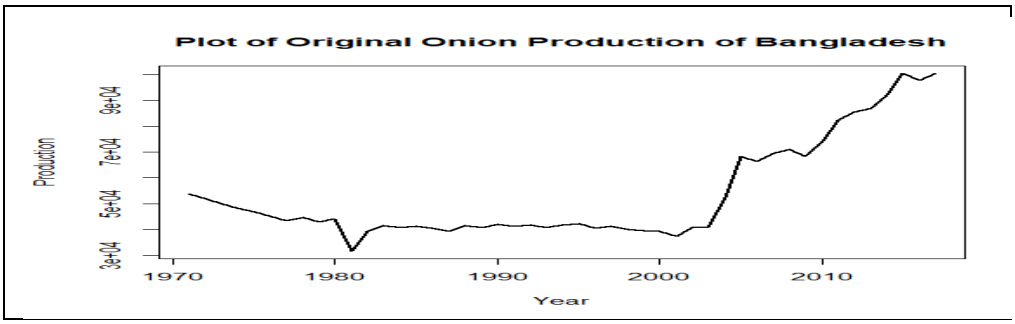


Fig. 1. Time series (original series) plot of onion production in Bangladesh

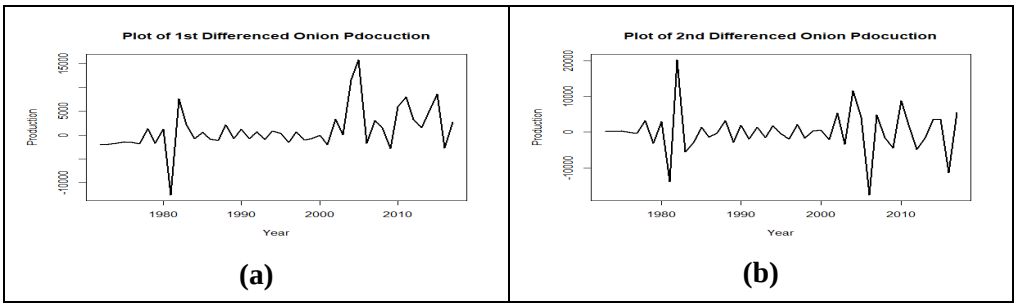


Fig. 2. Time series plot of first and second differenced onion production in Bangladesh

Stationarity Test

The test statistics for the Augmented Dickey-Fuller test and Phillips-Perron tests is

H_0 : The series has a unit root.

H_1 : The series does not have a unit root. That is the data series is stationary.

Table 1. ADF and PP tests for second differenced onion production series

Tests	Calculated value	Truncation lag parameter	P-value	Comment
ADF Test	-4.989	3	0.01	Stationary
PP Test	-56.838	3	0.01	Stationary

The p-values (=0.01) of the ADF and PP tests declared that the second differenced onion production data series is stationary, suggesting that there is no unit root.

Identification of Tentative Model

To detect AR and MA terms, the ACF and PACF plots of the second differenced onion production data are given below (Figure 3):

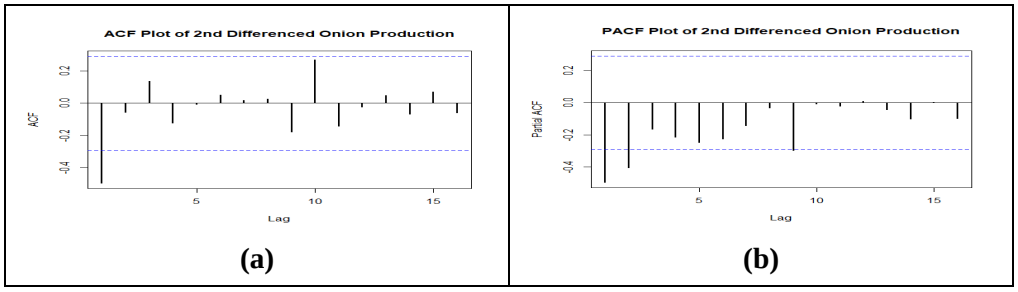


Fig. 3. ACF and PACF plots of second differenced onion production in Bangladesh

In PACF, there are significant negative spikes at lag 1 and lag 2, and not much else. Clearly, Figure 3(b) has a cut-off on the PACF curve after 2nd lag, which is primarily an AR(2) process. So, AR(2) may be effective for onion production in Bangladesh. Also, in ACF, there is a significant negative spike at lag 1 and not much else. Clearly, Figure 3(a) has a cut-off on the ACF curve after 1st lag, which is primarily an MA(1) process. So, MA(1) may be effective for onion production in Bangladesh. The alternative negative and positive ACF and exponentially decaying PACF indicate an autoregressive moving average process.

Selecting the Best ARIMA Model from Tentative Models

The best ARIMA model is selected based on the lowest AIC, AIC_C, and BIC values. The ARIMA model with auto-regressive of order $p = 2$, difference of order $d = 2$, and moving average of order $q = 1$, and all possible tentative models with appropriate combinations of AR (p) and MA (q) terms are given below.

Table 2 shows that the ARIMA (0, 2, 1) is the best-selected model for forecasting onion production in Bangladesh based on the lowest AIC, AIC_C, and BIC values.

Table 2. Several ARIMA models and their AIC, AIC_C, and BIC values

Tentative Models	AIC	AIC_C	BIC
ARIMA (2, 2, 1)	-80.87	-79.87	-73.65
ARIMA (1, 2, 1)	-82.87	-82.28	-77.45
ARIMA (0, 2, 1)	-84.14	-83.86	-80.53
ARIMA (2, 2, 0)	-74.41	-73.83	-68.99

Parameter Estimation and Diagnostic Test of Models

The parameter of the fitted model was estimated using the maximum likelihood method, and the diagnostic test of the fitted model's residuals was performed using the Ljung-Box test (Table 3).

Table 3. Summary and Ljung-Box test of the fitted model

Fitted Model	Summary statistics				Ljung-Box test		
	Parameter	Estimated value	SE	P value	Lag used	Q^*	P value
ARIMA (0, 2, 1)	q	-0.907	0.063	<0.001	9	3.169	0.923

SE: Standard Error of Parameter

The p-value (=0.923) of the Ljung-Box test strongly recommends no autocorrelation among the residuals of the fitted ARIMA model.

To further investigate the distribution of residuals in the fitted model, the residual plot, ACF and PACF plots of residuals, and histogram with a normal curve are presented below (Figure 4):

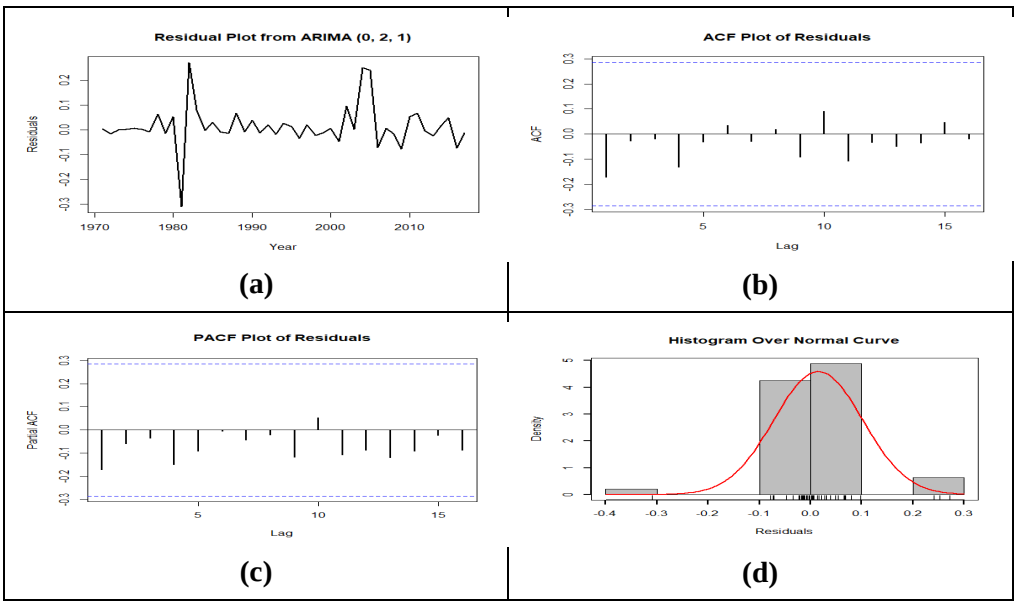


Fig. 4. Several plot of residuals and histogram with the normal curve

The residual plot (Figure 4(a)) illustrates that the standard errors are roughly constant in their mean and variance over time. However, there has been a higher variation in

the past and most recent decades. Figures 4(b) and 4(c) show all the autocorrelation and partial autocorrelation coefficients are within the 95% confidence intervals, providing reliable evidence of no autocorrelation among the residuals of the fitted ARIMA model. The histogram with a normal residual curve (Figure 4(d)) indicates that the residuals of the fitted models are roughly normally distributed. To further investigate the adequacy of the fitted model, forecasting criteria values were presented in the following table.

Table 4. Forecasting criteria values of the fitted model

Fitted Model	Forecasting Criteria			
	RMSE	MAE	MAPE	MASE
ARIMA (0, 2, 1)	4169.599	2479.866	4.795	0.864

RMSE: Root Mean Square Error, MAE: Mean Absolute Error, MAPE: Mean Absolute Percentage Error, MASE: Mean Absolute Scaled Error

The MAPE of the ARIMA (0, 2, 1) model is less than 10, which indicates that the model is highly accurate (Lewis, 1982). Therefore, ARIMA (0, 2, 1) is the best-fitted model and is adequate to forecast the onion production in Bangladesh. The study conducted in Bangladesh by Hossain et al. (2017) supports the outcome.

Forecasting

Forecasting onion production was made after selecting the best-fitted model. The first 47 years of data (1971–2017) were used to build the model. The model was then used to forecast onion production for 2018–2027. The five years of data (2018–2022) were used to compare the predicted and actual values to validate forecasting. Table 5 shows the best-fitted ARIMA (0, 2, 1) model's forecast value and 95% confidence interval (Figure 5). Table 5 shows that the ARIMA (0, 2, 1) model forecasts an increase in onion production from 2018 to 2027. The forecast and actual values are quite similar and in the 95% confidence interval. Figure 5 also shows that the forecast data series (dark blue color) fluctuates very little from the original data series (red color). Therefore, the forecasted onion production series is a much more accurate representation of the actual onion production series.

Table 5. Forecasted value of the onion production in Bangladesh

Year	Forecast value	Actual value	95% CI for forecast value	
			LCL	UCL
2018	104297	97348	87399	124462
2019	108245	104541	83303	140654
2020	112342	105455	80317	157137
2021	116595	116768	77786	174765
2022	121008	122542	75481	193996
2023	125589	--------	73294	215194
2024	130342	--------	71173	238703
2025	135276	--------	69085	264885
2026	140397	--------	67015	294132
2027	145711	--------	64953	326878

CI: Confidence Interval, LCL: Lower Confidence Limit, UCL: Upper Confidence Limit

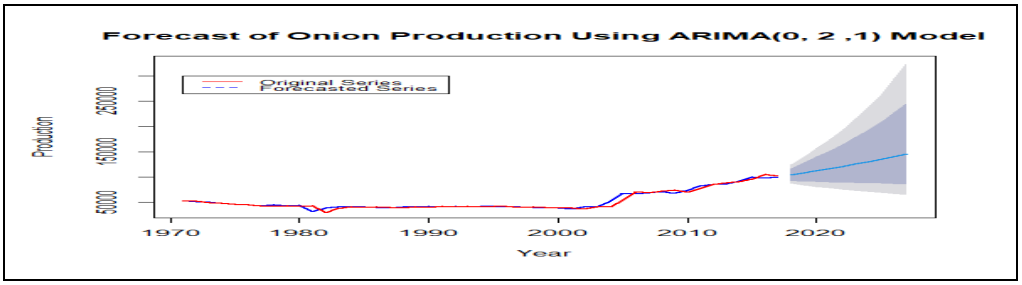


Fig. 5. Forecast from the best-fitted ARIMA model

Conclusions and Policy Implications

A time series model forecasts future values by identifying patterns in a variable's past movement. This study is intended to select the best time series ARIMA model to forecast onion production in Bangladesh. The Box-Jenkins ARIMA approach and several model selection criteria, such as AIC, AIC_C, and BIC, served the purpose. The experimental findings of this study conclude that ARIMA (0, 2, 1) is the best model to forecast onion production in Bangladesh. The graphical comparison between the observed and projected onion production shows slight variation, which indicates that the fitted model is forecasted well. The predicted values help businessmen or decision-makers identify whether to import or export the onion to meet the country's needs. The outcomes of the forecasting model also offer valuable insights for policymakers to stabilize onion prices, support farmers, and protect consumers' interests in the Bangladeshi market.

References

Anjum, A., and Barmon, B. K. (2017). Profitability and comparative advantage of onion (Allium cepa) production in Bangladesh: An economic study in some selected areas. *The Agriculturists*, 15(2): 66-78. http://dx.doi.org/10.3329/agric.v15i2.35466

Armstrong, J. S., and Collopy, F. (1992). Error measures for generalizing about forecasting methods: Empirical comparisons. *International Journal of Forecasting*, 8(1): 69-80. https://doi.org/10.1016/0169-2070(92)90008-W

BBS. (2018). *Yearbook of Agricultural Statistics of Bangladesh-2017*. Statistics and Informatics Division, Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh. https://bbs.portal.gov.bd

Goodwin, P., and Lawton, R. (1999). On the asymmetry of the symmetric MAPE. *International Journal of Forecasting*, 15(4): 405-408. https://doi.org/10.1016/S0169-2070(99)00007-2

Hossain, I. (2019). Onion market on fire: The price of 1 kg onion is now the same as 1 kg of broiler chicken. *Dhaka Tribune*. https://www.dhakatribune.com/bangladesh/nation/192054/

Hossain, M. M., Abdulla, F., and Parvez, I. (2017). Time series analysis of onion production in Bangladesh. *Innovare Journal of Agricultural Science*, 5(1): 1-4. https://www.researchgate.net/publication/310734848

Huda, F. A., Islam, M. S., Biswas, H., and Islam, M. S. (2008). Impact assessment study on selected spice crops under action plan in Bangladesh. *Progressive Agriculture*, 19(2): 229-241. http://dx.doi.org/10.3329/pa.v19i2.16965

Kondal, K. (2011). Growth rate of area, production and productivity of onion crop in Andhra Pradesh. *Indian Journal of Applied Research*, 4(3): 4-6. https://doi.org/10.15373/2249555 x/mar2014/2

Kumar, M., Sharma, R. K., Bhopala, U. D., and Suthar, B. (2024). Forecasting prices of onion in major wholesale markets of Gujarat. *International Journal of Statistics and Applied Mathematics*, 9(1S): 22-29. https://doi.org/10.22271/maths.2024.v9.i1Sa.1539

Lewis, C. D. (1982). Industrial and Business forecasting methods. *Journal of Forecasting*, 2(2): 194-196. https://doi.org/10.1002/for.3980020210

Ljung, G. M., and Box, G. E. P. (1978). On a measure of lack of fit in time series models. *Biometrika*, 65(2): 297–303. https://doi.org/10.1093/biomet/65.2.297

Mila, F. A., and Parvin, M. T. (2019). Forecasting Area, Production and Yield of Onion in Bangladesh by Using ARIMA Model. *Asian Journal of Agricultural Extension, Economics & Sociology*, *37*(4): 1–12. https://doi.org/10.9734/ajaees/2019/v37i430274

Mishra, P., Sarkar, C., Vishwajith, K. P., Dhekale, B. S., and Sahu, P. K. (2013). Instability and forecasting using ARIMA model in area, production and productivity of onion in India. *Journal of Crop and Weed*, 9(2): 96-101. https://www.researchgate.net/publication/275768973

Ray, S., and Bhattacharyya, B. (2020). Statistical modeling and forecasting of ARIMA and ARIMAX models for food grains production and net availability of India. *Journal of Experimental Biology and Agricultural Sciences*, 8(3): 296–309. http://dx.doi.org/10.18006/2020.8(3).296.309

Ray, S., Bhattacharyya, B., and Pal, S. (2016). Statistical modeling and forecasting of food grain in effects on public distribution system: An application of ARIMA model. *Indian Journal of Economics and Development*, 12(4): 739–744. http://dx.doi.org/10.5958/2322-0430.2016.00199.2

Sharma, H., Parihar, T. B., and Kapadia, K. (2017). Growth rates and decomposition analysis of onion production in Rajasthan State of India. *Economic Affairs*, 62(1): 157-161. http://dx.doi.org/10.5958/2230-7311.2017.00051.4

Warade, S. V. (2016). Forecasting of onion prices in Maharashtra: An approach to support vector regression and ARIMA model. *International Journal of Social Science and Humanities Research*, 4(2): 350–355. https://www.researchpublish.com/upload/book/Forecasting%20Of%20Onion%20Prices-3238.pdf

SAARC J. Agric., 22(2): 181-196 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.76201*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Chitosan-Based Zinc Oxide and Silver Nanoparticles Coating on Postharvest Quality of Papaya

S. Timilsina[1*], R. Adhikari[2], P.P. Khatiwada[3], G. Devkota[2] and K.C. Dahal[1]

[1]Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Nepal
[2]Research Center of Applied Science and Technology (RECAST), Tribhuvan University, Nepal
[3]Value Chain Development Project (VCDP), Lalitpur, Nepal

Abstract

The study aimed to investigate the effects of chitosan-based zinc oxide and silver nanoparticles coating on physicochemical properties of papaya and to optimize nanoparticles concentrations for extending its postharvest shelf life. The experiment was conducted in February, 2022 at the Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Kathmandu, Nepal, using a Completely Randomized Design (CRD) with nine treatments and three replications. The treatments consisted of different concentrations (50 ppm, 100 ppm, 150 ppm, and 200 ppm) of either Zinc oxide and silver nanoparticles, along with a control. Zinc oxide and silver nanoparticles were synthesized from banana peel extract and the average crystalline sizes were found to be 22.30nm and 4.46nm, respectively. Fruits were dipped in 1.5% (w/v) chitosan with 50–200 ppm of zinc oxide and silver nanoparticles and then stored at ambient temperature (14±1.6°C) and ~75% RH. The nanoparticles coatings slowed changes in total soluble solids (TSS) and total titratable acidity (TTA), delaying ripening. Treated fruits showed reduced physiological loss in weight and maintained firmness better than control, with firmness decreasing to 4.79 kg in untreated fruits compared to 7.35 kg in coated fruits on 18th day of storage. Coated fruits retained more ascorbic acid, and the storage life increased by 8 and 9 days with 150 and 200 ppm treatments, respectively. However, consumer preference declined for concentrations above 150 ppm. Thus, 100–150 ppm chitosan-based zinc oxide/silver nanoparticles are found to be effective for extending shelf-life and

* Corresponding author: rashidulhasan067@gmail.com

Received: 11. 09. 2024 *Accepted: 11. 12. 2024*

maintaining physiochemical characteristics of papaya. However, its residual and health-related dimensions need to be extensively studied before its commercial application.

Keywords: Chitosan, Coating, Nanoparticles, Postharvest

Introduction

Papaya (*Carica papaya* L. 2n = 18) is widely cultivated tropical fruit known for its nutritional and economic importance. It is native to Central America but now grown in tropical and subtropical regions of South America, Africa and Asia (Ming et al., 2008). It is a climacteric fruit, continues to ripen after being harvested, with a high respiration rate and significant ethylene production during the ripening process (Zhu et al., 2019). Perishability of papaya coupled with improper handling, poor storage conditions and its susceptibility to fungal diseases reduces the postharvest life and quality of fruits leading to higher postharvest losses. It has been reported that the average postharvest loss in fruit and vegetables are about 20-40% (El-Ramady et al., 2015), but the postharvest loss in papaya is much higher i.e., 40-100% (Vyas et al., 2014). These losses negatively affect all stakeholders in the supply chain, from growers to consumers (Shiga et al., 2009). Therefore, the shelf-life prolongation of papaya has become an essential issue to be addressed.

Applying safe, edible coatings has shown promise in extending the self-life of fruits. These coating form a protective layer that slows respiration and transpiration rates, reduces deterioration process, and preserves the internal quality (Joshy et al., 2020). Coatings also help to retain structural integrity and firmness, protect volatile compounds responsible for flavor and aroma and improve aesthetic appeal by covering physical damage and enhancing shine (Murmu and Mishra, 2018). Edible coating can be formulated with various materials such as polysaccharides, lipids, protein, and resin (Murmu and Mishra, 2018). Among these materials, polysaccharides like chitosan, alginate, carrageenan, carboxymethyl cellulose and pectin, being widely used due to their renewability, biodegradability and biocompatibility (Zhao et al., 2021). Although, polysaccharide-based coating provides an effective barrier to gaseous exchange, creating a modified atmosphere around the fruit, they typically have weak moisture barriers and limited mechanical strength (Meindrawan et al., 2018). This makes polysaccharide alone less suitable for high moisture contenting fruits like papaya (Yousuf et al., 2018).

Nanoparticles (NPs) can be added to enhance the performance of polysaccharide-based coating. The use of NPs in food science has grown globally in recent years (Bouwmeester et al., 2014). Adding NPs, such as zinc oxide (ZnO) and silver (Ag), to polysaccharides coatings can greatly improve mechanical strength, structural integrity, and barrier properties, while also providing antimicrobial effects (Butu et al., 2019). This combination of NPs and polysaccharide-based coating offers a promising approach for extending papaya's postharvest life, benefiting producers and traders by reducing losses. This study investigates the potential of ZnO and Ag NPs in enhancing the shelf life of papaya.

Materials and Methods

The experiment was conducted at the Laboratory of the IAAS, Tribhuvan University, Nepal (located at 27°39' latitude and 85°16' longitude, with an altitude of 1300 meters) during February, 2022.

Synthesis and Characterization of Nanoparticles

Preparation of banana peel extract

Two hundred gram of banana peel was heated with 1000 ml of distilled water at 70°C for 60 min on a magnetic stirrer. The extract was cooled and filtered through cheesecloth to remove water-insoluble fractions, then stored at 4°C for further use.

Green synthesis of nanoparticles

Zinc oxide nanoparticles: A 0.1M zinc acetate dihydrate solution was mixed with banana peel extract in a 9:1 ratio and heated at 70°C under constant stirring at 1000 rpm. A 0.1M sodium hydroxide (NaOH) solution was added dropwise to the mixture until it turned pale yellow and a white precipitate formed. The mixture was then cooled and filtered using Whatman No. 1 filter paper. The residue was washed three times with distilled water, dried at 40°C for 24 hours, and ground into a fine powder.

Silver nanoparticles: A 0.1M silver nitrate solution was heated to 70°C under constant stirring at 1000 rpm. Banana peel extract was added dropwise until the solution turned brown. The mixture was then incubated in the dark for 48 hours. After incubation, it was centrifuged at 8000 rpm for 50 minutes at 4°C and washed three times with distilled water. The resulting Ag NPs pellets were stored in a desiccator for 72 hours to remove moisture.

Characterization of nanoparticles

A light-yellow solution with white precipitation indicated the synthesis of ZnO NPs, while a color shift from colorless to yellowish-brown to radish brown signified the formation of Ag NPs (Jain et al., 2009; Ahmad et al., 2003). UV-Spectrophotometer (Model Shimadzu UV-1900i) was used to record the optical absorption spectra from 200–800 nm, with distilled water as a blank. The crystal size was calculated using Scherrer formula as described in Jain et al. (2009).

Fruit Sample Collection

Papaya cv. Red Lady (mature green with less than 10% color development) was taken from Nobel Agriculture Farm in Bharatpur-25, Chitwan, Nepal and transported to the Institute of Agriculture and Animal Science (IAAS) laboratory at night. The fruits were carefully chosen for uniformity in size, shape, maturation stage, color, and free from visible wounds or defects.

Research Design

The experiment was laid out in a completely randomized design (CRD) with nine treatments and three replications. The treatments consisted of different concentrations (50 ppm, 100 ppm, 150 ppm, and 200 ppm) of either ZnO or Ag NPs and a control.

Coating Materials Preparation and Fruit Coating

Firstly, chitosan solution was prepared by dissolving 1.5% (w/v) chitosan in 1% (v/v) acetic acid at 60°C with continuous stirring for 4 hours and then filtered. ZnO and Ag NPs (50-200 ppm) were dispersed in distilled water and added to the chitosan solution, adjusting the pH to 5.0 with 0.1N NaOH. Glycerol (1% v/v) was added to improve wettability of the coating solution. The papaya cv. Red Lady of uniform size were washed in tap water and then in a 2% (v/v) sodium hypochlorite solution. The fruits were dipped in coating mixtures for 3 min, then placed on a grid to drain excess coating. After drying, both coated and control (uncoated) fruits were stored at room temperature (14±1.6°C) and 75% relative humidity.

Evaluation of Fruit Quality Attributes

Physiological loss in weight was measured on the 4^{th}, 8^{th}, 14^{th}, and 18^{th} days of treatment. Firmness was assessed by destructive sampling method using a digital penetrometer (Model FR-5120) with an 8mm probe pressed perpendicularly to the fruit's equator, and was recorded in kg. Total soluble solids (TSS) in the pulp were determined with a digital refractometer (Model HI 96801). TTA was measured as per Ranganna (1991) by grinding 10 g of papaya pulp with distilled water, filtering through Whatman No. 1, and adjusting the volume to 50 ml. After that, three drops of 1% phenolphthalein were added and titrated with 0.1N NaOH until a stable pink color persisted (pH 8.1-8.3). The TTA was expressed as g of citric acid per 100 g fresh weight; this is the predominant organic acid in papaya cv. Red Lady. Ascorbic acid was quantified using the indophenol method (Sadasivam and Balasubraminan, 1987), by extracting 10 g of pulp in oxalic acid, adjusting to 50 ml, and titrating with indophenol dye and compared it with the standard ascorbic acid. The ascorbic acid content was calculated as mg per 100 g of fruit pulp. The shelf life was visually assessed, with five panelists ranking fruit from 1-5 for overall acceptability after 16 days; scores above 3 were deemed marketable. The storage life was calculated by counting the period between the day of treatment and the final marketable stage of the fruits. An organoleptic test was conducted with 20 panelists using a seven-point hedonic scale on the 14^{th} day of storage.

Statistical Analysis

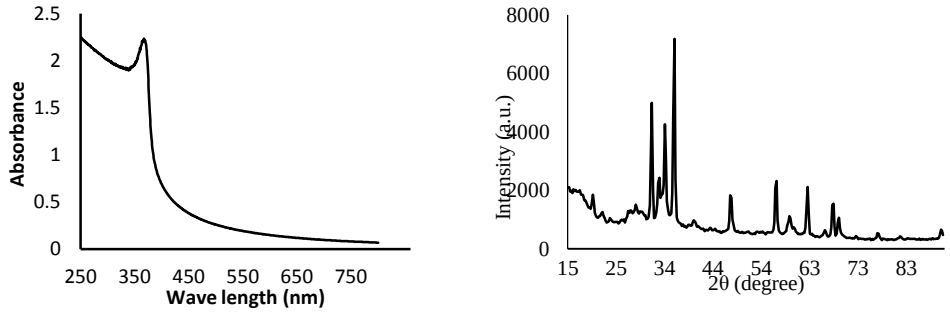
Data were analyzed using one-way ANOVA and the source of variation was treatment only. Mean comparisons were conducted with Fisher-protected least significant differences at $p \leq .05$. Statistical analysis was performed using Excel and GenStat (18th edition).

Results and Discussion

Characterization of Nanoparticles

Characterization of zinc oxide nanoparticles

The spectrum showed a characteristic absorption peak at 369 nm (Figure 1a), confirming ZnO NPs synthesis. X-ray diffraction revealed the characteristic ZnO NPs peak, with an average crystalline size of 22.3 nm (Figure 1b).

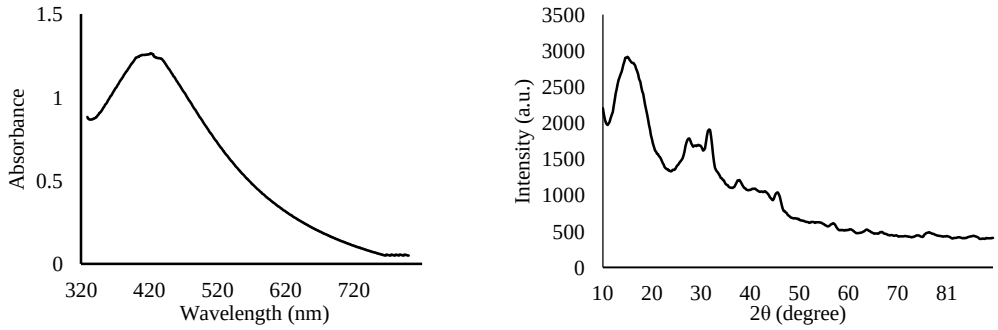


a b

Fig. 1. UV-Vi's absorption spectra (a) and X-RD pattern (b) of green synthesized zinc oxide NPs.

Characterization of silver nanoparticles

The absorbance peak was found at 422 nm, conformed the synthesis of Ag NPs (Figure 2a). The synthesis of Ag NPs was further supported by X-Ray Diffraction (X-RD) pattern and the average crystalline size was found to be 4.46 nm (Figure 2b).



a b

Fig. 2. UV-Vi's absorption spectra (a) and X-RD pattern (b) of green synthesized silver NPs.

Evaluation of Fruit Quality Attributes

Physiological loss in weight (PLW)

Weight loss is a key factor in determining the storage life and quality of fruits, as well as the effectiveness of coatings for preserving papaya (Ali et al., 2011). On the 4^{th} day, PLW was significantly ($p \leq .05$) higher on untreated fruits compared to treated, though no significant difference was observed among the treated fruits (Figure 3). On 8^{th} day of storage, fruits treated with 200ppm Ag NPs had the least

PLW statistically at par with 200ppm ZnO NPs and 150ppm Ag NPs, 150ppm ZnO NPs and 100ppm Ag NPs. On the 18th day, the lowest PLW was observed with 200ppm Ag NPs treated fruits, which is statistically ($p \leq .05$) at par with 150ppm Ag NPs, 200ppm ZnO NPs and 100ppm Ag NPs treated fruits.

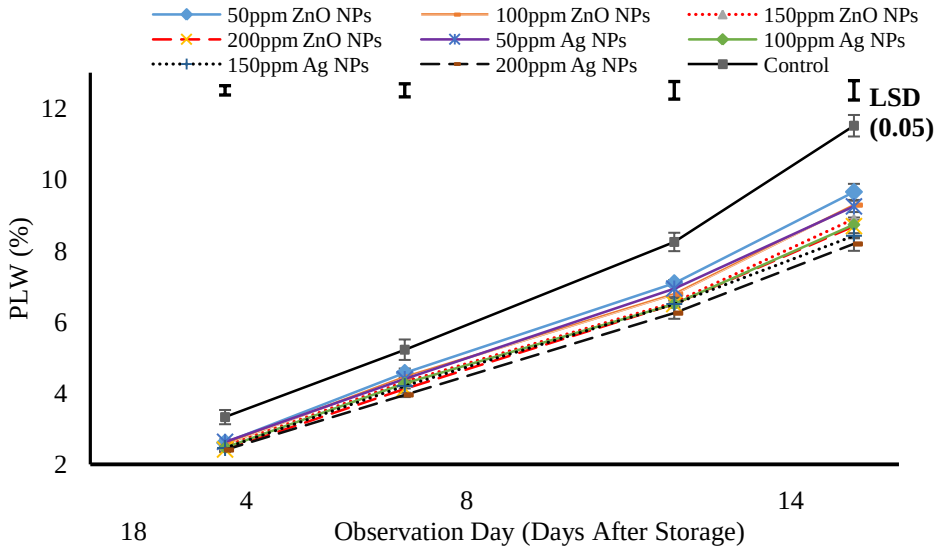


Fig. 3. Effect of ZnO and Ag NPs coatings on PLW in papaya cv. Red Lady stored at 14±1.6°C and ~75% RH.

Physiological loss in weight of the harvested fruits is mainly due to water loss from transpiration and carbon loss from respiration (Sogvar et al., 2016). Chitosan-based ZnO and Ag NPs create a thin barrier on the fruit, reducing moisture loss and slowing respiration by limiting gas exchange (Ali et al., 2020; Anugrah et al., 2020). This reduced respiration slows carbohydrate breakdown, minimizing PLW (Arowora et al., 2013). The reason for the reduction in PLW with the increase in the concentration of NPs might be due to the improvement of the coating's barrier properties, such as an increasing barrier to moisture and gaseous exchange with the increased concentration.

Hmmam et al. (2021), Saekow et al. (2019), and Taha et al. (2022) studies showed that the coating of polysaccharide-based coatings with ZnO and Ag NPs function as a partially permeable barrier to water and gas, effectively reducing moisture loss and weight loss. Additionally, Svagan et al. (2009) concluded that nanomaterials create crisscross structure within the coating layer, which prevents the exchange of oxygen and carbon dioxide and further minimizes moisture loss.

Fruit firmness

Firmness is a key fruit quality attribute for handling, consumer acceptability, transportability, marketability, and postharvest life (Ali et al., 2011). Firmness decreased during storage in all treatment, but higher concentrations of ZnO and Ag NPs slowed the decline (Figure 4). On the 4th day, NPs-treated fruits had significantly ($p \leq .05$) higher firmness than untreated fruits, though no significant difference was found among the treated fruits. On the 8th day, 200ppm ZnO NPs-treated fruits had the highest firmness, followed by 200ppm Ag NPs, 150ppm Ag NPs and 150ppm ZnO NPs all significantly ($p \leq .05$) higher than 50ppm ZnO, 50ppm Ag, and untreated fruits.

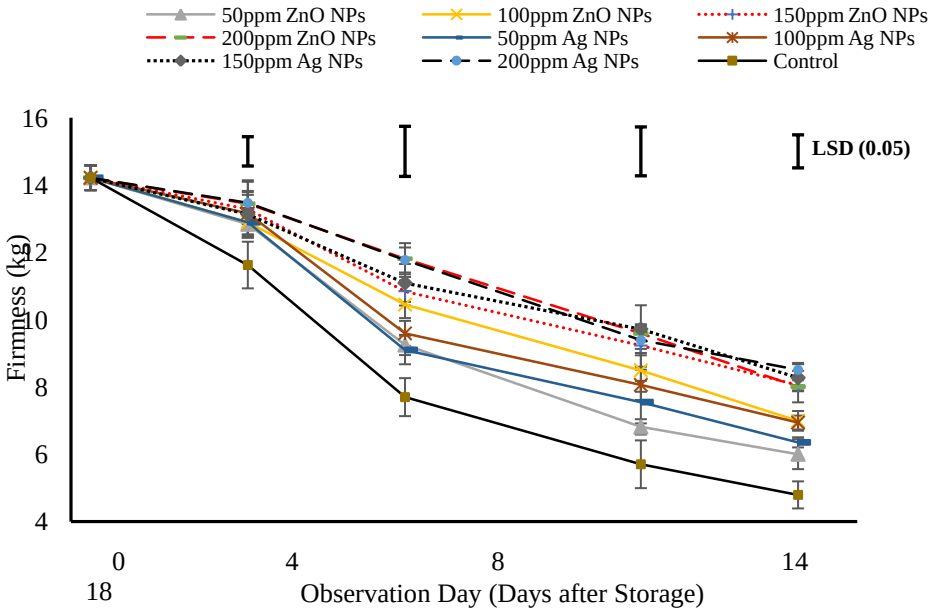


Fig. 4. Effect of ZnO and Ag NPs coatings on firmness in papaya cv. Red Lady stored at 14±1.6°C and ~75% RH.

On the 18th day, 200ppm Ag NPs maintained the highest firmness, followed by 150ppm Ag, 150ppm ZnO, and 200ppm ZnO, all significantly ($p \leq .05$) firmer than other treatments. The fruit firmness was 1.78, 1.72, 1.67 and 1.68 fold more in fruit treated with 200ppm Ag NPs, 150ppm Ag NPs, 200ppm, ZnO NPs and 150ppm ZnO NPs, respectively, compared to control on the 18th day of storage. While the firmness of untreated fruit decreased to 4.79 kg, the average firmness of treated fruit remained significantly higher at 7.35 kg on the same day. The reduced internal oxygen in NP-treated fruits slows cell wall-degrading enzymes like polygalacturonase, pectin methylesterase, and cellulase, preserving firmness longer by slowing carbohydrate conversion (Yahia et al., 2019). These findings are similar to Batool *et al*. (2022) and

La *et al*. (2021) which demonstrates that nano-ZnO NPs and nano-silver effectively maintain the firmness of fruits.

Total soluble solids (TSS)

Total soluble solids (TSS) is one of the vital parameters for assessing postharvest storage and fruit quality. TSS was 7.83 °Brix before coating and increased up to 11.03 °Brix on 18th day (Figure 5). On the 4th day of storage, untreated fruits had significantly higher TSS than those treated with NPs. On the 8th day, untreated fruits still had higher TSS, which is statistically at par with 50ppm Ag NPs treated fruits. After this, no significant differences in TSS were observed between coated and uncoated fruits. The result indicates that TSS increased more slowly in treated fruits, with slower increases at higher NPs concentration.

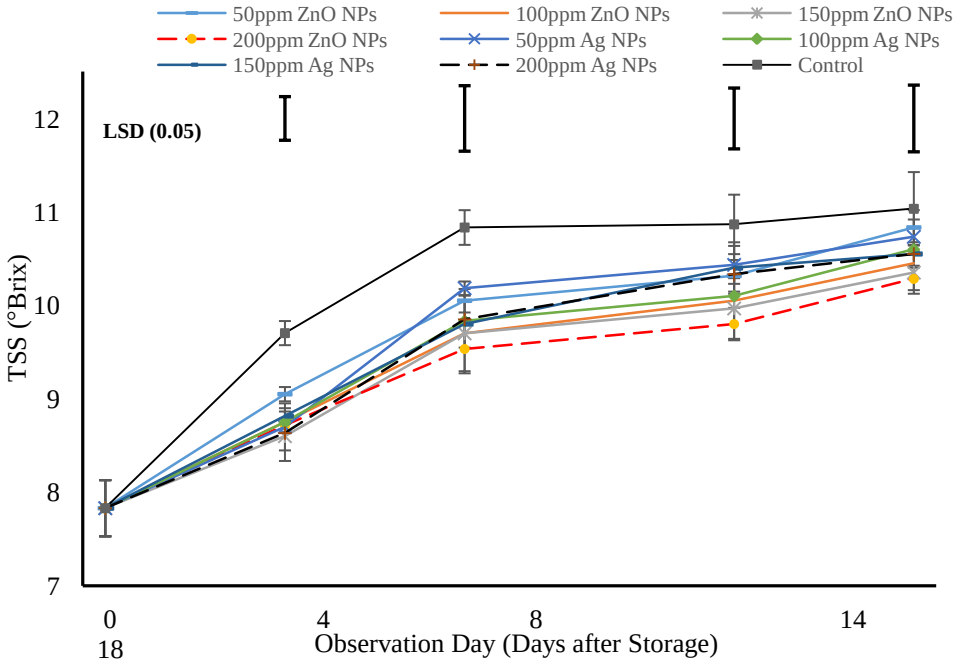


Fig. 5. Effect of ZnO and Ag NPs coatings on TSS in papaya cv. Red Lady stored at 14±1.6°C and ~75% RH.

The rise in TSS during storage primarily results from carbohydrate hydrolysis, particularly the conversion of starch into simple sugars driven by increased respiration and metabolic activity (Cordenunsi and Lajolo, 1995). Studies by Li et al. (2019) and Nguyen et al. (2021) revealed that polysaccharide-based coatings with ZnO and Ag NPs effectively slow the ripening process and reduce the rate of TSS accumulation. In contrast, Taha et al. (2022) found that starch-based Ag NPs coatings had no significant effect on the TSS content of strawberries, likely due to the fruit's

non-climacteric nature. Thus, concluded that chitosan-based NPs coatings have been shown to slow the increase in TSS in climacteric fruits.

Total titratable acidity (TTA)

TTA was 0.20 g citric acid/100 g at the start and decreased with storage time, regardless of treatments. However, the decrease was slower in coated fruits compared to uncoated ones (Figure 6). Among the coated fruits, the reduction in TTA slowed down as the concentration of both NPs increased.

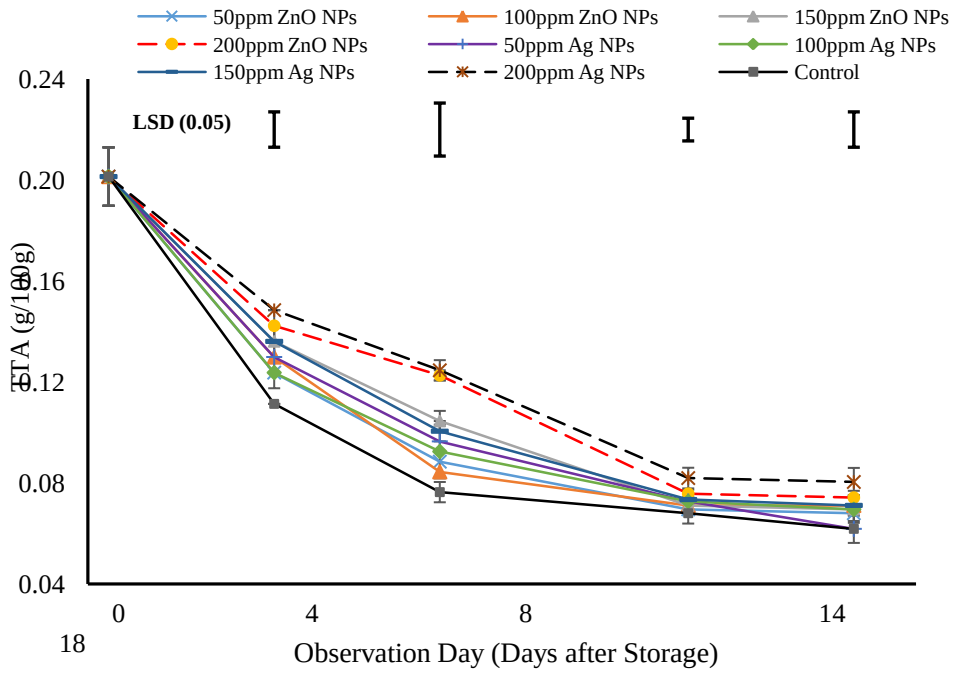


Fig. 6. Effect of ZnO and Ag NPs coatings on TTA in papaya cv. Red Lady stored at 14±1.6°C and ~75% RH.

On the 4th day of storage, TTA was found as the highest with 200ppm Ag NPs treated fruits that was statistically ($p \leq .05$) at par with 150ppm Ag NPs, 200ppm ZnO NPs and 150ppm ZnO NPs treated fruits. On the 8th day of storage, TTA was found higher on 200ppm Ag NPs treated fruits that are statistically ($p \leq .05$) at par with 200ppm ZnO NPs and 150 ppm ZnO NPs treated fruits. After that, though TTA was higher at increased NPs concentration, there was no significant ($p \leq .05$) difference among all treatments.

The reduction in fruit respiration rate slows the consumption of organic acids, primarily citric and malic acid (Xu et al., 2018), which act as substrates in the enzymatic reactions of respiration (Hazrati et al., 2017). The slower decline in TTA

with increased NPs concentration is largely attributed to the formation of a strong barrier to gas exchange, thereby reducing internal metabolic reactions. This observation is consistent with findings from Basumatary et al. (2021) and Hmmam et al. (2021), who showed that NPs coatings on fruits mitigate the loss of TTA.

Ascorbic acid

Ascorbic acid in papaya increases during ripening and then begins to decline (Chen and Paull, 1986). Ascorbic acid increased in all the treatments on 4th day of storage (Figure 7). The lowest increase was observed with 200 ppm Ag NPs (43 mg/100 g to 55.94 mg/100 g), statistically similar ($p \leq .05$) to 150 ppm Ag NPs and 100-200 ppm ZnO NPs. These results indicate that fruit coating slows ascorbic acid synthesis during ripening, with higher NPs concentrations further inhibiting this process. Consequently, treated fruits exhibited smaller increase in ascorbic acid compared to untreated ones.

On the 8th day of storage, the highest ascorbic acid was obtained in fruits treated with 150ppm Ag NPs, statistically ($p \leq .05$) at par with 200ppm Ag NPs and 200ppm ZnO NPs. On the 14th day, ascorbic acid was recorded as the highest in 200ppm ZnO NPs fruits, statistically ($p \leq .05$) similar to 200ppm and 150ppm Ag NPs treated fruits. The slower decline in ascorbic acid in coated fruits after the 4th day of storage likely results from a barrier that limits oxygen entry, delaying vitamin C oxidation (Ayranci and Tunc, 2004). On the 18th day, there was no significant difference in the ascorbic acid content between the coated and uncoated fruits.

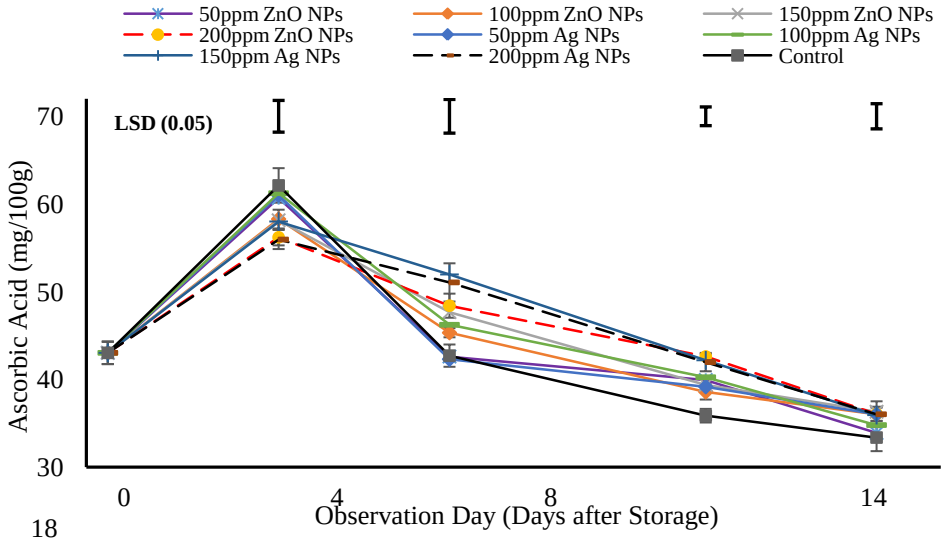


Fig. 7. Effect of ZnO and Ag NPs coatings on ascorbic acid in papaya cv. Red Lady stored at 14±1.6°C and ~75% RH.

Ezen et al. (2017) observed that half-ripe papayas contain the highest vitamin C levels, followed by ripe and unripe fruits. This aligns with findings that vitamin C increases during ripening but decreases during senescence due to ascorbic acid oxidation (Kamelia, 2019). Ascorbic acid is synthesized in the mitochondria through several proposed pathways, including the L-galactose pathway and the D-galacturonate pathway. The L-galactose pathway is the primary route for ascorbic acid synthesis, primarily active in fruits that are still attached to the parent plant (Wheeler et al., 1998). Consequently, most ascorbic acid in fruits is synthesized prior to detachment from the mother plant. However, after harvest, the D-galacturonate pathway becomes a viable route for ascorbic acid synthesis (Fenech et al., 2019). This pathway may explain the initial increase in ascorbic acid observed in papaya post-harvest. Additionally, a study by Badejo et al. (2012) demonstrated that supplementing red-ripe tomatoes with D-galacturonate increased ascorbic acid content, though genetic evidence supporting the D-galacturonate pathway's role in ascorbic acid synthesis remains limited.

Storage life

The storage life of fruit treated with 150 ppm and 200 ppm of both NPs was extended by 8 to 9 days compared to untreated fruits (Figure 8). Increasing NPs concentration enhances fruit storage life by reducing respiration rate and improving barrier properties, which help maintain physicochemical quality. Similar results were observed with ZnO and Ag NPs in fruits like banana, guava, strawberry and mango (Arroyo et al., 2020; La et al., 2021; Meindrawan et al., 2018; Sogvar et al., 2016).

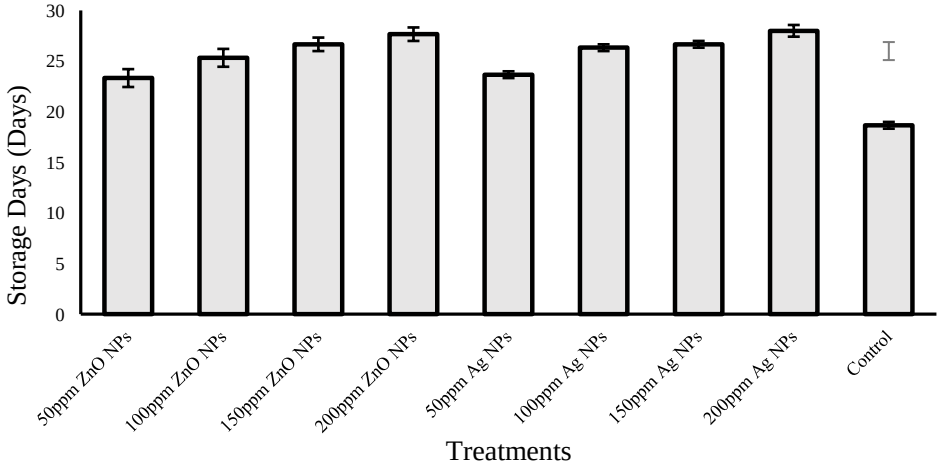


Fig. 8. Effect of ZnO and Ag NPs coatings on Storage life of papaya cv. Red Lady stored at 14±1.6°C and ~75% RH.

Organoleptic test

The untreated papaya fruit was preferred (like slightly or like moderately or like very much) by 70% of the respondent (Table 1). Fruits treated with 200 ppm ZnO and Ag NPs were disliked by 50% and 35% of respondents, respectively. Preference decreased as NPs concentration increased. It was evident that the most liked sample had a highest TSS (10.87 °Brix), highest weight loss, and lowest TTA, indicating that consumers prefer higher sugar content.

Table 1. Frequency of organoleptic test of papaya cv. Red Lady on the 14th day of storage at 14±1.6°C and ~75% RH.

Treatments	Frequencies						
	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much
50ppm ZnO NPs			1(5)	7(35)	6(30)	3(15)	3(15)
100ppm ZnO NPs		1(5)	1(5)	7(35)	8(40)	3(15)	
150ppm ZnO NPs		1(5)	4(20)	7(35)	6(30)	2(10)	
200ppm ZnO NPs		3(15)	7(35)	10(50)			
50ppm Ag NPs			2(10)	4(20)	3(15)	6(30)	5(25)
100ppm Ag NPs		1(5)	2(10)	3(15)	8(40)	5(25)	1(5)
150ppm Ag NPs			4(20)	5(25)	7(35)	4(20)	
200ppm Ag NPs		1(5)	6(30)	8(40)	2(10)	3(15)	
Control			1(5)	5(25)	3(15)	7(35)	4(20)

Figure in the parenthesis indicates percentage.

The organoleptic test indicated that panelists preferred fruits with lower concentrations of Ag NPs, as higher concentrations led to reduced acceptance. Although there was no significant difference in TSS among the concentrations tested (50–200 ppm) on the day of the organoleptic assessment, the reduced preference for higher NPs concentrations may be due to diminished aroma and flavor, a trend also observed in guava fruits coated with ZnO NPs (Arroyo et al., 2020).

Conclusions

Coating papaya with chitosan-based zinc oxide and silver nanoparticles enhances postharvest life by reducing physiological loss in weight, maintaining firmness and

delay the ripening process by inhibiting the respiration rate. This study concludes that coatings with 100-150 ppm concentration of zinc oxide and silver nanoparticles extent the postharvest life and preserve the fruit quality. Further research is needed to explore technology across various temperature regimes as well as the residual effects of nanoparticles on consumer health. A multi-dimensional assessment of nanoparticles should be considered before commercial application.

Acknowledgments

We gratefully acknowledge the Value Chain Development of Fruit and Vegetables Project (VCDP) for funding the research and the Research Center of Applied Science and Technology (RECAST), TU, for providing the laboratory facility and fostering such a conducive working environment. We extend our heartfelt gratitude to Prakriti Shrestha, Bidit Lamsal, Prasamsha Panta, and Samrat Paudel for their invaluable contributions to this research.

References

Ali, A., Muhammad, M.T.M., Sijam, K. and Siddiqui, Y. 2011. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. *Food Chemistry*, 124(2): 620–626.

Ali, M., Ahmed, A., Shah, S.W.A., Mehmood, T. and Abbasi, K.S. 2020. Effect of silver nanoparticle coatings on physicochemical and nutraceutical properties of loquat during postharvest storage. *Journal of Food Processing and Preservation*, 44(10):1-16.

Ahmad, A., Mukherjee, P., Senapati, S., Mandal, D., Khan, M.I., Kumar, R. and Sastry, M. 2003. Extracellular biosynthesis of silver nanoparticles using the fungus *Fusarium oxysporum*. *Colloids and Surfaces B: Biointerfaces*, 28(4): 313–318.

Anugrah, D.S.B., Alexander, H., Pramitasari, R., Hudiyanti, D. and Sagita, C.P. 2020. A review of polysaccharide-zinc oxide nanocomposites as safe coating for fruits preservation. *Coatings*, 10(10): 1-15.

Arowora, K.A., Williams, J., Adetunji, C.O., Afolayan, S.S., Olaleye, O.O., Ogundele, B.A., Fawole, O.B. and Adetunji, J.B. 2013. Effects of Aloe Vera coatings on quality characteristics of oranges stored under cold storage. *Greener Journal of Agricultural Sciences*, 3(1): 039–047.

Arroyo, B.J., Bezerra, A.C., Oliveira, L.L., Arroyo, S.J., de Melo, E.A. and Santos, A.M.P. 2020. Antimicrobial active edible coating of alginate and chitosan add ZnO nanoparticles applied in guavas (*Psidium guajava* L.). *Food Chemistry*, 309: 125566.

Ayranci, E. and Tunc, S. 2004. The effect of edible coatings on water and vitamin C loss of apricots (*Armeniaca vulgaris* L.) and green peppers (*Capsicum annum* L.). *Food Chemistry*, 87: 339–342.

Badejo, A.A., Wada, K., Gao, Y.S., Maruta, T., Sawa, Y., Shigeoka, S. and Ishikawa,T. 2012. Translocation and the alternative d-galacturonate pathway contribute to increasing the ascorbate level in ripening tomato fruits together with the D-mannose/L-galactose pathway. *Journal of Experimental Botany*, 63: 229–239.

Basumatary, I.B., Mukherjee, A., Katiyar, V., Kumar, S. and Dutta, J. 2021. Chitosan-based antimicrobial coating for improving postharvest shelf life of pineapple. *Coatings*, 11(11): 1–12.

Batool, R., Kazmi, S.A.R., Khurshid, S., Saeed, M., Ali, S., Adnan, A., Altaf, F., Hameed, A., Batool, F. and Fatima, N. 2022. Postharvest shelf life enhancement of peach fruit treated with glucose oxidase immobilized on ZnO nanoparticles. *Food Chemistry*, 366: 130591.

Bouwmeester, H., Brandhoff, P., Marvin, H. J., Weigel, S. and Peters, R.J. 2014. State of the safety assessment and current use of nanomaterials in food and food production. *Trends in Food Science & Technology*, 40(2): 200–210.

Butu, M., Rodino, S. and Butu, A. 2019. Application of silver nanoparticles on fresh fruits preservation. *Proceedings of the 5th World Congress on New Technologies* held at Lisbon, Portugal. Pp.156

Chen, N.M. and Paull, R.E. 1986. Development and prevention of chilling injury in papaya fruit. *Journal of American Society for Horticultural Science*, 111: 639–643.

Cordenunsi, B.R. and Lajolo, F.M. 1995. Starch breakdown during banana ripening: sucrose synthase and sucrose phosphate synthase. *Journal of Agricultural and Food Chemistry*, 43: 347–351.

El-Ramady, H.R., Domokos-Szabolcsy, E., Abdalla, N.A., Taha, H.S. and Fari, M. 2015. Postharvest management of fruits and vegetables storage. In: Lichtfouse, E., (Editor), Sustainable Agriculture Reviews, Springer, Cham, 65-152.

Ezen, E., Okeke, O., Ozuah, A.C. and Onwubike, R.O. 2017. Comparative assessment of the effect of ripening stage on the vitamin C contents of selected fruits grown within Nsukka Axis of Enugu State. *International Journal of Environment, Agriculture and Biotechnology*, 2(2): 712–714.

Fenech, M., Amaya, I., Valpuesta, V., Botella, M.A. 2019. Vitamin C content in fruits: Biosynthesis and regulation. *Frontiers Plant Science*, 9: 2006.

Hazrati, S., Kashkooli, A.B., Habibzadeh, F., Tahmasebi-Sarvestani, Z. and Sadeghi, A.R. 2017. Evaluation of aloe vera gel as an alternative edible coating for peach fruits during cold storage period. *Gesunde Pflanzen*, 69(3): 131–137.

Hmmam, I., Zaid, N., Mamdouh, B., Abdallatif, A., Abd-Elfattah, M. and Ali, M. 2021. Storage behavior of "seddik" mango fruit coated with CMC and guar gum-based silver nanoparticles. *Horticulturae*, 7(3): 1–21.Jain, D., Daima, H.K., Kachhwaha, S. and Kothari, S.L. 2009. Synthesis of plant-mediated silver nanoparticles using papaya fruit extract and evaluation of their anti microbial activities. *Digest Journal of Nanomaterials and Biostructures*, 4(3): 557–563.

Joshy, K.S., Jose, J., Li, T., Thomas, M., Shankregowda, A.M., Sreekumaran, S., Kalarikkal, N. and Thomas, S. 2020. Application of novel zinc oxide reinforced xanthan gum hybrid system for edible coatings. *International Journal of Biological Macromolecules*, 151: 806–813.

Kamelia, M., Widiani, N. and Damayanti, I. 2019. The Analysis of glucose and vitamin C on papaya (*Carica papaya* L.) with different time storage. *Journal of Physics: Conference Series*, 1338(1): 012026.

La, D.D., Nguyen-Tri, P., Le, K.H., Nguyen, P.T., Nguyen, M.D., Vo, A.T., Nguyen, M.T., Chang, S.W., Tran, L.D., Chung, W.J. and Nguyen, D.D. 2021. Effects of antibacterial ZnO nanoparticles on the performance of a chitosan/gum arabic edible coating for post-harvest banana preservation. *Progress in Organic Coatings*, 151: 106057.

Li, J., Sun, Q., Sun, Y., Chen, B., Wu, X. and Le, T. 2019. Improvement of banana postharvest quality using a novel soybean protein isolate/cinnamaldehyde/zinc oxide bionanocomposite coating strategy. *Scientia Horticulturae*, 258: 108786.

Meindrawan, B., Suyatma, N.E., Wardana, A.A. and Pamela, V.Y. 2018. Nanocomposite coating based on carrageenan and ZnO nanoparticles to maintain the storage quality of mango. *Food Packaging and Shelf Life*, 18: 140–146.

Ming, R., Hou, S., Feng, Y., Yu, Q., Dionne-Laporte, A., Saw, J.H., Senin, P., Wang, W., Ly, B.V., Lewis, K.L.T., Salzberg, S.L., Feng, L., Jones, M.R., Skelton, R.L., Murray, J.E., Chen, C., Qian, W., Shen, J., Du, P., . . . Alam, M. 2008. The draft genome of the transgenic tropical fruit tree papaya (*Carica papaya* Linnaeus). *Nature*, 452(7190): 991–996.

Murmu, S.B. and Mishra, H.N. 2018. The effect of edible coating based on Arabic gum, sodium caseinate and essential oil of cinnamon and lemon grass on guava. *Food Chemistry*, 245: 820–828.

Nguyen, T.T., Nguyen, T.H., Pham, B.T., Van Tran, T., Bach, L.G., Thi, P.Q.B. and Thuc, C.H. 2021. Development of poly (vinyl alcohol)/agar/maltodextrin coating containing silver nanoparticles for banana *(Musa acuminate*) preservation. *Food Packaging and Shelf Life*, 29: 100740.

Ranganna, S. 1991. Handbook of analysis and quality control for fruit and vegetable products. 2nd ed, Tata McGraw-Hill Publishing Company Ltd., New Delhi.

Sadasivam, S. and Balasubraminan, T. 1987. In: Practical manual in Biochemistry. Tamil Nadu Agricultural University, Coimbatore. Pp.14.

Saekow, M., Naradisorn, M., Tongdeesoontorn, W. and Hamauzu, Y. 2019. Effect of carboxymethyl cellulose coating containing ZnO-nanoparticles for prolonging shelf life of persimmon and tomato fruit. *Journal of Food Science and Agricultural Technology*, 5: 41–48.

Shiga, T.M., Fabi, J.P., Nascimento, J.R.O.D., De Oliveira Petkowicz, C.L., Vriesmann, L.C., Lajolo, F.M. and Cordenunsi, B.R. 2009. Changes in cell wall composition associated to the softening of ripening papaya: Evidence of extensive solubilization of large molecular mass galactouronides. *Journal of Agricultural and Food Chemistry*, 57(15): 7064–7071.

Sogvar, O.B., Saba, M.K., Emamifar, A., and Hallaj, R. 2016. Influence of nano-ZnO on microbial growth, bioactive content and postharvest quality of strawberries during storage. *Innovative Food Science & Emerging Technologies*, 35: 168–176

Sun, Q., Li, J. and Le, T. 2018. Zinc oxide nanoparticle as a novel class of antifungal agents: Current advances and future perspectives. *Journal of Agricultural and Food Chemistry*, 66(43): 11209–11220.

Svagan, A.J., Hedenqvist, M.S. and Berglund, L. 2009. Reduced water vapour sorption in cellulose nanocomposites with starch matrix. *Composites Science and Technology*, 69(3–4): 500–506.

Taha, I.M., Zaghlool, A., Nasr, A., Nagib, A., Azab, I.H.E., Mersal, G.A.M., Ibrahim, M.M. and Fahmy, A. 2022. Impact of starch coating embedded with silver nanoparticles on strawberry storage time. *Polymers*, 14(7): 1439.

Vyas, P.B., Gol, N.B. and Rao, T.V.R. 2014. Postharvest quality maintenance of papaya fruit using polysaccharide-based edible coatings. *International Journal of Fruit Science*, 14(1): 81–94.

Wheeler, G.L., Jones, M.A. and Smirnoff, N. 1998. The biosynthetic pathway of vitamin C in higher plants. *Nature*, 393: 365-369.

Xu, D., Qin, H. and Ren, D. 2018. Prolonged preservation of tangerine fruits using chitosan/ montmorillonite composite coating. *Postharvest Biology and Technology*. 143: 50-57.

Yahia, E.M., Carrillo-López, A. and Bello-Perez, L.A. 2019. Carbohydrates. In: Yahia, E.M. (Editor). Postharvest Physiology and Biochemistry of Fruits and Vegetables. Elsevier. Pp. 175– 205.

Yousuf, B., Qadri, O.S. and Srivastava, A.K. 2018. Recent developments in shelf-life extension of fresh-cut fruits and vegetables by application of different edible coatings: A review. *LWT - Food Science and Technology*, 89: 198–209.

Zhao, Y., Li, B., Li, C., Xu, Y., Luo, Y., Liang, D. and Huang, C. 2021. Comprehensive review of polysaccharide-based materials in edible packaging: A sustainable approach. *Foods*, 10(8): 1845–1892.

Zhu, X., Ye, L., Ding, X., Gao, Q., Xiao, S., Tan, Q., Huang, J., Chen, W. and Li, X. 2019. Transcriptomic analysis reveals key factors in fruit ripening and rubbery texture caused by 1-MCP in papaya. *BMC Plant Biology*, 19(1): 1–22.

SAARC J. Agric., 22(2): 197-207 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.76521*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Efficacy Assessment of Different Botanicals Against Rice Weevil (*Sitophilus Oryzae)* in Stored Rice

T.K. Roy[1*], A. Sannal[2], S. Akter[1], M.M.M. Kabir[1], M.N. Bari[1] and S.S. Haque[1]

[1]Entomology Division, Bangladesh Rice Research Institute, BRRI
[2]Plant Pathology Division, Bangabandhu Sheikh Mujibur Rahman Agricultural University, BSMRAU

Abstract

Rice weevil (*Sitophilus oryzae*) is the major seed destroyer in stored grain, causing both quantitative and qualitative losses. Traditional approaches utilizing chemical insecticides including fumigants to address this problem present environmental risks and health concerns. Focusing on the scenario, a study was conducted at laboratory condition of entomology division, Bangladesh Rice Research Institute (BRRI) to assess the efficacy of different botanicals for the management of rice weevils in stored rice. Employing a Complete Randomized Design (CRD) with three replications, the experiment comprised four treatments alongside an untreated control, namely Neem (*Azadirachta indica*) oil, Mahogany (*Swietenia macrophylla*) seed kernel powder, Neem (*A. indica*) leaf powder, Biskatali plants (*Polygonum hydropiper*) powder and Control (untreated). The findings unveiled that the highest percent of insect mortality was found in neem oil (85%) and which was followed by biskatali plants powder (75%), neem leaf powder (61.67%) and mahogany seed kernel powder (60%), respectively. The lowest emergence of F_1 progeny was recorded in neem oil treated seeds compared to mahogany seed kernel, Neem leaf powder, biskatali and untreated control indicating the efficacy in managing the reproductive capacities of rice weevils. Additionally, neem oil also exhibited the least weight (%) loss of grain compared to other treatments. Regarding seed germination, biskatali plants powder showed highest germination rate (94%) followed by neem leaf powder (90%), mahogany seed kernel powder (89.67%), neem oil (88%) and control (80.67%), respectively. The research finding indicated that the neem oil and biskatali plant powder has the greatest

[*] Corresponding author: tapon.entom@brri.gov.bd

Received: 29. 09. 2024 *Accepted: 29. 11. 2024*

potentiality to minimize the current use of synthetic insecticides for rice weevil management in stored rice.

Keywords: Eco-friendly; F_1 progeny; germination; mortality percentage; neem oils.

Introduction

Rice (*Oryza sativa* L., Family: Poaceae) holds a critical position as a staple among cultivated cereal crops worldwide, serving as a primary food source in many nations. Rice requires prolonged storage following harvesting and utilized for consumption, seeds or any other purposes (Roy *et al.,* 2023). In a standing rice field, rice crop is infected by various insect pests such as rice stem borer, armyworm, rice bug, rice hispa, fall armyworm and many more (Ali *et al*., 2023; Roy *et al.*, 2024a). However, during storage, stored rice is also damaged by various pests such as the rice weevil (*Sitophilus oryzae* L.), angoumois grain moth (*Sitotroga cerealella* Olivier), saw-toothed grain beetle (*Oryzaephilus surinamensis* L.), red flour beetle (*Tribolium castaneum* Herbst), and indian meal moth (*Plodia interpunctella* Hubner), leading to significant economic losses in production (Roy *et al.,* 2023). The rice weevil is recognized as one of the most destructive pests of stored agricultural products, including rice (Jyothi *et al.,* 2024). Rice weevils diminish both the quantity and quality of rice through their feeding and breeding activities on the grain. Under favorable conditions, a single pair of *S. oryzae* can reproduce approximately one million offspring within a three-month timeframe (Thomas *et al*., 2002) and these adult weevils, being internal feeders, inflict significant quantitative and qualitative damage to stored grains. The activities of this primary pest result in a reduction in grain weight, loss of nutrients, and diminished seed viability. Furthermore, their behaviors render the grains susceptible to contamination by mites and fungi (Costa *et al*., 2016; Zakladnoy, 2018). Hence, effective management of storage pests such as rice weevils is crucial for reducing post-harvest losses. Traditionally, the primary approach to managing weevil populations globally has relied on synthetic insecticides. However, utilizing chemical insecticides and widely used fumigation techniques to combat storage pests infestations during storage poses significant health risks and residues from these chemicals persist in both the stored grain and the surrounding environment, exacerbating potential hazards (Hossien *et al*., 2018; Roy *et al*., 2024b). Moreover, marginal farmers normally reserve tiny amount of rice for their consumptions as well as seed purposes, making it challenging for them to apply fumigation or chemical insecticides to manage rice weevils. Hence, an alternate strategy are suggested, which are prioritizes to environmental safety, less toxicity, and poses no risk to human health to manage this pest in stored rice. Ashamo & Akinnawonu, (2012) reported that various plant products are commonly used to minimize the storage losses by insect pests. . Botanicals can play a crucial role in this regards to the local communities as such insect repellent plant materials served as a readily accessible indigenous sources of insecticides and insect repellents. Although

their insecticidal effectiveness may not match that of synthetic insecticides and fumigants, except for natural pyrethrins, they do exhibit prolonged surface persistence. Moreover, they have minimal to no adverse effects on seed germination, cooking quality, milling and easily attainable at lower costs (Roy *et al.*, 2023; Roy *et al.*, 2024b). The bioactive metabolites (Azadirachtin, quircetin, quinolone, gingerols, shogaols, flavonoids, saponins, limonoids, phenylpropanoid derivatives, and sesquiterpenoids etc) present in botanicals are responsible for poisons, repellant and antifeedant effects on insect pests. Powdered, oil, or extract forms derived from various bioactive plants (such as *Azadirachta indica, Ocimum tenuiflorum, Nepeta cataria, Swietenia macrophylla, Persicaria hydropiper, Zingiber officinale* etc) can be used on stored grain for managing storage pests. Therefore, our present investigation aims to assess the efficacy of different botanicals for the management of rice weevils (*S. oryzae*) in stored rice.

Materials and Methods:

This experiment was conducted from September 09 to December 25, 2023 at laboratory of Entomology division in Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh.

Sample collection and preparations

Fresh leaves of neem tree (*Azadirachta indica* A.Juss) and biskatali plants (*Persicaria hydropiper* L) were collected from the BRRI, Gazipur campus. They were thoroughly washed with fresh water and then dried at fluctuating room temperature (25±2°C). After drying, the leaves were oven-dried at 50°C for 72 hours to reach a constant weight. Mature mahogany fruits (*Swietenia macrophylla* King) were also collected from the BRRI, Gazipur campus and sundried for 3 days. After sundrying, the carpels were detached from the pods, and the external layers were removed from the seeds. The naked seed kernels were then oven dried at 50°C for 72 hours. The dried neem leaves, biskatali plants, and mahogany seeds were grounded into powder using a mortar and pestle. The powder was then sieved (mesh number 20) and subsequently stored in airtight polyethylene bags within a freezer (Model: IRMCO CHL5 Basic, manufactured in Germany) at 4°C for future use. Neem oil (organic neem oil extracted by pressing, manufactured by Garden BD) was collected from the local market.

Insect Rearing and Treatments

At the beginning of the experiment, the population of rice weevils was sourced from the storage facility at BRRI. Subsequently, these weevils were cultured on rice (Var. BRRI dhan89) in the laboratory. Differentiation between female and male moths was achieved through visual observation of their abdominal tergites and body size, facilitated by a stereo microscope (Olympus Model SZ2-STU2, manufactured in Tokyo, Japan, equipped with a 4x scanning objective lens). The weight of the powder extracts was determined using a KERN ABJ220-4NM weighing balance, manufactured in Balingen, Germany.

Experimental Design & procedure: The experiment was conducted using a Complete Randomized Design (CRD), consisting of four treatments (Table 1) along with one control (untreated), with each treatment replicated three times. Previously collected BRRI dhan87 was kept in freezer (Rice were kept at -20°C temperature for 24 hour) and after then oven dried at 50°C for another 24 hour for sterilized from insect egg and larvae. Additionally, the rice was sieved to remove inert materials, dust and dead insects. Fifteen plastic container (20*12* 8 cm^3) were used and each container holding 200 g of rice. After then treatment were applied according to the design and the containers were shaken thoroughly for uniform adherence of powders and oil on the rice grain surface. After applying the designated treatments, each replication received 10 pairs (10 male & 10 female) of newly emerged adult insects. The containers were covered with nets (mesh size 25) for proper aeration. The environmental conditions for this process were maintained at 65 ± 2% RH and 25 ± 2°C temperature.

Table 1. Different plants used as treatment against rice weevil

Treatment	Common name	Scientific Name	Family name	Parts used	Dose /kg
T_1	Neem	*Azadirachta indica*	Meliaceae	Oil	5ml
T_2	Mahogany	*Swietenia macrophylla*	Meliaceae.	Seed kernel powder	10g
T_3	Ghora-neem	*Melia azedarach*	Meliaceae	Leaf powder	10g
T_4	Biskatali	*Persicaria hydropiper*	Polygonaceae	Plants powder	10g
T_0	Control	-	-	Untreated	-

Data collection

The number of dead insects was counted at 24, 48, 72, 96, and 120 hours after treatment (HAT), and the dead insects were removed after each count. After 120 hours of treatment, no dead insects were observed. The live insects were then allowed to remain for another 7 days to facilitate oviposition and were subsequently removed. The boxes were regularly observed for F1 adult emergence. Adults were removed, and data collection continued until no. F1 weevils were found (about 5 to 6 weeks). Observations regarding the mortality percentage were recorded for each treatment and calculated using the (Henderson & TILTON, 1955) formula.

$$\text{Mortality (\%)}=1 \times \frac{Ta \times Cb}{Tb \times Ca} \times 100$$

(Where, Ta is the number of weevils after treatment, Tb is the number of weevils before treatment, Ca is the number of weevils in untreated check after treatment, Cb is the number of weevils in untreated check before treatment).

Germination percentage: One hundred rice seeds were randomly taken from each replications of every treatment and placed in a Petri dish (99mm * 20mm). These seeds were then placed on moist filter papers within a germination box and maintained at room temperature. After completion of germination, the number of germinated seed was counted and recorded. The percentage germination was computed using the following formula.

$$\text{Germination (\%)} = \frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ tested\ seeds} \text{x}100$$

Grain damage percentage: Twenty-five damaged grains of rice were taken from each replication of each treatment by using magnifying glasses (5x magnifier). Their weight was determined using a KERN ABJ220-4NM weighing balance, manufactured in Balingen, Germany. Conversely, the weight of 25 undamaged grains from each replication was also measured. The percent weight loss of grains was computed using the following formula given by Mehta & Kumar (2020)

$$\text{Percentage weight loss} = \frac{U.Nd - D.Nu}{U(Nd + Nu)} \text{x}100$$

Where, U is the weight of undamaged grains, Nu is the number of undamaged grains, D is the weight of damaged grains, and Nd is the number of damaged grains.

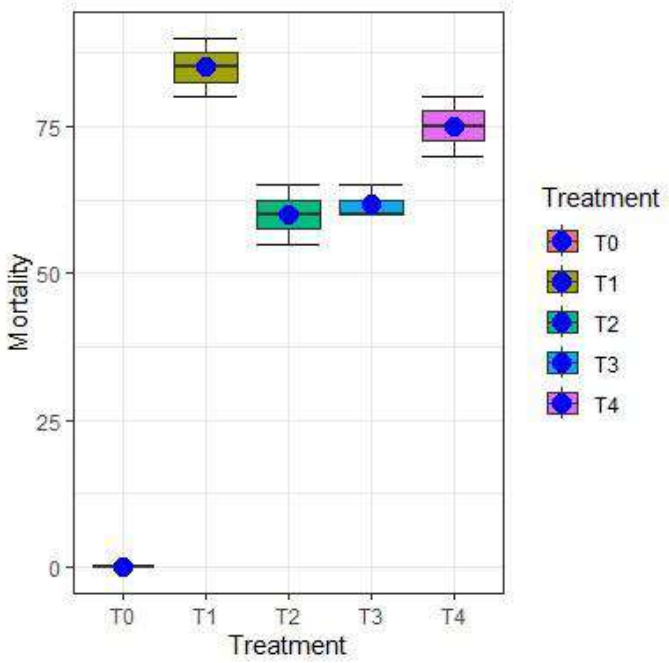
Data analysis

All data were subjected to statistical analysis separately by using the analysis of variance technique by R software (versions 2024.04.1). The "doebioresearch" package was utilize for ANOVA executed. To discern differences among treatment means, the Least Significant Difference (LSD) test was employed, maintaining a significance level of 5%. The “ggplot2” and “Rmisc” package were used for creating plots.

Results and Discussion

Insect mortality percentage: The highest percent mortality of rice weevils was recorded in T_1 i.e., neem oil (85%) which was statically different from other treatments, followed by T_4 (Biskatali plant powder, 75%). Treatment T_3 (Neem leaf powder, 61.67%) and T_2 (Mahogany seed kernel powder, 60%) showed statically identical results (Figure 1). No mortality of rice weevils were observed in T_0 (untreated control). Our findings indicated that T_1 (neem oil) showed highest mortality due to containing most bioactive compound including azadirachtin (Roy *et al.,* 2024b). But neem leaf powder (T_3) also contains bioactive compounds like azadirachtin but the concentration is lower than neem oil, resulting in lower mortality of rice weevils compared to neem oil (Roy *et al*., 2023). However, Jibrin & Mohammed (2020) demonstrated that the neem tree contains active ingredients that make the leaves bitter and bioactive ingredients including azadirachtin in neem, are effective as insect repellents and for causing mortality. The concentration of bioactive compounds might escalate during the conversion of neem leaves or seeds

into powder or oil, potentially due to the elimination of inert materials and the expansion of surface area and which is why neem oil causes higher mortality than neem leaf or seed powders (Roy *et al.*, 2024b). According to Zanuncio *et al*., (2016) neem oil has demonstrated to possess lethal effects, the intensity of which varies based on the concentration used and this natural insecticide exhibits potency compared to neurotoxic pesticides and growth inhibitors, establishing its efficacy in pest control. On the other hand, T_4 (biskatali plant powder) showed second highest mortality of rice weevil due to its insecticidal properties Bhattacharjee *et al*., 2020. Both the extract and powder form of *Persicaria hydropiper* (biskatali plant) contains flavonoids as well as drimane-type sesquiterpenes, sesquiterpenoids and phenylpropanoids which exhibit antioxidant, antibacterial, antifungal, antihelminth, antifeedant, cytotoxicity, anti-inflammatory, antifertility, antiadipogenicity, and neuroprotection propertics which contribute to insect mortality (Huq *et al.*, 2014). *Swietenia macrophylla* plants also exhibits antioxidant, anti-inflammatory, antimicrobial, antimutagenic, antifeedant activities (Borah *et al.*, 2023) which are responsible for insect mortality.

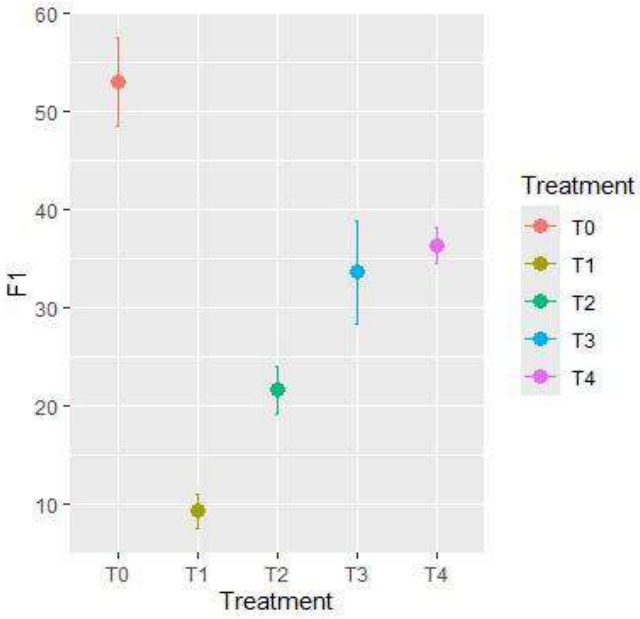


T_0=Untreated control, T_1=Neem oil, T_2=Mahogany seed powder, T_3=Neem leaf powder and T_4=Biskatali plant powder

Fig. 1. Effects of Plants on mortality percentage of rice weevil

Number of F_1 progeny emergence: The highest number of F_1 adults was emerged in T_0 (untreated control), which was significantly different from the other treatments,

followed by biskatali plants powder, neem leaf powder and mahogany seed powder. Biskatali plants powder and neem leaf powder showed significantly similar results (Figure 2). The lowest number of F_1 emerged in T_1 (neem oil), likely due to the highest mortality of rice weevils. Neem contains bioactive ingredient azadirachtin, which functions by impeding the growth of insects, diminishing their fertility, and reducing the emergence of F_1 populations (Roy *et al.,* 2024b). This compound influences the reproductive system of rice weevils, causing a decrease in fertility and the capacity for egg laying, also inhibiting the production of hormones crucial for molting (Ghazawi *et al*., 2007) consequently leading to a decline in rice weevil populations. According to Alexander *et al.,* (2023) and Roy *et al*., (2023) neem oils possesses insecticidal, anti-oviposition, and ovicidal characteristics, which decrease the emergence of F_1 generation of insects. Roy *et al*., (2023) also demonstrated that neem oil acts as a deterrent to feeding, thereby slowing down insect development and growth, diminishing fecundity and fertility, altering behavior, and inducing abnormalities in the eggs, larvae, and adults of storage insects like anguimous grain moth (*Sitotroga cerealella* Olivier). Although, T_2 (mahogany seed kernel powder) showed 2nd less F_1 progeny emergence but it's showed comparatively lower weevils mortality. While, this could be attributed to the presence of bioactive compounds in mahogany that may inhibit the oviposition, egg laying capacity, or egg hatching capacity of rice weevils.



Where, T_0=Untreated control, T_1=Neem oil, T_2=Mahogany seed powder, T_3=Neem leaf powder and T_4=Biskatali plant powder

Fig. 2. Effects of botanicals on number of F_1 adult emergence of rice weevil

Percentage Weight Loss of Grains

The percentage of grain weight loss showed statistically significant differences. The highest weight loss (%) was recorded in T_0 untreated control (32.97%) which was significantly different from other treatments (Table 2). Since, the highest F_1 emergence and no mortality of rice weevils were found in T_0, live weevils laid eggs without disturbance and fed on grains for meet up their starch, vitamin and protein requirements. The feeding and growth activities of rice weevils grubs result in the hollowing of grains, ultimately leading to significant grain damage characterized by extensive powdering. It was reported by Okpile *et al.,* (2021), that weevils require both starch and protein for growth and egg laying. The study conducted in in India reported that damage caused by rice weevils has been approximated to 30% weight loss under normal circumstances. The lowest weight loss was observed in T_1 (neem oil) and which was also significantly different from other treatments. Since, the mortality of neem oil treatment was highest and neem oil contained bioactive compound thus reduced feeding on rice grains by rice weevils.

Table 2. Effects of botanicals on weight loss of grains (%) and seed germination (%) against rice weevil

Treatments	Percentage weight loss of grains	Percentage of germinated seeds	Seed germination percentage over untreated control
T_0 (Untreated control)	32.97 a	80.67 c	-
T_1 (neem oil)	11.03 d	88.00 b	9.08
T_2 (mahogany seed powder)	19.14 c	89.67 b	11.16
T_3 (neem leaf powder)	21.81 b	90.00 b	11.56
T_4 (biskatali powder)	21.41 bc	94.00 a	16.52
Level of significance	***	***	-
LSD	2.54	3.79	-
CV%	6.56	2.35	-

Seed Germination (%)

Germination (%) of seeds showed statistically significant differences among treatments (Table 2). The highest seed germination percentage was observed in T_4 i.e., biskatali plant powder (94%), which was statically different from others, followed by T_3 (90%), T_2 (89.67%) and T_1 (88%). The lowest seed germination (%) was observed in T_0 (80.67%) due to absence of weevils mortality, the highest F_1 progeny emergence, and their feeding and breeding habits, which depend on rice grains, including damage to the seed embryo. As per Roy *et al.,* (2023) and Salam, (2018), the effectiveness of seeds treated with neem leaf powders and neem oil is

contingent upon the concentration of bioactive compounds, notably azadirachtin. Lower concentrations of azadirachtin have been observed to positively influence seed germination, while higher concentrations tend to hinder it. According to Kéita *et al*., (2001); Roy *et al.,* (2024b), mixing stored grains with leaf, neem seed powder, or oil extracts from plants led to a decrease in the rate of egg-laying and inhibited the emergence of adult bruchids, consequently lowering the rate of seed damage. Thus, T_1 treated with neem oil showed comparatively lower seed germination than others.

Conclusion

The research was undertaken to comprehensive investigate the effects of various treatments on managing rice weevils in stored rice grains. It specifically focused on factors such as mortality of rice weevils, emergence of F_1 progeny, percentages of weight loss and percentages of seed germination rates. Our findings showed significant differences in insect mortality (%), number of F_1 emergence, weight loss (%) and seed germination (%). Interestingly, the highest insect mortality was found in T_1 (neem oil) with a mortality rate of 85%, followed by T_4 (biskatali plants powders) with a mortality of 75%. Our study indicated that highest insect mortality (%) reduced the number of F_1 progeny emergence, with the lowest F_1 progeny was emerged in T_1, followed by T_2. The lowest percent weight loss of grain was found in T_1 followed by T_2, T_4, T_3 and T_0. The germination percentage of seeds varied significantly, with the biskatali plant powder showing the highest germination percentage. The germination percentage of T_1, T_2 and T_3 showed statically similar results. Therefore, it might be concluded that T_1 (neem oil) showed best performance among the treatments for both the highest mortality and the lowest emerged of F_1 progeny, followed by T_4.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgments

Authors are greatly thankful to Chief Scientific Officer and Head, Entomology Division, Bangladesh Rice Research Institute (BRRI), for their invaluable support in conducting the experiment.

References

Alexander, M.M., Mohammed, M.A., Emmanuel, O. and Ali, S. (2023). Toxicity of seed oils of neem (Azadirachta indica) and desert date (Balanites aegyptiaca) on the development of tropical warehouse moth (Ephestia cautella) in maize (Zea mays). *Discovery*, *59*(330), 59–69.

Ali, M.P., Haque, S.S., Hossain, M.M., Bari, M.N., Kabir, M.M.M., Roy, T.K., Datta, J., Howlader, M.T.H., Alam, S.N. and Krupnik, T.J. (2023). Development and

demographic parameters of Fall Armyworm (Spodoptera frugiperda J.E. Smith) when feeding on rice (Oryza sativa). *CABI Agriculture and Bioscience*, *4*(1), 29. https://doi.org/10.1186/s43170-023-00162-6

Ashamo, M.O. and Akinnawonu, O. (2012). Insecticidal efficacy of some plant powders and extracts against the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *Archives Of Phytopathology And Plant Protection*, *45*(9), 1051–1058. https://doi.org/10.1080/03235408.2012.655153

Bhattacharjee, S., Matin, M. and Nasiruddin, M. (2020). Insecticidal effects of two medicinal plants Polygonum hydropiper L. and Abrus precatorius L. leaves against the rice weevil Sitophilus oryzae L. (Coleoptera: Curculionidae). *Journal of Biodiversity Conservation and Bioresource Management*, *5*(2), 107–114. https://doi.org/10.3329/jbcbm.v5i2.44921

Borah, A., Selvaraj, S., Holla, S.R., and De, S. (2023). Analysis of the bioactive components in Swietenia macrophylla leaves for their antibacterial and antioxidant capabilities. *Bioresource Technology Reports*, *22*, 101411. https://doi.org/10.1016/j.biteb.2023.101411

Costa, D.C.da.S., Almeida, A.C.de.S., Araújo, M.da.S., Heinrichs, E.A., Lacerda, M.C., Barrigossi, J.A.F. and Jesus, F.G.de. (2016). Resistance of Rice Varieties to *Sitophilus oryzae* (Coleoptera: Curculionidae). *Florida Entomologist*, *99*(4), 769–773. https://doi.org/10.1653/024.099.0432

Ghazawi, N.A., El-Shranoubi, E.D., El-Shazly, M.M. and Rahman, K.M.A. (2007). Effects of Azadirachtin on Mortality Rate and Reproductive System of the Grasshopper Heteracris littoralis Ramb. (Orthoptera: Acrididae). *Journal of Orthoptera Research*, *16*(1), 57–65.

Henderson, C.F. and TILTON, E.W. (1955). Tests with Acaricides against the Brown Wheat Mite12. *Journal of Economic Entomology*, *48*(2), 157–161. https://doi.org/10.1093/jee/48.2.157

Hossien, M.I., Ali, M.R., Akter, S., Akter, M. and Roy, S. K. (2018). Eco-friendly Management of Angoumois grain moth, Sitotroga cerealella Olivier using some botanicals on stored paddy. *Journal of Bioscience and Agriculture Research*, *17*(2), 1422–1430. https://doi.org/10.18801/jbar.170218.176

Huq, A.K.M.M., Jamal, J.A. and Stanslas, J. (2014). Ethnobotanical, Phytochemical, Pharmacological, and Toxicological Aspects of *Persicaria hydropiper* (L.) Delarbre. *Evidence-Based Complementary and Alternative Medicine*, *2014*, 1–11. https://doi.org/10.1155/2014/782830

Jibrin, M.M. and Mohammed, A.D. (2020). Repellency Effect of Prepared Neem Tree Leaves Smoke against Mosquito. *Asian Journal of Research in Zoology*, 1–6. https://doi.org/10.9734/ajriz/2020/v3i330090

Jyothi, P., Sujeetha, A.R.P. and Gupta, C.S. (2024). DETECTION TECHNIQUES IN MONITORING OF STORED GRAIN INSECTS. In *Futuristic Trends in Agriculture Engineering & Food Sciences Volume 3 Book 9* (pp. 93–108). Iterative International Publishers, Selfypage Developers Pvt Ltd. https://doi.org/10.58532/V3BIAG9P2CH6

Kéita, S.M., Vincent, C., Schmit, J.P., Arnason, J.T. and Bélanger, A. (2001). Efficacy of essential oil of Ocimum basilicum L. and O. gratissimum L. applied as an insecticidal

fumigant and powder to control Callosobruchus maculatus (Fab.) [Coleoptera: Bruchidae]. *Journal of Stored Products Research*, *37*(4), 339–349. https://doi.org/10.1016/S0022-474X(00)00034-5

Mehta, V. and Kumar, S. (2020). Influence of Different Plant Powders as Grain Protectants on Sitophilus oryzae (L.) (Coleoptera: Curculionidae) in Stored Wheat. *Journal of Food Protection*, *83*(12), 2167–2172. https://doi.org/10.4315/JFP-20-153

Okpile, C., Zakka, U. and Nwosu, L.C. (2021). Susceptibility of ten rice brands to weevil, Sitophilus oryzae L. (Coleoptera: Curculionidae), and their influence on the insect and infestation rate. *Bulletin of the National Research Centre*, *45*(1), 2. https://doi.org/10.1186/s42269-020-00459-w

Roy, T.K., Kabir, M.M.M., Akter, S., Nayeem, A., Alam, Z., Hasan, M.R., Bari, M.N. and Sannal, A. (2024a). Seasonal variations of insect abundance: Correlating growth stage-specific metrics with weather patterns in Rangpur Region, Bangladesh. *Heliyon*, *10*(18), e38121. https://doi.org/10.1016/j.heliyon.2024.e38121

Roy, T.K., Sannal, A., Akter, S., Tonmoy, S., Chakrobarty, T., Hasan, M. and Bari, M. (2023). Pesticidal effect of naphthalene and different Botanicals against anguimous grain moth (Sitotroga cerealella). *Bangladesh Journal of Scientific and Industrial Research*, *58*(3), 155–162. https://doi.org/10.3329/bjsir.v58i3.66797

Roy, T.K., Sannal, A., Kabir, M.M.M., Monir. N., Tareq, K.H., and Rana, M.M. (2024b). Evaluation of the insecticidal effectiveness of Azadirachta indica plant parts and naphthalene on rice weevil infestation during storage. *African and Mediterranean Agricultural Journal-Al Awamia*, *142*, 73–88. https://doi.org/https://doi.org/10.34874/IMIST.PRSM/afrimed-i142.47704

Salam, M.A. (2018). Evaluation of Allelopathic Potential of Neem (Azadirachta indica. A. Juss) Against Seed Germination and Seedling Growth of Different Test Plant Species. . *American-Eurasian Journal of Sustainable Agriculture*, *2*(2), 20–25.

Thomas, K.J., Selvanayagam, M., Raja, N. and Ignacimuthu, S. (2002). Plant products in Controlling Rice Weevil sitophilus oryzea. *Journal of Scientific and Industrial Research*, *61*, 269–274.

Zakladnoy, G.A. (2018). Effect of Grain Infestation with the Rice Weevil Sitophilus oryzae L. (Coleoptera, Dryophthoridae) on the Quality of Grain and Grain Products. *Entomological Review*, *98*(6), 659–662. https://doi.org/10.1134/S0013873818060015

Zanuncio, J.C., Mourão, S.A., Martínez, L.C., Wilcken, C.F., Ramalho, F.S., Plata-Rueda, A., Soares, M. A. and Serrão, J.E. (2016). Toxic effects of the neem oil (Azadirachta indica) formulation on the stink bug predator, Podisus nigrispinus (Heteroptera: Pentatomidae). *Scientific Reports*, *6*(1), 30261. https://doi.org/10.1038/srep30261

SAARC J. Agric., 22(2): 209-226 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.76809*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Tradition of Cultivating Bean Mixture for Multiple Benefits and Sustainable Production System in Mountain Agriculture

B.K. Joshi[1*], R.C. Prasad[1], R. Gurung[2], S. Gautam[2], A. Subedi[2], A. Karkee[1], A.R. Adhikari[2] and D. Gauchan[3]

[1]Nepal Agricultural Research Council, Kathmandu, Nepal
[2]LI-BIRD, Pokhara, Nepal
[3]Bioversity International, Kathmandu, Nepal

Abstract

Bean mixture cultivation is a traditional practice in mountain agriculture, though it has been increasingly replaced by monoculture. This survey explored the ecological, cultural, and economic factors driving the widespread adoption of bean mixtures in the Karnali region of Nepal. A household survey consisting of 42 questions was conducted among 34 households in Humla and 40 households in Jumla district. On average, households in Jumla cultivated beans on 1.93 *ropani* of land, while in Humla, the average area was slightly larger at 2.4 *ropani* (1 ropani = 0.05 a). In Jumla, 55% of respondents reported cultivating bean mixtures, compared to only 30% in Humla. Jumla farmers cultivated 30 distinct landraces of beans, while Humla farmers grew 12 landraces. In Jumla, 44% of farmers grew mixtures of four landraces, and 5% grew as many as seven landraces. In Humla, 32% of farmers mixed five landraces, 23% mixed three or four, and 11% mixed six landraces. The most commonly grown landraces in Jumla were Kalo Male, Sano Kalo, Rato Male, Rato Sano, and Kalo Sano. In Humla, Kalo Male, Seto Male, and Kalo were the most frequently grown landraces. Most respondents noted that mixed beans have a good taste and reduce the risk of crop failure. Enhancing and promoting bean mixture technology could benefit farmers by increasing ecological yield and supporting agroecological practices.

Keywords: Bean mixture, landrace, disease, insect pest

[*] Corresponding author: joshibalak@yahoo.com

Received: 06. 11. 2024 *Accepted: 06. 12. 2024*

Introduction

Beans are a vital pulse crop in Western Nepal, particularly in the districts of Jumla and Humla (Bhujel, 2014, Prasad et al., 2016, Palikhey et al., 2016). The practice of cultivating mixed landraces of beans has been passed down through generations in these regions maintaining a rich diversity of bean varieties (Parajuli et al., 2016, Joshi et al., 2020b). This unique practice not only preserves crop diversity but also provides effective solutions for managing biotic and abiotic stresses (Ssekandi et al., 2016, Bhujel et al., 2014). The growing bean mixtures helps farmers cope with threats such as disease outbreaks, pest infestations (Castro, 2001, Finckh et al., 2000, Koizumi, 2001, Mundt, 2002, Zhu et al., 2000, Joshi et al., 2020b, Ssekandi et al., 2016) and poor soil conditions.

A wide range of variations in traits such as seed coat color, shape, plant type, leaf size, pod characteristics, and root structure has been observed in the Jumli bean collections (Neupane et al., 2007, Vista et al 2020, Bhujel et al., 2014, Palikhey et al 2016, Parajuli et al., 2016). These local mixtures serve as a valuable gene pool for the development of pure-line varieties (Neupane et al., 2007; Bhujel et al., 2014).

This survey aimed to provide deeper insights into the ecological, cultural, and economic factors driving bean mixture cultivation in Karnali. This study has explored the reasons behind the widespread adoption of bean mixtures and why this method was less common for other crops.

Methodology

Two villages in each of Jumla and Humla districts were selected based on the predominance of bean mixture cultivation. These sites were identified through key informant surveys including input from officials from District Agriculture Development Offices and traders. In Humla, Sarkideu and Chhipra were chosen, while in Jumla, Hanku and Depalgau were selected, representing diverse production systems, ecological zones, and the dominance of bean mixtures (Figure 1). The selection process considered the entire district, and the detailed methodology is outlined in Figure 2.

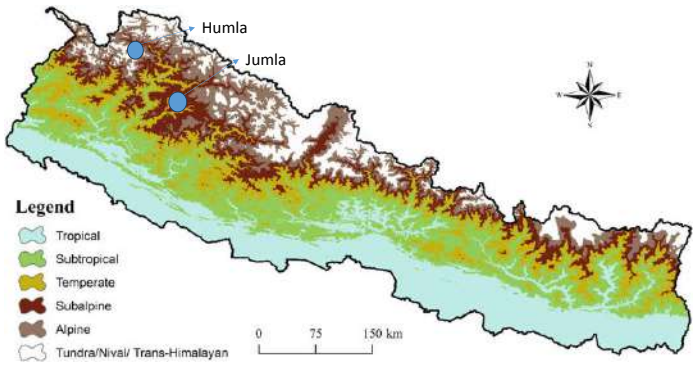


Fig. 1. Survey sites (Humla and Jumla districts)

Source of Map: Paudel et al., 2021

The survey was conducted using 42 structured questionnaires developed based on findings from a focus group discussion (FGD) and key informant surveys (KIS) published in Joshi et al. (2020b). The study explored several themes, including the reasons behind cultivating beans in mixtures. It aimed to understand if modern farmers were aware of the rationale behind this method, which includes risk management (pests, disease, climate uncertainty, poor soil conditions) (Joshi et al., 2020b, Koizumi, 2001, Mundt, 2002) and the reduction of labor, especially for women.

The household survey sample size included 34 households in Humla (11 male and 23 female respondents) and 40 in Jumla (19 male and 21 female respondents). These households were chosen from areas where bean mixture cultivation is predominant, ensuring diverse representation across different production systems.

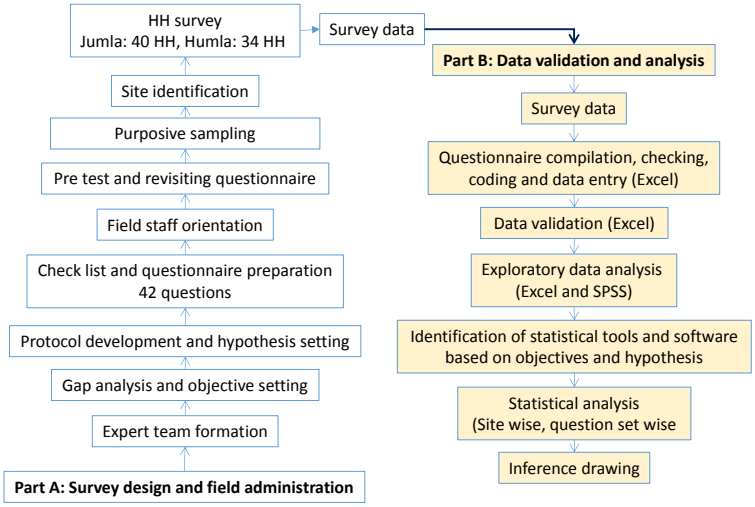


Fig. 2. Steps for bean survey in Jumla and Humla districts, and data analysis used in this study, HH: Household.

Field staff received training prior to administering the questionnaire in the field. After data collection, the project team worked closely with the field staff to validate the data by reviewing each question and conducting exploratory analysis. The responses were coded and entered into MS Excel for further analysis, where frequencies and percentages were calculated.

Findings and Discussion

Regarding gender distribution, there were 21 female respondents in Jumla and 23 in Humla, highlighting women's significant role in farming activities in both districts (Table 1). The average family size was slightly larger in Jumla, with 6.15 members per household, compared to 5.9 members in Humla. On average, households in Jumla cultivated beans on 1.93 *ropani* (1 *ropani* = 0.05 ha) of land, while in Humla, the average area was slightly larger at 2.4 *ropani*.

Table 1. Respondent details and their land areas

SN	Particular	Jumla	Humla
1.	Total respondent, n	40	34
2.	Male and female, n	19 and 21	11 and 23
3.	Family size (Min-Max), n	6.15 (3-13)	5.9 (3-11)
4.	Total cultivated area, (Min-Max), *ropani*	4.8 (1.5-15)	10.5 (1.06-30)
5.	Area under bean, (Min-Max), *ropani*	1.93 (0.5-4.5)	2.4 (0.5-10)

One *ropani* = 0.05 ha

Bean mixture and their characters

In Jumla, 55% of respondents reported growing bean mixtures, while only 30% did so in Humla (Figure 3). Additionally, 40% of Jumla farmers cultivated sole and mixed beans, a practice not observed in Humla. The names of the various landraces are generally based on seed color, size, and shape, such as *Kalo Sano Dalle*, where the first part refers to color, the second to shape, and the third to size.

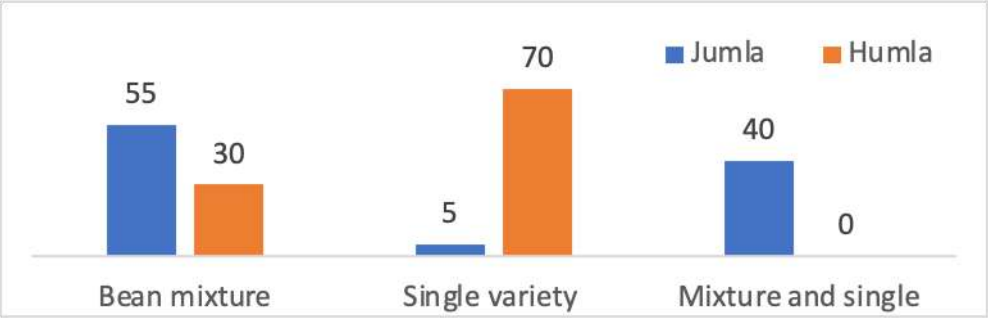


Fig. 3. Percentage of mixture and single varieties growers

Farmers in both districts have maintained and cultivated different numbers of landraces per household. In Jumla, 52% of single landrace growers cultivated only one type of bean, while 18% grew up to three landraces and 11% grew up to four landraces. Similarly, in Humla, single landrace growers maintained between one and seven types of beans per household, with 10% growing two landraces, 25% growing up to four landraces, and 4% growing as many as seven landraces separately. The number of landraces in mixtures also varied. In Jumla, 44% of farmers grew mixtures of four landraces, 15% grew five, 17% grew three, and 5% grew as many as seven landraces. In Humla, 32% of farmers mixed five landraces, 23% mixed three or four, 11% mixed six, and 6% mixed two.

The most commonly grown landraces in Jumla were *Kalo Male* (34.2%), *Sano Kalo* (13%), *Rato Male* (10.5%), *Rato Sano* (10.5%), and *Kalo Sano* (10.5%). Less common varieties included *Rajma Bean* (5%), *Pahenlo Besare* (2.6%), and *Kalo Lamo* (2.6%). The main reasons for cultivating these varieties included consumer preference (*Rato Male*), easy marketing (*Rato Sano*), high production (*Kalo Sano*), high market price (*Rajma Simi*), and taste (*Kalo Male, Kalo Sano, Kalo Lamo*). Some landraces were also chosen for their adaptability to less irrigated land (*Rato Sano*) or resistance to pests and diseases (*Pahenlo Besare*). In Humla, *Kalo Male* was the most commonly grown landrace, favored by 89% of farmers, followed by *Seto Male* (21%) and *Kalo* (7%). Less common varieties included *Kalo Dalle* (3.5%), *Seto* (3%), and *Seto Rato* (2%). Farmers in Humla primarily grew these landraces because of their taste and good performance in local conditions. Kalo Male Simi is a highly preferred landrace of bean known for its rich protein content (Joshi et al 2020a) and ability to fetch higher prices in the market.

Farmers in Jumla reported cultivating 30 distinct landraces of beans, while those in Humla grew 12 landraces. The specific characteristics of these landraces, along with the percentage of seed used in cultivation, are detailed in Table 2. In Jumla, *Rato*

Sano was the most widely grown landrace, followed by *Kalo Sano*, *Kalo Male*, and *Rato Male*. In contrast, in Humla, *Kalo Male* was the most popular landrace, followed by *Seto*, *Kalo*, *Pahenlo*, and *Rato*.

In Jumla, the average percentage of landraces in a mixture was 9.88%, with a minimum of 0.80% and a maximum of 43%. In Humla, the average proportion was slightly higher at 11.22%, with a range from 0.5% to 40%. Farmers in both Jumla and Humla prioritized traits such as production, taste, and resistance to insect pests and diseases when selecting landraces for cultivation.

Table 2. Landraces and status in mixture and reasons of mixing

SN	Landrace	Jumla			Humla		
		Grower, n	Mixture (%)	Reason	Grower, n	Mixture (%)	Reason
1.	Besare	2	2.2	Higher production, Insect/pest/water stress tolerance			
2.	Ghiu Simi				1	4.5	Vegetable purpose
3.	Kaleji Chirke	2	9.4	Tasty			
4.	Kalo	7	6.7	Higher production, Tasty	24	18.4	Higher production, Early maturity, Tasty
5.	Kalo Chirbire	9	8.7	Early maturity, Tasty, High market price			
6.	Kalo Dalle				2	17.3	Early maturity
7.	Kalo Lamo	1	0.8	Compensate each other			
8.	Kalo Male	19	16	Higher production, High market price, Insect/pest/water stress tolerance, Non spreading type	32	40.1	Higher production, Early maturity, Tasty
9.	Kalo Rajma	3	19	Higher production, High market price			

SN	Landrace	Jumla			Humla		
		Grower, n	Mixture (%)	Reason	Grower, n	Mixture (%)	Reason
10.	Kalo Sano	23	27	Higher production, Tasty, Compensate each other, Easy for intercultural operation			
11.	Kalo Thulo	1	2	Local variety			
12.	Khairo Dalle				1	8.3	Low production and taste
13.	Khairo Male	1	7.7	Higher production			
14.	Khairo Sano	2	7.3	Hardy			
15.	Pahenlo	1	2.1	Higher production	17	8.2	Early maturity, Not tasty
16.	Pahenlo Chiribire	1	3.4	Higher production	1	1	Tasty
17.	Rajma	2	13	Tasty, High market price			
18.	Rato	8	6.2	Tasty, Insect/pest/water stress tolerance, Non spreading type	15	5.3	Early maturity, Not tasty
19.	Rato Chiribire	2	7.9	Higher production, Tasty			
20.	Rato Dalle				1	0.5	Not tasty
21.	Rato Male	11	7.7	Higher production, Tasty, Compensate each other	2	3	Late maturity, Tasty
22.	Rato Sano	26	23	Higher production, Compensate each other, Insect/pest/water stress tolerance			
23.	Rato Seto Chiribire	2	5	Tasty			

SN	Landrace	Jumla			Humla		
		Grower, n	Mixture (%)	Reason	Grower, n	Mixture (%)	Reason
24.	Rato Seto Sano	5	7	Higher production, Insect/pest/water stress tolerance			
25.	Rato Thulo	3	2.5	Medium type			
26.	Seto	3	5.4	Higher production, Insect/pest/water stress tolerance, Water lodging resistant	26	19.3	Higher production, Early maturity, Tasty
27.	Seto Lamo	2	3.8	Higher production, Early maturity			
28.	Seto Male	7	9	Higher production, High market price	17	8.7	Higher production, Tasty, Early maturity
29.	Seto Rajma	2	11	Higher production, High market price			
30.	Thulo Male	2	43	Compensate each other			

In Jumla, the practice of mixing multiple bean landraces is quite common, with variations in the number of landraces used. About 8% of respondents reported mixing five landraces, 31% mixed four, 34% mixed three, and 26% mixed two landraces. There are also a few farmers who mix six or seven landraces. A list of the landrace combinations is given in Table 3. In Humla, of those who cultivate mixed beans, 62% reported mixing four landraces, 12.5% mixed three, and 25% mixed two landraces. This diversity in the number of landraces highlights the farmers' strategy to enhance resilience and productivity through varietal mixtures. These different types could be the result of growing same mixtures over the generation and keeping seed from the same field. Advantages of mixtures have been explored by many researchers (Castro, 2001, Finckh et al., 2000, Mundt, 2002). Despite farmers maintaining their own seeds for centuries, there have been no concerns regarding seed quality, making this traditional practice both sustainable and reliable. However, further research is needed to clarify potential naming inconsistencies, as there may be different names for the same landrace, or the same name could be assigned to distinct genotypes.

Table 3. List of landraces in bean mixtures

Jumla	Humla
Kalo Sano+Rato Sano	Kalo+Kalo Male
Male+Kalo Sano	Kalo Dalle+Pahelo
Kalo Male+Rato Sano	Kalo Male+Kalo Dalle+Seto Male
Rato Sano+Seto Thulo	Kalo Male+Kalo+Pahenlo+Seto
Kalo Male+Rato Male	Kalo+Kalo Male+Seto Male+Seto Dalle
Kalo Male+Rato Male+Seto Male	Kalo Male+Kalo+Rato Dalle+Seto Male
Seto+Kalo+Ghue Simi	Kalo Male+Kalo+Rato Dalle+Seto Male
Kalo Male+Kalo Sano+Rato Male	
Kalo Sano+Rato Sano+Seto Lamo	
Kalo Sano+Kalo Chiribire+Rato Sano	
Kalo Sano+Kalo Chiribire+Rato Lamcho	
Rato+Kalo+Kalo Chiribire+Rato Chiribire	
Kalo Sano+Kalo Thulo+Rato Sano+Rato Thulo	
Kalo Sano+Rato Sano+Seto Male+Kalo Male	
Rato+Kalo Sano+Rato Thulo+Seto Sano	
Kalo Sano+Rato Sano+Seto Thulo+Pahelno Thulo	
Kalo Male+Kalo Sano+Rato Sano+Rato Male	
Rato Male+Kalo Male+Rato Sano+Seto	
Kalo Male+Rato Male+Rato Sano+Kalo Sano	
Sano Rato+Rato Thulo+Kalo Chiribire+Rato Chiribire	
Kalo Male+Rato Male+Rato Sano+Kalo Sano	
Kalo Male+Kalo Thulo Male+Rato Sano+Rato Male	
Kalo+Seto+Pahelo+Male	
Rato Sano+Seto+Kalo Male+Kalo	
Kalo Male+Kalo Sano+Rato Sano+Rato Male	

Jumla	Humla
Seto+Kalo Sano+Kalo Chiribire+Rato Sano+Rato Chiribire	
Rato Sano+Besare Lamo+Kalo Male+Kaleji Chirke+Seto Chirke+Seto	

They identified specific landraces that posed challenges, and the common reasons for these concerns are detailed in Table 4. These drawbacks may include issues such as uneven maturation times, lower yields, or susceptibility to pests and diseases.

Table 4. Percent respondents on landraces that are not considered good in mixture

Landrace	Jumla, %	Reasons	Humla, %	Reason
Rato	12.5	Insect problem, difficult to sell, late maturity, less production, less/ not tasty, more black, less white, not tolerate to water lodging and small size grain	12	Insect problem, difficult to sell, late maturity, less production, less/ not tasty, more black, less white, not tolerate to water lodging and small size grain
Seto	5		18	
Rato Sano	55			
Kalo Sano	12.5			
Kalo				
Rato Male			3	
Pahenlo Chiribire			15	
Khairo Chirke	2.5		3	
Rato Dalle			3	

In both Jumla and Humla, the most preferred landrace to include in bean mixtures was *Kalo Male*. In Jumla, 45% of farmers reported favoring this landrace in their mixtures, while a significant 76% in Humla preferred it. In Jumla, other commonly preferred landraces for mixing were *Kalo Sano* (32.5%), *Kalo Chiribire* (10%), *Rato* (5%), and both *Kalo Lamo* and *Kalo Thulo* (each 2.5%). Additionally, 18% of respondents in Jumla indicated they did not want to mix landraces, while 16% preferred an improved variety, and 13% mentioned the *Seto Thulo* landrace. In Humla, farmers showed preference for *Kalo* and *Kalo Dalle* (each 6%), followed by *Rato*, *Kalo Thulo*, and *Seto Male* (each 3%). Furthermore, 6% of Humla farmers wanted to mix *Seto Sano*, *Kalo Dalle*, and *Chaumase* landraces.

Regarding whether their mixtures were similar to their neighbors', 69% of farmers in Jumla said their mixtures were the same, while in Humla, 18% reported having the same mixtures as their neighbors, and another 18% indicated they used different combinations.

Crop mixture

In addition to bean mixtures, farmers in both districts also practice crop mixtures, where different crops are grown together in the same field. In Jumla, 83.78% of respondents reported practicing crop mixtures, while in Humla, only 15.15% did, with 69.70% of Humla farmers not engaging in this practice.

The reasons for mixing different crops vary and are presented in Table 5. While cultivar mixtures are widespread in bean cultivation, they are less common in other crops, especially in Jumla, due to differences in maturity times and lower yields. In Humla, 36% of farmers found it difficult to separate seeds in mixed cropping, and 3% mentioned challenges with crops not maturing simultaneously. Despite these challenges, crop mixtures remain an important traditional practice in the region.

Table 5. Crop mixture practices in Jumla and Humla districts

Crop mixture practice	Reason
Jumla	
Potato, Maize and Finger millet	Produce more than one crop, gives higher production, benefit each other from both crops
Proso millet, Potato and Maize	Higher production, produce even if one crop fail, mature early, make soil fertile, take two crops form the same land
Maize and Potato	Harvest 2 crops from same field
Finger millet and Potato	Increase production
Finger millet, Potato and Proso millet	Increase production
Potato and Proso millet	Production of more than one crops
Finger millet and Proso millet	Production of more than one crops
Finger millet, Proso millet and Soybean	Production of more than one crops, improve soil
Humla	
Proso millet, Finger millet, Potato, Foxtail millet	High production, less insect and disease, more than one crop from same land
Gram and Soybean	Improve soil, harvest two crops from same field
Seto potato and Rato potato	Harvest and conserve diversity of potato

History and trend of bean mixture

The practice of cultivating bean mixtures has deep roots in both Jumla and Humla. In Jumla, 85% of respondents indicated that this tradition has been passed down from generation to generation, while 15% mentioned it started only a few years ago. Similarly, in Humla, 73% of farmers reported practicing bean mixtures for generations, with 20% noting that it began more recently.

Knowledge about bean mixture cultivation in Jumla is primarily inherited, with 73% of farmers learning it from their families, while others learned from neighbors. In Humla, however, only a small portion (7%) attributed their knowledge to generational learning, and 32% of respondents indicated that they did not practice bean mixtures at all. Over time, the trend of cultivating bean mixtures has been declining, with many farmers shifting towards monoculture, influenced by modern agricultural practices and promoting single high-yield varieties.

Reasons of cultivating bean mixture

In Jumla, 69% of respondents cited tradition as the main reason for maintaining this practice, with an additional 15% emphasizing the taste of mixed beans. In contrast, 57% of farmers in Humla highlighted high production as the primary motivation for growing bean mixtures. These reasons vary across districts and households, reflecting different farming conditions and cultural practices. Other reasons for cultivating bean mixtures, as shown in Table 6, include ease of cultivation, reduced risk of crop failure, and good production even in poor soil.

Table 6. Percent respondents on reasons of growing bean mixtures

Reason	Jumla	Humla
High production and profitable	47	57
Early maturity	5	3
For consumption	12.5	
Less chance of whole crop loss due to insect/pest	15	18
Compensation in production from each other	5	18
Time saving and easy production practice	20	10
Less storage problem	5	3
Tasty	70	15
Conservation of rare variety	5	3
Drought tolerant	5	
High preference by consumer	15	2

Consumer preferences for mixed beans varied between Jumla and Humla. In Jumla, 21% of consumers liked the mixture because it looked attractive, while 60% favored

it for its taste. However, in Humla, only 3% appreciated its appearance and taste, with 24% of respondents indicating that they did not like mixed beans at all. This shows a distinct difference in consumer perceptions and preferences between the two districts.

Traditional system of mixing bean

In Jumla, 40% of farmers reported using the same method for mixing over the years, while 30% based their mixtures on experience and production, and 5% used selection techniques. In Humla, some farmers also followed the traditional method, while others preferred mixing early-maturing beans (Table 7).

In terms of bean preferences, 42% of farmers in Jumla preferred including "Kalo Male" in the mixture, followed by 29% who preferred "Kalo Sano." In Humla, 16% favored mixing "Kalo," followed by "Rato" and "Dalle Kalo." In Jumla, 51% reported modifying their mixtures by adding or removing landraces over time, while in Humla, only 12% made changes. Additionally, a significant portion of farmers 66.67% in Jumla and 64% in Humla—performed seed selection during seeding. During harvesting, most farmers in both districts—95% in Jumla and 91% in Humla harvested bean mixtures together in bulk from the same plot. In Jumla, 23% of farmers intercropped bean mixtures with other crops, whereas in Humla, 94% preferred intercropping, indicating a stronger reliance on mixed cropping systems in Humla.

Table 7. Percent respondents on mixing methods of landraces in cultivar mixture

Basis	Jumla	Humla
Selection based on insect/pest severity	5	3
Based on production	17	NA
Consultation with neighbor	12	NA
Based on fast growing and early maturing type	NA	18
Own experiences	27	NA

Market values and demand of bean mixture

The primary outlets for selling bean mixtures in Jumla and Humla are local markets and villages, with 54% of respondents in Jumla and 63% in Humla reporting these as their main selling points (Figure 4). Other market channels include retailers, sales through offices, and direct sales from homes. Notably, a barter system still exists in Humla, where some farmers exchange beans for other goods. The pricing of mixed beans varies between the two districts. A majority of respondents perceive mixed beans as cheaper, with 61.5% in Jumla and 94% in Humla stating this view. Conversely, 20.5% of respondents in Jumla reported higher prices for mixed beans, while 12% in both districts indicated that the prices are the same.

Demand for mixed beans differs significantly between the districts: 40% of respondents in Jumla noted a high demand for mixed beans, whereas 84% in Humla reported low demand. In terms of usage, 72.5% of Jumla respondents indicated that the harvest is primarily for dal and consumption, while 20% noted it is used for both selling and consumption. In contrast, all respondents in Humla stated that their beans are mainly for consumption. When it comes to taste preferences, all respondents in Jumla expressed a liking for the bean mixture, whereas only 27% of Humla respondents reported a preference for mixed beans. Additionally, while every respondent in Jumla described mixed beans as very tasty, only 39% of those in Humla shared this sentiment. This disparity in taste perception may influence the market dynamics and demand for bean mixtures in the two regions. Consumers in urban areas favor a mix of beans.

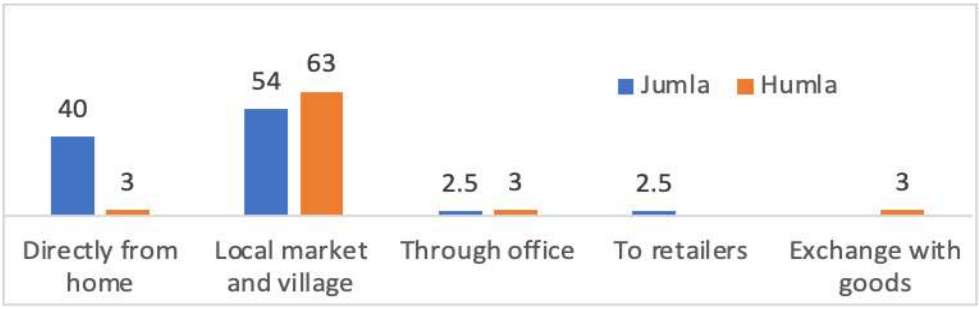


Fig. 4. Percentage of respondents for marketing beans in different market outlets

Advantages and disadvantages of bean mixture

The majority of respondents highlighted that bean mixtures result in high production, taste, resilience to climate fluctuations, and reduced susceptibility to insect pests and diseases (Table 8). Additional advantages include easier marketing, improved soil fertility, better retention of soil moisture, and the presence of medicinal properties. Bean mixtures are also recognized for their drought tolerance, absence of storage issues, multiple harvest opportunities, and their role in conserving genetic diversity. Notably, 56% of respondents in Jumla and 58% in Humla indicated that the various bean varieties in the mixtures compensate for each other's production, thereby enhancing overall yields.

One of the most significant advantages of bean mixtures is the reduced risk of total crop failure. The survey revealed that the likelihood of complete crop failure is considerably higher when growing a single crop compared to a mixture. In Jumla, 63% of respondents reported complete failure in monoculture, while 90% stated there was no failure in mixed cultivation. Similarly, in Humla, 76% of respondents experienced complete crop failure in monoculture, whereas 15% reported no failures in their bean mixtures. This highlights the resilience offered by mixed cultivation, allowing farmers to maintain productivity even in challenging conditions.

Furthermore, bean mixtures are noted for their compatibility with maize cultivation, requiring less land and resulting in lower weed infestation. The conservation of rare landraces is another crucial advantage of growing bean mixtures. By maintaining genetic diversity, farmers foster the evolution of new genotypes, which can enhance resilience and adaptability. This practice can lead to increased profits, as reported by 11% of respondents in Jumla, who noted that if one variety fails, the other landraces can still yield produce. Bean mixtures are nutritionally superior and healthier compared to single landrace grains. They require less rainfall, making them a sustainable option for farmers in regions where water availability can be a concern.

Table 8. Percentage of respondent on advantages of bean mixture compared to sole culture

Feature	Jumla	Humla
Higher production from mixture	65	91
Less diseases in mixture	50	100
Less insect attack in mixture	42.5	100
Mixture gives good production even in marginal land and with low input	42.5	100
Less problem in storage of mixture	35	100
Mixture improved soil	98	61
Higher price of mixture	27.5	80
Better test of varietal mixture	70	100
Compensation in production if one landrace failed	56	58

The 5.4% of respondents in Jumla and 9% in Humla identified differing maturity periods among the bean varieties as a significant issue. This variation can complicate the harvesting process, as beans with different maturation times may require staggered harvesting, leading to increased labor and logistical challenges. In addition, farmers reported other problems, including difficulties in seed separation, insect infestations during heavy rainfall, and low market prices for mixed beans. Less than 5% in both districts reported difficulty to sale mix bean. Specifically, 10.8% of respondents in Jumla and 9% in Humla cited low market prices as a concern, while the challenges of insect infestation were mentioned in relation to adverse weather conditions. Despite these reported challenges, a majority of respondents indicated that they experienced no significant problems with bean mixtures.

Conservation of Genetic Diversity

In Jumla, 27 landraces of beans are conserved, while 12 landraces are preserved in Humla. Farmers cultivate a range of bean varieties, from a minimum of one to as many as seven landraces together. The variation in seed size, color, shape, plant type,

and color across different landraces creates micro-environmental variations within and around the plants and plots, enhancing the overall resilience of the agricultural system. The farmers' autonomous management of seed cycles demonstrates their deep knowledge of local varieties and ecological conditions. By maintaining and promoting landraces that exhibit high "ecological yield," the farmers prioritize not just grain output but other important factors like resilience to pests, diseases, and climate variability.

Ecological and Economic Benefits

Genetic diversity within a cropping system increases its ability to withstand biotic and abiotic stresses, reducing the risk of total crop failure. The diversity of landraces acts as a buffer against pests and diseases, as different varieties may possess varying levels of resistance (Zhu et al., 2000, Mundt, 2002, Castro, 2001, Koizumi, 2001, Petchey and Gaston, 2002). In particular, sole cropping of a single landrace can be devastating in the event of an outbreak of pests or diseases, whereas the mixture of landraces creates a more resilient system, reducing the likelihood of large-scale damage.

Conclusion

The tradition of cultivating bean mixtures, blending genetic diversity and traditional knowledge, has sustained mountain farming but is declining due to the rise of uniform varieties. Bean mixtures offer tastier, more nutritious beans that fetch higher market prices, however, farmers have reported low price in the market. Mixing landraces with similar maturity periods simplifies harvesting and ensures reliable yields, even in difficult conditions like drought or pest outbreaks.

Acknowledgements

This survey was financially supported by the UNEP-GEF and implemented by Bioversity International, NARC, DoA, and LI-BIRD. Special thanks go to Kabita Jaisi, Dalaki Sherpa, and Paras Mahat in Jumla; Hira Devi Hamal and Sundar Rawat in Humla; and Surendra Shrestha and Safal Khatiwada in Kathmandu for their efforts in facilitating the experiment.

References

Bhujel, R.B., Rana, C.B., Mahat, P.M., Subedi, S. and Shrestha, L.L. (2014). Evaluation of Bean (*Phaseolous vulgaris*) as an Important Pulse and Cash Crop in Jumla and Similar High Hill Region of Nepal. In: *Proc. 27th national Summer Crops Workshop*. National Maize Research Program, NARC, Chitwan. Pp.22-27.

Castro, A. (2001). Cultivar mixtures. *The Plant Health Instructor*. https://doi.org/10.1094/PHI-A-2001-1230-01.

Finckh, M.R., Gacek, E.S., Goyeau, H., Lannou, C., Merz, U., Mundt, C.C., Munk, L., Nadziak, J., Newton, A.C., Vallavieille-Pope, C. and Wolfe, M.S. (2000). Cereal

variety and species mixtures in practice, with emphasis on disease resistance. *Agronomie* 20:813-837.

Joshi, B.K., Ojha, P., Gauchan, D., Ghimire, K.H., Bhandari, B. and KC, H.B. (2020a). Nutritionally unique native crop landraces from mountain Nepal for geographical indication right. In: D Gauchan, BK Joshi, B Bhandari, HK Manandhar and D Jarvis (Editors). Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal. NAGRC, LI-BIRD and the Alliance of Bioversity International and CIAT, Nepal. Pp.87-99.

Joshi, B.K., Vista, S.P., Gurung, S.B., Ghimire, K.H., Gurung, R., Pant, S., Gautam, S. and Paneru, P.B. (2020b). Cultivar mixture for minimizing risk in farming and conserving agrobiodiversity. In: D Gauchan, BK Joshi, B Bhandari, HK Manandhar and D Jarvis (Editors). Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal. NAGRC, LI-BIRD and the Alliance of Bioversity International and CIAT, Nepal. Pp.14-25.

Koizumi, S. (2001). Rice blast control with multilines in Japan. In: TW Mew, E Borromeo and B Hardy B (Editors). Exploiting biodiversity for sustainable pest management. Proc impact symposium on exploiting biodiversity for sustainable pest management, Kunming, China. International Rice Research Institute. Pp.143-157.

Mundt, C.C. (2002). Use of multiline cultivars and cultivar mixtures for disease management. Annu. Rev. Phytopathol. 40:381–410. https://doi.org/10.1146/annurev.phyto.40.011402.113723.

Neupane, R.K., Shrestha, R., Vaidya, M.L., Bhattarai, E.M., and Darai, R. (2007). Agromorphological diversity in common bean (*Phaseolus vulgaris* L.) landraces of Jumla, Nepal. In: MC Kharkwal (Editor). Proc. Fourth International Food Legumes Research Conference, India. Pp.1-11.

Neupane, S.P., Joshi, B.K., Aair, D., Ghimire, K.H., Gauchan, D., Karkee, A., Jarvis, D.I., Mengistu, D.K., Grando, S., and Ceccarell, S. (2023). Farmers' preferences and agronomic evaluation of dynamic mixtures of rice and bean in Nepal. *Diversity*, 15:660. https://doi.org/10.3390/d15050660

Palikhey, E., Sthapit, S.R., Gautam, S., Gauchan, D., Bhandari, B., Joshi, B.K. and Sthapit, B.R. (2016). Baseline Survey Report III. Hanku, Jumla. LI-BIRD, NARC and Bioversity International, Nepal.

Parajuli, A., Subedi, A., Adhikari, A.R., Sthapit, S.R., Joshi, B.K., Gauchan, d., Bhandari, B. and Sthapit, B.R. (2016). Baseline Survey Report: IV. Chhipra, Humla. LI-BIRD, NARC and Bioversity International, Nepal.

Paudel, B., Panday, D., Dhakal, K. (2021). Climate. In: RB Ojha and D Panday (Editors). The Soils of Nepal. World Soils Book Series. Springer, Cham. https://doi.org/10.1007/978-3-030-80999-7_3

Prasad, R.C., Ghimire, N.H. and Joshi, B.K. (2016). Cultivars mixtures in bean reduced disease infestation and increased grain yield under mountain environment of Nepal.

Agronomy Journal of Nepal 4:126-133. https://www.nepjol.info/index.php/AJN/article/view/15535

Ssekandi, W., Mulumba, J.W., Colangelo, P., Nankya, R., Fadda, C., Karungi, J., Otim, M., De Santis, P. and Jarvis, D.I. (2016). The use of common bean (*Phaseolus vulgaris*) traditional varieties and their mixtures with commercial varieties to manage bean fly (*Ophiomyia* spp.) infestations in Uganda. *J. Pest Sci.* 89:45-57. https://doi.org/10.1007/s10340-015-0678-7.

Vista, S.P., Ghimire, N.H., Mahat, P.M. and Joshi, B.K. (2020). Performance of trailing type bean genotypes under sole and mixed cultivation in mountain environment. In: D Gauchan, BK Joshi, B Bhandari, HK Manandhar and D Jarvis (Editors). Traditional Crop Biodiversity for Mountain Food and Nutrition Security in Nepal. NAGRC, LI-BIRD and the Alliance of Bioversity International and CIAT; Kathmandu. Pp.30-33.

Zhu, Y., Chen, H., Fan, J., Wang, Y., Li, W., Chen, J., Fan, J., Yang, S., Hu, L., Leunak, H., Mewk, T.W., Tengk, P.S., Wanak, Z., and Mundt, C.C. (2000). Genetic diversity and disease control in rice. *Nature* 406:718-722.

SAARC J. Agric., 22(2): 227-238 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.77547*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Evaluation of Different Chemical Insecticides and Biopesticides Against Vegetable Leaf Miner, *Liriomyza Sativae* in Tomato

K.R. Das[1*], M.A. Latif[2], M.M. Rahman[2], M.S. Hossain[2] and A.K. Paul[3]

[1]Deputy Director (Jute Production and Marketing), Crops wing, Department of Agricultural Extension, Khamarbari, Dhaka. Email: kdaeo@yahoo.com

[2]Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka.

[3]Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka.

Abstract

Vegetable leaf miner once considered as a secondary pest is now emerging as a primary pest of vegetables including tomato. It is also considered as an A1quarantine pest. Two experiments were performed to evaluate the efficacy of various insecticides against vegetable leaf miner in entomology laboratory and central farm of Sher- e- Bangla Agricultural University during October, 2019 to April, 2020. Seven insecticides such as Imidacloprid, Lamda cyhalothrin, Emamectin benzoate, Spinosad, abamectin, Matrine, azadirachtin at recommended dosages were evaluated to control vegetable leaf miner at both laboratory and field conditions. In case of laboratory experiment, treatments were evaluated using leaf dip technique in a completely randomized design (CRD) with three replications. In field study the treatments were laid in a completely randomized block design with three replications. Among all the tested chemicals and bio pesticides, Proclaim 5SG (Emamectin benzoate) @ 1.0g L^{-1} water, Tracer 45SC (Spinosad) @ 0.4 ml L^{-1}water and Vertimec 018 EC (abamectin) @ 1.2 ml L^{-1}water were most effective against *Liriomyza* leaf miner in both conditions. Thus three timely sprays of any one of these pesticides viz. Proclaim 5SG (Emamectin benzoate), Tracer 45SC (Spinosad) and Vertimec 018 EC (abamectin) at recommended dosages could be helpful to reduce the infestation of vegetable leaf miner.

Keywords: Vegetable leaf miner, insecticides, Laboratory evaluation, Tomato

[*] Corresponding author: kdaeo@yahoo.com

Received:07. 11. 2024 *Accepted: 07. 12. 2024*

Introduction

Tomato, being an important and widely consumed vegetable plays a crucial role in the nutritional status and livelihood of Bangladeshi people. Considering production, it is the fourth most produced vegetable in Bangladesh (BBS, 2020). But unfortunately, the susceptible nature of tomato plant to various kinds of insect pests hinders its potential production rate. Among the insect pests infesting tomato plants, highly polyphagous vegetable leaf miner *Liriomyza sativa* Blanchard belong to the family Agromyzidae is now appearing as a primary pest.

Seven species of genus *Liriomyza* have been recorded as economically important vegetable pest in Indonesia (Nonci and Muis , 2011) while in Bangladesh so far four leaf miner species have been identified as crop pest (Mazumdar and Bhuiya, 2014). The tiny feeding and oviposition punctures made by adult female flies in the leaf surface develop a stippled and yellowish appearance to the infested leaves. After hatching inside the leaf the newly formed larvae feeds the mesophyll contents and proceeds forwards forming continuous mines which turns parchment white and affects photosynthesis. Tomato foliage may be lost up to 90% when uncontrolled population increase occurs (Schuster, 1978) while heavy infestation can causes up to 70% yield losses (Zoebisch et al., 1984). As vegetable leaf miner is an A1 quarantine pest, besides direct damage producers also have to lose export markets. Even after withdrawal of complete bans, phytosanitary measures such as fumigation and irradiation are needed to be performed to fulfill the requirements of importing countries resulting in raised export costs (Reitz et al., 2013).

To cope with these problems tomato farmers apply large quantities of broad spectrum chemical pesticides with more frequencies. It is also notable that a pivotal part of the biology of leaf miner is its capability to develop resistance to insecticides (Parrella, 1987) resulting in failure of adopted chemical control measures of this pest. Thus an ideal pesticide for effective management of vegetable leaf miner is one that is selective and considered safer than conventional pesticides for parasitoids associated with this pest or other natural enemies as well as has low toxicity to vertebrates. Most commonly used pesticides against Leaf miner were organophosphate, carbamate and pyrethroid insecticides but this pest has already gained resistance/tolerance against these groups (Reitz et al., 2013). Rapid failures of these groups of chemical insecticides have led to development of pesticides with new chemistries. Among the invented new groups, two translaminar novel larvicide abamectin (Avermectins) and spinosad (Spinosyns) from soil microorganisms are effectively used against leaf miner (Schuster and Everett, 1983). Neem extracts containing Azadirachtin are also proved effective against leaf miner as well as safe for natural enemies and surrounding environment. Recently another plant extract alkaloid matrine derived from roots of genus *Sophora* has high toxicity against various insect pests and can be efficaciously used to control leaf miner (Marcic et al., 2012). It is worthy to mention that rotation among insecticides of various classes with different mode of action can

delay the incident of resistance to any insecticide. In Bangladesh available information on management of leaf miner is not sufficient. Against this backdrop, the present study was undertaken to evaluate the effect of different pesticides with various mode of action on this obnoxious pest.

Materials and Methods

The effect of various chemicals and biopesticides on vegetable leaf miner was evaluated in both laboratory and field condition.

a) Laboratory evaluation of chemical insecticides and biopesticides against *Liriomyza sativae*

Leaf dip technique was used to evaluate the synthetic insecticides and bio pesticides at entomology laboratory, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during November, 2019 to January, 2020.Vegetable leaf miner infested leaves having 3rd instar larvae were collected from natural tomato field without spraying and placed in zipped polythene bag. To keep moisten inside the polybag, a soaked cotton piece was placed inside the bag. With the help of a sharp object few holes were made on the polybag to facilitate air circulation. The polybags containing infested leaves were brought in the laboratory to perform further investigation.

Each treatment solution was prepared using distilled water and applied at recommended dosages (Table 1).

Table 1. List of pesticides with recommended concentration

Sl. no.	Trade name	Chemical name	Concentration
1	T_1 = Imitaf 20SL	Imidacloprid	0.25 ml L^{-1} water
2	T_2 = Fighter 2.5EC	Lamda-cyhalothrin	1.0 ml L^{-1} water
3	T_3 = Proclaim 5G	Emamectin benzoate	1.0 g L^{-1} water
4	T_4 = Tracer 45SC	Spinosad	0.4 ml L^{-1} water
5	T_5 = Vertimec 018EC	Abamectin	1.2 ml L^{-1} water
6	T_6 = Bikao	0.36% Matrine aqua solution	1.0 ml L^{-1} water
7	T_7 = Dr. Neem	Azadirachtin	0.5 ml L^{-1} water
8	T_8 = Control	Distilled water	

Collected leaves along with 3rd instar larvae were dipped into the prepared treatment solution for 5 seconds and placed separately on a paper for air drying. In case of

control treatment, the leaves containing larvae were dipped into distilled water and air dried on a paper. The leaves were then kept in glass petridishes. For each treatment (10) ten 3rd instar larvae were maintained in a glass petridish. To keep moisten inside; the petridish bottom was covered with a water soaked tissue paper. The Petridishes were placed on a table at a room temperature, in a completely randomized design (CRD) with three replications. The leaves were examined at 24 hours intervals to ensure that there was no desiccation. Data on larval mortality was collected at 24 hours, 48 hours, 72 hours, and 6 days after application of treatment. The collected larval mortality data after 6 days of treatment application was converted into percent mortality and was corrected for untreated treatment (control) using Abbot's formula.

$$\text{Corrected mortality} = \frac{\text{\% test mortality- \% control mortality}}{\text{100 - \% control mortality}} \times 100$$

The number of pupa and adults of leaf miner were also recorded at the time of daily observation and their percentages were also calculated.

$$\text{Pupa formation percent} = \frac{\text{Number of formed pupa}}{\text{Number of taken larvae}} \times 100$$

$$\text{Adult leaf miner emergence percent} = \frac{\text{Number of emerged adult leaf miner}}{\text{Number of taken larvae}} \times 100$$

b) Field evaluation of different chemical and biopesticides against vegetable leaf miner on tomato

This experiment was conducted during October, 2019 to April, 2020 using susceptible host plant tomato in the central farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka. The farm is located at $23^0 74^/$ N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level. The seeds of hybrid tomato KB1020 were collected from Bangladesh Agricultural Development Corporation (BADC) and seedlings were raised at the nursery bed of Folbithi Horticulture center, Asad gate, Dhaka following recommended methods. After final land preparation, the layout of the experiment was prepared by following Randomized Complete Block Design (RCBD) with eight treatments (same as in table 1) and three replications. Research layout was consisted of 24 plots each 2.5 m × 2.5 m in size with a 1.0 m distance between blocks and between plots. Fertilization was accomplished as per recommendation for tomato by BARI (2013).Thirty five days

old healthy tomato seedlings were transplanted in the experimental plot maintaining 60 cm × 50 cm spacing. Various intercultural operations such as training of plants with rope, staking with bamboo, weeding, loosening the soil and irrigation were performed as per needed.

After calibration of sprayer, desired volume of spray solution prepared with tap water was sprayed by knapsack sprayer. Treatment application was started at the time of first appearance of damage symptoms and spraying was performed three times at 10 days interval. Prior to first spraying, data was recorded on different parameters to obtain baseline information. After each spraying data was recorded from five tagged plants plot^{-1} on different parameters such as number of healthy plants, number of infested plants, number of healthy leaves plant^{-1}, Number of infested leaves plant^{-1}, number of larvae plant^{-1}and yield of the plot. Leaf infestation percent was calculated with the help of recorded data.

Efficacy percent

Efficacy percent of experimented insecticides based on number of larvae leaf^{-1} was calculated by using the following formula

$$\text{Efficacy percent} = \frac{\text{Precount} - \text{Post spray count (mean)}}{\text{Precount}} \times 100$$

Efficacy percent based on leaf infestation=

$$\frac{\text{Pre spray leaf infestation percent} - \text{Post spray leaf infestation percent (mean)}}{\text{Pre spray leaf infestation percent}} \times 100$$

Results and Discussion

Laboratory evaluation of different chemical and biopesticides against *Liriomyza sativae*

Effect on larval mortality percent

Larval mortality percent with various chemicals and biopesticides presented in Table 2 showed significant differences among the treatments over 6 days after treatment application. The highest mortalily was recorded on Tracer 45SC (T_4) with 96.26 % larval mortality as well as Proclaim 5SG (T_3) and Vertimec 0.18EC (T_5) both having similar percent value (88.88) while all three treatments were statistically similar. On the contrary, the lowest larval mortality percent (10.00) was observed in Control (T_8) followed by Bikao (T_6) and Dr. Neem (T_7) both having similar percent (48.14).

Table 2. Larval mortality, Pupal formation and adult leaf miner emergence percent of *L. sativae* in various treatments at different intervals in the laboratory condition

Treatments	No. of tested larvae	Mean mortality percent after 6 days	Corrected Mortality percent after 6 days	Mean percent of pupal formation	Mean percent of adult Leaf miner emergence
T_1 (Imitaf)	10	63.303 b	59.25 b	36.66 c	26.66 bc
T_2 (Fighter)	10	70.00 b	66.66 b	30.00 c	23.33 c
T_3 (Proclaim)	10	90.00 a	88.88 a	10.00 d	6.66 d
T_4 (Tracer)	10	96.66 a	96.26 a	3.33 d	0.00 d
T_5 (Vertimec)	10	90.00 a	88.88 a	10.00 d	0.00 d
T_6 (Bikao)	10	53.33 c	48.14 c	46.66 b	23.33 c
T_7 (Dr. Neem)	10	53.33 c	48.14 c	46.66 b	33.33 b
T_8 (Control)	10	10.00 d	10.00 d	90.00 a	63.33 a
CV(%)		6.20	7.31	11.95	22.64
LSD (0.05)		7.06	7.85	7.06	8.65

Same lettering in a column denotes statistical similarity among treatments whereas different lettering denotes statistically dissimilarity among treatments.

In case of larva to pupal formation, it was observed that the treatment Tracer 45 SC (T_4) resulted in the lowest percent of pupa formation (3.30) along with two statistically similar treatments Proclaim 5SG (T_3) and Vertimec 018 EC (T_5). This obtained result was close to Seal et al. (2002) who found no pupal formation for the treatment Abamectin. Considering larva to adult emergence, Tracer 45SC (T_4) and Vertimec 018EC (T_5) resulted in no adult emergence of leaf miner which were statistically similar with the treatment Proclaim 5SG (T_3). Contrarily, the highest number of leaf miner adult emergence (6.33) was observed in Control (T_8) followed by the treatment Dr. Neem (T_7).

Based on the above findings it can be summarized that Tracer 45SC (T_4), Vertimec 0.18 EC (T_5) and Proclaim 5SG (T_3) were most effective insecticides against *Liriomyza* leaf miner followed by Fighter 2.5EC (T_2) and Imitaf 20 SL (T_1). Some other researcher's findings (Reitz et al., 2013) were also pursuant to present work

indicating the effectiveness of Abamectin and Spinosad against leaf miner larva while Ishaaya et al. (2002) reported emamectin benzoate as an effective insecticide against *Liriomyza*. According to Guntai et al. (2015) Abamectin was most effective against *Liriomyza* larva in laboratory while Imidacloprid was less effective than aforementioned one which was in agreement with the present result.

On the contrary, Bikao (T_6) and Dr. Neem (T_7) showed less effectiveness in causing larval mortality compared to aforementioned treatments which was supposed to due to their action mechanism as both are plant extracts. Approximately similar result was observed by Dimetry and El- Haraway (1995) in laboratory condition stating that the feeding deterrent activity of Neem seed kernel extract was significant against *Liriomyza* adults particularly at high concentrations while less effective against larva. According to Banchio et al. (2003) slow action of Azadirachtin allowed more leaf miner larvae to pupate which also justified the present finding regarding Dr. Neem treatment. Present result is also in line with the findings of Weintraub and Horrowitz (1997) indicating that the low concentration of azadirachtin had a minor effect on the larvae. On the other hand, as Bikao (Matrine aqua solution) was a new product used against *Liriomyza* larva in laboratory, it was not possible to relate its result with previous findings for want of information in published literature.

Field evaluation of different chemical and biopesticides against *Liriomyza sativae* on tomato

Among all the tested treatments the lowest number mean no. of larvae leaf^{-1} with 1st spray was observed in the treatment T_5 (Tracer 45SC) followed by treatments T_6 (Vertimec 018EC), T3 (Proclaim 5SG) and T_8 (Dr. Neem) which were also statistically similar with the treatment T_5. In case of efficacy percent the rank of the treatments are as follows:

Tracer 45SC (T_5) (57.65%) >Vertimec 018EC (T_6) (51.64%) > Dr. Neem (T_8) (42.35%)> Proclaim 5SG (T_3) (36.36%) > Bikao (T_7) (32.73%) >Imitaf 20SL (T_2) (31.20%) > Fighter 2.5 EC (T_4) (25.00%). Therefore, after 1st spray Tracer 45SC was found as most effective treatment against leaf miner among tested bio pesticides as well as among all applied treatments followed by Vertimec 018EC and Dr. Neem while among the chemical insecticides Proclaim 5SG was most effective in controlling leaf miner. Present findings are also in line with the work of Ravipati et al. (2020) indicating that after first spray Spinosad exerted as next best superior treatment while Azadirachtin showed less efficacy than Spinosad.

After second spray the lowest mean number of larvae leaf^{-1} was found with the treatment T_5 followd by T_3 and T_6 which was also on par with T_5 and these treatments were significantly superior to other treatments. Considering efficacy percent based on

Number of larvae leaf^{-1} the treatments followed the order as: Tracer 45SC (T_5) (81.97%) > Vertimec 018EC (T_6) (78.96%) > Proclaim 5SG (T_3) (76.67%) > Dr. Neem (T_8) (69.67%) >Bikao (T_7) (63.03%) > Imitaf 20SL (T_2) (62.40%) > Fighter 2.5 EC (T_4) (58.50%).

From Table 3, it was observed that like previous two sprays all the tested treatments followed the similar pattern with third spray. In case of efficacy percent the rank of the treatments are as follows:

Tracer 45SC (T_5) (78.96%), Vertimec 018EC (T_6) (78.96%) > Proclaim 5SG (T_3) (73.30%) > Dr. Neem (T_8) (66.67%) > Bikao (T_7) (63.03%) > Imitaf 20SL (T_2) (57.80%) > Fighter 2.5 EC (T_4) (55.75%).

Table 3. Efficacy percent based on mean number of larva leaf ^{1} after 1st spray, 2nd spray and 3rd spray with different treatments

Treatments	Pre count	After 1st spray		After 2nd spray		After 3rd spray	
		Mean no. of larvae leaf^{-1}	Efficacy percent	Mean no. of larvae leaf^{-1}	Efficacy percent	Mean no. of larvae leaf^{-1}	Efficacy percent
T_1 (Control)	3.30 d	5.55 a	--	7.11 a	--	7.77 a	--
T_2 (Imitaf 20 SL))	5.00 a	3.44 b	31.20	1.88 b	62.4	2.11 b	57.8
T_3 (Proclaim 5SG)	3.30 d	2.10 cd	36.36	0.77 de	76.67	0.88 e	73.33
T_4 (Fighter 2.5EC)	4.00 b	3.00 b	25.00	1.66 bc	58.5	1.77 c	55.75
T_5 (Tracer 45SC)	3.66 c	1.55 d	57.65	0.66 e	81.97	0.77 e	78.96
T_6 (Vertimec 018EC)	3.66 c	1.77 cd	51.64	0.77 de	78.96	0.77 e	78.96
T_7 (Bikao)	3.30 d	2.22 c	32.73	1.22 cd	63.03	1.22 d	63.03
T_8 (dr. Neem)	3.66 c	2.11 cd	42.35	1.11 de	69.67	1.22 d	66.67
CV (%)	2.84	12.25		13.94		8.38	
LSD (0.05)	0.18	0.57		0.45		0.30	

Same lettering in a column denotes statistical similarity among treatments whereas different lettering denotes statistically dissimilarity among treatments.

Table 4. Efficacy percent of different treatments based on percent leaf infestation

Sl No	Treatments	Pre Leaf infestation percent	After 1st spray		After 2nd spray		After 3rd spray	
			Percent (%) leaf infestation	Efficacy percent	Percent (%) leaf infestation	Efficacy percent	Percent (%) leaf infestation	Efficacy percent
1	T_1 (Control)	35.55	47.27 a	--	58.26 a	--	61.68 a	--
2	T_2 (Imitaf 20SL)	27.77	24.51 bc	11.74	23.90 b	13.94	21.10 b	24.02
3	T_3 (Proclaim 5SG)	37.78	25.20 b	33.3	10.28 f	72.79	9.65 f	74.46
4	T_4 (Fighter 2.5EC)	30.55	25.84 b	15.42	22.79 c	25.41	16.75 c	53.41
5	T_5 (Tracer 45SC)	34.22	21.69 d	36.62	6.84 h	80.01	7.99 g	76.65
6	T_6(Vertimec 018EC)	36.23	23.13 cd	36.16	9.58 g	73.56	10.06 f	72.23
7	T_7 (Bikao)	32.80	23.34 cd	28.84	12.88 e	60.73	13.53 e	58.75
8	T_8 (Dr. Neem)	32.11	23.25 cd	27.59	16.19 d	49.58	15.75 d	50.95
	CV (%)		3.89		2.24		1.33	
	LSD (0.05)		1.80		0.77		0.44	

Same lettering in a column denotes statistical similarity among treatments whereas different lettering denotes statistically dissimilarity among treatments.

Present results are partly in line with Variya and Patel (2012) who recorded lowest number of larvae leaf^{-1} with emamectin benzoate while highest number of larvae with Imidacloprid after first spray. They also reported Spinosad and Emamectin benzoate as most effective insecticides against leaf miner after 2nd spray on Tomato while Imidacloprid as less effective insecticide.

Considering percent leaf infestation (Table 4), after first spray all the treatments showed significantly low leaf infestation percent compared to Control. Among the treatments, Tracer 45SC (T_5) treated plot showed lower leaf infestation percent while it was statistically similar with the treatments Vertimec 018EC (T_6), Bikao (T_7) and Dr. Neem (T_8). However, Imidacloprid 20Sl (T_2), Proclaim 5SG (T_3) and Fighter 2.5EC (T_4) had higher leaf infestation percent compared to Tracer 45SC (T_5). Actually previous findings showed that Lamda cyhalothrin, as with other pyrethroids has a documented resistance against several agricultural pests (Rodriguez et al., 2001; Ahmad et al., 2002) which may be the reason behind the less effectiveness of these pesticides. After second and third spray Tracer 45SC (T_5) was best effective treatment followed by Vertimec 018EC (T_6) and Proclaim 5SG (T_3).

Comparing of treatments performances based on percent leaf infestation among three sprays it was noticed that all treatments showed lower leaf infestation percentage after second & third sprays than first spray except untreated control which showed higher leaf infestation percent. Actually first spraying of insecticides decreased the buildup of leaf miner population as well as oviposition resulted in comparatively lower larval population as well as percent leaf infestation in subsequent sprays.

Seal et al. (2002) reported Abamectin and Spinosyn as highly effective against leaf miner which confirmed this study. Mondol (2016) found Imidacloprid 17.8 SL moderately effective against leaf miner while emamectin benzoate less effective. As azadirachtin does not possess oviposition deterrent ability (Webb et al., 1983), Dr. Neem treated plots had significantly more infestation as compared to Tracer 45SC, Vertimec 018EC and Proclaim 5SG but the rates were significantly lower than untreated control. Devkota (2015) confirmed the obtained result indicating inability of Azadirachtin to work as feeding deterrent but ability to work as larvicide due to its high larvicidal property. The findings are also in line with Vietmeyer (1992) who mentioned that due to slow action of Neem insects continue to damage plants even after spraying resulting in higher infestation percentage.

In case of efficacy percent of treatments based on percent leaf infestation, after first, second and third spray Proclaim 5SG, Tracer 45SC and Vertimec 018 EC showed almost higher efficacy than other tested insecticides. After 3rd spray some variations occurred among other treatments and it is supposed that this varied efficacy percent was due to the impact of some biotic as well as abiotic factors such as parasitism, intraspecific competition, crop phenology, temperature and so on. Build up of Leaf miner population may be influenced by the effects of insecticides on natural enemies or amount of remained plant residue for the control of emerging adults. Moreover, several literatures indicated that depending on temperature insecticides efficacy may alter as temperature affects insecticidal toxicity by swaying volatility, stability, degradation and metabolism (An et al., 2020). Besides, temperature can also alter the behaviour of insects to insecticides (Xiong et al., 2019). Moreno (2009) also observed the varied efficacy of Abamectin in different seasons which is in line with the present result.

Some researchers have already documented development of resistance of *Liriomyza* species against Abamectin and Spinosad in other part of the world (Ferguson, 2004). Hernandez et al. (2011) reported harmful effects of Novaluron, Abamectin, Spinetoram and Lamda cyhalothrin against leaf miner parasitoids. It can be assumed that these insecticides may have detrimental effects on parasitoids or as these treatments also caused highest larval mortality there existed a little chance for parasitoids to parasitize larva or pupa of *Liriomyza.*

Conclusion

Based on the results of the experiment it can be stated that three timely sprays of any one of these pesticides viz. Proclaim 5SG @ 1.0 g L^{-1}, Tracer 45SC @ 0.4 ml L^{-1}water and Vertimec 018 EC @ 1.2 ml L^{-1} are capable to reduce the infestation of vegetable leaf miner and to keep a check on concerned pest for increasing crop yield. During pesticide selection the safety of the parasitoid guilds associated with this pest should be kept in mind. To delay the development of resistance against Spinosad, Abamectin and Emamectin it is recommended to use Bikao and Dr. Neem as alternative management options against leaf miner.

References

Ahmad, M., Arif, M., Ahmad, Z. and Denholm, I. (2002).Cotton whitefly (*Bemesia tabaci*) resistance to organophosphate and pyrethroid in Pakistan. *Pest Management Science,* 58: 203-208.

An, J.J., Liu, C., Dou, Y.N., Gao, Z.L., Dang, Z.H., Yan, X., Pan, W.L., Li, Y.F. (2020). Analysis of differentially expressed transcripts in *Apolygus lucorum* (Meyer) exposed to different temperature coefficient insecticides. *International Journal of Moelcular Sciences,* 21(21): 658.

Banchio, E., Valladares, G., Defago, M., Palacios, S. and Carpinella, C. (2003). Effects of *Melia azadirachta,* (Meliaceae) fruit extracts on the leaf miner *Liriomyza huidobrensis*, (Diptera, Agromyzidae): assessment in laboratory and field experiments. *Annals of Applied Biology,* 143(2): 187-193.

BARI. (2013). Krishi Projukti Hatboi, Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. p.123.

BBS. (2020). Bangladesh Bureau of Statistics. Statistical Year book. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Devkota, S. (2015). Ecology and management of the American serpentine leaf miner, *Liriomyza trifolii* (Bugress) (Diptera: Agromyzidae) on five major vegetable crops grown in south Florida. M.S. thesis, University of Florida, Gainesville, Florida.

Dimetry, N.Z. and El- Hawary, F.M. (1995). Neem Azal- F as an inhibitor of growth and reproduction in the cowpea aphid Aphis craccivora Koch. *Journal of Applied Entomology,* 119 (5): 67-71.

Ferguson, J.S. (2004). Development and stability of insecticide resistance in the leafminer *Liriomyza trifolii* (Diptera: Agromyzidae) to cyromazine, abamectin, and spinosad. *Journal of economic Entomology,* 97(1): 112-119.

Guantai, M.M., Ogol, C.P.K.O., Salifu, D., Kasina, J.M., Akutse, K.S. and Flaboe, K.K.M. (2015). Differential effects of pesticide application on *Liriomyza huidobrensis* (Diptera: Agromyzidae) and its parasitoids on pea in Central Kenya. *Journal of Economic Entomoogy,*108 (2): 662-671.

Hernández, R., Harris, M. and Liu, T-X. (2011). Impact of insecticides on parasitoids of the leaf miner, *Liriomyza trifolii*, in pepper in south Texas. *Journal of Insect Science,* 11: 1-14.

Ishaaya, I., Kontsedalov, S. and Horowitz, A.R. (2002). Emamectin, a novel insecticide for controlling field crop pests. *Pest Management Science,* 58(11): 1091-1095.

Marcic, D. Prijovic, M. Drobnjakovic, T. Medo, I. Peric, P. and Milenkovic, S. (2012). Greenhouse and field evaluation of two biopesticides against *Tetranychus urticae* and *Panonychus ulmi* (Acari: Tetranychidae). *Pesticides and Phytomedicine,* 27(2):313 – 320.

Mazumdar, S. and Bhuiya, B.A. (2014). Vegetable leafminers (Diptera: Agromyzidae) and their plant hosts in Bangladesh. *Journal of Threatened Taxa,* 6(6): 5894-5899.

Mondol, D. (2016). Efficacy of some insecticides in the management of *Liriomyza brassicae* on *Pisum sativum*. *International Journal of Engineering and computer Science*, 6: 1640-1642.

Moreno, R.H. (2009). *Liriomyza* leaf miners, associated parasitoids and insecticide evaluation in South Texas.M.Sc.thesis, New Mexico State University.

Nonci, N. and Muis, A. (2011).Bioecology and leaf miner control *Liriomyza chinensis* Kato (Diptera: Agromyzidae) on the red onion. *Journal of Agricultural Research*, 30(4): 148-155.

Parrella, M.P. (1987). Biology of *Liriomyza. Annual Review of Entomoogy*, 32: 201-224.

Ravipati, N.S.N., Shukla, A. and Sahu, B. (2020). Influence of weather parameters on the incidence of serpentine leaf miner, Liriomyza trifolii (Burgess) on tomato. *International Journal of Current Microbioogy and Applied Sciences*, 9(5): 2260-2265.

Reitz, S.R., Gao, Y. and Lei, Z. (2013). Insecticide use and the ecology of invasive *Liriomyza* leaf miner management**. In:** Insecticides- Development of safer and more effective technologies. Intech, Croatia: 233-246.

Rodriguez, M. M., Bisset, J., Molina, D., Lauzan, L. and Soca, A. (2001). Detection of insecticide resistance in *Aedes aegypti* (Diptera: Culicidae) from Cuba and Venezuela. *Journal of Medical Entomology*, 38: 623-628.

Schuster, D.J. and Everett, P.H. (1983). Response of *Liriomyza trifolii* (Diptera:Agromyzidae) to insecticides on tomato. *Journal of Economic Entomology*, 76: 1170-1174.

Schuster, D.J. (1978). Vegetable leaf miner control on tomato, 1977.*Insecticides Acaricides Tests*, 3(1): 108.

Seal.D.R., Betancourt, R. and Sabines, C.M. (2002). Control of *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) using various insecticides. *Proceedings of the Florida State Horticultural Society*, 115: 308-314.

Variya, M.V. and Patel, J.J. (2012).Evaluation of different insecticides against leaf miner (*Liriomyza trifolii* Burgess) in tomato.*AGRES*.1: 453-462.

Vietmeyer, N.D. (1992). Neem: a tree for solving global problems. Report of an ad hoc panel of the Board on Science and Technology for International Development, National Research Council. National Academy Press.

Webb, R.E., Hinebaugh, M.A., Lindquist, R.K. and Jacobson, M. (1983). Evaluation of aqueous solution of neem seed extract against *Liriomyza sativae* and *L. trifolii* (Diptera: Agromyzidae). *Journal of Economic Entomology*, 76**(**2): .357-362.

Weintraub, P.G. and Horowitz, A.R, (1997). Systemic effects of a neem insecticide on *Liriomyza huidobrensis* larvae. *Phytoparasitica*.26:231-240.

Xiong, Y., Liu, X.Q., Xiao, P.A., Tang, G.H., Lia, S.H., Lou, B.H., Wang, J.J. and Jlang H.B. (2019). Comparative transcriptome analysis reveals differentially expressed genes in the Asian citrus Psyllid (*Diaphorina citri*) upon heat shock. *Comparative Biochemistry and Physiology-Part D: Genomics and Proteomics*, 30**:** 256-261.

Zoebisch, T.C., Schuster, D.J. and Gilreath, J.P. (1984).*Liriomyza trifolii*: Oviposition and development in foliage of tomato and common weed hosts. *Florida Entomologist*, 67(2): 250-254.

SAARC J. Agric., 22(2): 239-255 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.77599*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Genetic Parameters Estimation and Identification of Promising Rice Genotypes Grown in Rainfed Condition using Mgidi Index in Rampur, Chitwan

P. Roka[1*], B.N. Adhikari[2], S. Shrestha[3], D. Roka[4], A. Adhikari[5] and B. Shreepaili[3]

[1]Gokuleshwor Agriculture and Animal Science College, Institute of Agriculture and Animal Science, Tribhuvan University, Nepal.
[2]National Maize Research Program, Rampur, Chitwan, Nepal.
[3]Agriculture and Forestry University, Rampur, Chitwan, Nepal.
[4]Institute of Agriculture and Animal Science, Lamjung Campus, Lamjung, Nepal.
[5]Budhanilkantha International Academy, Kathmandu, Nepal.

Abstract

This study evaluated 24 rice genotypes, including 22 pipeline varieties from the National Rice Research Program (NRRP) in Dhanusa and two checks, Bahaguni-2 and Sabitri. The Multi-Trait Genotype-Ideotype Distance Index (MGIDI) was used as selection tool to rank genotypes based on their proximity to an ideal genotype. Broad-sense heritability (h^2) estimates ranged from 0.03 for panicle length to 0.96 for days to 80% maturity, suggesting high potential for selection gains in days to 80% maturity ($h^2 = 0.96$) and plant height ($h^2 = 0.91$), while tiller number and grain yield showed low heritability ($h^2 > 0.5$). Variance analysis indicated substantial genetic control for plant height and days to 80% maturity, while panicle length and grain yield were more influenced by environmental factors. Principal component analysis revealed four factors explaining 76.5% of the trait variation, with FA1 (days to 50% flowering, days to 80% maturity) accounting for the most variation. Selection gains were assessed using MGIDI and FAI-BLUP indexes, with MGIDI achieving a 15.13% gain for targeted traits and FAI-BLUP yielding 1.25%. Selected genotypes from MGIDI included SVIN 127, SVIN 098, SVIN 643, SVIN 084, and IR 18F1085, with SVIN 127 and SVIN 098 also appearing in the FAI-BLUP index, highlighting their potential value for breeding. This research

[*] Corresponding author: punamroka40@gmail.com

Received: 08. 11. 2024 *Accepted: 08. 12. 2024*

demonstrates the effectiveness of both selection indexes in identifying superior genotypes for enhanced breeding efficiency.

Keywords: rice, MGIDI, selection gain, grain yield, ideotype

Introduction

Rice (*Oryza sativa* L.) ranks as the second most crucial cereal crop after wheat and is a staple food for more than half of the world's population. As the global population is expected to reach 8 billion by 2025, there is an increasing need to boost rice production (Mohidem et al., 2022).

Selection gain is a fundamental objective in plant breeding, guiding the development and progress of breeding programs to improve crop performance. Traditionally, breeding efforts have focused on a limited number of traits, but this approach has been recognized as insufficient for achieving comprehensive crop improvement (Sinha et al., 2021). Selecting a few traits in isolation can neglect potential enhancements in other vital characteristics, limiting the overall genetic advancement. Consequently, modern breeding programs seek to combine desirable traits into a single genotype, aiming to create an ideotype-a plant model with optimized traits for superior performance (Donald, 1968).

The concept of ideotype breeding has long been central to crop improvement programs, where the goal is to develop a genotype that integrates a range of traits for optimal agronomic and economic outcomes (Carbajal-Friedrich and Burgess, 2024). However, the complexity of breeding for multiple traits simultaneously poses significant challenges. This is particularly true when accounting for natural correlations between traits, which traditional methods often overlook. In this context, the Multi-Trait Genotype-Ideotype Distance Index (MGIDI) offers a novel approach that addresses these limitations by incorporating data from multiple traits into the selection process (Olivoto and Nardino, 2021). Unlike conventional selection indices, MGIDI leverages multivariate techniques to account for trait correlations and efficiently selects genotypes based on their proximity to an ideal genotype (Alam et al., 2024). MGIDI represents a significant advancement in multivariate selection methodologies, providing a more holistic and effective tool for crop improvement. By computing a weighted Euclidean distance between genotypes and the ideal genotype, MGIDI ranks genotypes according to their overall performance across multiple traits (Olivoto et al., 2022). It applies Principal Component Analysis (PCA) to reduce dimensionality, transforming correlated traits into independent components, thus minimizing redundancy and multicollinearity (Shafizadeh-Moghadam, 2021). This approach enables plant breeders to evaluate genotypes more effectively, considering the strengths and weaknesses of each genotype (Olivoto and Nardino, 2021).

MGIDI offers breeders a powerful approach to achieving genetic gain and improving rice traits holistically by leveraging multivariate data and offering a comprehensive assessment of rice genotype performance. The objective of this study was to evaluate the genetic parameters of key agronomic traits in rice genotypes to enhance the

efficiency of breeding programs. This study also explored the application of MGIDI in evaluating rice genotypes, aiming to provide insights into its utility as a selection tool and identify the high potential genotypes.

Materials and Methodology

Experimental site

The experiment was performed at National Maize Research Program (NMRP) rice research field, Chitwan between June and October 2022. Geographically, the site is positioned at 27°39.27' North latitude and 84°21.28' East longitude, at 228 meters above sea level. The region has a humid, subtropical climate characterized by cool winters, hot summers, over 1500 mm of annual rainfall, a pronounced monsoon season, and sandy loam soils with slight to acidic solid characteristics.

Planting materials

The experiment involved 24 genotypes (Table 1), comprising 22 pipeline varieties obtained from the National Rice Research Program (NRRP), Dhanusa and two check varieties, Bahaguni-2 and Sabitri.

Table 1. List of twenty-four genotypes of rice used in research.

S.N.	Genotype	Sources
1	HARDINATH-4	NRRP, Dhanusa
2	IR 15L1801	NRRP, Dhanusa
3	IR 16 F 1148	NRRP, Dhanusa
4	IR 16 L 1855	NRRP, Dhanusa
5	IR 16A 5125	NRRP, Dhanusa
6	IR 16F1065	NRRP, Dhanusa
7	IR 16L 1795	NRRP, Dhanusa
8	IR 17L1415	NRRP, Dhanusa
9	IR17A12038	NRRP, Dhanusa
10	IR17A2252	NRRP, Dhanusa
11	NR 2233-3-1-1-3-3	NRRP, Dhanusa
12	P# 14-16-SP #52	NRRP, Dhanusa
13	P# 14-30-SP #27	NRRP, Dhanusa
14	SVIN 028	NRRP, Dhanusa
15	SVIN 060	NRRP, Dhanusa
16	SVIN 064	NRRP, Dhanusa
17	SVIN 095	NRRP, Dhanusa
18	SVIN 098	NRRP, Dhanusa

S.N.	Genotype	Sources
19	SVIN 127	NRRP, Dhanusa
20	SVIN 131	NRRP, Dhanusa
21	SVIN 191	NRRP, Dhanusa
22	SVIN 195	NRRP, Dhanusa
23	SVIN 312	NRRP, Dhanusa
24	SVIN 643	NRRP, Dhanusa

Design of experiment and cultural practices

The experiment followed an alpha-lattice design with three replications and two blocks containing 12 genotypes. Rice seedlings were grown in a wet seedbed for 25 days before being transplanted into well-prepared soil in plots measuring 10 m² (5 m * 2 m), with a spacing of 20 cm * 20 cm. Fertilization was done using 100:40:30 kg NPK per hectare, with half the nitrogen and all phosphorus and potassium applied during field preparation. Additional nitrogen was top-dressed at 20-25 days and 40 days after transplantation.

Data collection

The data were recorded on individual plants and plotted for nine quantitative traits at the appropriate growth stage of the crop as per Bioversity International et al. (2007). Five plants were randomly selected from each plot. Data was collected on plant height (PH), tiller number (TN), leaf number (LN), panicle per square meter (PASQM), panicle length (PLL), days to 50% flowering (DTF), days to 80% maturity (DTM), chlorophyll content (CC), and grain yield (YD). The final grain yield was adjusted at 12% moisture content, and calculated using the following formula on Equation (1).

$$\text{Grain yield } \left(\frac{\text{ton}}{\text{ha}}\right) = \frac{plot\ yield\ (kg) \times 1000(m^2) \times (100 - MC)}{(100 - Adjusted\ MC) \times Plot area\ in\ Sq.m} \quad (1)$$

Where, MC= Moisture content of grain (%) just before weighing the bulk

Y= Net plot yield (kg)

A= Net plot area (m^2)

(100-MC)/(100-Adjusted MC) = Conversion factor for grain yield at adjusted moisture content.

1000/A= Conversion factor for the actual harvested area into hectare basis.

This formula was also adopted by Paudel et al. (1995) to adjust the grain yield (ton ha^{-1}) at 12% moisture content.

Statistical analysis

The data were processed using the software MS-excel and analyzed through R-Studio. The MGIDI index theory is based on four key steps: (i) standardizing all traits to a range of 0 to 100, (ii) applying factor analysis to capture the correlation structure and reduce the data's dimensionality, (iii) designing an ideal genotype using known or desired trait values, and (iv) calculating the distance between each genotype and the designed ideotype (Olivoto and Nardino, 2021).

Rescaling the trait

Consider a two-way table with i rows representing genotypes and j columns representing traits. The rescaled value (X_{ij}) for the i^{th} row and j^{th} column was expressed as Equation (2).

$$X_{ij} = \frac{n_{nj} - \varphi_{nj}}{n_{oj} - \varphi_{oj}} \times (\theta_{ij} - \eta_{oj}) + \eta_{nj} \quad (2)$$

In this context, η_{nj} and φ_{nj} represent the new maximum and minimum values for trait j after rescaling. At the same time, η_{oj} and φ_{oj} are the original maximum and minimum values of trait j. The symbol θ_{ij} refers to the original value of the j^{th} trait for the i^{th} genotype or treatment. The values for η_{nj} and φ_{nj} are selected based on the desired direction of gains: if negative gains are preferred, η_{nj}=o and φ_{nj} =100 are applied; if positive gains are preferred, η_{nj} =100 and φ_{nj} = 0 are used instead. After rescaling, the values in the two-way table (X_{ij}) fall within a 0 – 100 range, considering the preferred direction of selection (whether to increase or decrease). This process also preserves the correlation structure of the original set of variables.

Factor analysis

The next step involved performing an exploratory factor analysis with (X_{ij}) to group the correlated traits into factors. Afterward, the factorial scores for each row, genotype, or treatment are calculated as Equation (3).

$$X = \mu + Lf + \epsilon \quad (3)$$

In this context, X represents a p×1 vector of rescaled observations, while μ represents a p ×1 vector of standardized means. L is p ×f of factor loadings, with f being a p ×1 vector of common factors. ϵ represents the p×1 vector of residuals, where p is the number of traits and f corresponds to the number of retained common factors. Eigen values and Eigen vectors are derived from the correlation matrix. The initial factor loadings are selected based on Eigen values more significant than one, and the final loadings are calculated using varimax rotation (Kaiser, 1958). Factor scores are then computed accordingly as per Equation (4).

$$F = Z\,(A^T R^{-1})^T \quad (4)$$

In this case, F is a g× f matrix containing the factor scores, and Z is a g×p matrix of (rescaled) standardized means. A refers to a p×f matrix of canonical loadings, while R represents the p×p correlation matrix between traits. Here, *g, p, and f* denote the

number of rows (genotypes or treatments), retained factors, and traits analyzed, respectively.

Ideotype planning

According to the definition in Equation (2), the ideotype was characterized by having the highest rescaled value (100) across all traits analyzed. Therefore, the ideotype can be represented by $1\times p$ vector I such that I = [100, 100, …, 100]. The scores for the ideotype were also calculated as per Equation (4).

The MGIDI index

The final step involved calculating the multi-trait genotype–ideotype distance index (MGIDI) as per Equation (5).

$$\text{MGIDI}_i = [\sum_{j=1}^{f} (\gamma_{ij} - \gamma_j)^2]^{0.5} \quad (5)$$

In this context, MGIDI_i represented the multi-trait genotype–ideotype distance index for the i^{th} row/genotype/treatment, while γ_{ij} denotes the score of the i^{th} row/genotype/treatment for the j^{th} factor (i=1, 2,…,g; j=1,2,…, f), where g and f are the total number of rows/genotypes/treatments and factors, respectively. γ_j represents the score of the ideotype for the j^{th} factor. The row/genotype/treatment with the smallest MGIDI value is closest to the ideotype and thus exhibits the most desirable values across all p traits. The proportion of the MGIDI index for the i^{th} row/genotype/treatment explained by the j^{th} factor (ω_{ij}) is calculated to highlight the strengths and weaknesses of each genotype/treatment as per Equation (6).

$$\omega_{ij} = \frac{\sqrt{D_{ij}^2}}{\sum_{j=1}^{f} \sqrt{D_{ij}^2}} \quad (6)$$

Here, D_{ij} represented the distance between the i^{th} genotype/treatment and the ideotype for the j^{th} factor. A lower contribution from a factor suggests that the traits associated with that factor are closer to the ideotype.

FAI-BLUP

The FAI-BLUP index (Rocha et al., 2018) was used to evaluate genotypes based on their proximity to a desired ideotype (DI). The DI was defined by assigning "min" values for traits where lower values are preferred and "max" values for traits where higher values are desired. The distance to the DI was calculated using the Euclidean distance formula for each genotype. These distances were then transformed into spatial probabilities by taking the inverse of the distance, with probabilities normalized to sum to 1. Genotypes were ranked based on their normalized spatial probabilities, with higher values indicating more excellent proximity to the ideal as demonstrated in Equation 7.

$$P_{ij} = \frac{\frac{1}{dij}}{\sum_{i=1;j=2}^{i=n;j=m} \frac{1}{dij}} \quad (7)$$

In this context, P_{ij} represents the likelihood of the i[th] genotype (where i=1, 2,……..,n) being similar to the j[th] ideotype (where j=1,2,……,m). The term d_{ij} refers to the distance between the i [th]genotype and the j[th] ideotype, calculated using the standardized mean Euclidean distance.

Genotype Selection in breeding Programs

The index was illustrated using a real dataset obtained from a trial involving 24 genotypes. Nine agronomic traits were evaluated. The selection of genotypes focused on identifying those with lower values (negative gains) for DTF, PH, and DTM, while aiming for higher values (positive gains) for YD, PLL, PASQM, CC, TN, and LN.

Each trait was analyzed using the gamem () function from the R package metan, which utilizes the mixed-effects model represented by Equation 8.

$$y = Xb + Zu + e \quad (8)$$

where y is an $n = [\sum_{j=1}^{r}(gr)] \times 1$ vector of response variable, i.e. the response of the i[th] genotype in the j[th] block (*i=1,2,.....,g; j=1,2,.....,r;* $y = [y_{11}, y_{12}, \ldots, y_{gr}]'$); b is an $1 \times r$ vector of unknown and unobservable fixed effects of block $b = [\gamma_1, \gamma_2, \ldots, \gamma_r]'$; u is an $m[= 1 \times g]$ vector of unknown and unobservable random effects of genotype $u = [\alpha_1, \alpha_2, \ldots, \alpha_g]'$; X is an n×r design matrix of 0s and 1s relating y to b; Z is an n×m design matrix of 0s and 1s relating y to u; and e is an *n ×1* vector of random errors $e = [y_{11}, y_{12}, \ldots, y_{gr}]'$;The variance components obtained from the analysis were utilized to calculate the broad-sense heritability (h^2) based on the mean of the genotypes, as shown below in Equation 9.

$$h^2 = \hat{\sigma}_{\alpha}^2/(\hat{\sigma}_{\alpha}^2 + \hat{\sigma}_{\epsilon}^2/r) \quad (9)$$

The predicted selection gain obtained with the index, SG (%), was computed for each trait considering a α % selection intensity was expressed in Equation 10.

$$SG(\%) = \frac{(\bar{X}_s - \bar{X}_o) \times h^2}{\bar{X}_o} \times 100 \quad (10)$$

Where $\bar{X}_s$ is the mean of the selected genotypes is, $\bar{X}_o$ is the mean of original population and h^2 is the heritability.

Results

Deviance analysis, variance components, and genetic parameters

The deviance analysis using the MGIDI and BLUP methods, with random effects of genotype and fixed effects of replication, revealed significant genotype effects across several agronomic traits (Table 2). Highly significant genotype effects ($p < 0.05$)

were observed for PH, DTF, and DTM, indicating robust genetic control over these traits. Moderately significant genotype effects ($p < 0.05$) were noted for LN, PASQM, and CC suggesting an intermediate genetic influence. In contrast, TN and YD did not show significant genotypic effects.

Broad-sense heritability (h^2) estimates varied across the traits, ranging from 0.03 for PLL to 0.96 for DTM. DTM exhibited high heritability ($h^2 = 0.96$) with an accuracy of 0.98, indicating strong genetic control and potential for selection gains. Similarly, PH also showed high heritability ($h^2 = 0.91$) with an accuracy of 0.96 after DTM. In contrast, TN and YD exhibited low broad-sense heritability values ($h^2 < 0.5$), suggesting a greater environmental influence on these traits.

The analysis of variance components further elucidated the contributions of genetic and environmental factors to trait variation, as presented in Table 3. PH and DTM showed substantial genotypic variances relative to residual variances, indicating predominant genetic control. In contrast, PLL and YD exhibited higher residual variances, underscoring their sensitivity to environmental factors.

Table 2. Deviance analysis and genetic parameters for agronomic traits evaluated in 24 rice genotypes.

Traits	h^2	Accuracy	C_Vg	CV_r	p-value
PH	0.91	0.96	10.2	4.59	6.92E-15
TN	0.2	0.45	6.5	18.5	3.77E-01
LN	0.55	0.74	11.8	15.2	3.09E-03
PASQM	0.44	0.71	5.47	7.88	1.05E-02
DTF	0.55	0.74	7.93	10.3	3.49E-03
DTM	0.96	0.98	5.7	1.81	5.85E-21
PLL	0.03	0.15	0.79	7.36	9.27E-01
CC	0.66	0.82	7.09	7.24	9.45E-05
YD	0.23	0.48	5.76	15.3	3.19E-01

Table 3. Estimated variance components.

Traits	Genotypic Variance	Residual Variance	Genotypic Variance (%)	Residual Variance (%)
PH	140	28.3	83.2	16.8
TN	0.43	3.42	11	89
LN	31.3	52.1	37.5	62.5
PASQM	185	385	32.5	67.5
DTF	42.6	72.3	37.1	62.9

Traits	Genotypic Variance	Residual Variance	Genotypic Variance (%)	Residual Variance (%)
DTM	40.4	4.07	90.8	9.16
CC	5.04	5.27	48.9	51.1
PLL	0.04	3.03	1.11	98.9
YD	0.06	0.36	12.5	87.5

Eigenvalues and Varimax Factor Loadings

The eigenvalue analysis and varimax factor loadings identified four principal components with eigenvalues greater than 1, collectively explaining 76.5% of the total trait variation (Table 4). Post-varimax rotation enhanced interpretability, with an average communality (h) of 0.76 across traits. Communalities ranged from 0.58 for PH to 0.85 for PLL, indicating that the factors captured a substantial portion of each trait's Variance. The nine traits analyzed were grouped into four factors (FA): FA1 (DTF, DTM), FA2 (YD, PASQM), FA3 (TN, LN), and FA4 (PLL, CC). FA1, encompassing DTF and DTM, accounted for the highest variation in the dataset, highlighting its significance in identifying genotypes suitable for further breeding.

Table 4. Eigenvalues, explained Variance, factorial loading after varimax rotation, and communalities

Traits	FA1	FA2	FA3	FA4
PH	-0.23	0.04	0.59	0.58
DTF	-0.92	-0.07	-0.13	0.18
DTM	-0.91	-0.05	-0.14	0.03
TN	0.14	-0.14	0.77	-0.23
LN	0.42	0.23	0.7	-0.09
PLL	-0.07	0.06	0.08	-0.85
PASQM	0.1	-0.89	-0.04	0.01
CC	0.36	0.05	0.29	-0.69
YD	0.25	0.81	-0.03	-0.07
Eigenvalues	2.93	1.46	1.41	1.09
Variances	32.5	16.2	15.6	12.2
Accumulated	32.5	48.7	64.3	76.5

Predicted selection gain

The selection gains (SG) comparison between the MGIDI and FAI-BLUP indexes indicated that both indexes effectively achieved desired gains across all evaluated

traits (Table 5). Specifically, the MGIDI index demonstrated an overall selection gain of 15.13% for traits targeted for improvement and -0.42% for traits requiring reduction. Among the traits, LN showed the highest selection gain with 6.41%, followed by chlorophyll content with 4.32% for MGIDI. For FAI-BLUP, the overall selection gain was 1.25% for traits targeted for improvement and -11.09% for traits requiring reduction. The highest selection gain for FAI-BLUP was observed for CC with 1.07%, followed by YD with 0.17%. These results underscore the efficacy of both indexes in enhancing breeding objectives and achieving balanced genetic improvements across multiple traits.

Table 5. Selection Gain Percentage of MGIDI and FBI-BLUP

Traits	Factor	Goal	Selection Gain (%)	
			MGIDI	FBI-BLUP
DTF	FA1	Decrease	1.43	-2.52
DTM	FA1	Decrease	2.1	-3.82
PASQM	FA2	Increase	-0.21	-1.74
YD	FA2	Increase	0.1	0.17
PH	FA3	Decrease	-0.21	-1.42
TN	FA3	Increase	0.76	-0.31
LN	FA3	Increase	6.41	-1.28
PLL	FA4	Increase	0.01	0.01
CC	FA4	Increase	4.32	1.07
Total (Increase)			15.13	1.25
Total (Decrease)			-0.42	-11.09

Selected genotypes by MGIDI index and BLUP

The genotypes selected by the MGIDI Index include SVIN 127, SVIN 098, SVIN 643, SVIN 084, and IR 18F1085 (Fig. *1*). Notably, three of these genotypes: SVIN 127, SVIN 098, and SVIN 643—are also selected by the FAI-BLUP index, indicating consistency in their selection criteria (Fig. *2*). SVIN 127 and SVIN 098 were found near the cutoff point in the MGIDI index, whereas Hardinath-4 was found near the cutoff point in the FBI-BLUP index, suggesting they possess potentially valuable traits that warrant further investigation. MGIDI and FAI-BLUP indexes demonstrate effectiveness in identifying superior genotypes, contributing to balanced trait selection and enhancing breeding efficiency.

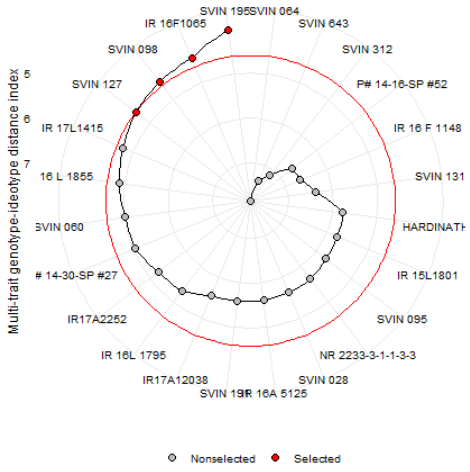


Fig. 1. Genotype ranking in ascending order for the MGIDI index. The selected genotypes are shown in red in the electronic version of the article. The circle represents the cut-point according to the selection pressure.

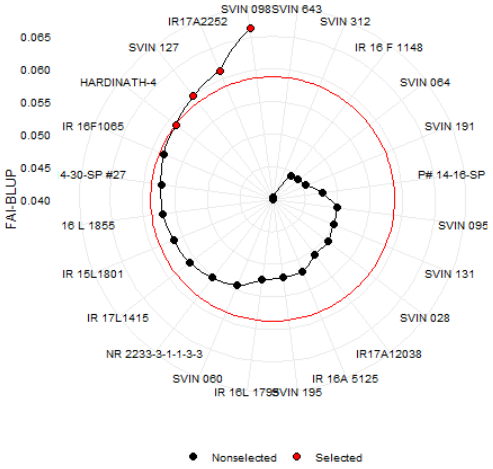


Fig. 2. Genotype ranking in ascending order for the FAI-BLUP. The selected genotypes are shown in red in the electronic version of the article. The circle represents the cut point according to the selection pressure.

MGIDI and FAI-BLUP Comparison

The comparison revealed that the MGIDI and FAI-BLUP achieved the desired gains across all evaluated traits. Specifically, the MGIDI index demonstrated a higher overall selection gain, with an improvement of 15.13% for traits targeted for

enhancement and a reduction of -0.42% for traits requiring minimization. In contrast, the FAI-BLUP index improved by 1.25% for traits seeking enhancement and a reduction of -11.09% for traits needing minimization. This suggests that both indexes effectively meet breeding objectives, with MGIDI showing a more pronounced impact on enhancing desirable traits, while FAI-BLUP offers substantial reductions in traits requiring minimization.

Strength and Weakness view

The radar plot visualizes the strengths and weaknesses of various rice genotypes based on four factors (FA1, FA2, FA3, and FA4) contributing to the MGIDI index (Fig. *3*). FA1 includes DTF, DTM, and YD. FA2 encompasses PASQM and PH. FA3 covers TN and LN. FA4 includes PLL and CC.

Genotype SVIN 191 exhibited strong overall performance across all traits, particularly excelling in FA1 traits such as DTF, DTM, and YD. In contrast, SVIN 064 showed weaknesses in most traits, demonstrating lower FA1, FA3, and FA4 performance. Genotype SVIN 312 performed well in FA2 traits like PASQM and PH, while IR 18L 1855 showed strengths in FA3 traits such as TN and LN. Additionally, IR 16A 5125 performed consistently well in FA1 and FA2 traits, indicating a balanced genetic potential. Conversely, SVIN 028 and IR 15L 1801 exhibited weak performance across all factors, with slight strengths in specific FA2 and FA4 traits. These insights underscore the utility of the MGIDI index in identifying genotypes with superior trait performances and facilitating targeted breeding strategies.

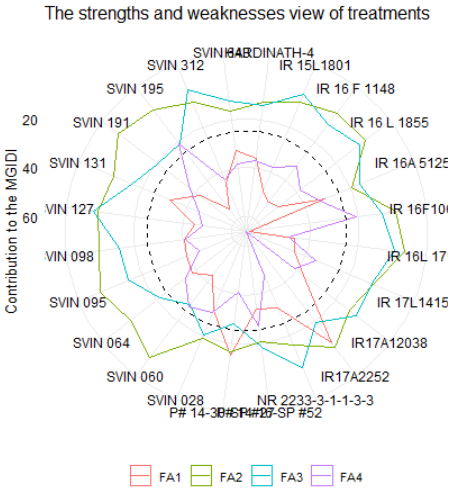


Fig. 3. The strengths and weaknesses of the selected genotypes are shown in the proportion of each factor on the computed multi-trait genotype–ideotype distance index (MGIDI). The most minor the proportion explained by a factor (closer to the external edge),

Discussion

Deviance analysis, Variance Components, and genetic parameters

The findings from Azevedo et al. (2023) aligned with existing research which also showed lower narrow sense heritability for GY and high narrow sense heritability for PH. Additionally, GY is a quantitative trait that is significantly influenced by environmental factors (dos Reis et al., 2015; Li et al., 2018; Zhang et al., 2022) . Higher residual variance was observed in PLL and YD, consistent with Akhouri (2022), which identified higher residual variance in these traits within environments 1 and 2.

The high heritability in PH and DTM indicated their potential for use in breeding programs focused on enhancing adaptation and productivity. Despite the DTM and DTF are usually strongly correlated, their heritability differences can arise due to factors like environmental interactions and specific genetic loci. DTF is often more environmentally sensitive than DTM because flowering initiation is affected by temperature, photoperiod, and other growth conditions (González et al., 2016; Shi et al., 2022). This aligned with the views of De Oliveira Neto et al. (2021), who emphasized the importance of genetic variability in selecting superior genotypes for better agricultural performance. On the other hand, the low heritability and non-significant genotypic effects observed in TN and GY suggest that environmental factors play a more dominant role, supporting studies that highlight the environmental sensitivity of traits such as TN and GY.

Research by Pallavi et al. (2024) and Al-Ashkar et al. (2023) highlighted the importance of genetic factors in trait variation, especially within the MGIDI framework, which focuses on capturing genetic diversity. Their studies stressed the essential role of genotype effects in fostering genetic diversity, supporting the broader goal of improving crop resilience and adaptability through genetic enhancement strategies.

Eigenvalues and Varimax Factor Loadings:

Eigenvalues indicated the amount of variance each factor explains, with FA1 explaining 32.5% of the total Variance, followed by FA2 (16.2%), FA3 (15.6%), and FA4 (12.2%). The cumulative Variance showed that the first two factors explained 48.7% of the variance, and all four factors together explained 76.5%. This highlighted that the factors represent different combinations of traits contributing to the variability in the dataset, with higher eigenvalues indicating more influential factors (Eze et al., 2021). Al Mamun et al. (2024) and Palaniyappan et al. (2024) also reported the factors with Eigen value greater than 1 representing the most variability.

FA1, indicating this factor favored early flowering and maturing genotypes. TN was positively associated with FA3, implying this factor was related to higher tiller numbers. LN showed positive associations with FA1, FA2, and especially FA3, indicating a relationship with increased leaf production. PLL was negatively

associated with FA4, suggesting this factor favors shorter panicle lengths. PASQM was strongly negatively associated with FA2, implying this factor favored genotypes with lower PASQM. The CC was positively associated with FA1 and FA3 but negatively with FA4, indicating factors FA1 and FA3 may favor higher chlorophyll content. YD was strongly positively associated with FA2, closely linking this factor to higher yields.

In the rice breeding program context, these factors guide genotype selection by highlighting key traits contributing to performance variability. Factors aligning with breeding objectives, such as increasing yield, can be prioritized in the selection process. Retaining principal components with eigenvalues exceeding 1, as suggested by Kaiser (1958) and supported by studies from Prasad et al. (2020), Pallavi et al. (2024), Bermudez and Pinheiro (2020) and Olivoto and Nardino (2021) demonstrates the robustness of factor analysis in distilling numerous traits into significant factors for breeding selection.

Predicted Selection Gain:

The observed selection gains validated the robustness of the MGIDI and FAI-BLUP indexes in breeding programs, with significant improvements across evaluated traits. The MGIDI index demonstrated superior performance, particularly in traits like LN and TN, achieving higher overall gains. MGIDI showed a total gain of 15.13% for traits targeted for increase, compared to 1.25% for FAI-BLUP. MGIDI achieved -0.42% for traits targeted for decrease, whereas FAI-BLUP achieved -11.09%. This indicated that MGIDI is slightly more effective, especially for traits needing significant improvement, aligning with the objectives of enhancing genetic diversity and crop adaptability for sustainable agriculture. Similar findings by Olivoto and Nardino (2021) and Al-Ashkar et al. (2023) also reported success of MGIDI in selecting traits with genetic gain.

MGIDI and FAI-BLUP Comparison:

The evaluation of MGIDI versus FAI-BLUP revealed that both indices are effective but with notable differences. MGIDI excelled with a 15.13% increase in traits targeted for enhancement and a minimal -0.42% reduction in traits that needed to be minimized, reflecting its robust performance in boosting desirable traits while maintaining others. Conversely, FAI-BLUP showed a smaller 1.25% gain in enhancement traits and a significant -11.09% reduction in traits requiring minimization. The MGIDI index's balanced approach to improving primary traits like grain yield without compromising secondary traits underscores its suitability for modern breeding programs, especially in light of the importance of stress-resilient traits discussed by Nelimor et al. (2020).

Strength and Weakness view:

This analysis provided valuable insights for breeders by highlighting the strengths and weaknesses of various rice genotypes using the MGIDI. Genotype SVIN 191's

robust performance across key traits, especially within FA1 (DTF, DTM, and YD), positioned it as a top candidate for breeding programs. Conversely, SVIN 064's underperformance across multiple factors, including FA1, FA3, and FA4, indicated areas that need improvement.

The favorable results of genotypes like IR 18L 1855, which exceled in FA3 traits (TN and LN), and IR 16A 5125, which showed balanced performance in FA1 and FA2 traits, underscored their potential to enhance rice production. While exhibiting weak overall performance, Genotypes SVIN 028 and IR 15L 1801 showed some strengths in specific FA2 and FA4 traits, suggesting targeted improvements might be beneficial.

In contrast, the weak performance of SVIN 051 and IR 17L 14 pointed to a need for significant enhancement or reconsideration for breeding use. The detailed evaluation of these strengths and weaknesses highlighted the potential of MGIDI as an effective tool for identifying and selecting genotypes with desirable traits, such as early seedling vigor and high grain yield. These insights were crucial for developing improved rice varieties and making strategic decisions in breeding programs, as emphasized by Pallavi et al. (2024).

Conclusion

This study evaluated genetic variability and heritability of key agronomic traits in rice genotypes using the MGIDI and FAI-BLUP methods. Significant genotype effects were identified for PH, DTF, and DTM, indicating their suitability for breeding programs focused on enhancing adaptability and productivity. High heritability estimates for these traits suggested robust genetic control, while lower heritability for YD and TN highlighted environmental influences. The analysis also demonstrated the MGIDI index superior performance in predicting selection gains, particularly for LN and TN, with selected genotypes like SVIN 191 showing strong potential. These findings underscored the importance of genetic diversity and strategic selection in rice breeding. Overall, the study supported the use of MGIDI as an effective tool for improving crop resilience and quality. Future research should focus on genotype- environment interactions and the application of multivariate techniques to further refine selection strategies.

Refrences

Alam, Z., Akter, S., Khan, M. A. H., Amin, M. N., Karim, M. R., Rahman, M. H. S., ... and Sarker, U. (2024). Multivariate analysis of yield and quality traits in sweet potato genotypes (Ipomoea batatas L.). *Scientia Horticulturae*, *328*, 112901. DOI: https://doi.org/10.1016/j.scienta.2024.112901

Palaniyappan, S., Arunachalam, P., Banumathy, S., and Muthuramu, S. (2024). Introspection of discriminate function analysis and MGIDI selection index for selection to improve yield in rice (*Oryza sativa* L.). *Indian journal of genetics and plant breeding*, *84*(02), 202-208. DOI: https://doi.org/10.31742/ISGPB.84.2.7

Al-Ashkar, I., Sallam, M., Almutairi, K. F., Shady, M., Ibrahim, A., and Alghamdi, S. S. (2023). Detection of high-performance wheat genotypes and genetic stability to determine complex interplay between genotypes and environments. *Agronomy*, *13*(2), 585. DOI: https://doi.org/10.3390/agronomy13020585

Akhouri, A. (2022). "Genetic Diversity and Stability Analysis for Heat Stress Tolerance in Wheat (*Triticum* Species)." Retrieved from: https://krishikosh.egranth.ac.in/server/api/core/bitstreams/c92c0da9-a94f-4f49-a029-650843973113/content

Azevedo, C. F., Barreto, C. A. V., Suela, M. M., Nascimento, M., Silva Júnior, A. C. D., Nascimento, A. C. C., ... and Soraes, P. C. (2022). Updating knowledge in estimating the genetics parameters: Multi-trait and Multi-Environment Bayesian analysis in rice. *Scientia Agricola*, *80*, e20220056. DOI: https://doi.org/10.1590/1678-992X-2022-0056

Carbajal-Friedrich, A. A., and Burgess, A. J. (2024). The role of the ideotype in future agricultural production. *Frontiers in Plant Physiology*, *2*, 1341617. DOI: https://doi.org/10.3389/fphgy.2024.1341617

Donald, C. T. (1968). The breeding of crop ideotypes. *Euphytica*, *17*, 385-403. DOI: https://doi.org/10.1007/BF00056241

Al Mamun, S. A., Ivy, N. A., Khan, M. A. I., Rehana, S., Sultana, M. S., Adhikary, S. K., and Islam, M. M. (2024). Genotype Selection from Azide- Induced Rice Mutants Using Multitrait Genotype–Ideotype Distance Index (MGIDI): Unveiling Promising Variants for Yield Improvement. *Advances in Agriculture*, *2024*(1), 5719580. DOI: https://doi.org/10.1155/2024/5719580

Bioversity International, International Rice Research Institute (IRRI), and The Africa Rice Center (WARDA). (2007). Descriptors for Wild and Cultivated Rice *(Oryza spp.)*. Bioversity International. 63p. https://hdl.handle.net/10568/72595

Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. *Psychometrika*, *23*(3), 187-200. DOI: https://doi.org/10.1007/BF02289233

Li, X., Wu, L., Geng, X., Xia, X., Wang, X., Xu, Z., and Xu, Q. (2018). Deciphering the environmental impacts on rice quality for different rice cultivated areas. Rice, 11, 1-10. DOI: https://doi.org/10.1186/s12284-018-0198-1

Olivoto, T., Diel, M. I., Schmidt, D., and Lúcio, A. D. (2022). MGIDI: a powerful tool to analyze plant multivariate data. *Plant Methods*, *18*(1), 121. DOI: https://doi.org/10.1186/s13007-022-00952-5

Olivoto, T., and Nardino, M. (2021). MGIDI: Toward an effective multivariate selection in biological experiments. *Bioinformatics*, *37*(10), 1383-1389. DOI: https://doi.org/10.1093/bioinformatics/btaa981

Shafizadeh-Moghadam, H. (2021). Fully component selection: An efficient combination of feature selection and principal component analysis to increase model performance. *Expert Systems with Applications*, *186*, 115678. DOI: https://doi.org/10.1016/j.eswa.2021.115678

Rocha, J. R. D. A. S. D. C., Machado, J. C., and Carneiro, P. C. S. (2018). Multitrait index based on factor analysis and ideotype- design: Proposal and application on elephant grass breeding for bioenergy. *Gcb Bioenergy*, *10*(1), 52-60. DOI: https://doi.org/10.1111/gcbb.12443

Sinha, P., Singh, V. K., Bohra, A., Kumar, A., Reif, J. C., and Varshney, R. K. (2021). Genomics and breeding innovations for enhancing genetic gain for climate resilience and nutrition traits. *Theoretical and Applied Genetics, 134*(6), 1829-1843. DOI: https://doi.org/10.1007/s00122-021-03847-6

Mohidem, N. A., Hashim, N., Shamsudin, R., and Che Man, H. (2022). Rice for food security: Revisiting its production, diversity, rice milling process and nutrient content. Agriculture, 12(6), 741. doi: https://doi.org/10.3390/agriculture12060741

Paudel, M. N. (1995). Nutrient management for Sulphan buri-90 rice variety in acid sulfate soil with green leaf manure. *Asian Institute of Technology, Bankok, Thailand*, 23-51.

Zhang, A., Pérez-Rodríguez, P., San Vicente, F., Palacios-Rojas, N., Dhliwayo, T., Liu, Y., ... and Zhang, X. (2022). Genomic prediction of the performance of hybrids and the combining abilities for line by tester trials in maize. *The Crop Journal*, *10*(1), 109-116. DOI: https://doi.org/10.1016/j.cj.2021.04.007

González, A. M., Yuste-Lisbona, F. J., Saburido, S., Bretones, S., De Ron, A. M., Lozano, R., and Santalla, M. (2016). Major contribution of flowering time and vegetative growth to plant production in common bean as deduced from a comparative genetic mapping. *Frontiers in plant science*, *7*, 1940. DOI: https://doi.org/10.3389/fpls.2016.01940

Shi, J., Wang, Y., Wang, C., Wang, L., Zeng, W., Han, G., ... and Li, P. (2022). Linkage mapping combined with GWAS revealed the genetic structural relationship and candidate genes of maize flowering time-related traits. *BMC Plant Biology*, *22*(1), 328. DOI: https://doi.org/10.1186/s12870-022-03711-9

De Oliveira Neto, S. S., Zeffa, D. M., Ebertz, O. F., Zoz, T., and Zanotto, M. D. (2021). Genetic variability, adaptability and, stability of safflower genotypes developed for the Brazilian conditions by REML/BLUP. *Agronomy Journal*, *113*(4), 3100-3109. DOI: https://doi.org/10.1002/agj2.20775

Pallavi, M., Prasad, B. M., Shanthi, P., Reddy, V. L. N., and Kumar, A. N. (2024). Multi trait genotype-ideotype distance index (MGIDI) for early seedling vigour and yield related traits to identify elite lines in rice (Oryza sativa L.). *Electronic Journal of Plant Breeding*, *15*(1), 120-131. DOI: 10.37992/2024.1501.020

Eze, N. M., Asogwa, O. C., and Eze, C. M. (2021). Principal component factor analysis of some development factors in Southern Nigeria and its extension to regression analysis. *Journal of Advances in Mathematics and Computer Science*, *36*(3), 132-160. DOI: https://doi.org/10.9734/jamcs/2021/v36i330351

Prasad, P., Savadi, S., Bhardwaj, S. C., and Gupta, P. K. (2020). The progress of leaf rust research in wheat. *Fungal biology*, *124*(6), 537-550. DOI: https://doi.org/10.1016/j.funbio.2020.02.013

Bermudez, F., and Pinheiro, J. B. (2020). Selection to high productivity and stink bugs resistance by multivariate data analyses in soybean. *Bragantia*, *79*, 250-259. DOI: https://doi.org/10.1590/1678-4499.20190380

Nelimor, C., Badu-Apraku, B., Garcia-Oliveira, A. L., Tetteh, A., Paterne, A., N'guetta, A. S. P., and Gedil, M. (2020). Genomic analysis of selected maize landraces from Sahel and Coastal West Africa reveals their variability and potential for genetic enhancement. *Genes*, *11*(9), 1054. DOI: https://doi.org/10.3390/genes11091054

SAARC J. Agric., 22(2): 257-273 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.77603*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Assessment of Food Safety Regulation and Assurance System in Bangladesh's Milk Value Chain: Addressing Discrepancies and Strategies for Improvement

S.M.R. Rahman[1*], M. Gallo[2] and J. Woodford[3]

[1]Livestock and Nutrition Expert, IRG-WB Group, Bangladesh; Former National Livestock and Dairy Expert, UNIDO. [2]Lead Senior Veterinary Inspector at UK Border Control Post, UK. [3]Gap analysis and Veterinary Legislation Expert, WOAH, France.

Abstract

This study assesses the food safety regulation and assurance systems in Bangladesh's milk value chain, identifying discrepancies and proposing strategies for improvement. Conducted in three phases, it begins with a comprehensive review of secondary sources and consultations with experts, leading to the development and validation of checklists based on international food safety standards such as the World Organization for Animal Health (WOAH), Codex Alimentarius Commission (CAC), Hazard Analysis and Critical Control Points (HACCP), Good Animal Husbandry Practices (GAHP), Good Hygiene Practices (GHP), and the Global GAP system. These standards were harmonized with national regulations, and data were collected using actor-specific checklists via a mobile application. The final phase involved field observations, stakeholder workshops, and expert panel discussions, using triangulation and Delphi techniques to validate findings and develop improvement strategies. The study reveals distinct challenges in both the formal and informal milk marketing sectors, with the informal sector often bypassing essential safety measures. Even within the formal sector, small and medium-scale operations struggle with maintaining adequate safety protocols. Specific concerns included the lack of registration and licensing, especially for cattle and buffalo farms, and the absence of certification for milk collectors. While chilling centers and sweetmeat shops showed moderate compliance with regulatory standards, significant gaps remain in biosecurity measures, waste management,

[*] Corresponding author: smrajiurrahman@yahoo.com

Received: 08. 11. 2024 *Accepted: 08. 12. 2024*

animal housing, and record-keeping. Challenges in animal health management, such as improper disposal of veterinary waste and inadequate isolation of sick animals, were prevalent. Concerns about poor hygienic practices during milking, insufficient cool chain facilities, and inconsistent use of quality control measures were also noted. Only a small proportion of chilling plants and sweetmeat shops followed proper labeling and traceability protocols, posing risks to consumer safety. To address these issues, the study recommends strengthening the regulatory framework, improving laboratory testing, and ensuring comprehensive record-keeping. A theory of change approach is proposed, focusing on capacity building, harmonizing regulations with international standards, and engaging stakeholders to improve food safety outcomes. The findings underscore the urgent need to address critical gaps in the food safety system in Bangladesh's dairy sector to safeguard public health and promote the sustainability of the industry.

Keywords: Milk Value Chain, Food Safety Regulations, Dairy Sector Compliance, Biosecurity, Hygiene, and Sustainability.

Introduction

The dairy sector in Bangladesh is primarily driven by small and marginal farmers, with few large-scale commercial farms. In recent years, this sector has transitioned from traditional, subsistence-oriented practices to a more market-driven, technology-based approach to meet rising consumer demands both domestically and internationally (Nahar et al., 2022; Rashid and Miah, 2017). Dairy farming predominantly involves cattle, though recent government initiatives have also spurred interest in buffalo as important milk producers. This shift highlights the growing significance of the dairy sector in Bangladesh's economy.

Economic Contribution

The livestock sector is crucial to Bangladesh's economy, with its contribution to agricultural GDP at 13.10% as of 2020-21. It employs around 20% of the population directly and another 50% indirectly. According to the Department of Livestock Services (DLS, 2022), Bangladesh has approximately 24.7 million cattle, 1.5 million buffalo, and 26.77 million goats. Of the 8.72 million milking cows, 53% are indigenous, while 47% are crossbred, primarily with Holstein Friesian, Sahiwal, and Sindhi breeds.

Technological Advancements

Bangladesh's dairy sector is advancing through smart dairy farming, integrating artificial intelligence, IoT, robotics, machine learning, and automation to meet the demands of the Fourth Industrial Revolution (Hassan et al., 2024; Mahbuba, 2024; Rahman, 2023ac). Leading mega-farms such as Masco Dairy Farm, Dutch Dairy Farm, and Eon Group have adopted these technologies to monitor animal health, feed intake, drug application, and breeding. This technological shift supports safe milk

production, satisfying local demand and potentially expanding to export markets. The government's Dairy Development Board Act, 2022, aims to foster policy development and sectoral growth.

Current Challenges

Despite technological progress, smallholder farmers still dominate the sector, comprising over 70% of dairy farmers and producing 70-80% of the country's milk. Bangladesh's current milk production of 13.07 million metric tons (MMT) falls short of the 15.67 MMT required, resulting in a 16% deficit (DLS, 2022). The complex milk value chain, involving procurement, transportation, processing, storage, and distribution, presents challenges in ensuring both quantity and quality.

Food Safety Issues

Food safety is a critical concern in Bangladesh, with around 26 million people suffering from foodborne illnesses each year, leading to a 2% GDP loss (Huda, 2023). Milk, a dietary staple, faces contamination risks from pathogens, chemical additives, and environmental pollutants throughout the value chain. Tests have revealed milk adulteration with substances like sodium carbonate and nitrates, alongside microbial contamination (Sultana et al., 2024). Unsafe milk products pose severe health risks, particularly for children. Therefore, adherence to international standards, such as WOAH, CAC, and HACCP, is essential for improving safety across the value chain (Rahman, 2023bc; Ruegg, 2003; Reneau et al., 1998).

Government and International Initiatives

Bangladesh's expanding economy has led to increased demand for high-value animal protein. The government, with World Bank support, has initiated the Livestock and Dairy Development Project (LDDP), focusing on sustainable production with quality and safety assurances. UNIDO's collaboration aims to enhance regulatory frameworks for food safety in animal-origin products.

Study Objectives

This study aims to identify gaps in food safety practices across the milk value chain, assess regulatory compliance, and suggest improvements. By addressing these objectives, the study will contribute to safer food practices, supporting consumer health and the growth of Bangladesh's dairy sector.

Methodology

The study was designed to evaluate food safety practices within the milk value chain in Bangladesh, employing a multi-phase methodology to achieve comprehensive and reliable findings. The research process was divided into three phases, each incorporating specific activities and methodological steps tailored to meet the study's objectives. Triangulation methods were utilized to ensure validity and credibility, drawing upon multiple datasets, research methods, theories, and investigators

(Rahman et al., 2018; Denzin, 1970; Lauri, 2011). Additionally, the Delphi technique was used to gather consensus from experts across multiple rounds of questioning, enhancing the accuracy and rigor of the conclusions (Sablatzky, 2022).

Phase I: Initial Planning and Preparation of Data Collection Tools

The first phase focused on creating a solid foundation for the study, starting with an extensive review of secondary sources. These included government censuses, project reports, relevant Acts and Rules, as well as international food safety standards like the World Organization of Animal Health (WOAH), Codex Alimentarius Commission (CAC), Hazard Analysis and Critical Control Points (HACCP), and Good Animal Husbandry Practices (GAHP). To enrich the understanding of the milk value chain, consultations with experts were held to create a value chain map. This mapping facilitated the development of actor-specific checklists for assessing food safety practices across various points in the value chain, including dairy cattle farmers, dairy buffalo farmers, chilling centers, milk collectors, and sweetmeat shops.

After refinement by experts, these checklists were digitized into the ODK/Kobo Toolbox mobile application, enabling efficient data collection. Study locations were selected based on dairy farming prevalence, covering subdistrict and District levels across six divisions. Sixteen enumerators from 16 subdistrict were trained to collect food safety information, providing valuable insights into the state of the milk value chain despite resource limitations. In each subdistrict, 5 respondents for each actor were randomly selected, in this way 20 respondents for four actors were considered and finally from the 16 subdistricts, 320 respondents were interview for the study.

Phase II: Data Collection and Management

During the second phase, 16 enumerators conducted data collection using the Kobo Toolbox application. Prior to field deployment, a debriefing session introduced them to the study's objectives, and a four-day field test was conducted to validate the checklists. After harmonizing field test feedback, final data collection was completed within 15 days across 16 subdistrict, focusing on each actor in the milk value chain. Data was centrally monitored and later exported to Excel for analysis, providing a quantitative basis for understanding food safety practices.

Phase III: Report Preparation

In the final phase, data analysis was followed by verification through field observations and a stakeholder workshop. Expert panel discussions and team meetings were conducted to validate food safety findings across the milk value chain. These discussions helped resolve discrepancies and enrich the data with qualitative insights gathered through focus group discussions (FGDs) on key topics like biosecurity, hygiene, traceability, disease control, and maintenance of the cool chain. The findings were presented in a workshop to identify food safety gaps, map the value chain, and discuss support mechanisms to mitigate hazards. Observations and insights from field visits were integrated into a draft report, finalized to represent a comprehensive overview of food safety practices within the milk value chain.

This methodologically rigorous study offers valuable insights into the challenges and gaps in food safety practices in Bangladesh's dairy industry and provides a framework for enhancing food safety standards across the value chain.

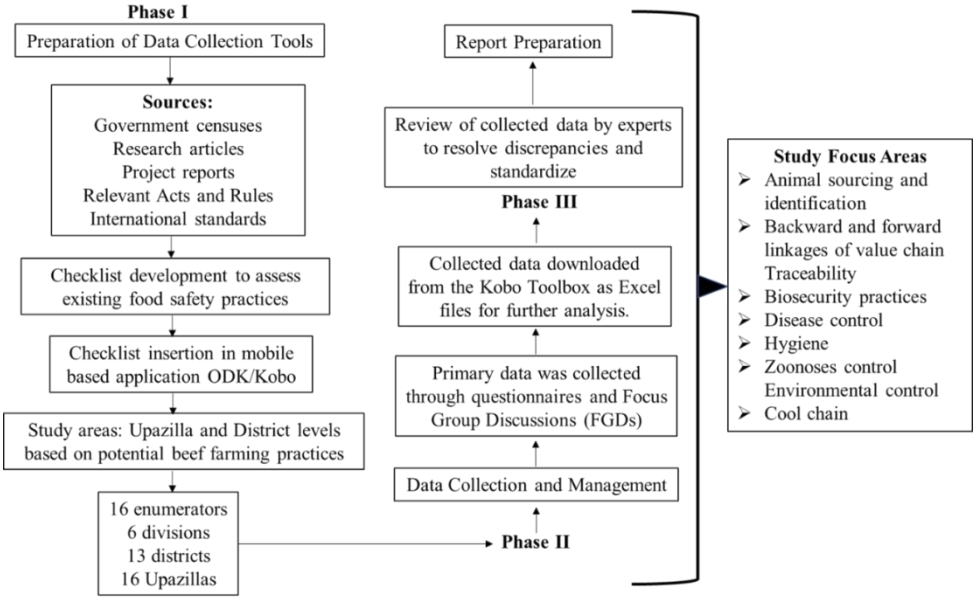


Fig. 1. Study methodology

Result and Discussion

Mapping of milk value chain in Bangladesh

The milk value chain in Bangladesh consists of two primary marketing channels: the formal and informal sectors. In the informal sector, milk is either sold raw or used in dairy products without significant processing. This sector primarily serves peri-urban and urban consumers, where raw milk is highly valued and rarely goes to chilling or pasteurization centers, instead being consumed directly or used by sweetmeat shops to produce dairy-based goods.

The formal sector, in contrast, processes milk and distributes it in Ultra-Heat Treated (UHT) or pasteurized forms, along with other value-added dairy products like butter, ghee, yogurt, and cheese. Major dairy companies, such as Milk Vita, Arong, Akiz, and Pran, manage processing facilities that utilize advanced cooling and transport technologies to ensure product safety and quality. According to observations by Sadek Agro, 57% of milk is used as drinking milk, while the remaining 43% is used for different value-added milk products. Under the brand name Shahi Mithai, 35% of the milk is utilized for manufacturing fermented milk (Labang), 25% for various sweetmeats, 20% for cheese, and 20% for ghee. American Dairy Limited (ADL) reports 80% of milk is used by sweetmeat shops for value-added products.

Shwapno's best-selling item is cheese, sourced from companies like Milk Vita, Arong, Akiz, and Pran, though food safety standards need improvement in small and medium-scale productions.

Dairy farms in Bangladesh vary significantly in size and practices, impacting food safety standards. Mega dairy farms (with over 100 cattle) make up 2% of the sector and follow advanced safety protocols with minimal food safety risk. Large farms (30-100 cattle), comprising 18% of the sector, also employ good practices but face medium safety risks. Medium farms (6-30 cattle), making up 45% of farms, exhibit some safety practices but are moderately risky, while small farms (1-5 cattle), which represent 35% of the sector, often lack proper food safety protocols, posing higher risks. These various farms follow distinct value chains based on farm size, with milk eventually reaching consumers via retailers, supermarkets, or direct delivery, indicating a diverse yet stratified value chain structure in Bangladesh.

Food safety practices in milk value chain

The study evaluated food safety practices across the dairy value chain, involving dairy farmers (cattle and buffalo), chilling centers, milk collectors (Goyala), sweetmeat shops, and feed processors. During a stakeholder meeting, discrepancies emerged, with 22% of dairy cattle farmers, 11% of buffalo farmers, 33% of milk collectors, 15% of chilling centers, 28% of sweetmeat shops, and 32% of feed processors disagreeing with initial data. Expert panel discussions resolved these differences, ensuring accuracy.

Registration and licensing

Registration and licensing are critical for food safety and quality in the dairy sector. Farm registration, particularly when integrated with traceability systems, enhances disease control and compliance with safety standards (Lin, 2021; Kumperščak, 2019). Although 24% of dairy cattle farms are registered, no registration has started for buffalo farms, revealing gaps in regulatory oversight. Milk collectors ("Goyalas") also lack certification, posing potential health risks. However, milk chilling plants and sweetmeat shops show strong compliance—87% of chilling plants and 80% of sweetmeat shops meet licensing and safety requirements. Chilling plants follow standards by holding various licenses (sanitary, environmental, industry, fire safety, trade, and BSTI certificates), while sweetmeat shops meet standards through trade licenses, sanitary certificates, and BSTI packaging compliance.

The livestock feed sector also demonstrates significant compliance. Feed companies, regulated by District Livestock Officers of DLS, must obtain trade licenses and adhere to global food safety practices, including Hazard Analysis Critical Control Point (HACCP) systems, hygiene, supplier verification, and recall plans, ensuring food safety and traceability (Nyokabi et al., 2023). This regulatory adherence across the dairy value chain underscores the importance of certification and oversight in protecting public health.

Animal Housing

Animal housing is essential for ensuring animal welfare and food safety by supporting health, productivity, and well-being. Manteca et al. (2021) found that enriched environments reducing stress-related pathogens positively impact food safety. While commercial dairy farms generally meet standards for ventilation and flooring, family-run farms face challenges. Although 76% of these farms provide sufficient space for cattle movement, only 72% have brick floors, and 4% still use muddy floors, notably in extensive systems like the Shajadpur dairy hub. Inadequate ventilation and flooring affect both animal health and milk safety. Buffalo farms face greater challenges in meeting these housing standards, impacting animal welfare and the safety of dairy products. Fraser (2008) emphasizes that appropriate housing conditions, including space, flooring, and ventilation, are vital for animal health, which directly influences dairy quality and safety, underscoring the need for standard adherence in sustainable dairy farming.

Biosecurity and Hygienic Measures

Biosecurity and hygiene measures are critical for preventing disease outbreaks in livestock farms, protecting food safety (Goldstein et al., 2021). Despite the importance, many farms lack essential biosecurity practices like foot baths and fenced entries, increasing disease risks (Wong and Chang, 2017). Only 64% of farmers isolate sick animals, and 70% lack proper storage for medicines, which compromises the efficacy of treatments. Proper isolation and storage facilities are crucial for effective disease management. Improper disposal of syringes, with only 20% burned safely, poses environmental and public health risks. Regarding hygiene, 80% of milk collectors follow good practices by feeding cattle post-milking, reducing microbial risks (Feyisa et al., 2024; Deddefo et al., 2023). However, only 30% of farmers and 50% of collectors adhere to hygiene protocols, including washing udders and utensils before milking, posing contamination risks (Barkema et al., 1999). Disposal of spoiled milk is also a concern, with 80% of collectors discarding it improperly. At chilling plants, 46% use safe water, while 85% of sweetmeat shops use disinfectants for cleaning, and 75% ensure safe water use. However, only 30% of workers wear protective clothing, indicating a need for improved hygiene practices across the industry.

Inspection and Record Keeping

Effective record-keeping is crucial for tracking animal health, feed usage, and farm management practices, but current standards among dairy cattle and buffalo farmers are inadequate. For dairy cattle farms, while 32% keep farm animal records, 36% document treatments/vaccinations, and 56% record feed purchases, there is a notable lack of laboratory testing records for feed contaminants, such as chemicals or pesticides. Buffalo farms show even poorer record-keeping, with only animal counts documented, 6.67% of treatments recorded, and 13.33% of feed purchases tracked, and similarly, no records of feed laboratory testing are available. These

documentation gaps undermine food safety and traceability, risking contaminated feed entering the food chain undetected (Balaine et al., 2020; Sudarshan et al., 2017). Although 40% of chilling centers receive regular inspections, no official inspection records or observation letters are issued, with inspectors providing only oral advice. This lack of formal documentation and the limited record-keeping (13% of plants) for safety tests present significant challenges to maintaining consistent standards and water quality in dairy production.

Cool Chain Facilities

Maintaining a robust cool chain is vital for milk safety; however, only 10% of milk collectors (Goyala) have access to cooling facilities, which significantly increases spoilage risks during transportation, typically lasting 2.4 ± 1.42 hours (Sharma et al., 2012; Gran et al., 2002). Additionally, while 45% of sweet meat entrepreneurs employ cool vans, ensuring milk quality during transport, only 64% of sweet meat shops utilize refrigeration for storage. The remainder relies on glass enclosures, raising potential spoilage and health concerns (Desessa et al., 2020; Omore et al., 2005). Expanding access to cooling facilities and improving storage practices are essential to enhance dairy safety and reduce public health risks.

Animal health management

Effective disease management is critical for food safety in the milk value chain. Practices among dairy farmers show considerable variation, with 32% of dairy cattle farmers isolating sick animals, 6% selling them, 19% consulting registered veterinarians, and 43% relying on local health workers. In contrast, only 13% of dairy buffalo farmers isolate sick animals, 28% sell them, 37% consult veterinarians, and 22% rely on local health workers. The sale of sick animals poses a major risk to public health by potentially introducing diseases into the food supply (Spigarelli et al., 2021). Furthermore, inadequate isolation—68% in cattle and 87% in buffalo—heightens the risk of disease spread on farms, affecting both animal welfare and food safety.

Additionally, 36% of dairy cattle farmers are advised to avoid selling milk after administering certain drugs, observing withdrawal periods and avoiding steroid-treated milk, while only 13% of buffalo farmers receive similar guidance. This gap in milk safety advice, with lower adherence among buffalo farmers, raises concerns given buffalo milk's popularity and the potential health risks of drug residues. This disparity underscores a need for better veterinary support and education on disease management, as milk safety practices remain limited in Kenya, aligning with other studies (Feyisa et al., 2024)

Environmental Management

Proper manure management is essential to prevent contamination of animal housing and feed storage areas. Despite this, many farmers fail to keep manure well-

separated, with only 24% of dairy cattle and 33% of buffalo manure heaped away from clean areas. This increases the risk of contamination and associated food safety issues. Less than half of chilling centers have adequate waste disposal systems, and improper disposal leads to some waste being discarded in common water bodies (7%), posing significant environmental and public health risks. Spoiled milk and milk products are often disposed of in drains (55%), ponds (27%), or buried (15%), with 3% returned to farmers. Effective disposal methods at farms and chilling and processing plants are crucial for preventing environmental contamination and protecting public health. Studies by Jiang et al. (2014), Fan et al. (2017), and Ehmann et al. (2017) emphasize the environmental risks of poor manure management, supporting the need for improvements in these practices.

Laboratory Facility and Testing

To ensure the safety and quality of water, animal feed, milk, and milk products, laboratory testing for contaminants is critical, especially given the public health risks from contaminated water and feed (Todd, 2020). Routine testing for chemicals, pesticides, and contaminants in feed is essential to uphold food safety standards. Hashem et al. (2022) found low but detectable levels of heavy metals (e.g., Pb, Cr, Cd, Zn, Cu) in Bangladesh's livestock feed, underscoring the need for continuous monitoring despite concentrations being below maximum residue levels (MRLs). Milk adulteration remains a serious concern, with reports indicating frequent additions of water, detergent, urea, and other substances, which can lead to health issues like renal failure and vomiting (The Dhaka Tribune, 2023). While chilling plants have on-site testing labs for milk quality assurance, the absence of rapid testing at collection points poses food safety risks, as contaminated milk could enter the supply chain undetected.

Support and Subsidies

The discussion on improving compliance with food safety practices centers around the need for government subsidies to support farmers in the responsible use of antibiotics and veterinary drugs during animal illness. Ensuring that withdrawal periods are observed is critical, as it helps prevent harmful residues from entering the food chain. This aligns with the studies of Haque et al. (2018) and Shashikumar et al. (2018), which highlight a widespread lack of farmer awareness regarding the consequences of improper drug use. These studies emphasize the need for both education and financial support to ensure food safety compliance. Islam et al. (2020) further explore this issue by examining the awareness levels among dairy farmers in Bangladesh, specifically regarding the proper use of antibiotics and the significance of withdrawal periods. Their findings suggest that financial incentives, such as government subsidies, could play a pivotal role in improving compliance with food safety standards and minimizing antibiotic residues in dairy products.

Quality Control and Traceability

In the milk and dairy sector, food labeling is essential for safety, traceability, and consumer transparency. Proper labeling, with unique identifiers like chemical composition, manufacturer details, and expiration dates, is crucial for preventing foodborne illnesses. Only 15% of chilling plants currently meet adequate labeling standards, highlighting gaps in compliance. Bai et al. (2023) emphasize that traceability in cold chain systems reduces safety risks and minimizes product loss, aligning with U.S. FDA (2023) and Grace (2015) regulations mandating food product labeling.

A study of sweet meat shops revealed that only 20% fully comply with labeling standards, while 55% show partial compliance and 25% lack adherence, posing risks to consumer health. In addition, 80% of these shops source raw milk from village markets, with only 5% holding farm contracts, complicating traceability. Despite 90% maintaining dedicated dairy production spaces, milk testing practices vary: while 75% of large shops test each batch, only 20% retain proper records.

Milk allergens, such as casein and whey proteins, present serious risks, underscored by studies highlighting the need for accurate allergen labeling and monitoring (Chavan et al., 2024). Cross-contamination risks emphasize the importance of worker training; Zavala and Revoredo (2022) report that 60% of milk processing workers lack such training, which is critical for consistent food safety standards, as Ruegg (2003) notes. In the EU, Regulation (EU) No. 1169/2011 sets comprehensive labeling requirements, underscoring harmonized protocols as essential for safety and traceability (European Union,2011).

Food Safety Regulatory Framework of the Milk Value Chain

The food safety regulatory framework for the milk value chain in Bangladesh is comprehensive but fragmented, with challenges in uniform implementation. Key legislation, such as the Food Safety Act of 2013, and oversight by the Bangladesh Food Safety Authority (BFSA) set essential standards. However, compliance is better under the Department of Livestock Services (DLS) for the Fish Feed and Animal Feed Act (2010) and Animal Feed Rules (2013), though enforcement at the farm level remains inadequate, especially among smaller milk producers facing financial and technical challenges (Bashar, 2017; Haque et al., 2022). Similar issues are seen in India and Kenya, where informal sectors and infrastructure gaps, such as inadequate cold chain systems, compromise milk safety (Kumar et al., 2020; Muriuki, 2019). In Kenya, up to 80% of milk is supplied through informal markets, often bypassing formal regulatory frameworks (Muriuki, 2019; Omore et al., 2021). Bangladesh's initiatives, like UNIDO's gap assessment, show promise but face coordination challenges among stakeholders. Haque et al. (2022) note poor communication between operators, regulators, and support organizations, hindering effective safety protocol implementation. The Dairy Development Board Act of 2022 aims to address these challenges, with sustained collaboration and training needed to improve milk quality, safety, and competitiveness in the industry (Chowdhury, 2017; Rahman et al., 2023c).

Strategies for Improvement

i. Strengthening Regulatory Frameworks

- Update and Enforce Food Safety Laws: Modernize food safety regulations specific to the dairy industry, ensuring enforcement of standards for milk quality, hygiene, and residue limits.
- Establish Clear Guidelines: Develop actionable guidelines covering all aspects of food safety from producers to retailers.

ii. Capacity Building and Training

- Training for Dairy Farmers: Regular training on animal husbandry, milking hygiene, and proper use of veterinary drugs to minimize contamination risks.
- Skill Development for Handlers: Train handlers, processors, and distributors on hygienic practices in handling, transportation, and storage.

iii. Infrastructure Development

- Improve Milking and Storage Facilities: Invest in quality milking equipment and storage facilities to reduce contamination risks.
- Enhance Cold Chain Management: Strengthen cold chain infrastructure for consistent milk quality from farm to consumer.

iv. Monitoring and Surveillance

- Implement Routine Testing: Regular milk testing for contaminants at multiple points along the value chain.
- Strengthen Traceability Systems: Implement systems for tracking milk from farm to consumer for rapid issue resolution.

v. Public Awareness and Consumer Education

- Consumer Education Campaigns: Launch awareness campaigns on the importance of chill milk benefit and safe milk handling.
- Promote Safe Consumption Practices: Educate consumers on safe storage practices at home.

vi. Collaboration and Stakeholder Engagement

- Multi-stakeholder Partnerships: Foster collaboration among government agencies, cooperatives, private sector, and NGOs for a unified approach.
- Engage with Dairy Cooperatives: Work with cooperatives to monitor food safety at the grassroots level.

vii. Research and Innovation

- Invest in Research: Support initiatives to identify risks and develop innovative solutions for food safety.
- Adopt New Technologies: Encourage the use of rapid testing kits and blockchain for traceability.

viii. Economic Incentives and Support

- Provide Incentives for Compliance: Offer financial incentives for farmers and processors complying with standards.
- Support Smallholders: Targeted support for smallholders to upgrade practices and facilities.

ix. Policy and Advocacy

- Advocate for Policy Support: Work with policymakers to prioritize food safety within national agendas.
- Develop Risk-based Approaches: Advocate for risk-based regulation focusing on high-risk areas.

x. Continuous Improvement

- Regular Review and Update of Practices: Continuously monitor and adapt food safety practices.
- Feedback Loops: Establish feedback mechanisms for continuous learning and improvement.

Theory of Change

Enhancing the food safety regulatory framework for the milk value chain in Bangladesh, a theory of change approach focuses on strengthening institutional capacity, improving regulatory standards, and fostering stakeholder collaboration. The theory posits that by first investing in training and resources for regulatory bodies and local dairy producers, the government can ensure more rigorous enforcement of safety standards. Next, updating and harmonizing regulations with international best practices will address gaps and inconsistencies in the current framework. Engaging with stakeholders, including dairy farmers, processors, and consumers, through awareness campaigns and feedback mechanisms will promote adherence to safety protocols and encourage transparency. Ultimately, these combined efforts will lead to a more robust food safety system, reducing contamination risks and improving public health outcomes across the milk value chain. Last but not least, several assumptions underlie this theory of change and need to be considered in implementing our change strategy (Ruth 2015).

Conclusion

In conclusion, the assessment of food safety regulation and assurance systems in Bangladesh's milk value chain reveals critical discrepancies that need to be addressed through a comprehensive and coordinated approach. A thorough gap analysis of existing policies, infrastructure, and practices is essential to improving dairy farm management, ensuring proper animal health care, and enhancing milking hygiene. Strengthening regulatory frameworks, fostering collaboration between government

agencies, private stakeholders, and international organizations, and investing in infrastructure such as cold chain facilities and testing laboratories are vital for preserving milk quality. Additionally, promoting technology adoption for traceability and raising consumer awareness on food safety can further bolster efforts to ensure safer dairy products and increase the competitiveness of Bangladesh's dairy industry in the global market.

Acknowledge

The researchers extend their sincere gratitude to the United Nations Industrial Development Organization (UNIDO) and the World Bank-funded "Livestock and Dairy Development Project" for their invaluable support and collaboration during the implementation of the UNIDO/LDDP Food Safety Package 74. The information gathered through this collaboration was instrumental in developing the manuscript titled "Assessment of Food Safety Regulation and Assurance System in Bangladesh's Milk Value Chain: Addressing Discrepancies and Strategies for Improvement." Additionally, we acknowledge the IRG-WB Group Cool Chain Project, "Clean and Energy Efficient Cooling for Livestock Supply Chains in Bangladesh" (Contract No: 7210554), funded by the World Bank Group, for providing critical insights that significantly contributed to our research. We are deeply appreciative of all individuals and organizations involved for their unwavering support and valuable contributions to this study.

References

Bai, L., Liu, M., and Sun, Y. (2023). Overview of food preservation and traceability technology in the smart cold chain system. *Foods*, 12(15). https://doi.org/10.3390/foods12152881

Balaine, L.S., Singh, M.K., and Sharma, K.S. (2020). Review of on-farm recording tools for smallholder dairy farming in developing countries. *Tropical Animal Health and Production*, 52, 1120–1127. https://doi.org/10.1007/s11250-020-02200-1

Barkema, H.W., Vand der Ploeg, J.D., Schukken, Y.H., Lam, T.J.G.M., Benedictus, G., and Brand, A. (1999). Management style and its association with bulk milk somatic cell count and incidence rate of clinical mastitis. *Journal of Dairy Science*, 82, 1655–1663.

Bashar, A.I. (2017). Food safety laws of Bangladesh: A critical evaluation. *South Asian Legal Studies*, October 20, 2017. Retrieved from https://sclsbd.org/food-safety-laws-bangladesh-critical-evaluation/

Chavan, Y., Paul, K., and Kolekar, N. (2024). Food safety and hygiene: Current policies, quality standards, and scope of artificial intelligence. In Chakraborty, R., Mathur, P., and Roy, S. (Eds.), *Food production, diversity, and safety under climate change* (pp. 341-360). Springer. https://doi.org/10.1007/978-3-031-51647-4_26

Chowdhury, A.R. (2017). *Food safety in Bangladesh* (LL.M. thesis, Premier University, Chittagong, Bangladesh).

Deddefo, A., Mamo, G., Asfaw, M., Amenu K. (2023). Factors affecting the microbiological quality and contamination of farm bulk milk by *Staphylococcus aureus* in dairy farms in Asella, Ethiopia. *BMC Microbiology*, 23, 65. https://doi.org/10.1186/s12866-022-02746-0

Denzin, N. (1970). *Sociological Methods: A Sourcebook*. New Brunswick: Transaction Publishers.

Desessa, D. K., Alemu, G. G., and Alemayehu, R. (2020). Influence of transportation time and temperature on the quality of raw milk collected from smallholder dairy farms in Ethiopia. *International Journal of Food Science*, 2020. https://doi.org/10.1155/2020/8896459

DLS (2022) Department of Livestock Services, *Annual Report*, Division of Livestock Statistics. Ministry of Fisheries and Agriculture, Farmgate, Dhaka, Bangladesh.

Ehmann, A., Bach, I.-M., Laopeamthong, S., Bilbao, J., and Lewandowski, I. (2017). Can phosphate salts recovered from manure replace conventional phosphate fertilizer? *Agriculture*, 7(1), 1. https://doi.org/10.3390/agriculture7010001

European Union. (2011). Regulation (EU) No 1169/2011 on the provision of food information to consumers. *Official Journal of the European Union*.

Fan, J., Xiao, J., Liu, D., Ye, G., Luo, J., Houlbrooke, D., Laurenson, S., Yan, J., Chen, L., Tian, J., and Ding, W. (2017). Effect of application of dairy manure, effluent, and inorganic fertilizer on nitrogen leaching in clayey fluvo-aquic soil: A lysimeter study. *Science of the Total Environment*, 592, 206–214. https://doi.org/10.1016/j.scitotenv.2017.03.060

Feyisa, B. W., Haji, J., and Mirzabaev, A. (2024). Adoption of milk safety practices: Evidence from dairy farmers in Ethiopia. *Agriculture and Food Security*, 13, 25. https://doi.org/10.1186/s40066-024-00479-z

Fraser, D. (2008). Understanding animal welfare. *Acta Veterinaria Scandinavica*, 50(Suppl 1), S1. https://doi.org/10.1186/1751-0147-50-S1-S1

Goldstein, M. R., Yates, S. A., and Pendergrast, J. (2021). Biosecurity practices for cattle farms to prevent disease spread. *Journal of Veterinary Preventive Medicine*, 45(1), 28–35.

Gran, H. M., Mutukumira, A. N., Wetlesen, A., and Narvhus, J. A. (2002). Smallholder dairy processing in Zimbabwe: Hygienic practices during milking and the microbiological quality of the milk at the farm and on delivery. *Food Control*, 13(1), 41-47. https://doi.org/10.1016/S0956-7135(01)00086-5

Grace, D. (2015). Food safety in developing countries: Research gaps and opportunities. *Journal of Food Control*, 57, 84-91. https://doi.org/10.1016/j.foodcont.2015.03.015

Haque, M. A., Godefroy, S., and Barry, M. (2022). *Food Safety Regulatory Landscape Study and Investment Plan*. United Nations for Industrial Development Organization (UNIDO). Report submitted to Livestock and Dairy Development Project, Department of Livestock Services. Retrieved from https://lddp.portal.gov.bd/sites/default/files/files/lddp.portal.gov.bd/download/7c04dae8_882c_4f61_8793_a6e375d006d1/2024-03-31-08-45-a13a19a9504c2e41e3144d5a1c16143f.pdf

Haque, M. F., Rahman, M., and Amin, M. R. (2018). Antibiotic residues in milk and their impact on public health in Bangladesh. *Bangladesh Journal of Animal Science*, 47(1), 41-45. https://doi.org/10.3329/bjas.v47i1.39570

Hashem, M. A., Kamal, M., Al-Mamun, M., Hossain, M., and Razzaque, M. (2022). Assessment of heavy metals in feed and beef in Bangladesh: A safety issue. *Meat Research*, 2(1). https://doi.org/10.55002/mr.2.1.10

Hassan, M. M. R., Pehan, E. A., Sultana, S., Hosen, A., Afsana, A. S., and Sultana, N. (2024). IoT-based dairy farming for smart monitoring and heat stress mitigation. In *Souvenir: World Milk Day 2024* (pp. 33-38). Department of Dairy Science, Bangladesh Agricultural University.

Huda, M. M. (2023). Adulterated-food culture in Bangladesh: A new form of epidemic. *The Dhaka Tribune*. Published on June 8, 2023. Retrieved from https://www.dhakatribune.com/bangladesh/284997/adulterated-food-culture-in-bangladesh-a-new-form

Islam, M. A., Shamsuddin, M., and Alam, M. M. (2020). Awareness of antibiotic usage and its withdrawal period in dairy farms in Bangladesh. *Journal of Advanced Veterinary and Animal Research*, 7(3), 512-517. https://doi.org/10.5455/javar.2020.g454

Jiang, X., Chen, Z., and Dharmasena, M. (2014). The role of animal manure in the contamination of fresh food. In *Advances in microbial food safety* (Vol. 2, pp. 312-350). ISBN 1782421157, 9781782421153.

Kumar, A., Roy, D., and Joshi, P. K. (2020). Regulatory and institutional frameworks for milk safety in India. *Indian Journal of Dairy Science*, 73(1), 34-42.

Kumperščak, S., Medved, M., Terglav, M., Wrzalik, A., and Obrecht, M. (2019). Traceability systems and technologies for better food supply chain management. *Quality Production Improvement QPI*, 1(1). https://doi.org/10.2478/cqpi-2019-0076

Lauri, M. A. (2011). Triangulation of data analysis techniques. *Papers on Social Representations*, 20, 34.1-34.15. © 2011 The Authors. ISSN 1021-5573. Retrieved from http://www.psych.lse.ac.uk/psr/

Lin, J. (2021). Agricultural product quality and safety supervision mechanism based on information traceability system. In: Chang, J. W., Yen, N., and Hung, J. C. (Eds.), *Frontier Computing. FC 2020* (Lecture Notes in Electrical Engineering, vol. 747). Springer, Singapore. https://doi.org/10.1007/978-981-16-0115-6_66

Mahbuba, T. (2024). Revolutionizing the dairy industry: Exploring the impact of 4IR. In *Souvenir: World Milk Day 2024* (p. 57). Department of Dairy Science, Bangladesh Agricultural University.

Manteca, X., Velarde, A., and Jones, B. (2021). Animal Welfare Components. In *Welfare of Production Animals: Assessment and Management of Risks* (pp. 61-77). Wageningen Academic Publishers. https://doi.org/10.3920/9789086866908_005

Muriuki, H. G. (2019). *Dairy Development in Kenya: The Past, Present, and Future*. Food and Agriculture Organization of the United Nations (FAO). FAO Dairy Reports, Pages 1-64.

Nyokabi, N.S., Phelan, L., Gemechu, G., Stefan B., Johanna F. L., Adane M., James L. N. W., and Henrietta L. M. (2023). From farm to table: exploring food handling and hygiene practices of meat and milk value chain actors in Ethiopia. *BMC Public Health* **23**, 899 . https://doi.org/10.1186/s12889-023-15824-3

Nahar, A., Mila, F. A., Culas, R. J., and Amin, M. R. (2022). Assessing the factors and constraints for value chain development of dairy food products in Bangladesh. *Heliyon, 8*(10), e10787. https://doi.org/10.1016/j.heliyon.2022.e10787

Omore, A., Lore, T., and Staal, S. (2021). The Role of Informal Milk Markets in Milk Safety in Kenya. *International Livestock Research Institute (ILRI)*. Dairy Value Chain Series, Pages 10-25.

Omore, A., Lore, T., Staal, S., Kutwa, J., Ouma, R., Arimi, S., and Kang'ethe, E. (2005). Addressing the public health and quality concerns towards marketed milk in Kenya. *Smallholder Dairy Project Research, Research Report 3*. https://doi.org/10.22004/ag.econ.12654

Rahman SMR and Hossain MM (2023a) Establishments mapped, survey designed, gap assessment conducted and upgrading plan developed for milk and meat value chain, *Project Report*, submitted to Livestock and Dairy Development Project (LDDP), Department of Livestock Services (DLS), United Nations Industrial Development Organization (UNIDO), October 2023.

Rahman, S. M. R. (2023b). Actor-based surveys and data collection, a report submitted to LDDP, DLS. *Project Report, Deliverable 1.1.5*. United Nations Industrial Development Organization (UNIDO), October 2023. https://lddp.portal.gov.bd/sites/default/files/files/lddp.portal.gov.bd/download/7c04dae8_882c_4f61_8793_a6e375d006d1/2024-03-31-08-35-98152ff68c28e24299a5166c2b7a85e0.pdf.

Rahman, S. M. R. (2023c). Legal framework for food safety of animal origin food in Bangladesh. *Souvenir, Livestock Service Week 2023*, Department of Livestock Service.https://www.researchgate.net/publication/369067194_Legal_framework_for_Food_safety_of_animal_origin_food_in_Bangladesh

Rahman, S. M. R., Islam, M. N., Rashid, M. H., Siddiki, M. S. R., and Islam, M. A. (2018). Dairy buffalo production system under semi-intensive management in the coastal area of Bangladesh. *SAARC Journal of Agriculture, 16*(2), 43-59. https://doi.org/10.3329/sja.v16i2.40257

Rashid, M. H., and Miah, M. A. (2017). Transformation of dairy sector in Bangladesh: Innovations and practices. *Asian Journal of Dairy and Food Research, 36*(4), 293-299. https://doi.org/10.18805/ajdfr.v36i04.7932

Reneau, J. K., Marsh, W. E., Craven, R. H., Coleman, W. W., Richardson, D. W., Friertag, J., Stoll, W., and Bartholomew, D. (1998). DairyTQM: A tool for use in on-farm dairy HACCP programs. In *Proc. Natl. Mast. Counc.* (pp. 236–237). Natl. Mast. Counc., St. Louis, MO.

Ruegg, P. L. (2003). Practical food safety interventions for dairy production. *Journal of Dairy Science, 86*(Suppl. E1-E9). https://doi.org/10.3168/jds.S0022-0302(03)74034-X

Ruth, J. S. (2015). A theory of change for capacity building for the use of research evidence by decision makers in Southern Africa. *Evidence and Policy: A Journal of Research*

Debate and Practice, 11(4), 547-557. https://doi.org/10.1332/174426414X 1417545274793

Sultana S., Hosen A., Afsana A.S., Sultana S., Pehan E.A., Islam A., Sultana N., Hassan M.R. (2024). Physio-chemical and microbiological quality assessment and detection of adulterants in different sources of milk in Bangladesh. *Journal of Food Quality and Hazards Control*. 11: 214 -222.https://doi.org/10.18502/jfqhc.11.3.16593

Sablatzky, T. (2022). Methods Moment: The Delphi Method. *Hypothesis, 34*(1). Retrieved from https://orcid.org/0000-0001-5656-3206

Sharma, R., Rajput, Y. S., and Tomar, S. K. (2012). Effect of different cooling systems on the microbial quality of raw milk during storage. *Journal of Food Science and Technology*, 49(5), 613–618. https://doi.org/10.1007/s13197-011-0325-3

Shashikumar, T., Kumar, G. S., and Suresh, M. N. (2018). Monitoring of veterinary drug residues in milk and meat from livestock in southern India. *Indian Journal of Dairy Science*, 71(5), 427–432. https://doi.org/10.18805/ijds.v71i05.11523

Spigarelli, C., Berton, M., Corazzin, M., Gallo, L., Pinterits, S., Ramanzin, M., Ressi, W., Sturaro, E., Zuliani, A., and Bovolenta, S. (2021). Animal welfare and farmers' satisfaction in small-scale dairy farms in the eastern Alps: A "One Welfare" approach. *Frontiers in Veterinary Science*, 8, Article 741497. https://doi.org/10.3389/ fvets.2021.741497

Sudarshan, S., Kamal, R., and Pal, R. N. (2017). Impact of scientific record-keeping on livestock health and productivity. *International Journal of Livestock Research*, 7(3), 212–220.

The Dhaka Tribune. (2023). Adulterated-food culture in Bangladesh: A new form of epidemic. A daily Newspaper Published on 08 Jun 2023. https://www.dhakatribune.com/bangladesh/284997/adulterated-food-culture-in-bangladesh-a-new-form

Todd, E. (2020). Food-borne disease prevention and risk assessment. *International Journal of Environmental Research and Public Health*, 17(14), 5129.https://doi.org/10.3390/ ijerph17145129

U.S. Food and Drug Administration. (2023). Guidance for industry: Labeling of milk and milk products. FDA.

Wong, F. W. L., and Chang, T. D. H. (2017). Biosecurity practices in livestock farms and their association with food safety. *Journal of Food Protection*, 80(11), 1857–1867. https://doi.org/10.4315/0362-028X.JFP-16-341

Zavala N. H., and Revoredo-Giha, C. (2022). Food safety and the informal milk supply chain in Kenya. *Agriculture and Food Security*, 11(8). https://doi.org/10.1186/s40066-021-00349-y

SAARC J. Agric., 22(2): 275-287 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.77683*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Coconut Oil and Bees Wax Edible Coating for Postharvest Quality Maintenance of Bari Malta-1 at Ambient Storage

T.A.A. Nasrin[1*], M.A. Rahman[1], M.S. Arfin[1], M. Afroz[1], M.M. Molla[2], A.A. Sabuz[2], M.T. Naznin[3] and M.A. Matin[4]

[1]Horticulture Research Centre, Bangladesh Agricultural Research Institute
Gazipur 1701, Bangladesh
[2]Postharvest technology division, Bangladesh Agricultural Research Institute
Gazipur 1701, Bangladesh
[3]University of Nevada, Reno, USA
[4]International Maize and Wheat Improvement Center (CIMMYT)
Southern Africa Regional Office, Harare, Zimbabwe

Abstract

An experiment was conducted to assess the influence of coconut oil and beeswax edible coating on postharvest storage quality of BARI Malta-1 (*Citrus sinensis*) at ambient condition (27±4°C and 65±5% RH). Sorted fruits were washed with drinking water; after removing surface water, fruits were coated with coconut oil and beeswax mixture (90:10 or 80:20 or 70:30) or only coconut oil. After coating, fruits were kept in plastic crates and stored at 27±4°C and 65±5% RH. Weight loss, firmness, external colour (hue angle and lightness), TSS, pH, ascorbic acid, total sugar and reducing sugar were analyzed periodically during storage. After 18 days of storage, uncoated BARI Malta-1 had lost 45.6% of its firmness, while only coconut oil coated Malta had lost 32.7%, and combinations of coconut oil and beeswax Malta had lost just about 20% of its firmness. The maximum weight loss of 16% was recorded in the uncoated BARI Malta-1, whereas only 6% was lost in the Malta coated with a mixtures of coconut oil beeswax (7:3) at the last day of storage. During the eighteenth day of storage, uncoated BARI Malta-1 retained 44.00 mg/100g of ascorbic acid, indicating a significant loss during storage. The levels of ascorbic acid in coated BARI Malta-1 that had either been coated with coconut oil alone or with coconut oil and beeswax at the final day (18) of storage ranged from 54 to 58 mg/100g. The findings showed that using coconut oil alone or in

[*] Corresponding author: taanasrin@gmail.com

Received: 12. 11. 2024 *Accepted: 12. 12. 2024*

combination with a beeswax coating was effective in maintaining the ascorbic acid content, preventing weight loss, and maintaining the firmness of the BARI Malta-1 throughout storage.

Keyword: Ascorbic acid, Beeswax, Edible coating, Firmness, Hue angle

Introduction

The major citrus fruits are sweet orange (Malta, mandarin), lime, lemon, pomelo, and other exotic citrus fruits. In this sub-continent, juicy sweet oranges were locally introduced with the name of Malta fruit. This fruit is very popular in Asian countries including Bangladesh. Malta is one of the major commercial fruit crops that is widely consumed both as fresh fruit or juice attributed to its high vitamin C content and its antioxidant potential (Kiong et al., 2008). Home production increased in the last 15 years and growers are interested in producing more quality sweet oranges because of consumer preference and the market price. Bangladesh Agricultural Research Institute has developed a sweet orange variety named BARI Malta-1. It produces a lot of fruit (20 t/ha) and is a regular fruit-bearing variety. The round, medium-sized (146g) BARI Malta-1 fruits are juicy (33.7%) and delicious (TSS 7.8% and total acid 0.36%) and are collected between October and December (DHCP, 2017). It is the good source of vitamin C and minerals as well as people prefer it because of its sweet-sour test and pleasant flavor. Proper time and method of harvesting along with transportation, storage, and proper packaging materials determines the postharvest losses of sweet orange (Arun and Ghimire, 2019). Physical weight loss and quality deterioration are the main causes of postharvest losses.

Lack of adequate postharvest technology and handling practices to maintain the quality and shelf life of these fruit are now the main concern for growers, handlers and processors. After harvest, growers are forced to sell their fruit at undesirable prices due to insufficient storage technology and fruit decay. Farmers are not able to cool the fruit or maintain low temperatures during storage and marketing or utilize controlled atmosphere storage facility because of insufficient and expensive electrical equipment. Therefore, affordable technologies are needed to support the fresh citrus industry to ensure delivery of quality fruit. One way other than temperature control that may be used to slow down the respiration rate and fruit metabolism is to modify the fruit internal atmosphere. Modified atmosphere within the fruit can be created by either modification of the atmosphere surrounding the fruit, as in modified atmosphere packaging (MAP), or by applying a semipermeable coating on the fruit surface.

Pure coconut oil as edible coating of fruits has gaining interest for its anti-senescence property by controlling respiration rate, transpiration rate and binding of the ethylene biosynthesis process. Coconut oil is a natural well-being food product rich in lauric acid. There is evidence that a part of this acid converts endogenously to monolaurin that is known to possess a broad spectrum of antiviral, antibacterial and antifungal activities (Liberman et al, 2006). Coconut oil coating closed the opening of stomata

and lenticels thereby, reducing the transpiration and respiration rate and also reduce microbial activity (Bisen et al., 2012). Nasrin et al., (2020) observed that uncoated open lemon was acceptable up to 6 days, coconut oil-beeswax (90:10 and 80:20) coated lemon kept open was acceptable up to 15 days and coconut oil-beeswax (both formulations) or only coconut oil coated lemon in MAP was acceptable more than 18 days retaining fresh like appearance and quality at ambient storage.

Citrus commercial coatings are generically known as waxes due to the fact that composition of initial formulations was based on paraffin wax or a combination of various other waxes such as beeswax or carnauba. Their main purpose is to reduce fruit weight loss, shrinkage and improve appearance, but they can also reduce the incidence of chilling injury or other citrus rind disorders (Porat, et al., 2004; Bajwa and Anjum, 2007). Thus, the objective of this research was to evaluate the performance of edible coating (coconut oil-beeswax coating and only coconut oil) on physico-chemical quality of fresh BARI Malta-1 during storing in open crates at ambient condition.

Materials and Methods

Material and Methods

BARI Malta-1 (*Citrus sinensis*) was collected from the field of one progressive farmer of Tangail district, Bangladesh. BARI Malta-1 was harvested in the month of October, based on maturity, uniformity of size and absence of physical damage. Chemicals that were used in this study as a treatment or for chemical analysis were chemical grade.

Edible coating formulations

To prepare 100 ml of three different mixtures of coconut oil-beeswax edible coating (9:1, 8:2 and 7:3 w/w basis) 90, 80 & 70 g coconut oil was mixed with 10, 20 & 30 g of beeswax respectively in three separates beakers by stirring on a low flame in order to obtain a homogenous mass that would become viscous upon cooling (Nasrin et al., 2020). Fruits were divided into 5 lots, i. 1st lot fruits were without coating, ii. 2nd lot fruits were coated with 100% coconut oil, iii. 3rd lot fruits were coated with coconut oil-beeswax mixture edible coating (9:1), iv. 4th lot fruits were coated with coconut oil-beeswax edible coating (8:2), and v. 5th lot fruits were coated with coconut oil-beeswax mixture edible coating (7:3). Upon cooling, the coating was applied carefully on the fruit skin by a soft and clean brush. Each fruits lot were kept in plastic crates and stored at ambient condition (27±4°C and 65±5% RH). Each lot was acted as treatments and each treatment consisted of 5 replications. Measurements on various physical and chemical attributes were done at the day of experiment setting and on 3 days interval up to 18 days of storage.

Measurement of whole fruit firmness

Firmness of BARI Malta-1 was analyzed by Fruit Texture Analyzer (GUSS, Model Number: GS-25, SA). An 8 mm dia. flat end probe was pushed to a depth of 3 mm

into BARI Malta-1 (same position of each sample) at 5 mm per sec speed. The utmost penetration force was used as firmness value of BARI Malta-1in Newton. Three BARI Malta-1 (two opposite locations for each) from each replication were analyzed and the mean value was used (Nasrin et al., 2018a).

Measurement of weight loss

Initial weight of 10 fruits from each replication was taken after treatment and then 3 days interval throughout storage time. It was calculated by the weight difference between initial and specific time interval divided by initial weight and finally denoted by percent.

Measurement of surface colour

External colour of BARI Malta-1 was evaluated with a Chroma Meter (Model CR-400, Minolta Corp., Japan) based on CIE (L*a*b*). L* is lightness whereas a* and b* values were transformed to chroma (c) and hue angle (h°) automatically in this Chroma meter. Before measurement, calibration was done using supplied white plate (Nasrin et al., 2017).

Determination of ascorbic acid, pH, total sugar, reducing sugar and total soluble solids (TSS)

The ascorbic acid content, total sugar and reducing sugar of BARI Malta-1 juice were analyzed according to AOAC (1994). TSS of BARI Malta-1 juice was determined by using refractometer. pH of BARI Malta-1 juice was assessed by pH meter (HANNA Instrument Inc, pH-211; Microprocessor, pH Meter, Italy).

Statistical analysis

A completely randomized design (CRD) was done with three replications for each experiment and mean ± standard deviation was shown. Analysis of variance (ANOVA) was done according to the procedures of MSTAT-C software. Comparison among data was performed using Duncan's Multiple Range Test (DMRT) ($p < 0.05$).

Results and Discussion

Firmness

Firmness or texture is an important quality parameter of fresh fruits for consumer preference. Degradation of insoluble protopectin to the more soluble pectic acid and pectin contribute to a decrease of firmness in many fruits. These changes occur relatively slowly and are less pronounced to citrus fruits as compared to climacteric fruits (Ladaniya, 2004). However, some softening of fruits also occurs due to the change of turgor pressure and or respiratory loss of dry matters during growth development and senescence. Figure 1 illustrates the effect of edible coating during storage at ambient temperature (27±4)°C on the firmness of BARI -1. Initially the firmness value of BARI Malta-1 was 2.69N and it was decreased gradually with time

but the rate was different for different treatments. Among the treatment, BARI Malta-1 coated with all three mixtures of coconut oil-beeswax edible coating retained their firmness effectively throughout the storage period. Uncoated BARI Malta-1 had lost 45.6% firmness while only coconut oil coated BARI Malta-1 lost 32.7% and mixtures of coconut oil- beeswax BARI Malta-1 had lost only around 20% at 18 days of storage.

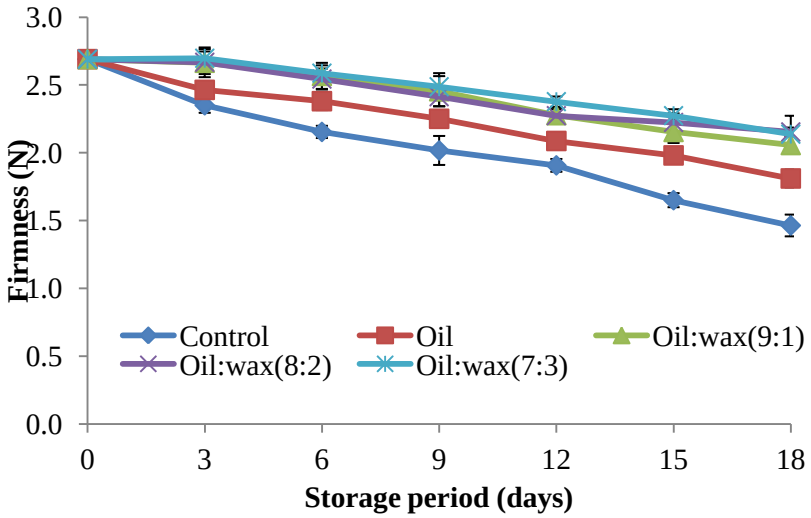


Fig. 1. Firmness of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C. Note: Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Vertical bars indicate standard deviation.

Nasrin et al., (2020) reported that the firmness value of fresh lemon was 5.43N and uncoated open lemons stored at ambient condition had lost 62.62% firmness at 6th day of storage while MAP lemon was as firm as initial up to 12th day during storage. Nasrin et al., (2018b) also observed in another study that among the treatment, coconut oil coated mandarin was most firm during ambient storage and it lost about 38% firmness while uncoated or control fruits had lost 68% firmness at 16 days of storage period. When applying the beeswax edible coating to sweet orange Shahid and Abbasim (2011) discovered that the coatings not only prevented the moisture loss but improved the texture and the general appearance of the fruits for a long period of storage.

Weight loss

Figure 2 illustrates the effect of edible coating on the weight loss of BARI Malta-1 during storage at ambient temperature (27±4) °C. Weight loss of fruits, in general, increased with the advancement in storage period. Maximum weight loss around 16%

occurred in uncoated BARI Malta-1 whereas it was only around 6% in BARI Malta-1 coated with coconut oil and beeswax (7:3) during18 days of storage at 27±4°C. Nasrin et al (2023) stated that maximum weight loss, around 33% occurred in uncoated lemon kept open whereas it was only 4% in coated (only coconut oil or coconut oil-beeswax) lemon packaged in MAP at 6th week of storage at 12±1 °C. Moreover, they reported that lemon coated with coconut oil-beeswax and kept open had lost 5.96% weight at 4th week of storage period. Shahid and Abbasim (2011) speculated that the beeswax coatings decreased the respiration rate of the fruits, thus reducing the weight loss and increased the shelf life of sweet orange. Weight loss is a consequence of fruit dehydration due to changes in surface transfer resistance to water vapour, in respiration rate, and the occurrence of small fissures connecting the internal and external atmospheres (Woods, 1990). Coating on fruits creates a barrier between fruit skin and outer atmosphere which controls movement of O_2, CO_2, moisture, and solute movement, thereby reducing respiration, water loss, and oxidation rates. Sakhale and Kapse (2012) found that dipping of sweet orange in the solution (150 ppm GA3 + 500 ppm Bavistin) and further wrapping resulted in lowest weight loss (3.9%) as against 25.7% in the fruits were given only a plain water dipping treatment (control) stored for 24 days at ambient condition (27±2°C).

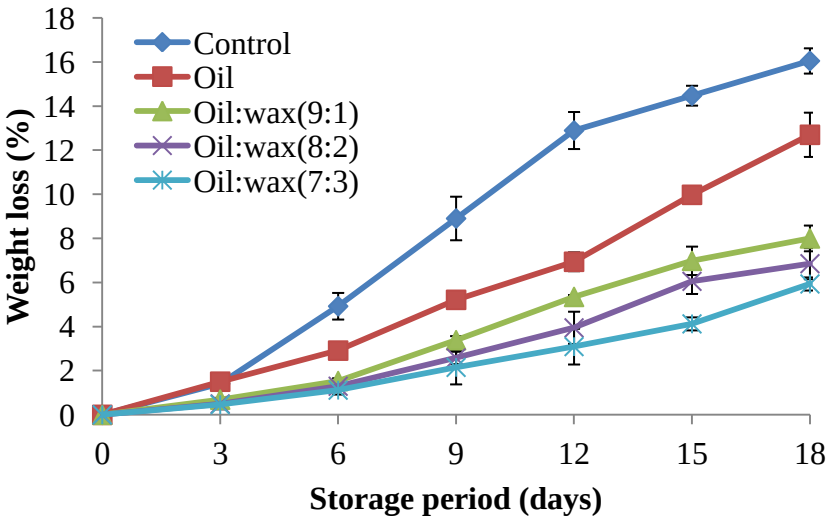


Fig. 2. Weight loss of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C. Note: Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Vertical bars indicate standard deviation.

External fruit colour (Hue angle)

Colour is an important factor in the perception of fruit quality. Figure 3 illustrates the changes in surface colour in terms of hue angle of BARI Malta-1 influenced by edible coating during storage at ambient temperature (27±4) °C. Initial hue angle value of BARI Malta-1 was 120.26 that mean, fruits were dark green colour. It is clear from the figure 3 that hue angle value is decreasing gradually with storage period as BARI Malta-1 turns from green to yellow skin colour with storage period. The reason is there, after this period, ethylene production and respiration rate were increased that stimulate to degreening BARI Malta-1.

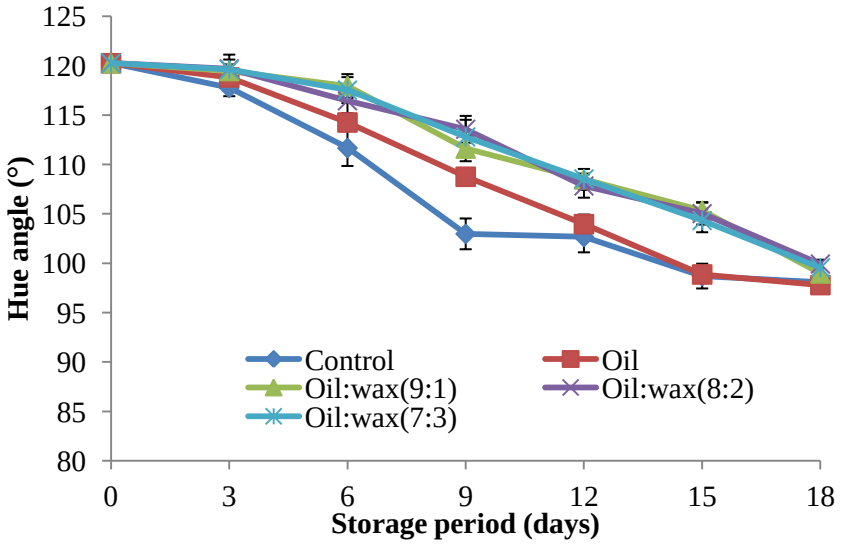


Fig. 3. External colour (hue angle) of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C. Note: Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Vertical bars indicate standard deviation.

Figure 3 illustrates those changes of colour (from green to yellow) was significantly less in BARI Malta-1 coated with all three mixtures of coconut oil-beeswax edible coating throughout the storage period. Hue angle value was 102.98 in uncoated BARI Malta-1 while, it was around 113 in all coconut oil-beeswax coated BARI Malta-1 and 108.77 in coconut oil coated BARI Malta-1 at 9th day of storage. But this value was similar around 99 in all coated and uncoated BARI Malta-1 at last day (18th day) of storage period. Obeed and Harhash (2006) found the similar results like our findings, changes of skin colour from green to yellow in "Mexican" lime during storage. Initially hue angle value of lime had 106.57, after 4 weeks of storage, it was

97.45 when fruits were treated with hot water containing calcium chloride 2% and stored at 12°C.

External fruit colour (Lightness)

Figure 4 illustrates the changes in surface colour in terms of lightness of BARI Malta-1 influenced by edible coating during storage at ambient temperature (27±4) °C. The L* parameter is an indicator of darkening. Initial lightness value of BARI Malta-1 was 37.88 and it is increasing gradually with storage period as BARI Malta-1 turns from green to yellow skin colour with storage period. Green colour reflects less light than yellow/orange colour. Lightness value was 60.67 in uncoated BARI Malta-1 while, it was between the range of 46 to 48 in all coconut oil-beeswax or only coconut oil coated BARI Malta-1 at 9th day of ambient storage. However, on the last day (18th day) of the storage period, these values were close to one another and varied from 58 to 63 in all coated and uncoated BARI Malta-1. Pure coconut oil coating helps to delay in ripening of fruits and uniform colour development of Kagzi lime in later period of storage (Besin et al., 2012). When applying the beeswax edible coating to sweet orange Shahid and Abbasim (2011) discovered that the coatings not only prevented the moisture loss but improved the texture and the general appearance of the fruits for a long period of storage.

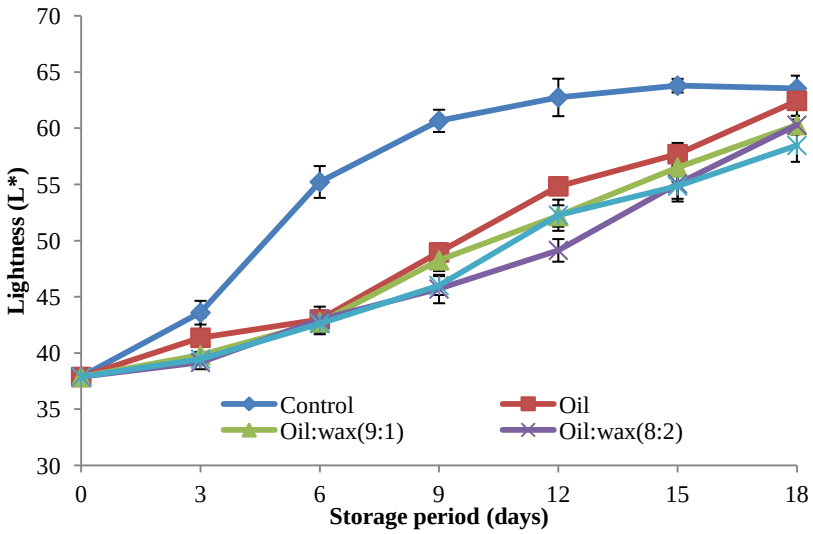


Fig. 4. External colour (lightness) of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C. Note: Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Vertical bars indicate standard deviation.

Ascorbic acid, TSS, pH, total sugar, reducing sugar and non-reducing sugar

Ascorbic acid, TSS and pH content of fresh BARI BARI Malta-1 was 60.67 mg/100g, 6.1(° Brix) and 4.67 respectively as shown in Table 1. During storage uncoated BARI Malta-1 lost ascorbic acid severely and retained 44.00 mg/100g at 18th day of storage. While coated BARI Malta-1 with only coconut oil or coconut oil-beeswax preserved ascorbic acid ranged from 54 to 58 mg/100g) up to the last day (18) of storage. Unlike ascorbic acid, TSS content was increased moderately throughout the storage period and maximum (7.9° Brix) TSS was observed in uncoated BARI Malta-1 at 18th day of storage. pH content was also increased slightly irrespective to the treatments throughout the storage. But, there were no significant differences ($p < 0.05$) in case of TSS and pH among different treatments during storage period.

Table 1. Ascorbic acid and TSS content of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C.

Treatment	Ascorbic acid (mg/100g)			TSS (°Brix)			pH		
	0 day	9 days	18 days	0 day	9 days	18 days	0 day	9 days	18 days
Control	60.67	49.00^{b}	44.00^{b}	8.17	8.30	8.87	4.67	4.89	4.89
Oil	60.67	55.00^{a}	54.33^{a}	8.17	8.27	8.73	4.67	4.82	4.88
Oil:wax(9:1)	60.67	54.67^{a}	56.67^{a}	8.17	8.00	8.25	4.67	4.77	4.84
Oil:wax(8:2)	60.67	56.00^{a}	55.00^{a}	8.17	7.90	8.17	4.67	4.73	4.86
Oil:wax(7:3)	60.67	57.67^{a}	58.00^{a}	8.17	7.97	8.20	4.67	4.69	4.85

Control=Uncoated; Oil=Coated with only coconut oil; Oil: wax (9:1)=Coated with coconut oil and beeswax (9:1); Oil: wax (8:2)=Coated with coconut oil and beeswax (8:2); Oil: wax (7:3)=Coated with coconut oil and beeswax (7:3). Means with different letters within each column are significantly different ($p < 0.05$).

Nasrin et al., (2018b) reported that ascorbic acid, TSS and pH content in fresh mandarin were 31.39 mg/100g, 4.1 % and 9.1%, respectively and during 16 days of storage, ascorbic acid content reduced severely to 14.3 mg/100g in control or uncoated fruits, while 22.4 mg/100g in the fruits coated with coconut oil. Pure coconut oil and castor oil helped in reducing the rate of ripening in Kagzi lime which results in dissolution of ascorbic acid to dehydro ascorbic acid during storage (Bisen et al., 2012). Porras et al., (2015) found that ascorbic acid content in fresh Verna lemon was 47.2 mg/100g in his study. Piga et al., (1997) found that after harvest "libson" lemon retained pH 2.55, acidity 7.33 (%) and TSS 6.4 (°Brix) and during storage acidity value was decreased slightly.

Table 2 represents the changes of total sugar, non-reducing sugar and reducing sugar content of BARI Malta-1throughout the storage period. Initial value of total sugar,

non-reducing sugar and reducing sugar of BARI Malta-1 was 7.77%, 4.94% and 2.83%, respectively and during storage all sugar values were increased slightly but there were no significant differences ($p < 0.05$). Nasrin et al (2018b) reported that total sugar and reducing sugar of mandarin was 10.78% and 4.17%, respectively at initial stage, but these values were increased slightly with storage period. Initial value of ascorbic acid, total sugar and reducing sugar of Nagpur mandarin was 30.8 mg/100 ml, 8.1% and 3.7%, respectively found by Ladaniya (2011). Figure 5 depicts the visual perspectives of BARI Malta-1 as impacted by edible coating during experimental investigations conducted at room temperature (27±4) ℃.

Table 2. Sugar contents of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) ℃.

Treatment	Reducing sugar (%)			Non-reducing sugar (%)			Total sugar (%)		
	0 day	9 days	18 days	0 day	9 days	18 days	0 day	9 days	18 days
Control	2.83	2.89	3.05	4.94	6.43	7.1	7.77	9.34	10.15
Oil	2.83	2.98	3.88	4.94	5.70	6.14	7.77	8.68	10.02
Oil:wax(9:1)	2.83	3.11	3.24	4.94	5.51	6.99	7.77	8.62	10.23
Oil:wax(8:2)	2.83	2.73	3.19	4.94	5.84	6.81	7.77	8.57	10.00
Oil:wax(7:3)	2.83	2.69	3.28	4.94	6.04	6.79	7.77	8.73	10.07

Control=Uncoated; Oil = Coated with only coconut oil; Oil: wax (9:1) = Coated with coconut oil and beeswax (9:1); Oil: wax (8:2) = Coated with coconut oil and beeswax (8:2); Oil: wax (7:3) = Coated with coconut oil and beeswax (7:3).

Fresh BARI Malta-1 at the day of harvest

Uncoated BARI Malta-1 at 18 days of storage

Coconut oil coated BARI Malta-1 at 18 days of storage

Coconut oil & beeswax (7:3) coated BARI Malta-1 at 18 days of storage

Coconut oil & beeswax (8:2) coated BARI Malta-1 at 18 days of storage

Coconut oil & beeswax (9:1) coated BARI Malta-1 at 18 days of storage

Fig. 5. Pictorial view of Malta (BARI Malta-1) influenced by edible coating stored at ambient temperature (27±4) °C.

Conclusion

Coconut oil and 3 different mixtures of coconut oil and beeswax (9:1, 8:2 and 7:3 w/w basis) are a natural, low cost, healthy edible coating and also very easy to apply any fruits like BARI Malta-1. The physico-chemical parameters of BARI Malta-1 were positively influenced by coconut oil beeswax or only coconut oil coating up to 18 days during storage at ambient temperature (27±4) °C**.** Mixtures of coconut oil, beeswax or even only coconut oil coating assisted to preserve weight, firmness,

appearance and ascorbic acid content of BARI Malta-1 very efficiently than uncoated BARI Malta-1 throughout the storage period. In future, similar study can be carried out using these edible coatings in BARI Malta-1 at recommended low temperature or these coating can be applied in other fruits.

Acknowledgement

This work was supported by the grants from Bangladesh Agricultural Research Institute, Ministry of Agriculture, Government of Bangladesh.

References

AOAC, (1994). Official Methods of Analysis. Association of Official Analytical Chemists. 1111. North 19th Street, Suite 20, 16th Edi. Arlington, Virginia, USA. 22209.

Arun, G.C. and Ghimire, K. (2019). Estimating post-harvest loss at the farm level to enhance Food Security: A Case of Nepal. *International Journal of Agriculture, Environment and Food Sciences*, 3:127–136.

Bajwa, B.E. and Anjum, F.M. (2007). Improving storage performance of *Citrus reticulata* Blanco mandarins by controlling some physiological disorders. *International Journal of Food Science and Technology*, 42: 459–501.

Bisen, A., Pandey, S. K. and Patel, N. (2012). Effect of skin coatings on prolonging shelf life of kagzi lime fruits (Citrus aurantifolia Swingle). *Journal of Food Science and Technology*, 49(6):753–759. DOI 10.1007/s13197-010-0214-y.

DHCP. (2017). Digital herbarium of crop plants, Department of crop botany, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). https://dhcrop.bsmrau.net/references/

Kiong, A.L.P., Wan, L.S., Hussein, S. and Ibrahim, R. (2008). Induction of somatic embryos from explants different of *Citrus sinensis*. *Journal of plant Science*, 3(1): 18-32. DOI: 10.3923/jps.2008.18.32

Ladaniya, M.S. (2011). Physico-chemical, respiratory and fungicide residue changes in wax coated mandarin fruit stored at chilling temperature with intermittent warming. *Journal of Food Science and Technology*, 48(2): 150–158.

Ladaniya, M.S., (2004). Citrus: Postharvest Cold Chain, Pp. 239-276.

Liberman, S., Enig, M.G. and Preuss, H.G. (2006). A review on monolaurin and lauric acid: natural virucidal and bactericidal agents. *Alternative and Complementary Therapy*, 12(6): 310-314. https://doi.org/10.1089/act.2006.12.310

Nasrin, T.A.A., Arfin, M.S., Rahman, M.A., Molla, M.M. Sabuz, A.A. and Matin, M.A. (2023). Influence of novel coconut oil and beeswax edible coating and MAP on postharvest shelf life and quality attributes of lemon at low temperatures. *Measurement: Food*, 10:100084. https://doi.org/10.1016/j.meafoo.2023.100084

Nasrin, T.A.A., Rahman, M.A., Arfin, M.S., Islam, M.N., and Ullah, M.A. (2020). Effect of novel coconut oil and beeswax edible coating on postharvest quality of lemon at ambient storage. *Journal of Agriculture and Food Research*, 2:100019. https://doi.org/10.1016/j.jafr.2019.100019

Nasrin, T. A. A., Rahman, M. A., Hossain, M. A., Islam, M. N., and Arfin, M. S. (2018a). Effect of edible coating on postharvest quality of bell pepper at ambient storage. *Bulletin, Institute of Tropical Agriculture, Kyushu University*, 41:73-83. https://doi.org/10.11189/bita.41.73. 4.

Nasrin, T.A.A., Islam, M.N., Rahman, M.A., Arfin, M.S., Ullah, M.A. (2018b). Evaluation of postharvest quality of edible coated mandarin at ambient storage. *International journal of agricultural research innovation and technology.* 8 (1):18-25.

Nasrin, T.A.A., Rahman, M.A., Hossain, M.A., Islam, M.N., and Arfin, M.S. (2017). Postharvest quality response of strawberries with aloe vera coating during refrigerated storage. *Journal of Horticultural Science and Biotechnology*, 92:6, 598-605. https://doi.org/10.1080/14620316.2017.1324326

Obeed, R.S. and M.M. Harhash (2006). Impact of postharvest treatments on storage life and quality of "Mexican" Lime. *Journal of the Advances in Agricultural Researches*,11 (3):189-193.

Piga, A., Daquino, S., Agabbio, M., and Piergiovanni, L. (1997). Polyethylene film packaging affects quality of 'libson' lemons during long-term storage. *Italian Journal of Food Science*,1(9):25-34.

Porat, R., Weiss, B., Cohen, L., Daus, A. and Aharoni, N. (2004). Reduction of postharvest rind disorder in citrus fruit by modified atmosphere packing. *Postharvest Biology and Technology*, 33: 35-43.

Porras, J.M., Brotons, A., Conesa, R., Castaner, O., Perez-Tornero1, F. J., Manera. (2015). Quality and fruit colour change in Verna lemon. *Journal of Applied Botany and Food Quality*, 88: 215 -221.

Sakhale, B.K. and Kapse, B.M. (2012). Studies on shelf-life extension of sweet oranges (Citrus sinensis L.). *International Food Research Journal*, 19(2): 779-781.

Shahid, M.N. and Abbasim, N.A. (2011). Effect of bee wax coatings on physiological changes in fruits of sweet orange Cv. "Blood re". *Sarhad Journal of Agriculture*, 27(3): 385-394.

Woods, J. L. (1990). Moisture loss from fruits and vegetables. *Postharvest News Information*, 1: 195 - 199.

SAARC J. Agric., 22(2): 289-301 (2024) *DOI: https://doi.org/10.3329/sja.v22i2.76665*

SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Effect of Growing Media on Seed Germination and Seedling Growth of Chili (*Capsicum annuum* L.)

M.S. Shakhidar[1], N. Akter[2] and M.A. Sobahan[1*]

[1]School of Agriculture and Rural Development, Bangladesh Open University, Gazipur-1705
[2]Agronomy Division, Bangladesh Rice Research Institute, Gazipur-1701

Abstract

Suitable growing media is considered a basic requirement to get the maximum germination and growth. So, the present investigation was carried out at Mominpur Farmers Hub (name of model), Rangpur Sadar Upazila during February-March, 2023 to investigate the effect of growing media on germination percentage, germination emergence percentage, shoot length, shoot fresh weight, root length, root fresh weight, leaf number, shoot length vigor index, root shoot ratio of chili under open field condition. The experiment was sequenced according to Completely Randomized Design in three replicates. Five different growing media namely soil + sand, cocopeat, soil + sand + cocopeat, vermicompost + cocopeat, and vermicompost + soil + sand was used in the experiment. The results obtained from this study showed that the maximum germination percentage (94%), shoot length (9.62 cm), shoot fresh weight (7.16 g), root length (3.09 cm), root fresh weight (1.93 g), leaf number (7.02) and shoot length vigor index (1194.74%) were recorded when the seed was growing in the cocopeat. The findings of this study recommend to use of cocopeat as a growth media for raising nurseries by farmers as it had a significant positive effect on seed germination and plant growth parameters of seedlings that lead to increased production of chili.

Keywords: Chili, Germination percentage, Growth media, Cocopeat, Vermicompost

Introduction

Chili (*Capsicum annuum* L.) is an important vegetable as well as spice crop, used worldwide for domestic and commercial purposes (Khan *et al.*, 2012). Chili are the

* Corresponding author: sobahan_74@yahoo.com

Received: 05. 10. 2024 *Accepted:05. 10. 2024*

principal crops of the Solanaceae family having diploid species with 2n=2x=24 chromosomes, grown in sub-tropics and tropics. Chili is grown over an area of 9.68 thousand hectares with a production of 14.94 thousand ton's and an average yield of 1.54 ton ha^{-1} during 2018-19 (BBS, 2020). This species is known to be a vegetable that low in calories and high in potassium, vitamin A, and vitamin C content (Chew, 2018). Furthermore, green chili is proven to be a source of metabolites with an antioxidant activity which makes it potential to treat disease against cancer, precluding gastric ulcers and activating the immune system (Sun *et al*., 2007). The genus *Capsicum* spp. includes around 30 species, of which *C. annuum, C. chinense* and *C. frutescens* are the most widely cultivated (Moquammel *et al*., 2016). The species *C. annuum* L. is the widely distributed and important in the world due to its different uses and its adaptation (Toledo-Aguilar *et al*., 2016).

Growing media have an important effect on the growth of seedlings along with the climatic conditions. In vegetable production, the seedling stage of the plant life cycle is an important stage that is effective for growth and development. Production of healthy and vigorous chili seedlings is the key factor in successful commercial chili production and yield of quality chili fruits. The seedling production using traditional methods causes stress in plants. There are many kinds of materials that are used for seed-sowing medium. The main properties wanted in growing media are that they can be found easily, cheaply and abundantly, and it was also wanted that they are rich in nutrients, and have high water holding capacity and good aeration, and must also be easy to transport. Growing media used in the production of seedlings in nurseries include organic materials such as peat, tree bark, compost, coconut fiber, vermicompost, rice husk ash or inorganic materials such as perlite or vermiculite (Grunert *et al*., 2008; Nair *et al*., 2011). These growing substrates consist of either a single component or mixtures which support plants by providing water, air and nutrients (Yilmaz *et al*., 2014; Oagile *et al*., 2016). However, different growing media vary greatly in particle size, pH, aeration and ability to hold water and nutrients (Oagile *et al*., 2016).

Cocopeat is an organic material made from coconut peel. The long fibers of coconut are used in the manufacturing of brushes, spinning, car seats and mattress stuffing, while, short fibers (2 mm and less) and the dust are further cut, crushed and washed to produce a new product suitable to use as a planting medium. Prior studies showed that cocopeat has been used as an environment friendly substitute for peat in soilless growing media for containerized plants in recent years (Evans *et al*., 1996; Noguera *et al.,* 2000; Kumarasinghe *et al.,* 2015). Cocopeat is considered a good growing medium component with acceptable pH, electrical conductivity and other chemical attributes (Evans *et al.,* 1996; Abad *et al.,* 2002; Awang *et al.,* 2009). As a growing medium, it can be used singly or as a component of a medium to raise different plant species with acceptable quality (Blom, 1999; De Kreij and Leeuven, 2001; Treder, 2008). Yahya *et al*. (2009) stated that cocoa peat is an agricultural by-product obtained after the extraction of fiber from the coconut husk. As a growing medium, cocoa peat can be used to produce several crop species with acceptable quality in the

tropics. Cocoa peat is considered a good growing media component with acceptable pH, electrical conductivity and other chemical attributes.

Vermicomposting is a bio-oxidative mesophilic process of transforming organic waste into vermicompost where detritivorous earthworm species interact with microorganisms, intensely affect the breakdown processes, accelerate the steadiness of organic matter, and improve its physical, chemical, and biological properties (Dominguez and Gómez-Brandon, 2013). Vermicompost is widely used as a biofertilizer, soil activator, fertility booster, and soil conditioner because it contains plant nutrients, enzymes, vitamins, growth hormones, and beneficial microbes such as nitrogen-fixing, phosphate-solubilizing, denitrifying, and decomposing bacteria (Jemal and Abebe, 2020; Murunga *et al*., 2020). The application of vermicompost produced by biodegradable waste could be one of the most economical and attractive methods of solving problems like waste disposal and the requirement to increase the organic matter content of soil.

Keeping in view the influence of media in germination and seedling growth of chili, the present investigation was carried out to study the effect of different media viz. sand, vermicompost and cocopeat on the germination, seedling growth and vigour of chili seedlings. The specific objectives are as follows: i) to study the effects of different growing media on germination percentage of chili seeds and ii) to assess the effects of various growing media on different seedling attributes of chili.

Materials and Methods

Experimental Site, design, treatments and cultural practices

This experiment was carried out at Mominpur farmers hub name of farmers model, Rangpur sadar (90°38′N, 24°95′E), Rangpur, Bangladesh during February to March, 2023. Chili (*Capsicum* annuum L.) variety "Radhika" was used for this study. Seeds were obtained from ACI Ptv. Ltd., Rangpur. Chili seeds were sown singly in 100 Plastic Styrofoam seedling trays filled with the different commercial growing media (treatments) viz., T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Cocopeat and vermicompost were purchased from GBK Enterprise Ltd. Parbortipur, Dinajpur (Fig. 1). The experiment was laid out in a complete randomized design (CRD) with the three growing media treatments replicated three times. Seedlings were irrigated in the morning and afternoon until the termination of the experiment.

Data collection and analysis

Data collected comprised of seedling emergence, growth and development parameters (Shoot length, leaf number, shoot fresh weight, root length and root fresh weight). Seedling emergence was measured cumulatively on a daily basis by counting any emerging seedlings from the 100 plugs per tray until a constant reading. Ten seedlings in the middle of each tray were tagged for growth and development parameters measurements which commenced after the development of true leaves and continued weekly until the termination of the experiment (approximately seven

weeks duration). Shoot height was measured from the base of plant to the shoot tip and leaf number was determined by counting fully opened leaves. At the end of the experiment, all ten tagged plants were harvested and placed in brown paper bags for shoot fresh weight, root length and fresh weight determination. Shoot fresh weight was determined immediately after harvest using an electronic balance.

Seed germination characteristics

Germination percentage (%) was calculated using the following formula (Scott *et al.*, 1984):

$$\text{Germination (\%)} = \frac{\text{Total numbers of germinated seeds}}{\text{Total seed placed for germination}} \times 100$$

The vigor index was calculated using the following formula (Abdul-Baki and Anderson, 1973): Shoot length vigor index = Germination (%) × Plumule length + Radicle length,

Statistical analysis

Mean values were taken from measurements of three replicates and standard deviation (SD) of the means was calculated. The collected data was analyzed the statistically using statistics10 software.

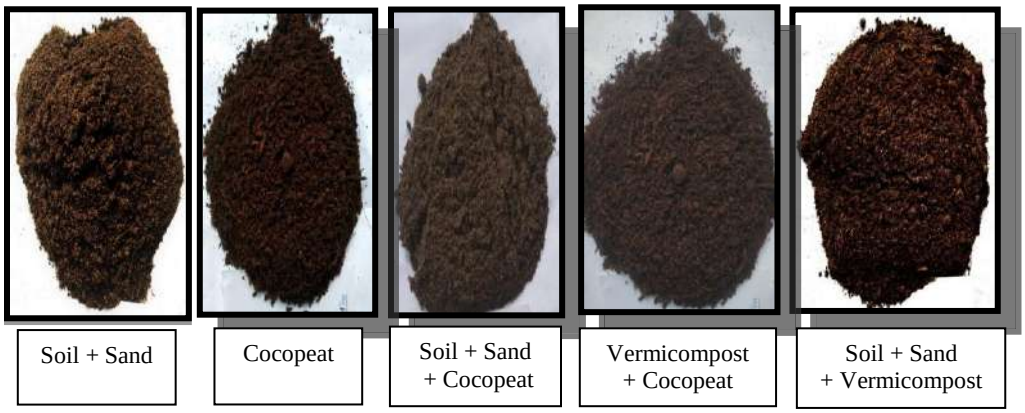


Plate 1. Pictorial view of different types of growing media

Results and Discussion

Effects of different growing media on germination (%) and seedling emergence of chili

The germination percentage of chili seeds was significantly affected by the growth medium (Figure 1). The significantly higher germination percentage of chili was found to be 94% in T_1 (cocopeat), while the lowest (78%) germination was recorded

in T_0 [soil + sand (1:1)]. Germination percentages varied from 86-89% in different growing media. The lowest germination in T_0 [soil + sand (1:1)] may be due to low water retention capacity and low nutrient availability (Meena et al., 2017). Growing media significantly increase seed germination, seedling emergence and growth of seedlings in a nursery because these media serve as reservoirs of moisture and plant nutrients. These results were supported by Utteker et al. (2021) who reported that media containing cocopeat resulted in the highest germination (%) while the lowest germination (%) was observed in media containing soil + sand (1:1) in mango seedlings. Cocopeat is considered the best growing medium component with acceptable pH, electrical conductivity and other chemical attributes (Evans *et al*., 1996, Abad *et al*., 2002, Awang *et al*., 2009).

The percent seedling emergence showed that emerged showed after fourteen days of seed sowing (Figure 2). There were no significant differences in seedling emergence among the treatments except T_0 treatment. The higher seedling emergence observed in the T_1 (cocopeat), T_2 (soil + sand + cocopeat) and T_4 (vermicompost + soil + sand) up to 20 days could also probably be attributed to the fact that the growing media possess good physical and chemical properties that enhanced seedling's emergence. Seed germination is influenced by different factors that include the type of growing media and environmental factors such as oxygen, nutrient and water availability, temperature and light (Baiyeri and Mbah, 2006). This result is consistent with the results of Bhandari and Kharal, (2019) they reported that the maximum speed of germination (1.964) was found in coco peat. The least speed of germination (0.974) was found in control (soil treatment).

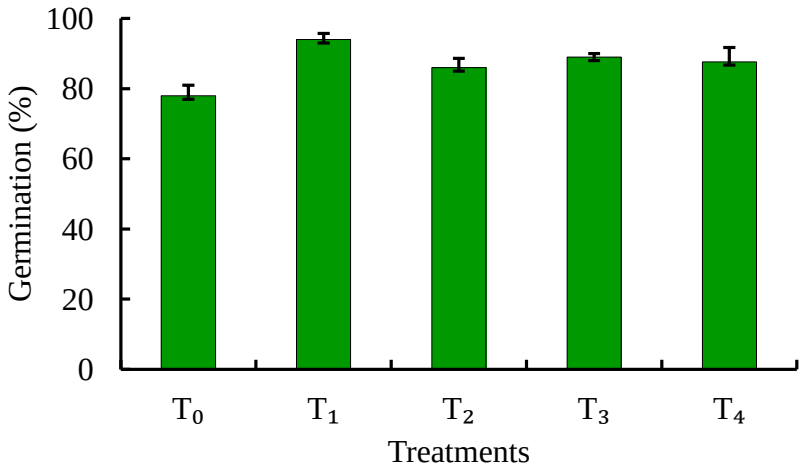


Fig. 1. Effect of different growing media on germination (%) of chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD and bars indicate SD.

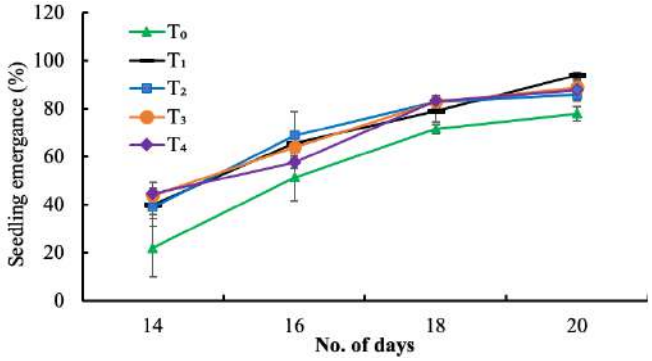


Fig. 2. Effects of different growing media on seedling emergence (%) of chili at different days after sowing. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of different growing media on shoot length of chili

Figure 3 shows that the shoot length varied significantly with the growing media at different days after sowing (DAS) i.e., at 20, 35 and 50 DAS. The growth of plants was increased (6.03 cm) significantly for the 35 DAS compared to the 20 DAS. The treatment T_1 (cocopeat) showed the highest performance (9.62 cm) among others until the 50 DAS. However, treatment T_3 (vermicompost + cocopeat) showed the lowest performance (5.61cm) compared to other treatments. According to Haring *et al*., 2021 stated the bara variety of chili with the planting medium of cocopeat had the highest plant height (81.50 cm). These outcomes are match with the results of Atif *et al.* (2016) found that equal proportion of compost, peat and traditional practicing media also enhanced tomato shoot length. After 30 days aged seedling higher shoot length were observed in coir pith media (Vivek and Duraisamy, 2017).

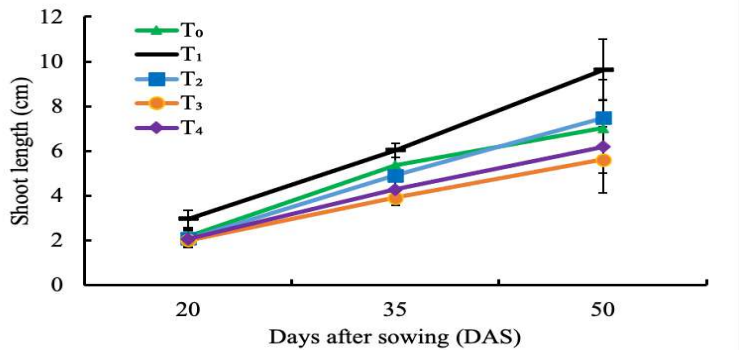


Fig. 3. Effects of different growing media on shoot height of chili at different days after sowing. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of different growing media on shoot fresh weight of chili

The significantly highest shoot fresh weight (7.16 g) was obtained by the treatment T_1 (cocopeat) compared with all other growing media (Figure 4). While the lowest shoot fresh weight (2.1 g) was obtained from the T_0 (soil + sand) treatment. No significant differences were observed in the shoot fresh weight among treatments T_2 [soil + sand + cocopeat (3.23 g)], T_3 [vermicompost + cocopeat (2.9 g)] and T_4 [vermicompost + soil + sand (2.66 g)], but was significantly different from T_0 (soil + sand). A similar result was reported by Cahyo, (2019) where fresh weight of Rubber plants increased with 100% cocopeat compared to control (soil). The higher N, P and K content in the cocopeat had possibly contributed to the better growth of the rubber trees where media containing cocopeat.

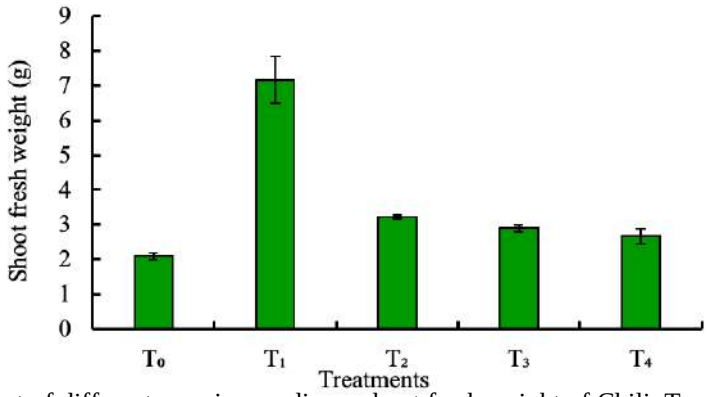


Fig. 4. Effect of different growing media on shoot fresh weight of Chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of different growing media on root length of chili

In figure 5 shows that the treatment of T_1 (cocopeat media) had the highest root length (3.09 cm), significantly different from the root length of other treatments, T_0 [soil + sand (1.58 cm)], T_3 [vermicompost + cocopeat (1.97 cm)] and T_4 [vermicompost + soil + sand (2.12 cm)]. Growing media, treatment T_2 (soil + sand + cocopeat) had the lowest root length (1.42 cm). These results suggested that the cocopeat media is more suitable than other media because of more physical properties and enhanced nutrient level. Cocopeat is a better growing media serve as a storage for nutrients and water for the plant, allow diffusion of oxygen in root zone and external atmosphere of root substrate which provide adequate support to the plant (Abad *et al*., 2002). These results matched with the finding of Unal (2013) reported that the best outcomes regarding tomato seedling root length in M4 (peat-stable manure-perlite) and M5 (peat-sand-NPK) media. Moreover, Kotur, (2014) observed that the highly porous and favourably moist cocopeat, in comparison to soil, did not

favour proper root growth in most cases except in capsicum in terms of overall vigour, and in pigeon pea, for length of tap root.

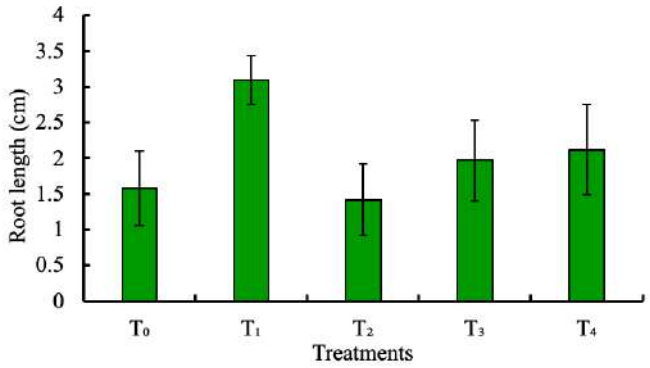


Fig. 5. Effect of different growing media on root length of Chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effect of different growing media on root fresh weight of chili

The total root fresh weight of chili was significantly highest (1.93 g) by the treatment of T_1 (cocopeat). The treatment of T_4 (vermicompost + soil + sand) produced the lowest (0.8 g) total root fresh weight of chili. However, there was no significant difference of T_0 (0.97 g), T_2 (1.00 g), T_3 (0.866 g) and T_4 (0.8 g) treatment growing media (Figure 6). This result is consistent with Cahyo (2019) and found that the good root growth of rubber on cocopeat can be seen from the gradual increment of root fresh weight and volume with increasing proportion of cocopeat.

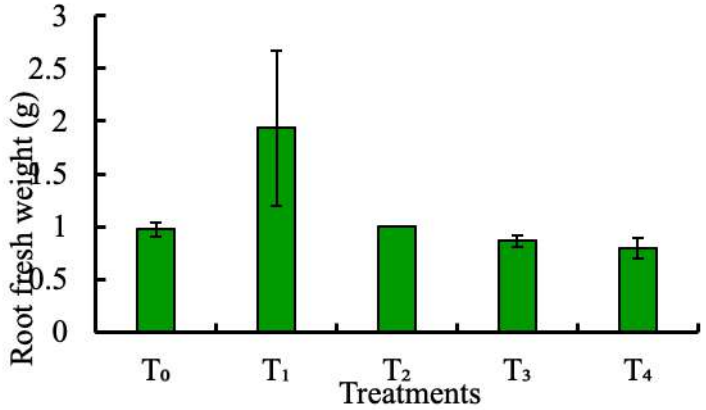


Fig. 6. Effect of different growing media on root fresh weight of chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of different growing media on leaf number of chili

The leaf is the major organ involved in light perception and the conversion of solar energy into organic carbon (Malinowsk, 2013, Du *et al*., 2019). The leaf number is a very important character for plant growth and development. The figure 7 showed the changes of mean in number of leaves for growing media over time. Plant using the medium of cocopeat (T_1) showed the highest mean number of leaves at 20DAS (2.00), 35DAS (5.3) and 50DAS (6.9). Meanwhile, planting media vermicompost + cocopeat (T_3) still the lowest mean number of leaves (2.00, 4.2 and 4.9 at 20DAS, 35DAS and 50DAS, respectively) were showed over the time planting. These consequences are similar with the conclusions of Kumarasinghe *et al*. (2015) found that cocopeat media is good to increase leaf number per tomato seedling. Higher number of leaves was produced due to nutritional contribution of the media.

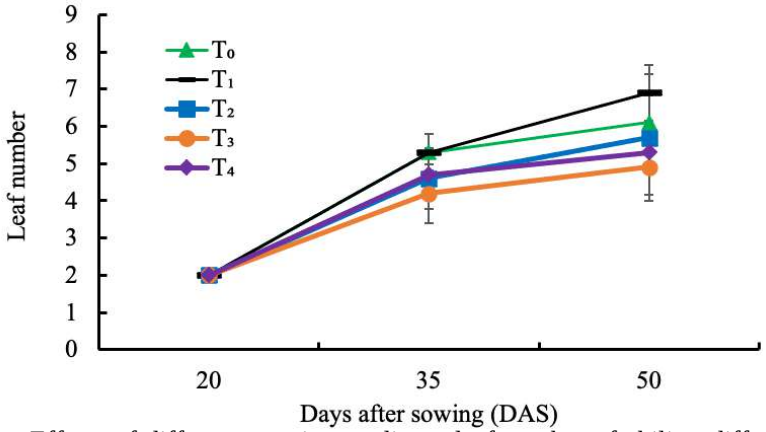


Fig. 7. Effects of different growing media on leaf number of chili at different days after sowing. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of different growing media on shoot length vigor index of chili

Copeland and McDonald, (1995) reported that vigor of seedlings relates with their ability upon germination to grow rapidly and well. Among the growing medium, higher shoot length vigor index was observed in T_1 [cocopeat (1194.74)], while lower in T_3 [vermicompost + cocopeat (664.83)] treatment. Moreover, there was no significant difference in shoot length vigor index of T_2 [soil + sand + cocopeat (765.4)], T_0 [soil + sand (670.82)], T_3 [vermicompost + cocopeat (664.83)] and T_4 [vermicompost + soil + sand (728.57)] treatments (Figure 8). It seems that good physical and biological conditions in cocopeat had positive effect on root development, which is helpful in increased seedling length vigor index of chili.

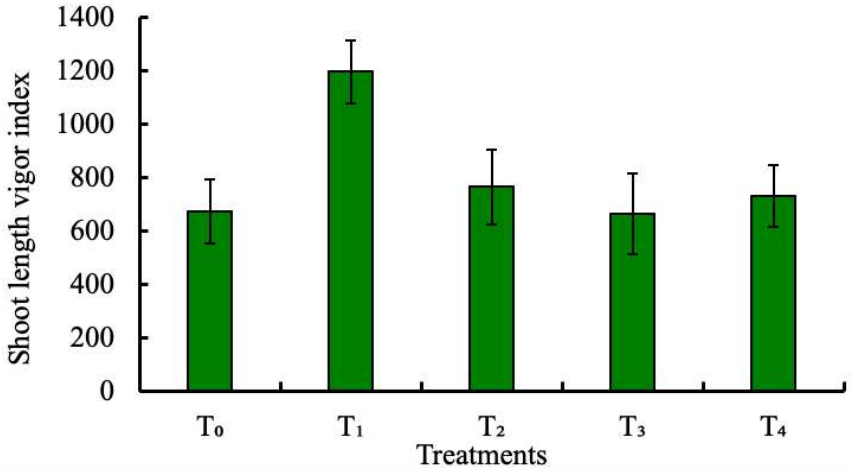


Fig. 8. Effect of different growing media on seedling length vigor index of chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of different growing media on root and shoot ratio of chili

The root and shoot length ratio were affected by growing media (Table 1). The root and shoot growth were influenced by different growing media to which the maximum root and shoot ratio (0.377) was recorded in the treatment T_3 and it was at par with T_1 and T_4. However, the minimum root and shoot ratio (0.199) was registered in T_2 (soil + sand + cocopeat). The better root and shoot ratio might be due to better aeration and water holding capacity of the media, which invigorates improved physiological activities of the plant and thus, helps in obtaining maximum root and shoot dry mass, which further results in higher root to shoot ratio. These findings are in close relation with earlier findings of Dhakar *et al*. (2016) in papaya.

Table 1. Effect of the different growing media on root and shoot length ratio of chili

Treatments	Root and shoot length ratio
T_0	0.226±0.073
T_1	0.329±0.077
T_2	0.199±0.086
T_3	0.377±0.167
T_4	0.338±0.125

Note: T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat and T_4 = vermicompost + soil + sand.

Conclusion

The presented results showed that cocopeat is the best due to suitable physical, chemical and biological properties could be used best media to grow. Considering the results, it may be concluded that sowing seeds of chili in growing media cocopeat gave higher parameter of germination, and enhanced growth of seedlings as compared to media without cocopeat. Based on the findings of this study cocopeat growing media may be advised for raising chili nurseries by farmers as it has a significant positive effect on plant growth parameters.

Acknowledgement

The authors are thankful to the Nutrition in City Ecosystem, Rangpur Dinajpur Rural Service for providing the opportunity and infrastructure to complete this research work.

References

Abad, M., Noguera, P., Puchades, R., Maquieira, A. and Noguera, V. (2002). Physico-chemical and chemical properties of some coconut dusts for use as a peat substitute for containerized ornamental plants. *Bioresources Technology*, 82, 241-245.

Abdul-Baki, A.A. and Anderson, J.D. (1973). Vigor determination in soybean seed by multiple criteria. *Crop science*, 13, 630-633.

Atif, M.J., Jellani, G., Malik, M.H.A., Saleem, N., Ullah, H., Khanand, M.Z. and Ikram. S. (2016). Different growth media effect the germination and growth of tomato seedlings. *Science Technology Development*, 35(3): 123-127.

Awang, B., Shaharom, A. S., Mohammad, B., Selamat, A., Ayub, M., Ullah, J. and A. Muhammad, A., (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of Celosia cristata. *American Journal of Agricultural and Biological Science*, 4, 63-71.

Baiyeri, K.P. and Mbah, B.N. (2006). Effects of soilless and soil-based nursery media on seedling emergence, growth and response to water stress of African breadfruit (Treculia africana Decne). *African Journal Biotechnology*, 5(15):1405-1410.

BBS (2020). Yearbook of Agricultural Statistics of Bangladesh-2019. Bangladesh Bureau of Statistics, Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Bhandari, A. and and Kharal, B. (2019). Effect of different growth media on seed vigor characteristics of tomato (*Solanum lycopersicum* L.) cv. Gaurav-555 in Agrhakhanchi, Nepal. *International Journal of Scientific & Engineering Research*, 10(9): 511-522.

Blom, T.J. (1999). Coco coir versus granulated roockwool and 'arching' versus traditional harvesting of roses in a recirculating system. *Acta Horticulture*, 481, 503-507.

Cahyo, A.N., Sahuri, Nugraha, I.S. and Ardika, R. (2019). Cocopeat as Soil Substitute Media for Rubber (*Hevea brasiliensis Müll*. Arg.) Planting Material. *Journal of Tropical Crop Science*, 6(1): 24-29.

Chew, B.H. (2018). Grow your own vegetables. Kuala Lumpur, Malaysia: MPH Group Publishing Sdn Bhd.

Copeland, L. O. and McDonald, M. B. (1995). Seed vigour and vigour tests. In: Principles of seed science and technology (3rd edn.). Chapman and Hall, New York. Pp. 153-180.

De Kreij, C. and Leeuven, G.J.L. (2001). Growth of pot plants in treated coir dust as compared to peat. *Communications Soil Science Plant Analysis*, 32(1314), 2255-2265.

Dhakar, S. S., Kaushik, R. A. and Sarolia, D. K., (2016). Influence of growing media and containers on germination & seedling growth of papaya (*Carica papaya* L.) cv. Pusa Nanha. *Green Farming*, 7, 451-454.

Domínguez, J. and Gómez-Brandón, M. (2013). The influence of earthworms on nutrient dynamics during the process of vermicomposting. *Waste Management Research*, 31, 859-868.

Du, B., Liu, L., Wang, Q., Sun, G., Ren, X., Li, C. and Sun, D. (2019). Identification of QTL underlying the leaf length and area of different leaves in barley. *Scientific Reports*, 9, 4431.

Evans, M. R., Konduru, S. and Stamps, R. H. (1996). Source variation in physical and chemical properties of coconut coir dust. *Horticultural Science*, 31, 965-967.

Grunert, O., Perneel M. and Vandaele, S. (2008). Peat-based organic grow bags as a solution to the mineral wool water problem. *Mires and Peat*, 3, 1-5.

Haring, F., Amin, A. R., Rabbi, K., Kaimuddin, Farid B. D. R. M., Widiayani, N., Novaty, E., Dungga, F. U. and Sahur, A. (2021). Test on Cayenne chili (*Capsicum frutescens* L.) varieties on different growing media bioponically. IOP Conf. Series: *Earth and Environmental Science*, 807, 042056.

Jemal, K. and Abebe, A. (2020). Effect of different bedding materials and waste feeds on vermicompost production and local earthworm performance in Wondo Genet Ethiopia. *Asian Journal of Plant Science and Research*, 10, 13-18.

Khan, A. L., Shinwar, Z. K., Kim, Y., Waqas, M., Hamayun, M. K. and Lee, I. (2012). Role of endophyte Chaetomium globosum lk4 in growth of *Capsicum annuum* by production of gibberellins and indole acetic acid. *Pakistan Journal of Bot*any, 44, 1601-1607.

Kotur, S. C., (2014). Influence of fermented cocopeat on seedling vigour in some vegetables, marigold and pigeon pea. *Journal of Horticultural Science*, 9, 191-195.

Kumarasinghe, H.K.M.S., Subasinghe, S. and Ransimala, D. (2015). Effect of cocopeat particle size for the optimum growth of nursery plant of greenhouse vegetables. *Tropical Agriculture Research Extension*, 18(1), 51-57.

Malinowski, R. (2013). Understanding of Leaf Development-The Science of Complexity. *Plants*, 2, 396-415.

Meena, S. K. and Meena, V. S. (2017). Importance of Soil Microbes in Nutrient Use Efficiency and Sustainable Food Production. In book: Agriculturally Important Microbes for Sustainable Agriculture, .3-23.

Moquammel, S. K. H. et al. (2016). Karyological studies of two hot chili pepper cultivars from two different geographical regions of India: Bhut jolokia, *Capsicum chinense* Jacq. and Bullet Lanka, *Capsicum annuum* L. *The Nucleus*, 59, 227-233.

Murunga, S. I., Wafula, E. N. and Sang, J. (2020). The use of freshwater sapropel in agricultural production: a new frontier in Kenya. *Advanced Agriculture*, 2020, 8895667.

Nair, A., Ngouajio, M. and Biernbaum, J. (2011). Alfalfa-based organic amendment in peat compost growing medium for organic tomato transplant production. *Horticultural Science*, 46, 253-259.

Noguera, P., Abad, M., Puchades, R., Noguera, V. and Martinez, J. (2000). Physical and chemical properties of coir waste and their relation to plant growth. *Acta Horticulture*, 450, 365-374.

Oagile, O., Ramalekane, O., Mojeremane, W., Matsuane, C., Legwaila G. M. and Mathowa, T. (2016). Growth and development response of Kale (Brassica oleracea var. Acephala L.) seedlings to different commercial growing media. *International Journal of Plant and Soil Science*, 12, 1-7.

Scott, S., Jones, R. and Williams, W. (1984). Review of data analysis methods for seed germination. *Crop Science*, 24, 1192-1199.

Sun, T., Xu, Z., Wu, C.-T. and Janes, M. (2007). Antioxidant Activities of Different Colored Sweet Bell Peppers (*Capsicum annuum* L.). Journal of Food Science, 72(2), S98-102.

Toledo Aguilar, R. et al. (2016). Morphological diversity of native population's poblano pepper. *Revista Mexicana de Ciencias Agrícolas*, 7, 1005-101.

Treder, J. (2008). The effects of cocopeat and fertilization on the growth and flowering of oriental lily 'star gazer'. *Journal Fruit Ornamental Plant Research*, 16, 361-370.

Unal, M. (2013). Effect of organic media on growth of vegetables seedlings. *Pakistan Journal Agriculture Science*, 50(3), 517-522.

Uttekar. (2021) Studies on production of quality seedlings for grafting and acclimatization of chili (*capsicum annum* L.) grafts. M. Sc. Thesis submitted to Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (Unpublished).

Vivek, P. and Duraisamy, V.M. (2017). Study of growth parameters and germination on tomato seedlings with different growth media. *International Journal Agriculture Science Research*, 7(3), 461-470.

Yahya, W., Shaharom, A. S., Mohamad, R. B. and Selama, A. (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of Celosia cristata. *American Journal of Agricultural and Biological Science*, 4, 63-71.

Yilmaz, E., Sonmez, I. and Demir, H. (2014). Effects of zeolite on seedling quality and nutrient contents of cucumber plant (*Cucumis sativus* L. cv. Mostar F1) grown in different mixtures of growing media. *Communications in Soil Science and Plant Analysis*, 45, 2767-2777.

SAARC Journal of Agriculture

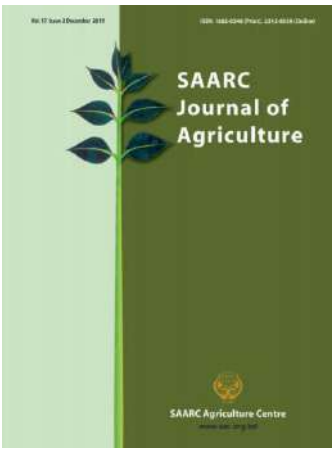
EDITORIAL BOARD

Editor-in-Chief
Dr. Md. Harunur Rashid
Director, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

Managing Editor
Dr. Ganga Dutta Acharya
Senior Program Specialist, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

Associate Editor
Md. Monirul Islam
Senior Program Officer, SAARC Agriculture Centre
BARC Complex, Farmgate, Dhaka-1215, Bangladesh

AUTHOR INFORMATION DESK



SAARC Journal of Agriculture

Affiliated organization: SAARC Agriculture Centre (SAC).

(A regional Centre under the framework of South Asian Association for Regional Cooperation).

DESCRIPTION

SAARC Journal of Agriculture (SJA) is a leading international journal focusing on all aspects of agrarian sector in South Asian region. The SJA publishes original article, review, short communication on the fundamental, applied and management areas of crop science, horticulture, animal science, fisheries, natural resource management, post-harvest processing, rural development, climate change, social sciences etc. The aim of SJA is to advance and disseminate the knowledge in all spheres of agriculture towards achieving the sustainable development goals.

PERIODICITY

Two issues per year.

AUDIENCE

Researchers, academicians, scholars, policy makers, developmental practitioners working in broader areas of agriculture including livestock and fishery.

GUIDE FOR AUTHORS

INTRODUCTION

SAARC Journal of Agriculture (SJA) is one of the official journals of the South Asian Association for Regional Cooperation (SAARC) and published from SAARC Agriculture Centre (SAC), Dhaka, Bangladesh. It is an open accessed, peer-reviewed international journal with two issues in each year. The aim of the journal is to advance and share scientific knowledge in all spheres of agricultural sciences. The SJA welcomes the manuscripts primarily relevant to the SAARC Member States namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. Articles from rest of the world are also welcome subject to its applicability over the agricultural sciences.

SCOPE OF JOURNAL

Topics include (but are not restricted to):

Crops: Agronomy, horticulture, soil science, plant breeding and genetics, cytogenetics, post-harvest technologies, agricultural engineering, agricultural biotechnology, agro-forestry, horticultural sciences, microbiology, pest, weed control, molecular biology, plant pathology, innovative technology, crop modeling, physiology and biochemistry, stress breeding, land use, forestry, climate change, conservation agriculture, extension, economics, watershed management, farm mechanization etc.

Livestock: Animal nutrition/ biotechnology/ production and management/genetics and breeding/ physiology/ reproduction, meat science, dairy technology, veterinary medicine/bacteriology/ virology/ surgery/ public health/ immunology/ parasitology/ epidemiology, fodder production and conservation, poultry production and management, nutraceuticals, safe food production, antimicrobial usages and antimicrobial resistance, greenhouse gas emission and mitigation, veterinary extension etc.

Fisheries: Aquaculture- cold water/freshwater/brackish-water fisheries, marine/inland fisheries, fish nutrition and biochemistry, aquatic animal health, aquatic ecosystem/resources management, fish processing and value addition, climate change, fisheries economics, fish genetics and bio-technology, aquaculture engineering etc.

Socio economics/cross cutting issues:

Gender, climate change, agricultural marketing, food safety, food supply chain system, value chain, safe food, biofortification, agricultural and food system transformation, agricultural and food policies and governance, nutrition etc.

TYPE OF ARTICLES

Authors are requested to mention the type of articles i.e., original research article, review, case study and short communication. At the time of submitting the article, the corresponding author must choose one or more areas mentioned above.

SUBMISSION OF ARTICLES

Articles from all SAARC Member Countries are invited. Nevertheless, manuscript from rest of the world with direct or indirect impact on agriculture/ livestock/ fisheries will also be considered for publication subject to its applicability in the SAARC region. Manuscripts complete in all aspects must be submitted online by the principal/corresponding author through registering as 'Author' at **banglajol.info.**

For any queries regarding the submission, potential authors are requested to contact with editorial desk of SAARC Journal of Agriculture through email.

STRUCTURE OF THE MANUSCRIPT

Follow this order while preparing the manuscript:

TITLE PAGE

Title, details of authors (names, affiliations, email), abstract, keywords, corresponding author. The corresponding author should be marked using asterisk.

MAIN MANUSCRIPT

Title, names of authors (full name), abstract, keywords, introduction, materials and method, results and discussion (combined), conclusion including future researchable issues, acknowledgment, conflict of interest if any, reference, tables with title, figure with captions.

TEXT LAYOUT

Prepare manuscript using 'Times New Roman' with font size 12 pt having double spacing and wide (0.3 cm) margins on right and left side in word format. Please ensure that each new paragraph is clearly indicated. Present table and figure with appropriate title and caption, respectively. Number all pages consecutively using 12 pt. font size and standard fonts.

MANUSCRIPT LENGTH

The maximum word count of the manuscript should be restricted to 5000, 4000, and 2500 for review, original research article and case-study/short communication, respectively.

PEER REVIEW

The SJA is a journal that operates on single blind review process. All submitted manuscripts are initially assessed by the editorial desk for its scientific merit and suitability of publication in the SJA. Manuscripts deemed appropriate are then sent to expert reviewer to assess the scientific merit of the article. The reviewer's comments are communicated to the corresponding author and she/he is expected to comply with recommendations/suggestions. All communications will be online through banglajol.info.

The author is expected to revise the manuscript after incorporating suggestions or remarks of the referee. The changes of the revised manuscript need to be marked in different colour. Finally, the corresponding author will submit revised manuscript online with colour marking, cleaned version and compliance report in separate files. The editorial team is responsible for the final decision regarding the publication of the manuscript.

ARTICLE STRUCTURE (Research articles)

Authors are requested to divide their manuscript into clearly defined sections as mentioned below:

TITLE

Please be concise and informative as it is often being used for the scientific information retrieval. Title should be self-explanatory to convey message about the article. Avoid stale words. A small running title may be provided.

ABSTRACT

The manuscript should contain an abstract. It should be self-contained and citation-free, and should not exceed 250 words. An ideal abstract should contain introductory lines, objectives, materials and method, results and conclusions of the experiment. Abbreviations that appear in the abstract must be defined before they are first used.

KEYWORDS

List up to 5 keywords in alphabetical order and separated by comma at the end of the abstract. The first letter of each of the keyword should be in upper case.

INTRODUCTION

Introduce the topic with relevant and appropriate background information evading detailed literature survey or results. Try to use latest references. This should not exceed three pages.

MATERIALS AND METHODS

Describe the methods in such a way that an independent researcher could reproduce the same during their future investigation. Methods which are already published should be mentioned in brief citing the reference. Any modifications or changes made on the established protocol should be described in detail.

RESULTS AND DISCUSSION

Results should be elaborated clearly and briefly. Discuss significance of the results based on available and published literature. Repeated citation and discussion should be avoided.

UNITS

Please follow internationally accepted rules. Always use the international system of units (SI).

CONCLUSION

The main conclusions arrived from results should be presented briefly (maximum 150 words). Authors may also point out the future research scope on the particular topic. Should be avoided repetition of sentences.

ACKNOWLEDGEMENTS

It should appear at the end of the article, before the references. Provide funding details with project or sanction number. Please acknowledge the individuals (if any) who have extended help during the research, assisted in language editing, helped in procurement of research materials etc.

ARTICLE STRUCTURE (Short communication)

It should restrict the word count to 2500 including title, names of authors and affiliation, abstract (150 words), brief introduction, materials and methods, results and discussion (combined), references, relevant tables and figures.

ARTICLE STRUCTURE (Review)

It should restrict the word count to 5000 including title, name of authors and affiliation, abstract (250 words), introduction, aim, headings and sub-headings (context specific), references, relevant tables and figures. The authors of the review should have adequate number of research publications on the subject.

REFERENCE STYLE IN TEXT

1. Single author: the author surname followed by year of publication (Singh, 2020).

2. Two authors: both authors surnames followed by the year of publication (Singh and Jahan, 2020).
3. Three or more authors: first author surname followed by 'et al.' and the year of publication (Singh et al., 2020).

REFERENCES

1. Restrict the references which are relevant to the particular topic. Recent and relevant, not more than 20 years old references are encouraged;
2. All references quoted in the text must appear at the end of the article and vice-versa. The spelling of names of author and date or year at the two places should be carefully checked;
3. The references should include names of all authors, year (within brackets), full title of the article, full name of the journal (in italic, no abbreviation), volume number, issue number in bracket, and pages. For book or monograph, the name of the publisher should also be given as well as its volume, edition and relevant pages;
4. The references cited together in the text should be arranged chronologically. The list of references should be arranged in alphabetical order. A few examples for correct citation of references are mentioned herewith.

JOURNAL ARTICLE

1. Khan, M.M.H. (2018). Abundance, damage severity and management of guava mealybug, Ferrisia virgata CkII. SAARC Journal of Agriculture, 16(2): 73-82.
2. Khan, M.M.H., Islam, M.M., Asaduzzaman, M. and Uddin, M.N. (2018). Mutants and weather parameters affecting the population dynamics of three major insect pests of mungbean. SAARC Journal of Agriculture, 16(2): 1-12.

REFERENCE TO A JOURNAL PUBLICATION WITH AN ARTICLE NUMBER

1. Van der Geer, J., Hanraads, J.A.J. and Lupton, R.A. (2018). The art of writing a scientific article. Heliyon, 19: e00205.

BOOK/ POLICY BRIEF

1. Gyeltshen, K. and Sharma, S. (2019). Integrated plant nutrition system modules for major crops and cropping systems in South Asia. SAARC Agriculture Centre, Dhaka, Bangladesh. Pp. 176.
2. Ali, Y., Shrestha, R.B., Bokhtiar, S.M. and Samanta, A.K. (2019). Food safety in South Asia: Challenge, opportunity and policy perspectives. SAARC Agriculture Centre, Dhaka, Bangladesh. Pp. 184

3. George, G. and Hassan, M.S. (2020). Policy briefs on "Guidelines for ensuring sustainability of fisheries and aquaculture in South Asia". SAARC Agriculture Centre, Dhaka, Bangladesh. Pp. 1-4.

CHAPTER IN A BOOK

1. Bhatta, R., Anandan, S. and Giridhar, K. 2019. Livestock feeds and feeding practices in India. In: Samanta, Ashis Kumar, Bokhtiar, Shaikh Mohammad and Ali, Mohammad Younus (Editors). Livestock feeds and feeding practices in South Asia. SAARC Agriculture Centre, Dhaka, Bangladesh. Pp. 64 - 100.

CONFERENCE/SYMPOSIUM/ PROCEEDINGS

Joshi, B.K. (2004). Crossing frequency and ancestors used in developing Nepalese mid and high hill rice cultivars: Possible criteria for yield improvement and rice genes conservation. Proceedings of 4th National Conference on Science and Technology held at Kathmandu, Nepal. Pp. 502-523.

REFERENCE TO A WEBSITE

Cancer Research UK. (2003). Cancer statistics reports for the UK. https://www.cancerresearchuk.org/about-cancer/bowel-cancer. Accessed on 8th June, 2019.

GRAPHS AND FIGURES

The number of graphs/figures should be restricted to 4 and it should have title below. The graphs/figures should not be copy/pasted and not in the image format. Citation of graphs/figures should appear within the main manuscript chronologically.

TABLES

The number of tables should be restricted to 4, should be numbered and have title (above the table). Avoid large tables, which are not comprehensible. In case of large tables, the data could be presented using graphs for better understanding. Citation of table should appear within the main manuscript chronologically. The combined number of tables and figures should be restricted to eight only.

ABBREVIATIONS

Should use internationally accepted abbreviations. New abbreviation for manuscript should be defined during their first use.

AUTHORSHIP AND ITS SEQUENCE

Before submission, authors are anticipated to consider carefully the list and order of authors and mention the definitive order of authors at the time of the original

submission based on their contribution. Any addition, deletion or rearrangement of author names will lead to rejection of the manuscript by the editorial board of the journal. Only in exceptional circumstances, the corresponding author can submit such request through their head of organization stating the reason.

MANUSCRIPT PREPARATION

Authors should follow "guide for authors" stringently, else the manuscript would be rejected without peer review. Editors reserve the right to adjust the style to certain standards of uniformity.

ARTICLE PROCESSING CHARGE

Articles of any type (review, research, short communication and case study) are accepted based on scientific merit and published free of cost.

SUBMISSION CHECKLIST

Before uploading the manuscript at banglajol.info for SJA, the authors are requested to undertake final check of the prepared manuscript:

i. Covering letter;

ii. Among all the authors, one has been designated as corresponding author;

iii. Affiliations along with email id of all authors at the title page;

iv. Full address of the organization where particular research has been approved and carried out;

v. Title page including title of manuscript, authors name/ address/email id, abstract, keywords, corresponding author;

vi. Entire file should have two parts:

Title page: as mentioned before.

Main manuscript: this part should include

title, running title, name of authors (initial followed by surname), abstract, keywords, introduction, materials and methods, results and discussion (combined), conclusion including future researchable issues, acknowledgment, conflict of interest if any, references, tables with title and figures with caption.

vii. Manuscript has been spelling and grammar checked

viii. Permission is taken for the use of copyright material;

ix. All references mentioned in the body of the manuscript are being cited in the reference list and vice versa.