Productivity Enhancement of Oilseed Crops in SAARC Member States

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SAARC Agriculture Centre (SAC)

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SAARC Agriculture Centre (SAC), Dhaka, Bangladesh, held a three-days regional consultation meeting on "Productivity Enhancement of Oilseed Crops in SAARC Member States" from November 18 to 20, 2024. National focal point experts from SAARC Member States, along with scientists working on various oilseed crops in the region, participated in the meeting.

Editors

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Foreword

Agriculture remains the backbone of South Asia's economy, nourishing millions and sustaining the livelihoods of diverse communities across the region. Today, this crucial sector stands at a transformative juncture facing the urgent need to feed a rapidly growing population while preserving our valuable natural resources. The SAARC Agriculture Centre (SAC), as the "Regional Centre of Excellence" under the South Asian Association for Regional Cooperation (SAARC), is mandated to advance research and development, policy planning, capacity building, and knowledge management across broad agricultural disciplines. SAC continues to work closely with its eight Member States- Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka to address emerging challenges in crops, livestock, fisheries, horticulture and natural resource management.

Oilseed crops hold immense strategic importance for the region, yet their productivity remains significantly below the potential. The Low and unstable yields across the SAARC Member States primarily result from cultivation on marginal lands, the use of poor-quality seeds and outdated varieties, minimal irrigation facilities and inadequate crop and input management. At the same time, farmers face constraints in expanding cultivation areas due to decreasing per capita arable land, competition with other crops and fluctuating market price. These challenges collectively limit domestic oilseed production, compelling countries to rely heavily on imports to meet the rising demand for edible oils.

Recognizing this pressing need, SAC convened the Regional Consultation Meeting on "Productivity Enhancement of Oilseed Crops in the SAARC Member States," held during 18-20 November 2024, bringing together government focal persons, and experts working on different oilseed crops across the region. The consultation served as an important platform to review the current status of oilseed production, share scientific insights and identify actionable pathways for enhancing productivity.

Given the diverse agro-climatic conditions of South Asia, almost major oilseed crops can be successfully cultivated in the region. Although improved varieties are widely available, farmers are not reaping the expected benefits due to limited awareness, inadequate extension support and gaps in access to modern machinery. To address these challenges, Member States must prioritize the adoption of high-yielding, climate-resilient varieties, improve crop management practices and promote mechanization tailored to oilseed crops. Integrating oilseeds into new and diversified cropping systems, alongside supportive government policies and stable market environments can play a vital role in boosting production.

Raising farmers' awareness and building their capacity is equally crucial. Empowering farmers with knowledge, training and timely guidance can significantly narrow yield gaps and contribute to sustainable productivity growth across the region.

This publication is a direct outcome of the regional consultation and presents valuable country papers, research findings and technical insights contributed by experts from the SAARC Member States. I extend my sincere appreciation to all the Focal Points, contributing scientists and authors for their dedicated efforts.

My heartfelt thanks and appreciations to Dr. Sikander Khan Tanveer, Senior Program Specialist (Crops), SAC, for organizing the consultation meeting and compiling this comprehensive document. I believe this piece of publication book will serve as a good source of updated knowledge for researchers, policymakers and extension personnel engaged in the development of oilseed crops in South Asia.

Dr. Md. Harunur Rashid
Director

Acronyms and Abbreviations

AARI	Ayub Agricultural Research Institute
ADS	Agriculture Development Strategies
AEI	Agricultural Engineering Institute
ALP	Agriculture Linkages Program
AMTC	Agriculture Machinery Centre
APSEA	All Pakistan Solvent Extractors Association
ARD	Agriculture & Rural Development
ARDCs	Agriculture Research and Development Centres
AVRDC	Asian Vegetable Research and Development Centre
AZRI	Arid Zone Research Institute
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BINA	Bangladesh Institute of Nuclear Agriculture
BTS	Bhutan Trade Statistics
CAGR	Compound Annual Growth Rate
CEFOR	Centre of Excellence for Olive Research and Training
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre
CP	Cropping patterns
CPO	Crude Palm Oil
DAS	Days after sowing
DES	Dietary Energy Supply
DOA	Department of Agriculture
DOPR	Directorate of Oil Palm Research
DoSAM	Development of Survey and Mapping

DSS	Decision Support System
FAO	Food and Agriculture Organization of United Nations
FCB	Food Corporation of Bhutan
FCBL	Food Corporation of Bhutan Limited
FFB	Fresh Fruit Bunches
FFS	Farmers Field School
FIH	Florescence In-Situ Hybridization
FNCCI	Federation Nepalese Chambers of Commerce and Industry
G.B	Governing Board
GAPs	Good Agricultural Practices
GDDs	Growing Degree Days
GDP	Gross Domestic Product
GHG	Green House Gas
GIS	Geographic Information System
GISH	Genomic In-Situ Hybridization
GMO	Genetically Modified Organisms
GVA	Gross Value Added
ICAR	Indian Council of Agricultural Research
ICARDA	The International Centre for Agricultural Research in the dry Areas
ICRISAT	The International Crops Research Institute for Semi-Arid Tropics
IIOR	Indian Institute of Oilseed Research
INM	Integrated Nutrient Management
IPM	Integrated Pest Management
IRRI	International Rice Research Institute
LDCs	Least Developed Countries
M/O NFS & R	Ministry of National Food Security & Research
MoAL	Ministry of Agriculture and Livestock
MSP	Maximum Support Price

MT	Metric Tons
NAGRC	National Agriculture Genetic Resources Centre
NAMEA	Nepal Agricultural Machinery Entrepreneurs' Association
NAMIS	National Agricultural Market Information System
NARS	National Agricultural Research System
NBPGR	National Bureau of Plant Genetic Resources
NCRPs	National Coordinated Research Program
NIAB	The Nuclear Institute for Agriculture and Biology
NMEO-OP	The National Mission on Edible Oils - Oil Palm
NPHC	National Post Harvest Centre
NSB	National Statistics Bureau
NSKE	Neem Seed Kernel Extract
NUYT	National Uniform Yield Trial
OECD	Organization for Economic Co-operation and Development
OPVs	Open pollinated varieties
ORP	Oilseed Research Program
PARC	Pakistan Agricultural Research Council
PET	Potential Evaporation
PKO	Palm Kernel Oil
PMAMP	Prime Minister Modernization Agriculture Project
PODB	Pakistan Oilseed Development Board
PPPs	Public -private partnerships
PVS	Participatory Varietal Selection
R&D	Research & Development
RS	Remote Sensing
SAC	SAARC Agriculture Centre
SDF	SAARC Development Fund
SME	Small and Medium sized enterprises
SSNM	Site specific nutrient management

SSP	Single super phosphate
SSR	Self -Sufficiency ratio
ST	Seed Treatment
TLS	Truthfully labelled Seed
VEC	Variety Evaluation Committee

Contents

Chapter 1

Productivity Enhancement of Oilseed Crops in SAARC Member States

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Oilseed crops are a diverse group of crop species which are utilized for production of oil that can be used for human consumption. These different types of oilseed crops are grown throughout the world under different agroclimatic conditions and are important commodities. About 40 oilseeds crops belonging to different families and genera are known to be consumable (Lennerts, 1983), however only a few are significant in total world trade. Oilseed crops can be categorized in two groups as edible seed oil, which is used for edible purposes and industrial oilseed crops which are used for industrial purposes. Oils are not only important for human diets but also serve as an important raw material for industrial use, such as these are used in making soaps, paints, vitamins varnishes, hair oils, lubricants, textile auxiliaries and pharmaceuticals and oil cakes and meals are used as animal feeds and manures Annual oilseed crops include rapeseed-mustard, soybean, sunflower, groundnut, sesame, Niger and safflower, while the perennial oilseed crops include oil palm and coconut. Edible oils are also produced from secondary sources such as rice bran, cotton seed, corn and other tree-borne oilseed (TBOs) besides some minor oil producing species of forest origin. Major world sources of the edible seed oils are soybean, sunflower, rapeseed, cotton and peanuts. Seed oil from flax (Linseed), castor beans and Jajuba-oilseed are used for industrial purposes. Though soybeans are the most produced type of oilseed, but the world's leading vegetable oil is palm oil.

Edible Plant Oils (EPOs) contain complex chemical components and are generally rich in fatty acids, micronutrients and active compounds and flavour substances (Kim et al., 2010; Puch et al., 2010; Ascension et al., 2014; Wang et al., 2019). These components together constitute the unique physiochemical properties of EPOs. EPOs is also rich in fat-soluble vitamins A, D, E and K and among which vitamin E has antioxidant properties and can devour the free radicals that lead to aging and carcinogenesis. There are also small quantities of trace elements in the human body that are necessary for human survival and health. Because human body cannot automatically synthesize trace elements, they must be obtained from the diet, for example the EPOs (Llorent-Martinez et al., 2011).

Edible oil plays an important role in human nutrition. It is not only a high source of energy food, but also a carrier for fat soluble vitamins (A, D, E and K) in the body. From the nutrition point of view, at least 15-20% calories should come from the fats and oils. Oilseed crops are the source of minerals, proteins and vitamins and these help under nourished group of people. Oils and fats are concentrated sources of calories. One gram of fat provides 9 calories against 4 starch or protein. Oils and fats of plant origin are superior to that of animal origin.

Global demand for vegetables oil is increasing with the passage of time. These are the primary source of energy in the human diet and are vital in food industry. Consumption of this type of oil is associated with health benefits. For example, it can help to reduce the LDL cholesterol (https://www.ecycle.com). These oils also serve an important function in the formulation of numerous ingredients. Oilseed crops are particularly used in the provision of cooking and vegetable oil (Fried et al., 1988) and the most important product produced from oilseed plants for food as well as feed stock is the oil (Harwood et al., 2013). Global production of vegetables oils in 2021 was 215 million tons, which was 123 million tonnes more in 2000. Out of total used edible oil, 37% was oil palm, 29% soybean, 12% rapeseed, 11% sunflower, while the remaining other types of edible oils were 13%. Three key oil palm producing countries were Indonesia, Malaysia and Thailand, main three soybean oil producing countries were China, United States of America and Brazil, core three rapeseed oil producing countries were Canada, Germany and China, while main three sunflower oil producing countries were Russian Federation, Ukraine and Argentina. Oilseed crops productions of different SAARC Member States including Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka were 0.22, 0.763, 6.867, 0.085, 1.22 and 0.061 million tons respectively (FAO, 2024).

Current population of SAARC Member States is about 2.0 billion on a landmass of 6.4 million square kilometres. Arithmetically, it implies approximately 25% of the global population in the 3.5% of Earth' s land areas. Maximum population of this region lives in rural areas and is mainly engaged in agriculture. Agriculture sector plays an important role in the South Asian economies and livelihoods. South Asia is the fastest - growing region in the world and it continues to face numerous difficulties in meeting the growing demands of food for its increasing population. According to FAO, during 2021-23, 8.2% population of South Asia was undernourished and their number was 385.2 million, while under nourished percentage of the total population of different SAARC Member States like Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka was 30.4, 11.9, 13.17, 5.7, 20.7 and 4.1 and their numbers were 12.5, 20.3, 194.6, 1.7,48.8 and 0.9 million respectively (FAO, 2024).

Achieving food and nutritional security for the region is, therefore a great challenge. Besides cereals, oilseeds are one of the valuable and desired crops in this region for achieving food and nutritional security. A wide range of agro-ecological zones prevailing in the SAARC Member States support diverse crops in general and an array of oilseed crops in particular coupled with demographic and dietary preference, diversity has sustained the industry and growth of each oilseed crop. Various types of oilseed crops are produced in this region and important of which are coconut, groundnut, oil palm, sunflower, safflower, rapeseed, sesame and olive.

The low and fluctuating yields of oilseed crops in this region are basically due to a large part of the cultivation being on marginal lands, lacking irrigation and with low levels of input use. Challenge for oilseed crops production in this region also include competition with other crops like rice and wheat, biotic and abiotic stresses like drought, heat, waterlogging, pests and diseases.

Lower yields are also due to the use of poor-quality seed and mostly these crops are planted under un - irrigated areas. Less than 25% of crop land area is under irrigation. Further the yields are more variable due to weather fluctuations, vulnerability to drought, poor dry farming practices low inputs use, poor soils, financial constraints and poor market access. These factors result in poor yields and increased vulnerability despite the regions potential to increase production.

Due to rising demand, scope for increasing oilseed crops in SAARC Member States is significant, but it relies heavily on yield improvements and the strategies to boost production includes use of seed of latest high yielding, climate resilient recommended varieties, promotion of location specific technologies, integrating oilseed crops into existing cropping systems like paddy-fallow cropping system and adopting conservation techniques to overcome the challenge of late planting and regional cooperation for exchange of seed etc. Use of latest technologies, i.e., use of hybrid seeds of different oilseed crops, precision agriculture, improved post-harvest handling, enhanced extraction methods and better market linkages can be helpful in improving the production of all oilseed crops.

Oilseed crops production in SAARC Member States can be increased by using the improved seed varieties and crop management practices, use of proper planting machinery and proper nutrient management. Strengthening of research, promotion of location specific technologies, strengthening of seed system and value chain development can play a pivotal role in increasing the productivity of oilseed crops in this region.

SAARC Member States need to promote research and development work, to achieve the maximum yields of all oilseed crops. It will help these States in saving of their lot of foreign exchange, which these countries are spending on import of edible oils. SAARC Member States can help each other in the form of exchange of germplasm, training of the scientists, farmers and other stake holders. Government policy support and stable market prices can also boost the productivity of all oilseed crops in these States. Present scenario of production of different oilseed crops of different SAARC Member States is given as under:

Bangladesh's economy and food security are dependent on agriculture and by 2030, the demand for edible oil is predicted to reach 3.9 million metric tons. Common cropping pattern in Bangladesh includes Rice-Mustard-Rice, Rice-Sunflower-Rice, Rice-Soybean and Jute-Mustard-Rice. The average person in Bangladesh consumes 2,393 kilo calories daily, of which 360 kilo calories- or at least 15% should come from fats and oils. Currently, Bangladesh requires 1.4 million tons of edible oil, equivalent to 22 grams per person daily for a population of 153 million. However, the domestic production of edible oils and oilseeds stands at 0.360 million tons and 0.847 million tons, respectively. This creates a substantial deficit of 74.3% between local production and requirements. Domestic oilseed production amounts to 722 thousand metric tons, cultivated over an area of approximately 353 thousand hectares. Currently, the demand for edible oil is around 2.0 million metric tons. Domestic edible oil production in Bangladesh meets only about 30% of the country's annual demand, with the remaining 70% being imported at a cost of more than 2892.70 million US$. Despite the increasing demand for oilseeds due to their diverse applications, there is limited scope for horizontal expansion of oilseed farming areas within the country. Mustard (Brassica spp.) including rapeseed, is the most significant edible oilseed crops in Bangladesh. It ranks first in terms of both cultivation area and production, accounting for over 72% of the nation's total oilseed acreage and 58% of its total vegetable oil production. At present, oilseed crops are cultivated on 1.36 million hectares of land, producing approximately 2.04 million tons annually.

The primary oilseed crops in Bangladesh include mustard-rapeseed, sesame, sunflower, groundnut, soybean and linseed. Over the past 5-10 years, mustard and rapeseed have dominated oilseed cultivation, occupying the largest area under oilseed cultivation. Other crops like soybean and sunflower have also gained attention due to their potential in addressing edible oil shortages. Mustard-Rapeseed is the most widely grown oilseed, covering around 1.1 million hectares (ha), with an average yield of 1.46 tons/ha. Sunflower is cultivated in coastal areas and saline-prone zones, covering about 25,000 hectares. Sesame is cultivated in dry and sandy areas, yielding an average of 0.8-1.2 tons/ha, while linseed is grown in limited areas, mainly in the northern regions.

One of the major challenges facing farmers is the limited availability of high-quality certified or TLS (Truthfully labelled seed) seeds. Oilseed crops also face significant threats from erratic weather patterns, drought and soil salinity. Similarly, one of the key challenges in Bangladesh's oilseed production is the limited availability of modern machinery for harvesting and processing, while mechanized options like combine harvesters for mustard and sunflower exist, their adoption is limited due to small farm sizes, lack of awareness and financial constraints among farmers. The processing sector also suffers from inefficiencies. The marketing of oilseed crops in Bangladesh faces several challenges. Inadequate infrastructure, limited market access, volatile pricing and a lack of awareness among farmers about market dynamics and quality standards are also the issues. Bangladesh imports a substantial portion of its edible oils, particularly palm oil, which is often cheaper than domestically produced oils. The Government of Bangladesh has implemented a series of policies aimed at boosting oilseed crop production to reduce dependency on imports and achieve self-sufficiency in edible oil.

Bhutan's edible oil and oilseed sector faces multiple challenges. The primary oil crops cultivated in Bhutan include rapeseed (*Brassica campestris* var. *toria*, locally known as *tori* or *peka*), mustard or Indian mustard (*Brassica juncea*), groundnut (*Arachis hypogaea*), sunflower (*Helianthus annuus*), Niger seed (*Guizotia abyssinica*) and soybean (*Glycine max*). Soybean and groundnuts are popularly grown in the eastern part of the country. However, soybeans are used as grain legumes, while groundnuts are used as a snack. Niger seed (*Guizotia abyssinica*) is grown in small areas during summer in the lower hills. Sesame (*Sesamumindic*a) grows in the southern parts of the country. Additionally, various perennial oil-bearing trees are harvested for oil extraction. *Jatropha curcas* (*Karshing* or *Kadam*), is widespread in the country and is mainly used as live fence and for erosion control and soap making and *Neolitsea* species (*Shingshe*) found in eastern parts of the country is used for consumption and lighting lamps.

The productivity is low and unstable and the availability of inexpensive, imported refined soybean oil makes locally-produced oilseeds less competitive. The post-production facilities are not developed and oil expelling is almost non-existent. The current average yield of oilseeds in Bhutan is approximately 284 kg per acre, which falls short of meeting the national demand. To fulfil domestic vegetable oil requirements, the country relies heavily on imports, spending more than Nu 1394 million annually on imported oils. Increasing local oilseed production is vital for reducing this import burden and enhancing Bhutan's food security. As Bhutan's economy develops and its population expands, the need for locally produced oilseeds will become even more pronounced, emphasizing the importance of boosting domestic production to meet both current and future demand.

In Maldives, agriculture plays a secondary role to fisheries and tourism, but coconuts remain a staple agricultural product. Coconut palms are cultivated throughout the islands, contributing significantly to the food, culture and economy of the country. Coconut oil, is used for cooking, skincare and export. It stands out as the primary source of oil production. Main challenges to Coconut include, declining soil fertility, pest issues and lack of availability of modern tools. Farmers need technical support from the Government for the improvement of coconut yield and as well for the availability of latest facilities for its oil extraction.

Main issues to Coconut include, less availability of high yielding varieties, labor-intensive harvesting methods, soil salinity, water scarcity and inadequate processing facilities for oil extraction. Growing export demand for organic and cold-pressed coconut oil has also been noted. To meet the future demand, production must be scaled through promotion of use of improved varieties, better farm management and similarly promotion of efficient processing technologies. Modern machinery for cold-press extraction can enhance oil quality, allowing Maldivian coconut oil to compete in premium export markets. Provision of financial incentives, capacity-building programs, loans for farmers and entrepreneurs, investment in R&D for development of resilient coconut varieties, promotion of modern processing techniques, can also be helpful in boosting the coconut productivity and in the development of diversified products of coconut oil in the country.

In Nepal's economy oilseed crops, including rapeseed, mustard, soybean, sesame, sunflower and groundnut, are very important due to their high demand, export potential and role in providing diversified income and nutrition. Despite this, oilseed production remains underdeveloped, with issues such as improper fertilization, micronutrient deficiencies, disease pest infestation and poor plant populations leading to decreased yields. Key oilseed crops include rapeseed, mustard, sarsoon, soybean, groundnut and sunflower, with rapeseed/mustard dominating production (85%).

Rapeseed is the dominate oilseed crops and it cover 76.34% of the area and contributes 76.84% of the production, followed by other crops including sarsoon, linseed, rayo, sesame, groundnut, sunflower and niger. Mustard also followed the similar pattern, with consistent growth from 2012/13 to 2016/17, but experienced a significant decline in area, production and yield in 2017/18 and 2018/19. From 2019/20 to 2021/22, mustard saw exponential growth in area and production, while yield remained stable. Similarly, linseed's yield has shown a steady increase throughout this period. Groundnut cultivation exhibited constant growth in area, production and yield from 2011/12 to 2021/22. Its yield increased in 2013/14 but fluctuated in the following years before stabilizing at 1 t/ha from 2020/21 to 2021/22. Sunflower cultivation fluctuated in area, production and yield, with a peak between 2016/17 and 2018/19, followed by a decline and stabilization from 2019/20 to 2021/22. Niger cultivation showed fluctuating trends in area, production and yield, with steady increases from 2012/13 to 2015/16, followed by a decrease and stabilization.

Demand for oilseed crops in Nepal is expected to rise significantly due to population growth, changing dietary habits and expanding industrial uses for oil products. With per capita oil consumption growing steadily, currently at 8-10 kg annually and projected to double by 2030, Nepal will face a growing import dependency unless local production increases. Currently, about 90% of Nepal’s edible oils are imported, primarily from India.

Oilseed crops play a crucial role in crop rotations, enhancing soil fertility, controlling pests and boosting farm productivity, particularly in regions focused on sustainable agriculture. The availability of certified seeds for oilseed crops is a significant challenge, limiting domestic production of oilseed crops including rapeseed, mustard, soybean, groundnut and sunflower. Seed availability and purity remain critical challenges for Nepal's oilseed crops.

Nepal's agriculture sector has prioritized research and development (R&D) to enhance the productivity of oilseed crops, addressing challenges like low yields, pest susceptibility and climate change. The focus is on developing high-yielding, pest-resistant and climate-resilient oilseed varieties to meet the rising demand for edible oils and reduce dependency on imports.

Oilseed consumption in Nepal has been significantly shaped by population growth, changing dietary habits and an increasing preference for edible oils in cooking. Currently, the demand for edible oil in Nepal is approximately 250,000 metric tons (MT) annually. However, domestic oilseed production stands at around 200,000-220,000 MT, which yields approximately 70,000-80,000 MT of oil after processing. More than 70% of the country's edible oil demand is met through imports, creating a significant dependency on foreign sources.

The Government of Nepal has been actively pursuing strategies to enhance oilseed crop production, aiming to improve food security, reduce reliance on imports and strengthen rural livelihoods. Existing initiatives focus on increasing productivity through the promotion of high-yielding, disease-resistant varieties of oilseeds like rapeseed, mustard, soybean and sunflower. The government provides subsidies for seeds, fertilizers and pesticides to reduce input costs, while also promoting mechanization through small-scale oilseed threshers and seed drills. Plans include expanding research to cover more oilseed crops, such as niger, sesame and sunflower and offering additional subsidies for machinery and processing units to modernize oilseed production.

The government of Pakistan has been encouraging oilseed cultivation through enhanced involvement of private sector and introduction of subsidies on seed, fertilizers and pesticides. Moreover, provincial and federal level institutions and private sector are working to develop higher-yielding and drought-resistant oilseed varieties with a focus on improving the overall production and quality of oilseed crops. There are also efforts to improve seed quality and provide training to the farmers. The domestic canola production is still not enough to meet the domestic demand. Sunflower is another significant oilseed grown in Pakistan. It is widely cultivated in the provinces of Punjab and Sindh. However, production is limited and often lower than the demand. Pakistan's edible oil consumption has been steadily increasing due to population growth and changing dietary preferences. The annual per capita edible oil consumption is estimated at 18-20 kg, above the global average of around 13 kg. Total edible oil consumption in Pakistan has grown at a compound annual growth rate (CAGR) of 3-4% over the last two decades. There is a growing preference for healthier oils, such as sunflower and canola, due to their lower saturated fatty acid content and perceived health benefits. Edible oil consumption is price-sensitive in Pakistan. Rising global prices of palm oil and soybean oil have impacted affordability, especially for lower-income groups. Palm oil remains the most consumed oil due to its lower price and wide availability. Domestic oilseed production has not kept pace, leading to a reliance on imports to fulfil over 80% of edible oil demand.

The area under oilseed crops has shown inconsistent growth due to competition with major crops like wheat, rice and sugarcane. Yield per hectare for oilseed crops remains below global averages due to the use of traditional varieties, poor farming practices and limited access to inputs. There has been an increasing focus on promoting non-traditional oilseed crops like sunflower and canola, which have shorter crop cycles and higher oil content. Traditional crops like rapeseed-mustard and cottonseed still dominate but with fluctuating production trends. The adoption of hybrid sunflower and canola varieties have improved yields in some regions. However, the lack of widespread availability and affordability limits their use.

The level of mechanization varies across different regions of the country and depends on the scale of farming operations. Most of the oilseed crops pose tremendous postharvest losses. The marketing of oilseed crops in Pakistan involves various stakeholders, needs to be strengthened to ensure the profitability of the farmers, stabilizing domestic oilseed supply and reducing dependence on imported edible oil.

During 2018-19 "National Oilseeds Enhancement Program" project was approved under the Prime Minister's Agriculture Emergency Program, with the cost of Rs.10,176 million for the period of 05 years. Under this project, work is in progress, for the productivity enhancement of oilseed crops. By increasing the domestic production, Pakistan can reduce its reliance on imports, improve its trade balance and create economic opportunities for farmers in rural areas.

In Sri Lanka, rice is the staple food of the country and field crops including grain legumes and oil crops, fruits and vegetables are mainly catering the needs of the country, while the export-oriented crops are tea, rubber, coconut and various spices. Coconut oil produced in Sri Lanka is 100% natural, which is extracted from dried kernel of the coconut fruit (copra). Sesame, Groundnut, Mustard and Sunflower are also grown in in the country. Presently, sesame has a higher export demand and is the only significantly exporting oil crop as seed of Sri Lanka. Mustard is an important oilseed crop which is used as a condiment and farmers traditionally cultivate mustard as a mixed crop with finger millet. Nearly 63% of supply is being utilized for industrial needs while 23% is used for household consumption. About 8%. of local oil is produced from coconut sector while another 9 % is supplied by existing palm tree plantations. Average household consumption of edible oil is about 1.6 litres of fats and oils per month, in which major share is of the coconut oil. Large portion (i.e. 50%) of the production of Coconut produced is used as fresh coconut consumption in the country besides the oil production and exporting. Although Sri Lanka has initiated palm oil cultivation, but recently government has banned further expansion of cultivation of oil palm due to environmental concerns. Groundnut and Sesame are the major oilseed crops, but Mustard and Sunflower are also cultivated produced in small areas.

The main reason for the less area and low production of other oilseed crops is that, the country is profoundly dependent on coconut oil for its edible oil requirements. Oil Industry is also not very well developed in the country. However, with the involvement of Department of Agriculture, several oilseed crops varieties have been developed to cater the needs of the country. As still use of appropriate machinery is very less for the planting and other operations of oilseed crops, which is the cause of higher cost of production. In addition to it, there is lack of availability of high yielding verities of different oilseed crops and similarly there is less use of latest crop management practices in the country. Use of latest Oil extraction machinery can increase the oil recovery of oilseed crops and similarly there is also need of diversification of edible oil consumption among the people. Promotion of public-private partnerships can also be helpful in increasing the overall productivity of all oilseed crops in the country.

Demand for oilseed crops in all SAARC Members States is increasing significantly due to population growth, changing dietary habits and expanding industrial uses for oil products. Due to diversified climatic conditions all most all types of oilseed crops are produced in all SAARC Member States, however oilseed crops production still needs to be improved. Main reasons, for less yield's oilseed crops in SAARC Member States include, less use of seed of latest high yielding, disease resistant and climate resilient varieties of different oilseed crops, improper use of fertilizers, micronutrient deficiencies, disease pest infestation, unavailability of irrigation water, poor plant populations and losses at crops harvesting stages etc. Science-based crop improvement efforts will be needed to enhance the yields of all oilseed crops which include availability and use of seed of latest varieties of all oilseed crops, better crop management, reduction of oilseed crops harvesting losses and stability of marketing of all oilseed crops. Similarly making the availability of irrigation, financial assistance, availability of proper farm machinery for all oilseed crops from planting to processing and training of the farmers, can enhance oilseed crops productivity. SAARC Member States can learn from the experiences of each other for different oilseed crops and similarly sharing of germplasm of different oilseed crops can boost the productivity of all oilseed crops in this region.

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Chapter 2

Present Status and Future Prospects of Oilseed Crops Production in Bangladesh

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Abstract

Bangladesh's economy and food security are dependent on agriculture, specifically on groundnuts, soybeans, mustard and sesame. By 2030, the demand for edible oil in the nation is predicted to reach 3.9 million metric tons. Common crop rotations in Bangladesh include Rice-Mustard-Rice, Rice-Sunflower-Rice, Rice-Soybean and Jute-Mustard-Rice. Despite the development of high-yielding varieties, challenges persist, such as inadequate certified seed availability, variable rainfall and volatile market pricing. To address these issues, Bangladesh has initiated farmer education and training programs focused on water and fertilizer efficiency, pest and disease control and modern agricultural practices. However, population growth, urbanization and shifting dietary habits have led to continued reliance on imports. To achieved self-sufficiency in oilseeds, Bangladesh must promote advanced crop management practices, develop high-yielding, disease-resistant and climate-resilient cultivars and extend cultivation into underutilized areas. Strategies such as climate-smart agriculture, financial incentives, subsidies and public-private partnerships (PPPs) to reduce production costs, enhance crop resilience and increase oilseed crop yields. Government priorities include advanced agricultural research, development of drought- and salt-tolerant cultivars, sustainable land and water management and crop diversification. PPPs further support the establishment of oilseed processing facilities, ensuring the availability of certified seeds and reducing post-harvest losses. Additionally, PPPs play a vital role in market access, farmer training and policy advocacy to address regulatory challenges and promote oilseed production. Modern agricultural practices, financial support and infrastructure development are crucial for diversifying income, expand market opportunities and ensure high-quality oilseed production.

Introduction

Agriculture is vital to Bangladesh's economy, contributing 11.38% to the GDP and employing nearly 40% of the labor force (Gautam et al., 2016). The country experiences a tropical monsoon climate with three distinct seasons: the hot and humid summer or pre-monsoon (March to May), marked by thunderstorms locally known as Kalbaishakhi, with temperature ranging from 30-40°C; the monsoon (June to October), characterized by heavy rainfall from southwest monsoon winds contributing 75-80% of annual precipitation, frequent flooding in low-lying areas, temperatures between 25-35°C; and the winter or dry season (November to February), featuring mild, dry weather with temperatures of 10-20°C, minimal rainfall and low humidity, during which most oilseed crops are cultivated (Fig. 1). Regional climate variations include warmer, cyclone-prone coastal areas and the cooler, wetter hill tracts, with Bangladesh's proximity to the Bay of Bengal exacerbating its vulnerability to cyclones, floods and rising sea levels (Ezaz et al., 2022).

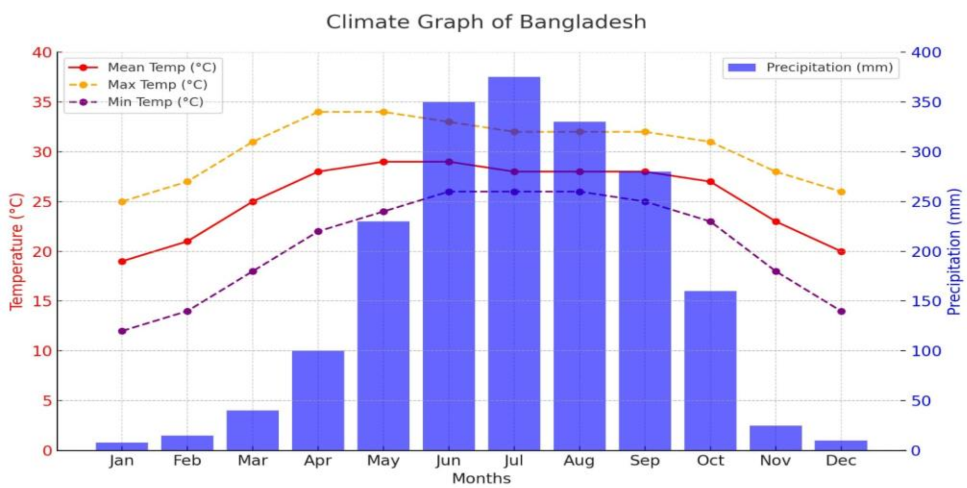

Fig 1. Climate of Bangladesh: seasonal variations in temperature and precipitation

Bangladesh's agricultural sector is diverse, producing rice, wheat, pulses, fruits, vegetables, spices and oilseeds (Nandi et al., 2024). Despite this diversity, the country faces a significant deficit in meeting its annual edible oil requirement of 1.4 million tons, with domestic production of oilseeds and edible oils at 0.847 million tons and 0.360 million tons, respectively, leaving a 74.3% shortfall (Islam et al., 2021; Mallik, 2013). This reliance on imports, valued at Tk. 24, 790 million in 2012 (BB, 2012), highlights the need to boost domestic production. Mustard (Brassica spp.), the dominant oilseed crop, accounts for over 72% of the country's oilseed acreage and 58% of vegetable oil production (Sarkar et al., 2020), followed by groundnuts, sesame and soybeans, which are critical for the poultry industry and alternative food products like soymilk and soy biscuits (BBS, 2022). Linseed oil also holds industrial importance for applications like wood varnishing. Fats and oils are essential nutrients, providing 15-25% of human energy requirements, facilitating the absorption of fat-soluble vitamins (A, D, E and K) and supporting biochemical functions like hormone synthesis and insulation (Meijaard et al., 2022). The average Bangladeshi diet supplies 2,393 kilocalories daily, with at least 15% derived from fats and oils (HIES, 2023). While plant-based fats supply essential fatty acids like linoleic and linolenic acid, they remain underutilized despite growing demand for industrial oils such as cottonseed and castor oil. With limited scope for horizontal expansion of oilseed cultivation (353 thousand hectares producing 722 thousand metric tons; BBS, 2012), vertical expansion through improved practices and advanced research remains the most viable solution to meet the rising demand for oilseeds and reduce dependency on imports.

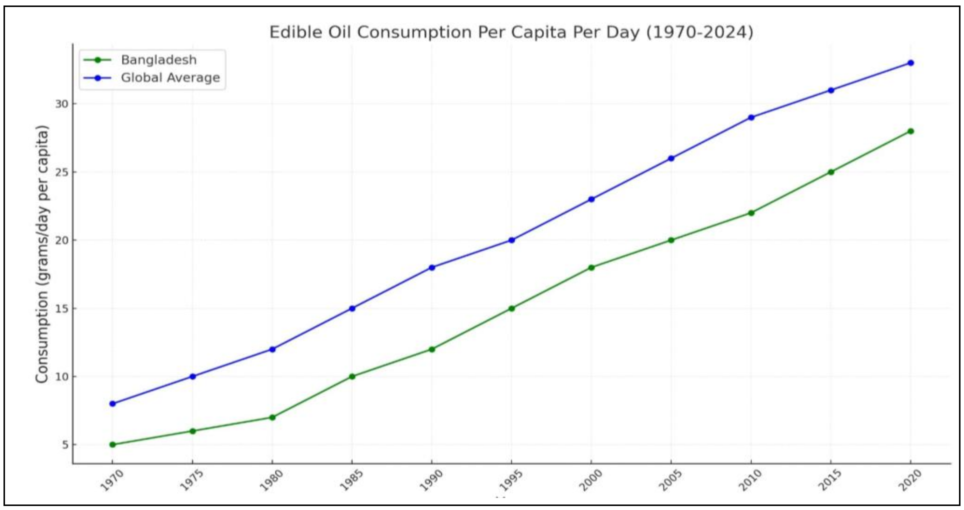

Fig 2. Edible oil consumption per capita per day in Bangladeshi people and global

Bangladesh has a highly favourable climate for rice cultivation, making it the nation's primary crop and staple food. Efforts to improve rice-based farming systems through advanced technologies and efficient resource utilization are critical for boosting rice production and national income (Shelley et al., 2016). Policy interventions and research are needed to enhance rice-based cropping patterns, such as integrating short-duration HYV mustard varieties between Boro and T. Aman rice, which can expand mustard cultivation areas significantly (Shahidullah et al., 2018).

Currently, oilseed crops are grown on 1.36 million hectares, producing approximately 2.04 million tons annually (Table 1), yet domestic edible oil production fulfils only 30% of the country’s annual demand. The remaining 70% is imported at a cost exceeding 2892.70 million USD (BBS, 2022). Mustard-Rapeseed is the most widely cultivated oilseed, covering around 1.1 million hectares with an average yield of 1.46 tons/ha. Popular varieties include BARI Sarisha-14, BARI Sarisha-15, BARI Sarisha-16 and BARI Sarisha-17. Sunflower, grown in coastal and saline-prone areas, offers high potential with varieties like BARI Surjamukhi-2 yielding 2.5 tons/ha. Soybean cultivation, concentrated in southern districts like Bhola and Noakhali has gained prominence, with BARI Soybean-6 yielding around 1.8 tons/ha. Sesame thrives in dry, sandy soils with average yields of 0.8-1.2 tons/ha, while linseed is cultivated on a smaller area in northern regions.

Bangladesh's edible oil demand is rapidly increasing, driven by population growth, economic development and dietary shifts (Bakhtiar et al., 2023). Currently, demand stands at 2.0 million metric tons, with projections indicating a rise to over 3.9 million metric tons by 2030 (Fig. 3). it is projected that the demand for edible oil will exceed, necessitating a significant increase in oilseed production (Fig. 3). Meeting this demand requires significant increases in oilseed production, guided by government policies, technological advancements and predictive modeling tools like ARIMA to align future production with national requirements.

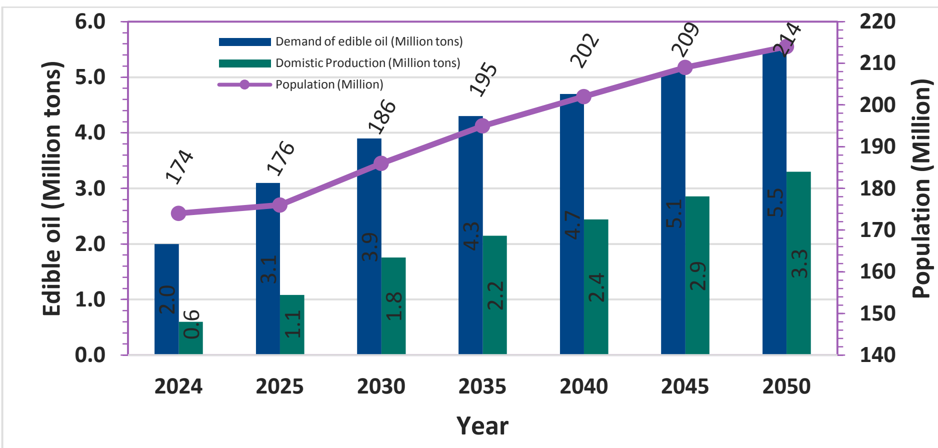

Fig 3. Projected population, edible oil demand and domestic production in Bangladesh (2025-2050)

In Bangladesh, various crop rotations involving oilseed crops are practiced based on ecological suitability, such as Rice-Mustard-Rice in northern and central regions, Rice-Sunflower-Rice in coastal saline areas, Rice-Soybean in southern districts and Jute-Mustard-Rice in regions favourable for jute cultivation. Cropping patterns, critical for increasing cropping intensity, vary with geography and land classification, with notable sequences like Jute/Aus-Fallow-Early Mustard in Jessore and Rajshahi and Boro-T. Aman-Mustard in Sirajganj and Tangail, where short-duration mustard varieties like BARI Sarisha-14, 15, 17 and 20 are widely adopted. Cropping patterns vary by geography and land type, with the top five rice-based patterns covering 51% of the net cropped area (NCA) out of 316 identified patterns (Table 1). Relay and mixed cropping of mustard with legumes and intercropping with sugarcane are also practiced in areas like Faridpur and Thakurgaon. Efforts by BARI, BINA and BADC have improved the availability of high-yielding varieties of mustard, sunflower, soybean and sesame; however, challenges remain, including insufficient certified seed supply, poor seed purity (especially for sunflower and sesame), erratic rainfall, limited access to training, irrigation and credit and unstable market prices. Farmers increasingly recognize the economic potential of oilseed crops but require better agronomic practices, quality seeds and post-harvest storage facilities. Addressing these challenges, along with enhancing local seed production, can meet the rising demand for edible oil, projected to exceed 3.9 million metric tons by 2030 (Bakhtiar et al., 2023) and improve yields significantly, as already seen with high-yielding varieties like BARI-developed mustard and sunflower cultivars (Table 2).

Table 1. Major Cropping Systems of Bangladesh.

Existing Cropping Pattern	Area (Ha)	NCA (%)	Improved Cropping Pattern
Boro−Fallow−T. Aman	2306005	26.92	Boro−Mustard−T. Aman
Boro−Fallow−Fallow	1139530	13.30	Boro−Fallow−Mustard
Fallow−Fallow−T. Aman	509480	5.95	Mustard−Fallow−T. Aman
Boro−Aus−T. Aman	209015	2.44	Boro−Aus−T. Aman-Mustard
Fallow−Aus−T. Aman	193275	2.26	Mustard−Aus−T. Aman

Research & Development for Enhancing Oilseed Crops Productivity in Bangladesh

Bangladesh has made significant progress in research and development of high-yielding oilseed varieties, spearheaded by organizations like Bangladesh Agricultural Research Institute (BARI), Bangladesh Nuclear Agricultural Research Institute (BINA), Bangladesh Agriculture University (BAU), Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Sher-e-Bangla Agricultural University (SAU) (Table 2). Notable achievements include high-yielding mustard/rapeseed varieties such as BARI Sarisha-14, BARI Sarisha-15, BARI Sarisha-16 and BARI Sarisha-17, with yield potentials of 1.5-2.0 tons/ha. Recently, drought and salt-tolerant varieties like BARI Sarisha-18 and BARI Sarisha-21 were introduced to address challenges in the coastal and Barind regions. To meet the growing demand for sunflower oil, BARI has developed salt-tolerant varieties like BARI Surjamukhi-2,3 which are well suited to saline-prone areas. Ongoing research focuses on developing resilient, high-yielding sunflower varieties to coastal regions. For soybean, high-yielding varieties such as BARI Soybean-5 and BARI Soybean-6 have boosted cultivation in southern regions, with efforts underway to develop drought-resistant and high-oil content varieties. Improved sesame varieties like BARI Til-4 and BARI Til-5, yielding up to 1.2 tons/ha, are adapted to dry, sandy soils, while research continues drought and heat-tolerance to mitigate climate change impacts. Research on minor oilseeds like linseed and Perilla is also advancing, with efforts to enhance oil content and yield for cultivation on marginal lands. Additionally, BARI, in collaboration with international partners like ICARDA and ACIAR, is utilizing advanced techniques such as biotechnology, marker-assisted selection and mutation breeding to develop next-generation oilseed varieties resilient to biotic and abiotic stresses.

Table 2. Research Achievements by Different Organization in Bangladesh

Oilseed Crops	**Variety Released by different Organization**					**Total**
	BARI	**BINA**	**BAU**	**BSMRAU**	**SAU**	
Rapeseed mustard	22	12	9	1	4	48
Groundnut	12	10	-	-	-	22
Sesame	6	6	-	-	-	12
Soybean	7	7	-	5	-	19
Sunflower	3	-	-	-	-	3
Linseed	3	-	-	-	-	3
Niger	1	-	-	-	-	1
Safflower	1	-	-	-	-	1
Total	**55**	**35**	**9**	**6**	**4**	**105**

Research is being conducted to optimize agronomic practices and ensure sustainable production of oilseed crops across diverse ecological zones (Shammary et al., 2024). Studies on balanced fertilization, including nitrogen (N), phosphorus (P), potassium (K) and micronutrients, are optimizing soil health and yield (Wang et al., 2024), while site-specific and integrated nutrient management (INM) systems are addressing fertility challenges in regions like Barind and the south. Efficient irrigation techniques such as drip irrigation and alternate furrow irrigation, are being promoted for mustard, soybean and sunflower in drought-prone areas, water logging-tolerant oilseed varieties are being tested in saline coastal regions. Integrated pest management (IPM) strategies, eco-friendly bio-pesticides and resistant varieties, aim to reduce reliance on chemical pesticides. Research on oilseed-based cropping systems, including Rice-Oilseed-Rice rotations and intercropping with cereals and pulses, is improving land use efficiency. Climate adaptation strategies, such as introducing heat-tolerant varieties, adjusting sowing times and refining management practices, are also being explored to combat extreme weather.

Dissemination of knowledge and practices is prioritized through initiatives like Farmer Field Schools (FFS) and demonstration plots, which train farmers in improved cultivation methods, pest control and resource-efficient practices. These efforts are particularly impactful in addressing salinity and drought challenges in the coastal belt and Barind tract. where specific challenges such as salinity and drought need tailored solutions. Demonstration plots showcasing high-yielding varieties like BARI Surjamukhi-2 and BARI Soybean-6 help farmers adopt improved oilseed production techniques. Workshops and seminars at upazila and district levels raise awareness of the economic potential of oilseed crops and government support programs, while specialized training on certified seed production, purity maintenance and post-harvest handling ensures a consistent supply of high-quality seeds. Collaborative efforts with private sector partners enhance processing, storage and marketing techniques, improving farmer profitability. These combined R&D and capacity-building efforts aim to boost oilseed productivity, achieve self-sufficiency in edible oil and address the unique challenges of Bangladesh's diverse agro-ecological zones.

Trends in Oilseed Supply and Demand in Bangladesh

The area and production of major oilseed crops have continuously declined over the last ten years (Fig. 4) in Bangladesh. The total area under major oil seed crops reduced from 400,000 ha in 1999-2000 to 317532 ha in 2005-06. Then the area again slightly increased and continued the trend up to 2008-09 and reached at 338471 ha. About 21% and 15% area under major oil crops have reduced in 2005-06 and 2008-09, respectively, compared to 2009-2000. Similarly, production has reduced from 313000 to 270130 tons during 1999-2000 to 2003-04.

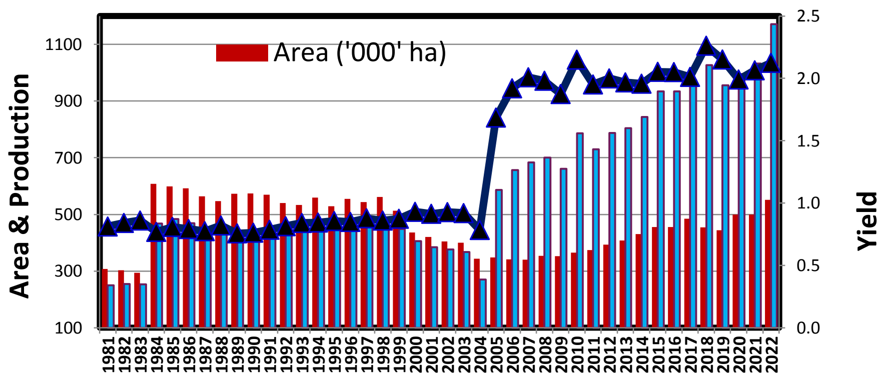

Fig 4. Area, production and yield trend of oilseeds crops in Bangladesh (1981-2022)

However, the production of oilseed crops has increased from 2004-05 and reached its maximum 358399 tons in 2007-08. But the total production again showed to decline in 2008-09. Individually mustard area has reduced from 328745 ha to 234019 ha, however, a little increase was found during last two years. Almost similar trend was found in production and reduced from 249000 tons to 202717 tons during this period. Sesame area was almost static from 1999-2000 to 2004-05 (around 38 thousand ha) but dropped down to 32947 ha in 2008-09. The production has increased slightly over the years and reached from 22000 tons in 1999-2000 to the highest at 39225 tons in 2005-06 then again declined sharply to 28461 tons in 2008-09. Groundnut area and production almost remained static over this period. However, a slightly decreasing trend was observed in area but an increasing trend was found in production. Climatic factors like drought and rainfall are mainly responsible for yield fluctuation over the years. The main reasons for declining area in oilseed crops are the expansion of irrigation facilities and crop competition in Rabi season. Farmers generally grow oil crops under rainfed conditions without much input and care. As a result, yields are low and they believe that oil crops are not as profitable as other crops like boro rice, potato, maize or vegetables.

The productivity of major oil crops is presented in Table-3. The analysis of productivity trend reveals that mustard yield has increased from 757 kg/ha in 1999-2000 to 866 kg/ha in 2008-09 with an annual grown rate of 1.44%. Similarly, sesame yield has increased from 591 kg to 864 kg/ha with a growth rate of 4.62% and groundnut yield has increased from 1235 kg to 1486 kg/ha with a growth rate of 2.03%. In case of soybeans the available data showed that yield increased from 1222 kg/ha in 2004-05 to 1478 kg/ha in 2008-09 with a growth rate 2.09%. The major reasons for the increase in growth rate of major oil crops are the adoption of modern HYV and improved production technologies by the progressive farmers. Over the past decade, oilseed production in Bangladesh has experienced a gradual upward trend, driven by the increasing demand for edible oil and government initiatives promoting oilseed cultivation (Table 1). Despite these efforts, domestic production remains insufficient to meet the national demand, resulting in a continued reliance on imports. Currently, rapeseed-mustard, the most widely cultivated oilseed crop, covers approximately 1.1 million hectares annually (Table 3). Figure 3. demonstrates that, from 2002-03 to 2013-14, the nation's total mustard production and area both decreased. Due to competition from numerous high-value winter crops, this decline is the result. Before Boro rice is grown, mostly mustard is grown. Many farmers typically keep their farms open for Boro rice because of the prolonged mustard season. Despite a reduction in area, there has been an increase in the yield of mustard per hectare over that time, primarily because of the use of better varieties and management techniques. In 2014-15 to 2020-21 overall area and production line fluctuate. In the recent past year, 2018-19 area and Production is low than the three previous years but yield increases. However, from 2019-20 through 2021-2022, production and yield rates are at their maximum.

Although yield fluctuations due to climate variability and soil fertility issues persist, the introduction of high-yielding, drought and salt-tolerant varieties such as BARI Sarisha-18, BARI Sarisha-19 and BARI Sarisha-21 has contributed to modest gains, with recent production reaching around 600,000 metric tons.

Table 3. Area, production and yield of oilseed crops in Bangladesh during 2023-24

Oilseed Crop	Area (Million ha)	Production (Million tons)	Yield (Tons/ha)
Rapeseed-mustard	1.10	1.61	1.46
Groundnut	0.09	0.18	2.05
Sesame	0.07	0.08	1.18
Soybean	0.09	0.17	1.84
Sunflower	0.02	0.03	1.65
Total	1.36	2.04	1.50

Source: DAE, 2024

Sesame

Figure 5. illustrates the fluctuation in sesame cultivation area and production from 1995-96 to 2021-22. Both area and production remained stable from 1995-96 to 1998-99, but experienced a sharp decline afterward. Between 2000 to 2010, a slow upward trend in both area and production of sesame was observed. Sesame yield remained relatively static from 1995-96 to 2003-04 but started to

decline in 2005-06. The yield rate peaked in 2015-16, followed by a period of stability in production from 2017-18 to 2020-21. In the years 2021-22, area and production decreased but yield rates increased.

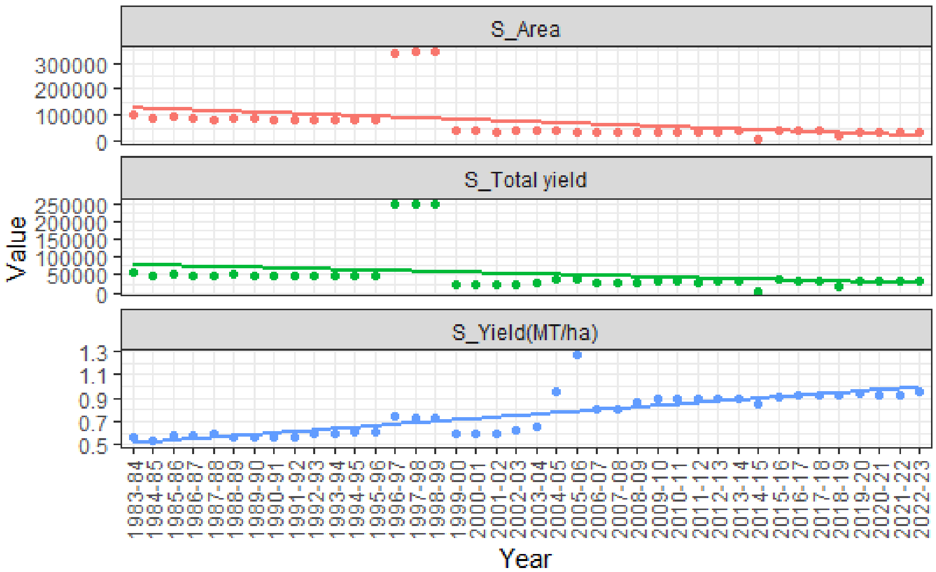

Fig 5. Trends of Sesame Cultivation Area, Production and Yield

Groundnut

Groundnut cultivation accounts for 6.97% of the total area and 6.73% of the total production of oilseed crops in Bangladesh (BBS, 2000-2021). From 1960 to 2019, oilseed crop production increased dramatically, rising from 64,000 MT to 956,000 MT a 14.9-fold growth in 2019, despite notable declines in 1975 (237,000 MT), 1980 (246,000 MT) and 2005 (274,000 MT). This increase is attributed to both area expansion and improved productivity, with yields rising from 0.18 MT/ha in 1960 to 2.1 MT/ha in 2019, reflecting the adoption of high-yielding varieties and improved farming practices (Bokhtiar et al. 2021). Figure 6 shows trend in the area, production and yield of groundnut from 1995-96 to 2021-22. The area and production remained stable from 1995-96 to 1998-99, followed by decline in cultivated area from 2000-01 to 2003-04. Afterward, the groundnut area displayed a fluctuating growth pattern. Production similarly declined during 1999-2000 to 2003-2004, but yields improved during the same period, likely due to the adoption of better cultivation technologies. The highest production and yield were observed in 2019-20, but both declined in 2020-21. In 2021-22, production and yield rebounded, surpassing levels of the previous two years.

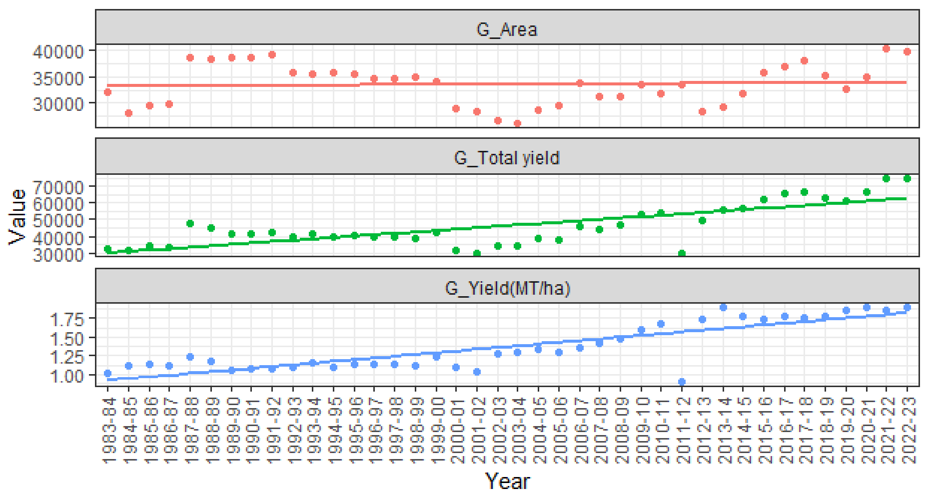

Fig 6. Trends of Groundnut Cultivation Area, Production and Yield

Source: BBS, 2023

Soybean

Bangladesh produces only 5-7% of its annual soybean demand, with cultivation largely confined to southern belt, including Noakhali and Lakshmipur (Chattagram Division) and Pirojpur, Patuakhali, Borguna and Bhola districts (Barishal Division). Domestically produced soybeans, predominantly used in the feed industry due to their poor quality and low oil content, are not utilized for oil production. The soybean planted area for 2024-25 is forecasted at 90,000 hectares, with production estimated at 155,000 MT, reflecting increases of 2% and 3%, respectively, over the 2023-24 estimates (Figure7). From 2007-08 to 2021-22 soybean area, production and yield fluctuated significantly, with notable increases between 2008-09 to 2011-12 and peaks in area and production during 2013-14 and 2018-19. The yield reached its highest in 2014-15 but has since shown a declining trend up to 2021-22.

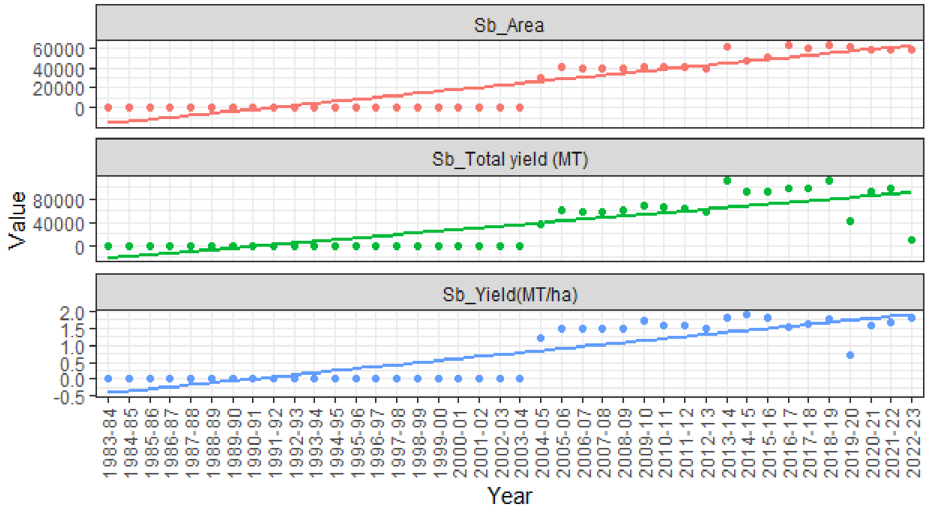

Fig 7. Trends of Soybean Cultivation Area, Production and Yield

Sunflower cultivation has been promoted in Bangladesh primarily over the past two decades as a climate-resilient crop, particularly in the saline-prone coastal regions. By 2024, sunflower farming covers approximately 14,700 hectares and the government aim to increase this to 34,600 hectares by 2025 to produce 53,400 tonnes of seeds annually. The average yield of sunflower seeds in Bangladesh is about 1.2 tonnes per hectare, with coastal regions showing potential for higher yields due to favourable conditions. Farmers are increasingly using fallow lands after Aman paddy harvests for sunflower cultivation Sunflower cultivation has expanded, particularly in saline-prone coastal areas, where it provides an alternative to traditional rice farming. Currently, sunflower production spans approximately 25,000 hectares, yielding around 50,000 metric tons. This crop has gained traction due to its resilience to saline soils and its high oil content, with further growth expected. Soybean cultivation has also increased, particularly in southern regions like Bhola and Noakhali, where it has become a profitable cash crop. However, while the cultivated area for soybeans is expanding, production levels, with average yields of 1.7 to 1.8 tons per hectare, still fall short of meeting domestic demand. Sesame, though a traditional oilseed crop, is mainly grown in marginal, dry lands. Recent development of higher-yielding, pest-resistant varieties like BARI Til-5 and BARI Til-6 has been aimed at encouraging broader adoption, but production remains steady at around 60,000 metric tons annually.

Despite these improvements, Bangladesh's oilseed production currently meets only about 30% of its edible oil requirements, leading to heavy reliance on imports (Table 1). The country consumes approximately 2.0 million metric tons of edible oil annually, a figure driven by population growth, urbanization and changing dietary habits (Figure 7).

Mustard oil is predominantly consumed in rural areas, while soybean oil is more popular in urban centres. Sunflower oil is also gaining popularity among health-conscious consumers. However, most of the edible oil demand is met through imports, with palm oil and soybean oil being the primary imports, sourced mainly from Malaysia, Indonesia and Argentina. Palm oil remains the most imported oil due to its lower cost, though there is a growing shift toward healthier oils like sunflower and soybean, a trend influencing both consumption patterns and policy direction.

To achieve self-sufficiency in oilseed production, several key areas require attention. Expanding the cultivation of oilseeds in underutilized regions, such as the coastal belt and the Barind Tract, is crucial. Currently, oilseed cultivation is often limited to small, fragmented plots, making it essential to scale up production to meet rising demand. The development and dissemination of high-yielding, disease-resistant and climate-resilient varieties, such as BARI Sarisha-17, BARI Surjamukhi-3 and BARI Soybean-6, are critical for boosting productivity across different ecological zones. Additionally, modern crop management practices, including proper fertilization, pest control and water management, must be widely adopted, with extension services playing a vital role in disseminating these techniques.

Table 4. Cultivation of oilseed crops in unfavourable ecosystems/fallow land

Unfavorable ecosystems	Area	Districts	Suitable variety
Char land	800 (000 ha)	Jamalpur, Gaibandha, Rangpur, Faridpur, Sirajgonj, Manikgonj, Kishorgonj, Tangail, Noakhali, Laxmipur, Barishal, Bhola	BARI Chinabadam-8, 9, 11 BARI Sarisha-14, 17, 18, 20 BARI Surjamukhi-3 BARI Soybean-5, 6, 7 BARI Til-4, 5, 6
Coastal areas (non saline & saline)	900 (000 ha)	Satkhira, Khulna, Bagerhat, Jhalokathi, Pirojpur, Borguna, Patuakhali, Bhola, Barishal, Laxmipur, Chandpur, Noakhali, Feni, Chattogram	<u>Non saline area</u> BARI Sarisha-14, 17, 18, 20 BARI Surjamukhi-3 BARI Soybean-5, 6, 7 BARI Til-4, 5, 6 <u>Saline area</u> BARI Sarisha-11, 18, 19 BARI Til-4

Unfavorable ecosystems	Area	Districts	Suitable variety
Barind tract	**300 (000ha)**	Dinajpur, Rangpur, Pabna, Rajshahi, Bogura	BARI Sarisha-14, 17, 18, 20 BARI Til-4, 5, 6
Haor areas	250 (000 ha)	Sylhet, Sunamgonj, Hobigonj, Moulovibazar, Kishorgonj, Netrakona, Bramanbaria	BARI Sarisha-14, 17, 20 BARI Surjamukhi-3
Hilly area	1600 (000 ha)	Rangamati, Bandarban, Khagrachari	BARI Sarisha-14, 17, 18, 20 BARI Til-4, 5, 6

One of the major challenges facing farmers is the limited availability of high-quality certified or TLS (Truthfully labelled seed) seeds, which are essential for improving yields. Strengthening the seed production and distribution system is necessary to ensure farmers have access to these resources. Oilseed crops also face significant threats from erratic weather patterns, drought and soil salinity. Therefore, research and development efforts must focus on creating climate-resilient varieties and promoting sustainable water and soil management practices, particularly in vulnerable regions.

Improving oil recovery efficiency in the processing of oilseeds is another key area. Currently, oil recovery varies depending on the crop and the processing methods used. For mustard, which has an oil content of 35-40%, traditional mills recover only about 30-32%, while modern mills can achieve up to 35%. Sunflower seeds, containing 40-45% oil, see a recovery efficiency of about 40% in modern facilities, though many small-scale farmers still use traditional methods with lower efficiency, around 35%. Soybean, with lower oil content (18-20%), has an oil recovery efficiency of about 18% in mechanized processing, but this can drop to 15% in smaller, less efficient units. Sesame, with an oil content of 45-50%, achieves recovery rates of only 30-35% in traditional methods, but this can increase to 40-42% with modern processing. Enhancing oil recovery efficiency through the introduction of modern extraction technologies, such as solvent extraction for soybean and sunflower, will be critical for reducing losses and increasing domestic oil production.

Overall, targeted interventions to boost oilseed production, improve processing efficiency and reduce import dependency are crucial for meeting the growing demand for edible oils in Bangladesh. These efforts will contribute significantly to enhancing the country's self-sufficiency in oil production and addressing the edible oil deficit.

Machinery Issue in Oilseed Crop Production and Processing in Bangladesh

One of the primary obstacles in oilseed production in Bangladesh is the lack of modern machinery for harvesting and processing, which significantly hampers the efficiency of pre- and post-harvest operations (Miah et al., 2017). Oilseed crops such as Mustard, rapeseed, sunflower, soybean and sesame are predominantly harvested manually, leading to elevated labor costs and time inefficiencies. Although mechanized solutions like combine harvesters for crops like mustard and sunflower exist, their adoption remains low due to challenges such as small farm sizes, limited farmer awareness and financial constraints (Mohammed et al., 2023). Coastal areas, where sunflower cultivation is expanding, face an acute shortage of specialized machinery, while soybean farmers similar rely on traditional hand tools, resulting in yield and quality losses. Multi-crop threshers designed for small seeds like mustard and sesame are available but are not widely distributed in rural areas, limiting their impact. The inefficiencies extend into the processing sector, where traditional ghani mills used for mustard and sesame extraction deliver low oil recovery rates (25-30%) compared to modern systems that 40-45%. These traditional methods also comprise oil quality due to high free fatty acid levels. Modern oil extraction plants, with their higher efficiency, are largely urban-centric, making them inaccessible to many rural farmers. Additionally, inadequate post-harvest practices, such as poor drying and storage, further degrade seed quality. Introducing solar or mechanical dryers could mitigate these issues by improving seed preservation. The oil processing sector also suffers from outdated methods that result in crude, unrefined oils with impurities, reducing both their nutritional value and marketability. Establishing modern oil refining units in rural areas could enhance the quality of locally produced edible oils. Furthermore, promoting packaging innovations and branding initiatives would improve market appeal and extend shelf life. The potential for value-added products, such as oilseed cakes for animal feed or biofuels, remains largely untapped due to inadequate infrastructure and limited technological interventions.

In summary, improving access to modern machinery, enhancing oil processing facilities and promoting value addition are crucial for improving oilseed productivity and profitability of oilseed crops in Bangladesh. Mechanization, efficient post-harvest handling and the adoption of advanced refining techniques will boost overall efficiency, improve oil quality and unlock the economic potential of the country’s oilseed sector.

Marketing Issues Related to Different Oilseed Crops in Bangladesh

The marketing of oilseed crops in Bangladesh faces multiple challenges that limit productivity and profitability. Key issues include poor infrastructure, limited market access, price volatility and inadequate farmer awareness of market dynamics and quality standards. Rural transportation infrastructure is underdeveloped, particularly during the monsoon season, which delays market access, increases post-harvest losses and raises transportation costs. The lack of adequate storage facilities compounds these problems, as oilseeds susceptible to moisture and pest damage often must be sold immediately after harvest at reduced prices. Additionally, the absence of cold storage affects seed quality and shelf life, further increasing losses.

Price volatility is a persistent concern for farmers, driven by seasonal supply variations, market speculation and fluctuating demand. Oversupply during the harvest season depresses prices, while off-season prices rise, creating uncertainty for farmers and complicating production planning. Smallholders are particularly disadvantaged, often relying on intermediaries who capture a large share of profits, leaving farmers with reduced income. Establishing direct marketing channels between farmers and processors or consumers would ensure fairer pricing and reduce intermediary dependence. Providing timely market intelligence through mobile apps or community platforms could also empower farmers to make better-informed decisions.

Quality inconsistency in oilseed production and handling is another obstacle. Poor post-harvest practices and inconsistent cultivation standards deter buyers from paying premium prices. Educating farmers on quality standards and implementing a certification system for high-quality oilseeds would enhance their marketability and boost both domestic and export opportunities. Branding locally produced oils and promoting their nutritional value could further improve competitiveness and enable premium pricing. The lack of local oilseed processing facilities also limits farmers' ability to add value to their produce. Most farmers sell raw seeds instead of processing them into oil or utilizing by-products, missing opportunities for higher earnings. Investments in local processing units and the establishment of cooperative models could help farmers access value-added markets.

There is growing demand for organic and specialty oils, such as cold-pressed mustard and sesame oil, but many farmers lack the necessary resources and knowledge to tap into these niche markets. Promoting organic farming practices and supporting the development of marketing strategies for high-value products would create additional income streams for farmers. Furthermore, imported edible oils, particularly palm oil, dominate the market due to their lower cost, putting downward pressure on prices for domestic producers. Policies that encourage the consumption of locally produced oils through incentives and public awareness campaigns could help counter this competition. Highlighting the nutritional benefits and superior quality of domestic oils may also shift consumer preferences toward local products.

Addressing these challenges requires a multifaceted approach. Improving rural infrastructure, providing access to fair pricing mechanisms, promoting value-added opportunities and establishing quality certification systems are essential. Collaboration between government, NGOs and private stakeholders is crucial to creating a more efficient and equitable marketing system for oilseed farmers in Bangladesh.

Government Policies for the Production Enhancement of Oilseed Crops in Bangladesh

The Government of Bangladesh has implemented a series of policies aimed at boosting oilseed crop production to reduce dependency on imports and achieve self-sufficiency in edible oil (USAID, 2022). Central to this effort is the National Agricultural Policy, which prioritizes oilseed crops like mustard, soybean, sunflower and sesame by encouraging research and development (R&D) for high-yielding, disease-resistant and climate-resilient varieties. Government institutions, including the Bangladesh Agricultural Research Institute (BARI) and the Oilseed Research Centre, play a key role in breeding and field trials to advance these goals. Additionally, public-private partnerships (PPPs) are promoted to leverage private sector expertise and investment for improving seed production, processing and market access. Extension services provided through the Department of Agricultural Extension (DAE) aim to improve farmer knowledge on modern farming techniques, pest management and post-harvest handling. These include regular training sessions, workshops and field demonstrations, often supported by farmer field schools, to disseminate best practices directly to the farmers.

To lower production costs and encourage the adoption of new practices, the government offers subsidies on fertilizers, pesticides and high-quality seeds. Access to credit is also facilitated through government-backed financial programs and microfinance institutions, providing farmers with low-interest loans to improve their farming operations. Rural infrastructure development, including the construction of better roads and storage facilities, has also been a priority to reduce post-harvest losses and enhance market access. Modern storage facilities, including cold storage for oilseeds, help maintain seed quality and increase their market value. The government is promoting local processing facilities to enable farmers to add value to their oilseed crops. This not only improves farm income but also ensures that high-quality edible oils and by-products are available to local markets. To further support domestic production, import tariffs on edible oils are regulated to protect local oilseed farmers from cheaper imported oils.

The government has implemented initiatives to reduce reliance on edible oil imports by boosting domestic production of oilseeds, including mustard, sunflower and sesame. A project launched in 2020 aims to increase mustard, sunflower and sesame acreage by 20% by 2025 and achieved 40% self-sufficiency.

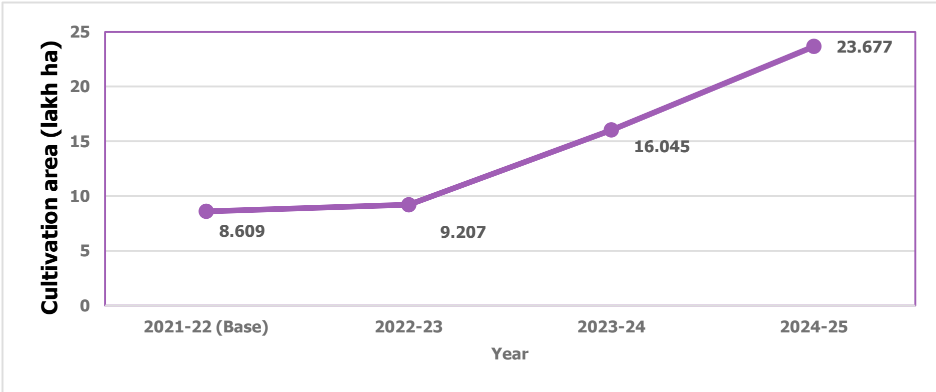

Fig 8. Planning for increasing oilseed cultivation during next three years (2022-25)

Climate-smart agriculture is emphasized to enhance the resilience of oilseed crops to climate change (Benitez-Alfonso et al., 2023). The development of drought- and salt-tolerant varieties, sustainable land and water management practices and the promotion of crop diversification are key strategies in this effort (Muhammad et al., 2024). These practices are disseminated through public awareness campaigns and training sessions. To ensure long-term sustainability, the government is increasing investment in advanced agricultural research, focusing on breeding techniques, biotechnology and precision agriculture to create varieties that yield more and are resistant to diseases and pests. Cooperative models are also being strengthened to improve collective bargaining and marketing power for oilseed farmers, allowing them to access better services and markets. As production increases, the government is also exploring opportunities for exporting high-quality oilseed products by enhancing quality standards and market competitiveness. By improving branding and market access, the government aims to tap into international markets.

Public-Private Partnerships (PPPs) have proven to be a critical mechanism in enhancing oilseed crop production and marketing. Collaborations between public research institutions, such as BARI and private agricultural firms foster the development of high-yielding and climate-resilient varieties. The private sector's role extends to promoting modern technologies like precision agriculture and integrated pest management, which reduce environmental impacts while increasing productivity. In terms of seed production, PPPs ensure the availability of certified, high-quality seeds, while private sector logistics and distribution improvements help minimize post-harvest losses. PPPs are also instrumental in establishing oilseed processing units, allowing farmers to produce refined oils and value-added products, thus increasing profitability and rural employment. Private sector engagement has also been crucial in providing farmer training on modern cultivation practices, post-harvest handling and market access. These partnerships help transfer knowledge and skills that directly improve farm productivity. Moreover, PPPs facilitate access to financing, with private banks offering low-interest loans and insurance products tailored to oilseed farming. Investments in rural infrastructure, such as processing facilities and transportation networks, enhance the overall efficiency of the oilseed supply chain, benefiting both farmers and processors. Market development is another area where PPPs have significant impact. The private sector aids in establishing digital marketing platforms, enabling farmers to reach broader markets and negotiate better prices. E-commerce solutions empower farmers by expanding their market reach and ensuring price transparency.

Finally, PPPs are key in policy advocacy by engaging public and private stakeholders to address regulatory challenges and create a favourable environment for oilseed production. By aligning goals, these partnerships enhance the sector's sustainability and resilience, leading to a more productive and profitable oilseed industry in Bangladesh. In summary, the government's comprehensive policies, coupled with strategic PPP initiatives, have laid the foundation for a more resilient and self-sufficient oilseed sector. Through R&D, infrastructure improvements, financial support and value addition, Bangladesh is positioning its oilseed industry for sustainable growth and export potential.

Way Forward for Enhancing Oilseed Crop Production in Bangladesh

To enhance oilseed crop production in Bangladesh, a comprehensive approach is essential, focusing on modern agricultural practices, financial support, diversification and infrastructure development (Miah et al., 2017). Encouraging the adoption of precision agriculture and Integrated Pest Management (IPM) will optimize resource use and minimize environmental impact. Upgrading oil extraction technologies, such as cold-press and solvent extraction methods, will improve oil recovery efficiency while maintaining quality. At the same time, stringent quality control standards must be enforced to ensure the oil meets international benchmarks, boosting both marketability and price.

Diversification of oilseed crops, including mustard, soybean, sunflower and sesame, is vital to reducing the risks associated with market volatility and climate changes. Developing and promoting climate-resilient varieties, particularly drought-resistant and salt-tolerant strains, will be key in mitigating the adverse effects of climate change, particularly in coastal and salinity-prone regions. Crop rotation and intercropping systems involving oilseeds should also be promoted to enhance soil health and improve pest management while optimizing land use. Identifying regions most suitable for different oilseed crops based on soil type, climate and water availability will enable more targeted policies to support growth in those areas.

Increased financial investment in agricultural research and development will play a critical role in advancing oilseed breeding programs and field trials. Strengthening extension services will ensure that farmers receive timely, relevant information on best cultivation practices and market opportunities. Financial incentives, such as input subsidies and access to low-interest loans, will encourage farmers to adopt improved, high-yielding oilseed varieties and invest in sustainable farming techniques. Capacity-building programs for farmers, cooperatives and agribusinesses should also be developed, emphasizing skills in production, marketing and financial management.

Developing a strong national brand identity for Bangladeshi oilseed products, focusing on quality, sustainability and local origins, will enhance both local and international market appeal. Expanding the range of oilseed-based products, including cooking oils, margarine and value-added by-products like oil cakes for animal feed, will help diversify income streams for both farmers and processors. Awareness campaigns promoting the health benefits and local origins of Bangladeshi oilseed products can further boost domestic demand.

Improving rural infrastructure is critical to facilitating market access and reducing post-harvest losses. Investments in roads, storage facilities and processing units will increase the efficiency of the oilseed supply chain. Encouraging the formation of farmer cooperatives will strengthen collective marketing efforts, enhance bargaining power and provide shared resources for processing and distribution. Conducting market research will help better understand consumer preferences, pricing trends and demand, thereby enabling more effective production and marketing strategies.

Bangladesh should also explore international market opportunities for its oilseed products, ensuring that producers meet the necessary quality standards for export. Additionally, climate adaptation strategies, such as promoting agroforestry, water conservation and soil health management will help farmers mitigate the effects of climate change on oilseed production. Collaborative efforts among farmers, government agencies, private sector players and research institutions will be essential in scaling up oilseed production, improving efficiency and achieving self-sufficiency in edible oils, thereby strengthening the agricultural economy and improving farmers' livelihoods.

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Chapter 3

Status of Oilseed Crops in Bhutan

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Abstract

Bhutan is a small, landlocked country located in the eastern Himalayas with a total area of 38394 km2. The country has a forest cover of 69 % and continues to remain carbon-negative and only 2.96% of the land is available for agriculture. Agriculture sector which comprises Crops and Livestock remains the cornerstone of Bhutan's economy engaging 43.5% of the population and contributing 12.09% to the GDP (NSB, 2023). Bhutan's' agriculture sector is largely subsistence with a slow transition towards commercial farming. Agriculture in Bhutan faces numerous challenges such as the small size of landholdings primarily located in difficult and mountainous terrain. This rugged geography restricts the adoption of mechanized farming techniques, resulting in labour-intensive farming practices. While cereal crops have traditionally been the focus, oilseeds are emerging as essential crops for promoting food and nutritional security. However, Bhutan's edible oil and oilseed sector faces multiple challenges. Oilseed crops are considered secondary to cereals and fruits and vegetables and receive much lower priority in terms of resource allocation. The primary oil crops cultivated in Bhutan include rapeseed (Brassica campestris var. toria, locally known as tori or peka), mustard or Indian mustard (Brassica juncea), groundnut (Arachis hypogaea), sunflower (Helianthus annuus), Niger seed (*Guizotia abyssinica*) and soybean (Glycine max). The productivity is low and unstable and the availability of inexpensive, imported refined soybean oil makes locally-produced oilseeds less competitive. The post-production facilities are not developed and oil expelling is almost non-existent. This situation has reduced the attractiveness of domestic oilseed production, negatively impacting the sector's growth and sustainability. The current average yield of oilseeds in Bhutan is approximately 284 kg per acre, which falls short of meeting the national demand. To fulfill domestic vegetable oil requirements, the country relies heavily on imports, spending more than Nu 1394 million annually on imported oils. Increasing local oilseed production is vital for reducing this import burden and enhancing Bhutan's food security. To achieve this, a comprehensive approach is needed. Investments in crop improvement programs, enhanced soil nutrient management, post-production and prioritization of activities across the entire oilseed value

chain will be critical. Strengthening these areas could lead to more sustainable production, increased yields and a more self-sufficient oilseed sector in Bhutan.

Keywords: Agriculture, Import, Oilseeds

Introduction

Despite its small size, Bhutan has a diverse ecosystem, from subtropical plains in the south to alpine landscapes in the north. The country lies on the southern slopes of the Eastern Himalayas, between latitudes 26°42′ N and 28°14′ N and longitudes 88°44′ E and 92°07′ E, spanning over an area of 38,394 square kilometres. As per the survey conducted by the Department of Survey and Mapping (DoSAM, 2023), only 2.96% of the land is available for cultivation, which is approximately 281,186.29 acres, while primary land cover falls under forest cover, which accounts for approximately 69.0%, underscoring the scarcity of arable land. Although Bhutanese farmers rely on subsistence farming, agriculture remains a key sector in Bhutan’s economy with its 43.5 % of the population engaged in agriculture, where female workers represent a higher portion (53.3%) than male workers (NSB, 2023). Over recent years, Bhutan has gradually progressed toward modernization, striving to balance economic development with cultural preservation and environmental sustainability. While historically focused on subsistence farming, the country’s food system is gradually transitioning to a more intermediate stage. Gurung (2012) highlights the transition in some communities from subsistence to semi-subsistence and even semi-commercial farming. The agricultural sector’s share of the economy stands at 12.09% (crop accounting 6.81% & Livestock 5.28%) of the GDP, with the Gross Value Added (GVA) record at Nu. 3,312.31 million in 2023, compared to Nu. 33,422.58 million in 2022 (NSB, 2024)

Agricultural practices in Bhutan face limitations due to the small size of landholdings, which are largely situated on challenging, rugged terrain. This geographical constraint hampers the adoption of mechanized farming techniques, making agricultural processes labour-intensive (Tobgay, 2005). Rice, maize, wheat, barley, buckwheat and millets are major staple cereals cultivated by the farmers and the average landholding size is approximately three acres, indicating that Bhutan's agricultural production system can be characterized as a smallholder system (Katwal, et al., 2015).

Besides cereals, oilseeds represent a valuable and essential crop within the SAARC region for ensuring food and nutritional security. However, the edible oils and oilseeds sector faces significant challenges. The horizontal expansion of oilseed cultivation is constrained by decreasing per capita arable land and competition with other crops as mustard is considered a marginal crop and receives low priority at a commodity level. Furthermore, low and unstable yields have made oilseed farming less appealing. A primary barrier to the widespread adoption of high-yielding oilseed varieties for productivity improvement is the limited availability of quality seeds. Access to seeds with high genetic purity is crucial for increasing production. The similarities in biotic, climatic and edaphic conditions among regional countries provide an opportunity to establish a collaborative platform for joint efforts. Consequently, substantial benefits can be achieved by sharing varietal evaluation tasks. Harmonized approaches facilitate the exchange of information, knowledge and collaborative efforts across countries.

The primary oil crops cultivated in Bhutan include rapeseed (*Brassica campestris* var. *toria*, locally known as *tori* or *peka*), mustard or Indian mustard (*Brassica juncea*), groundnut (*Arachis hypogaea*), sunflower (*Helianthus annuus*), Niger seed (*Guizotia abyssinica*) and soybean (*Glycine max*). In Bhutan, the term 'mustard' generally encompasses Brassica oil crops, specifically rapeseed and mustard, which are the dominant oilseeds used for oil extraction. Soybean and groundnuts are popularly grown in the eastern part of the country. However, soybeans are used as grain legumes, while groundnuts are used as a snack and not grown for oil extraction, mainly due to a lack of appropriate oil processing facilities. Niger seed (*Guizotia abyssinica*) is grown in small areas during summer in the lower hills. Sesame (*Sesamum indicam*) grows in the southern parts of the country. Two types of sesamum are grown, one with white seed and the other with black seed. Additionally, various perennial oil-bearing trees are harvested for oil extraction, including *Symplocus paniculata* (locally known as *Pangtsi*), found in abundance in the mid-altitude valleys of Punakha and Wangdue, *Madhuca butyracea* (*Yika*), which is found in Eastern Bhutan is mostly used for lamp oil. However, the oil and fruits are edible. *Jatropha curcas* (*Karshing* or *Kadam*), is widespread in the country and is mainly used as live fence and for erosion control and soap making and *Neolitsea* species (*Shingshe*) found in eastern parts of the country is used for consumption and lighting lamps (Ghimiray, 2005).

Significance of Oilseeds

Oilseed crops are critically important for agriculture, the economy and food security. They are a primary source of edible oils, rich in essential fatty acids, vitamins and nutrients essential for human health, need approximately 5 grams a day of linolenic acid, an unsaturated fatty acid that cannot be manufactured within the body. It is also a source of energy that provides over twice as much per gram as carbohydrates or protein. It is the most efficient means of meeting undernourishment, where sheer calorific intake is the primary dietary requirement (Pitts, Dorling, & Pattie, 2007). Vegetable oil is primarily used for cooking and food preparation (55%) and as a source of biodiesel (18%). Much of the cooking oil use involves frying, which generates used oil that can later be converted into biodiesel. Beyond these uses, vegetable oils are also used in cosmetics and varnishes and are increasingly used in animal feeds, especially aquaculture (OECD/FAO, 2024) . As per the findings of OECD/FAO, 2024, gglobally, per capita vegetable oil consumption for food is expected to dip slightly (about 0.2%) due to reduced demand in high-income nations. However, between 2014 and 2023, demand grew at an average rate of 0.8% per year. In countries like China (27 kg per person) and Brazil (28 kg per person), however, the per capita demand for vegetable oil for least developed countries (LDCs) is projected to remain stable at 6.5kg/capita. Bhutan relies heavily on the import of vegetable oils to meet its domestic demand, spending significant amounts annually. In 2023 alone, the country imported approximately 12,036 metric tons of edible oils, including soybean, sunflower, palm, rapeseed and mustard oils. According to Bhutan Trade Statistics (BTS, 2023), this import activity amounted to a total value of Nu. 1,394 million, highlighting the country's dependency on external markets for essential cooking oil supplies. Mustard seeds are also being imported into Bhutan for various purposes, including culinary and industrial applications. According to the Bhutan Trade Statistics, over the past five years (2019-2023), the country has recorded an import volume of 50 metric tons of mustard seeds. This import activity has a total estimated value of Nu. 4 million, highlighting the ongoing demand for mustard seeds beyond domestic production. According to a status report published by the Department of Agriculture (DoA), the self-sufficiency ratio (SSR) averages 28.86%. The per capita availability for consumption averages 2.19 kg annually, contributing an available dietary energy supply (DES) of 28.08 kcal per capita per day, along with 1.49 g/day of protein and 1.72 g/day of fat (Dukpa, et al., 2021).

Agronomically, oilseed crops improve soil health and fertility through crop rotation. Rotating oilseeds with cereals or legumes disrupt pest and disease cycles, adds organic matter and enhances soil structure, making them integral to sustainable agricultural systems. Oilseed crops exhibit drought resilience and can thrive under diverse climatic conditions, making them suitable for cultivation in arid and semi-arid regions. This adaptability provides a viable cropping option in response to climate change. The multifaceted roles of oilseed crops underscore their versatility and significant impact at both local and global scales.

Mustard Production System in Bhutan

Mustard and rapeseed are the predominant oilseed crops cultivated in Bhutan, spanning a wide elevation range from 200 meters to over 3,000 meters above sea level. The area under oilseed cultivation is gradually decreasing due to limited economic viability. This decline is driven by a restricted selection of cultivars and high production costs, which make domestic production less competitive against cheaper imports (Dukpa, et al., 2021). Mostly rapeseed & mustard are cultivated in non-terraced, rainfed drylands, while approximately 10% is grown in terraced paddy fields following the rice harvest. At present oilseeds occupies a mere 1.9 percent of the area covered by cereal and oil crops occupyy 7th position in terms of area and production after paddy, maize, buckwheat, wheat, millet and barley (NSB, 2024). Mustard production is primarily grown by subsistence farmers, aiming to meet household requirements for cooking oil and oil cakes used as animal feed. A small fraction of mustard is marketed and consumed as leafy greens. It is predominantly grown as a short-duration crop in rotation with staple crops such as maize, potatoes and rice, adapting well to varied farming systems across different elevations in Bhutan. The cropping system in which mustard cultivation is popular is maize and potato-based in dryland conditions, whereas in the wetland rice-mustard cultivation is more popular (Table 1).

Table 1. Mustard production system under different agroecological zones in the country

Agro Ecology	Altitude range	Cropping System	dryland/ wet land	Dzongkhag
Warm temperate	1800-2600	Mustard-Wheat	dry land	Gasa, Bumthang, Haa
		Potato-Mustard	dry land	Wangdi, Bumthang, Paro, Haa, Chukha, Thimphu, Trongsa, Trashigang, Mongar, Pemagatshel
Dr.y Subtropical	1200-1800	Maize-Mustard	dry land	Mongar, Trashigang, Lhuentse, Trashiyangtse, Pemagatshel,
		Rice- Mustard	Wetland	Punakha, Wangdi, Trongsa, Lhuentse, Trashigang
Humid Subtropical	600-1200	Maize - Mustard	dry Land	Sarpang, Samtse, SamDr.upjongkhar, Chukha, Zhemgang, Dagana, Trongsa, Tsirang
		Rice- Mustard	Wet Land	
Wet Subtropical	150-600	Maize - Mustard	dry Land	Sarpang, Samtse, Samdrupjongkhar, parts of Chukha, Tsirang & Dagana
		Rice- Mustard	Wet Land	

Source: Oilseed Strategy paper 2015, DoA

Mustard cultivation in dryland areas commences immediately after the harvest of maize and potatoes, with sowing generally conducted between August and September. In terraced rice fields, mustard sowing is delayed until November or December, following the completion of the paddy-growing season. Historically, rapeseed and mustard were widely cultivated as winter crops; however, this practice has been gradually declining, resulting in fields being left fallow after the rice harvest. On the other hand, in the wetlands, there are other competing crops, such as wheat and vegetables. Mustard is grown as a secondary crop in the dry land under rainfed conditions (Ghimiray, 2005).

The current production scenario for mustard is gradually declining and considerably low despite a fairly good existing production potential as oilseed crops are considered secondary to cereals and fruits and vegetables and receive much lower priority in terms of resource allocation. The total harvested area under mustard is reduced to 902.48 acres with a total production of 256.07 MT. (National Statistic Bureau, 2024) from 2685 acres with a total production of 790 MT. (NSB, 2012). The current average yield is estimated at 284 kg/acre.

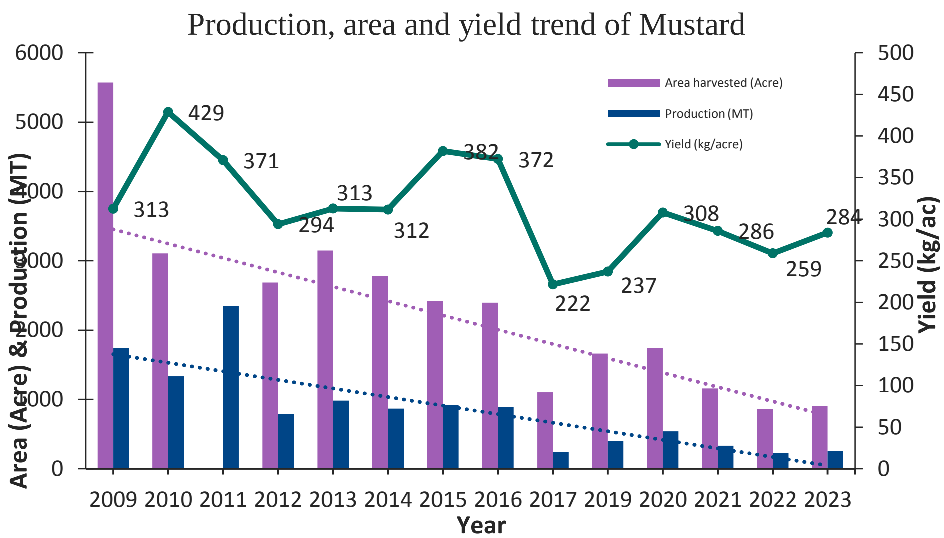

Fig 1. Production trend in Bhutan

Table 2. Oilseed production by type for the year 2023

Type	Sown Area (Acre)	Harvest Area (Acre)	Production (MT)
Mustard	1016.28	902.48	256.07
Sunflower	7.4	7.07	3.32
Soyabean	258.88	224.66	65.93
Groundnut	219.72	196.69	120.7
Perila	54.26	48.65	11.96

Source: National Statistical Bureau, 2023

Research & Development

Agricultural research in Bhutan began with introducing high-yielding crop varieties and evaluating modern agricultural practices. The Agriculture Research and Development Centres (ARDCs), under the Department of Agriculture (DoA), are primarily responsible for research in crop improvement for field crops and horticulture and disseminate agriculture technologies. The national mandate to conduct the field crop research has been designated to ARDC, Bajo and the oilseed program is subsumed under the field crop sector. However, over the years, the National Ooilseeds pprogram has been coordinated by different centres without continuity and focus of the oilseed commodity program. Currently, the National Centre for Organic Agriculture, Yusipang is the custodian of the oilseed research and development program. Therefore, it can be assumed that oilseeds R&D has been largely dependent on individual personnel, as reflected in the shift in areas. Most of the oilseed R&D is focused on rapeseed & mustard with little or no investment in other potential oil crops. Since the 1960s, Bhutan has been importing foreign germplasm. Sources of germplasm include CGIAR centres such as IRRI, CIMMYT, ICARDA and AVRDC, as well as countries like Bangladesh, India, Japan, Korea, Nepal and Thailand (Ghimiray & Vernooy, 2017). Varietal improvement is a key approach to developing technologies that address biotic and abiotic stresses in agriculture. Ghimiray & Katwal, 2013 state that over 60% of agriculture and research development Centers' resources and efforts are dedicated to germplasm evaluation, adaptation and promotion. Bhutan relies solely on donors and relevant institutes abroad for breeding lines and germplasm that are evaluated in the country.

Table 2. Mustard varieties released for different agroecological zones in the country

Sl. No	Name of the variety	Origin	Year of Release	Releasing agency	Yield potential (t ha^{-1})	Maturity days after sowing	Remarks
1	Type 9	India	1989	RDC Bajo	0.4	90-95	<2000 m
2	M 27	India	1989	RDC Bajo	0.4	85-90	<2000 m
3	Bajo Peka 1 (BSA)	Pakistan	1994	RDC Bajo	0.5	145-155	<2000 m
4	Bajo Peka 2 (PT 30)	India	1994	RDC Bajo	0.4	120-130	<2000 m
5	Yusi Peka 1 (Lumley Tori)	Nepal	2017	RDC Yusipang	1	90-95	Rainfed dryland
6	Yusi Peka 2 (Barisarisha 14)	Bangladesh	2017	RDC Yusipang	1	90-95	Terraced wetland

Source: Department of Agriculture

Of the six mustard varieties released, four varieties were released by the Research and Development Centre, Bajo and are over 20 years old while two new varieties introduced from Nepal and Bangladesh were released by the National Centre for Organic Agriculture, erstwhile Research and Development Centre, Yusipang (Table 2). The most widely grown variety, M-27, was released in 1989, specifically recommended for rainfed areas below 2000 masl. Similarly, PT-30, was released as Bajo Peka-2 in 1994 and is also recommended for rainfed conditions. The toria variety T-9, was released in 1989 for both irrigated and rainfed conditions while the variety from Pakistan, BSA was introduced in Bhutan as Bajo Peka-1 in 1994. This variety is later maturing than the other varieties and has a slightly higher yield potential. These mustard varieties have been cultivated in Bhutan for over two decades, with yields remaining stagnant over time. The two newly released varieties have more than double the yield potential compared to the old varieties. During the adaptation and evaluation of the new varieties, Lumle Tori 1 was targeted for temperate areas and is recommended for dryland farming systems. The two newly released mustard varieties exhibit more than double the yield potential of older varieties. During the adaptation and evaluation phase, *Lumle Tori 1*released as *Yusi Peka 1* in Bhutan was introduced from the Nepal Agriculture Research Centre (NARC) in 2014 and officially released in 2017. This variety was targeted for warm-temperate and is suitable for dryland farming systems. Another variety, *Bari Sarisha15*, introduced from the Bangladesh Agricultural Research Institute (BARI) and released as *Yusi Peka 2* in 2017, belongs to the *Brassica rapa* species and is distinguished by its white flowers. This variety is recommended for the subtropical zone, particularly in maize-based systems at altitudes between 300 and 1,400 meters above sea level, but it can also be cultivated within rice-based systems with assured irrigation.

The *M-27* variety has been widely adopted for mustard promotion programs. While the yield of the newly released varieties *Yusi Peka 1&2* is considerably high over *M-27*, the National Seed Center is not able to meet the demand. Commercial production of the older mustard varieties has been discontinued, with their cultivation now limited to maintaining of seed within the releasing agency. This led the Department of Agriculture to pursue new high-yielding varieties, resulting in the establishment of the National Oilseeds Program under the Eleventh Five-Year Plan (2013-2018). This program was designed to direct research and development efforts toward oilseed crops with a focus on:

- Enhancing the production of mustard which is the most predominant oil crop
- Supplementing household oil self-sufficiency by increasing production and oil extraction at the local level
- Targeting potential growing areas in traditionally mustard-growing Dzongkhags

- Addressing the seed supply and technology gaps through adaptive research and aggressive seed production
- Improving and enhancing the utilization of existing oil expellers efficiently

Trends in edible oils supply and demand

According to OECD/FAO 2021, vegetable oil has one of the highest trade shares (41%) of production among all the agriculture commodities and the global demand for vegetable oil is projected to expand by 33 MT by 2030, with food use accounting for 68% of total demand. India, the world's largest importer of vegetable oil, is expected to sustain a high import growth rate of 3.4% per year, driven by increasing domestic demand and limited potential for production growth. Likewise, the production of oilseeds has not kept pace with the increasing demand of the growing population and rise in per capita consumption. The demand for edible oils is increasing in Bhutan and to meet the growing need, the country is importing huge quantities of edible oils. The edible oil requirement of the country is met through imports. The total edible oil import is valued at Nu. 1394 million in 2003 (BTS, 2023) (Fig. 2). The edible oils include soybean, palm, sunflower, groundnut, rapeseed and mustard. Another key edible oil imported is in the form of Dalda which is largely used for lighting butter lamps for religious purposes. The import of edible oil combined with Dalda comes second to rice in terms of the import value which is quite alarming. To progressively reduce this huge import dependency, an aggressive and sustainable oilseed program has to be pursued. To enhance the household level of edible oil self-sufficiency, adequate oil expelling facilities is crucial.

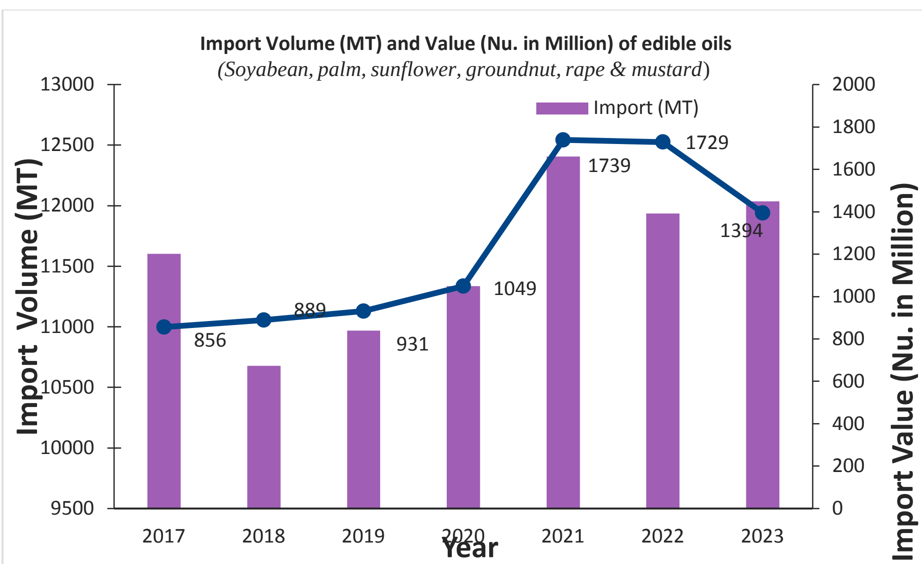

Fig 2. Import trend of edible oil in Bhutan

Table 3. Import of edible oils by type in the year 2023

Type	Import volume (MT)	Value in million
Soya bean oil	11224	1297
Palm oil	355	42
Sunflower oil	19	3
Rape oil	259	29
Mustard oil	180	24
	12036	**1394**

Source: BTS, 2023

In 2023, Bhutan imported approximately 12,036 metric tons (MT) of edible oils, including a variety of types such as soybean, sunflower, palm, rapeseed and mustard oils**,** according to the Bhutan Trade Statistics (BTS, 2023). This substantial volume of imports underscores the country's heavy reliance on external markets to meet its domestic demand for essential cooking oils. The total value of these imports reached an estimated Nu. 1,394 million, highlighting the significant financial burden this dependency places on Bhutan's economy. With local production accounting for only a fraction of the national requirement (256.07 MT), imports fill the substantial gap, ensuring a consistent supply of cooking oils for households and industries.

This dependency drains foreign exchange reserves and exposes Bhutan to risks associated with global supply chain disruptions, price volatility and geopolitical uncertainties. The high import costs further emphasize the need for sustainable strategies to reduce reliance on international markets, such as enhancing domestic production capabilities, diversifying oilseed cultivation and encouraging the consumption of locally-produced oils.

Major Constraints in Oilseed Production

The main challenges of oilseed production towards self-sufficiency and food and nutritional security in Bhutan can be linked to several socioeconomic, technological, infrastructure and institutional constraints.

Socio-economic challenges

Rapidly declining production and cultivated area- Over the years there has been a continuous decline in production and the harvested area under mustard as the oilseed crops have not received the desired attention in the past (Kumar, 2007). The decline in area and production can be attributed to various socio-economic and technical factors. Oilseed crops which used to be grown widely in the past have now been abandoned. The decline in the area under oilseed crop production is largely due to low productivity and less economical than other crops. This is due to the limited choice of cultivars and the high cost of production, the cost of production for mustard is estimated to be Nu.51 per kg (Dukpa, et al., 2021). This could also be attributed to inadequate access to production inputs mainly good quality seeds and farm labour availability. According to the mustard CCA survey reported (MoAF, 2008), the use of labour input in mustard cultivation is high averaging 70 person-days per hectare. In Bhutan, farm labour is scarce and costly with wages around Nu 100 per day with 2-3 meals provided. This labour shortage is due to the country's small population and various competing factors, such as opportunities for off-farm work, children attending schools and monastic institutions and migration to urban areas. The accessibility of cheap and non-pungent imported refined soybean oil from India has made local production less attractive and has negatively impacted the oilseeds production in the country.

Farmers feel that, it is more economical to rely on oil available in the market instead of cultivating the crop and then expelling it. While our consumers are reaping the benefits of free trade, the existing consumption trend poses critical questions about food and nutritional security.

In recent past, the Department of Agriculture has actively promoted and supported farmers in transitioning to commercial vegetable farming, encouraging a shift toward market-oriented crop production systems. As a result, farmers have increasingly allocated their land to cultivate crops with high market demand. Notably, mustard is now commonly harvested at an earlier growth stage and marketed as a green leafy vegetable, reflecting a shift in its utilization to align with consumer preferences and market trends. According to (Kumar, 2007) expelling oil by traditional means and insufficient oil expellers in Bhutan is one of the key issues in the oilseeds value chain. According to the 11th Five Year Plan document, there are 234 oil expellers spread across the country. These oil expellers are characterized by poor oil recovery and a high incidence of breakdown (MoAF, 2008). There is still a mismatch of location, spread and distance between oil expellers and the growers, which is a concern to the farmers.

The farm labour shortage in villages is the most important constraint faced by farming communities followed by human-wildlife conflict and lack of desired policy framework for the oilseeds sector (MoAF, 2008). These socio-economic factors created the dependency of the Bhutanese rural households on imported oils.

Agronomic challenges

Agronomic challenges include limited access to quality seeds, a lack of improved varieties, declining soil fertility and suboptimal crop management practices. The high-yielding mustard varieties currently available in Bhutan were released over two decades ago and their seed quality has deteriorated over time. Low productivity is the key constraint in the adoption of oilseed development program. The average productivity of the predominant oilseed crop mustard stands at 284kgs/acre which is relatively low when compared to the average yield in the neighbouring countries. In response to this issue, researchers at the Research and Development Centres accelerated efforts to release mustard varieties compatible with different cropping systems. As a result, two new varieties, *Yusi Peka 1* and *Yusi Peka 2*, were released in 2017 (Table 2), both varieties are significantly superior to older varieties and are in high demand by farmers. However, post-release seed distribution has primarily consisted of the older variety (*M27*), highlighting a major challenge for oilseed farmers: limited access to improved, high-yielding seeds. Additionally, no improved varieties of other potential oil crops, such as sunflower and groundnut, have been released in Bhutan and the four existing soybean varieties are old and need replacement (Table 3).

Table 3. Soyabean varieties released for different agroecological zones in the country.

Sl No	**Name of the variety**	**Year of release**	**Releasing agency**	**Yield Potential ($t\ ha^{-1}$)**	**Maturity days after sowing**	**Remarks** (masl)
1	One Daughter	1994	DSC	1	150-160	<2000
2	KhangmaLibi 2	2002	RDC Wengkhar	1	150-160	800-1500
3	Brag	2002	DSC	1-1.5	145-160	800-1500
4	AGS 258	1999	RDC Wengkhar	1-1.5	154-164	600-2000

Source: Department of Agriculture, Bhutan

Bhutanese agriculture is predominantly characterized by subsistence farming, with a smallholder system where farmers cultivate limited land areas (Katwal et al., 2015). Smallholder farmers contribute significantly to national food security; however, due to low input usage and limited adoption of available technologies, cereal and oilseed yields remain far below potential. The use of chemical fertilizers is minimal, as many farmers believe prolonged use harms soil health. Although integrated nutrient management technologies have been introduced, oilseed crops, including mustard, are typically grown with little to no inorganic fertilizer. Ministry of Agriculture and Forest, 2008 reports that this has been identified as a major constraint to mustard production. Farmers report that mustard yields are especially low when grown after maize, which heavily depletes soil nutrients. The subsistence-oriented nature of mustard farming further discourages the use of chemical fertilizers, as most of the harvest is used for household consumption, offering no cash return to offset input costs. Oilseed production faces significant challenges from both biotic and abiotic stresses, including pests and diseases. Rapeseed-mustard crops in Bhutan are significantly affected by various insect pests and diseases, with mustard aphids, Alternaria leaf spot and white rust being the most prominent. These issues contribute to an average yield loss of 35-50% in these crops. However, mustard has received limited attention in terms of research and development in Bhutan (MoAF, 2008).

Marketing and Processing

Currently, Oil expelling is done using oil expellers supplied by the agriculture machinery Training Centre (AMTC). Going by figures there are around 234 numbers of oil expellers supplied to all 20 districts. In sufficient oil expellers in Bhutan are one of the key issues in the oilseeds value chain (Kumar, 2007). The oil expellers are owned by individual farmers and operated sub-optimally. The lack of use of these machinery leads only to wastage and abrasion and there is a need to improve the use efficiency of farm machines. Due to the low volume of mustard oil production in the country, marketing is not a major issue. The low volume and economy of scale itself is a bottleneck for marketing the mustard oil. Farmers using mechanized methods admit that distance to oil expellers, high charge for expelling and low quality of expelled oil are the major problems faced. On the other hand, farmers expressed that the time taken for expelling is less and there is higher oil recovery with mechanized oil expellers (MoAF, 2008).

Lack of continuity and focus of the oilseed's commodity program

The oilseeds program is subsumed under the Field Crops Research Program and has received little or no attention. Consequently, the program lacked a clear focus and strategic direction, which hindered its development. As a result, there is currently very limited technical expertise or capacity to undertake meaningful research and implement development interventions in oilseeds.

Opportunities

Bhutan allocates substantial foreign exchange for edible oil imports, with the latest import figures reaching a total of 11908 MT and costing Nu 1380 million in 2023 (BTS, 2023). The volume and value of imported edible oils reflect the significance of the oilseed trade in the country. Given the growing population and rising living standards, edible oil imports are expected to increase exponentially. This underscores a strong opportunity to enhance domestic oilseed production to meet the expanding market demand. Current yields of improved oilseed varieties remain low, suggesting a considerable potential to boost production through productivity improvements. Two newly released mustard varieties, introduced after two decades, have demonstrated the potential to double yields compared to older high-yielding varieties. These varieties are well-suited to diverse cropping systems, making them highly promising for scaling up production. However, the exchange and development of oilseed germplasm remain underdeveloped compared to cereals, highlighting a critical opportunity to enhance germplasm inflow and further boost productivity in the oilseed sector.

Ghimiray and Vernooy (2017) emphasize that reciprocity in germplasm exchange is instrumental in advancing crop improvement and ensuring food security. The study underlines the importance of strengthening institutional linkages to streamline and facilitate the germplasm exchange process, thus fostering collaboration and innovation in agricultural development.

Supporting community-based seed production is critical to complement the National Seed Centre's efforts. There is also potential to boost oilseed production by enhancing the breeding capacity of research institutions and the National Seed Institute in Bhutan. The relatively low production base for oil crops presents an excellent opportunity to foster public-private partnerships (PPP). PPPs are essential for the efficient achievement of national objectives and are vital for the oil industry's long-term sustainability. These partnerships would strengthen links between producers and consumers and help reduce post-harvest losses (Singh, Bhatt, & Upaadhaya, 2012). Despite the limited production base for mustard, numerous private entrepreneurs express strong interest in establishing public-private partnerships for oil extraction ventures. This interest likely stems from the reliable market for edible oils and Bhutan's high dependency on imports. Engaging private entrepreneurs is crucial for ensuring the long-term sustainability of the oil industry.

Mustard remains Bhutan's principal oil crop and is currently the only one processed for oil extraction. Other dual-purpose crops, such as soybean, sunflower, groundnut and sesame, have considerable potential for oil production if processing facilities are developed. Additionally, there is significant market potential for organic products domestically and internationally, indicating that Bhutan could capitalize on the growing demand for certified organic oil.

Way forward

To strengthen Bhutan's oilseed sector, several strategic initiatives have been initiated.

Support and encourage the participation of private sector

A key focus is to support and facilitate the commercialization of oilseed production, processing and marketing, encouraging active participation from both farmer groups and the private sector. This approach aims to increase production and create more robust market opportunities for local farmers. Further to enhance local processing capacity, efficient oil expellers are to be installed and redeployed in strategic locations. This will streamline the production process, making it more efficient and accessible for farmers and processors across the country. In addition to improving processing, there is a strong emphasis on product development and value addition within the oilseed industry. These efforts will enhance the competitiveness of Bhutanese oilseed products in the market and make them more appealing to consumers, both domestically and potentially internationally. Furthermore, the Ministry of Agriculture and Livestock (MoAL) could formalize the initiative to market mustard oil through the Food Corporation of Bhutan (FCB). This step will help ensure a stable market for mustard oil, supporting farmers and aligning with national food security and economic goals. Together, these actions represent a comprehensive strategy to develop and modernize Bhutan's oilseed sector.

Strengthen the Oilseed Commodity Program

To advance the Department of Agriculture (DoA) could focus on initiatives to strengthen research, seed production and technical capacity. One key area is the evaluation of germplasm through SAARC Regional Adaptive Trials and identify varieties best suited for Bhutan’s climate and farming systems. In addition, Nationally Coordinated Trials could be perused to determine the adaptability and yield potential of new, high-performing varieties, which could contribute significantly to oilseed productivity. Furthermore, evaluations and adaptations of technologies for other oil crops, such as groundnut, sunflower and soybeans, should be looked at as an opportunity. As (Shekhawat, Rathore, Premi, Kandpal, & Chauhan, 2012) proposes horizontal and vertical intensification of mustard to enhance self-sufficiency in the oilseeds sector, this could broaden the focus of Bhutan’s oilseed program beyond traditional crops, creating opportunities to diversify and improve overall oilseed production. By focusing on both horizontal and vertical intensification, Bhutan could reduce its dependence on imported edible oils and create a more resilient agricultural sector. Moreover, ensuring that these modern cultivars are accessible and affordable to local farmers will be essential to sustaining and increasing oilseed production in the long term. Additionally, efforts should focus on enhancing crop management practices through targeted trials and demonstrations. Improvements should be made in key areas such as seed rate, planting time, soil fertility and overall crop management.

To address the persistent shortage of quality mustard seed, an aggressive seed increase and distribution strategy should be pursued through the National Seed Centre. Recognizing that farmers have long faced challenges due to inadequate seed supply, a robust seed production mechanism should be established to ensure that ample, high-quality seed is made available.

Mechanization

The shortage of farm labour is one of the most significant constraints faced by farmers in Bhutan To address this challenge, substantial investment in farm mechanization is essential In modern agriculture, farm mechanization plays a crucial role in commercial farming and has the potential to encourage Bhutanese youth to pursue agriculture as a viable employment opportunity. The mechanization of agricultural activities would significantly support oilseed farmers by addressing this issue and enhancing productivity. The other most important consideration for the oilseed sector is to prioritize every activity across the entire value chain. These actions aim to strengthen the oilseed sector by improving production efficiency, expanding market opportunities and enhancing the value chain for oilseed products in Bhutan to meet the country's growing demand for edible oils.

Post Production

Oil extraction in Bhutan is predominantly carried out using traditional inefficient methods, resulting in poor oil recovery. To improve this, there is a pressing need to popularize efficient oil expellers that can enhance recovery rates and optimize production. Currently, the processing sector is fragmented, inefficient and operates with low-capacity utilization. Therefore, a well-structured policy framework is essential to address the key challenges of oilseed and oil processing.

This framework must balance the interests of four crucial stakeholders. First, farmers must be assured of incentive prices, which can only be achieved by an efficient processing industry with low operational costs. Second, consumers must have access to edible oil and related products at affordable prices, ensuring the oilseed sector remains sustainable for consumption. Third, the industry itself should be able to secure reasonable profit margins, creating incentives for modernization and cost reduction. Lastly, public interest must be considered by ensuring satisfactory levels of employment, income generation, export opportunities and public revenue (Kumar, 2007).

The processing sector in Bhutan requires systematic organization to enhance post-production activities. Soybean processing presents untapped opportunities, as soybean seeds are currently consumed directly by households without any processing. Soybeans can be transformed into oil and a variety of value-added products, including soya milk, soya flour, soya tofu (paneer), soya nuggets and other edible items. Developing small-scale industries to produce value-added products can significantly contribute to the agricultural and industrial landscape of Bhutan.

Market

Bhutan's mustard oil industry predominantly caters to household consumption, with minimal formal marketing of mustard seeds or oil. The by-product of oil processing, oil cake, is often utilized as cattle feed by producers, while in some cases, it is retained by oil expellers to offset processing costs. To enhance the marketability and efficiency of the mustard oil and oilseed industry, a comprehensive strategy is necessary. A key aspect of this strategy involves forming oilseeds processing and marketing groups. These cooperative groups will empower producers by enabling collective marketing, streamlined processing and stronger negotiation power, ensuring better outcomes for all stakeholders.

Expanding market access through the support of the Price Guarantee Scheme can be instrumental in establishing a structured system for oilseed procurement. This would encourage larger-scale production and provide producers with a reliable market. Additionally, mechanisms for the efficient collection and processing of oilseeds, including soybeans, must be established to optimize marketing processes and ensure better returns for farmers and processors. Alongside this, improved storage facilities are crucial to preserve the quality of oilseeds and oils, preventing losses and maintaining product standards in the market.

Collaboration between key institutions, including the Food Corporation of Bhutan Limited (FCBL), Agriculture Machinery Training Centre (AMTC) and the National Post Harvest Centre (NPHC), is essential to support the processing, trading and fair pricing of oilseeds, oil and oil cake. Furthermore, implementing edible oil packaging standards will enhance the quality of products, reduce the prevalence of adulterated oil and build consumer confidence. Collectively, these measures aim to create a sustainable and efficient mustard oil and oilseed industry in Bhutan, fostering local production, ensuring fair prices for stakeholders and reducing the nation's reliance on imports.

Policy Interventions

Imported edible oils often dominate the market due to their lower prices, which makes it challenging for locally-produced oils to compete. Without adequate policy support, local producers struggle to sustain their operations against cheaper, mass-produced imports. Implementing higher import tariffs on edible oils to narrow the price gap between imported and locally produced oils would be crucial. This would provide local producers with a competitive edge in the domestic market. Offer tax exemptions or reduced tax rates on equipment, inputs or the final product for local oil production to lower production costs. Impose temporary trade restrictions or quotas during periods of excessive imports that threaten the viability of local oil production.

Conclusion

The Bhutanese population will consistently rely on oil for cooking and as a Buddhist nation, a significant portion of vegetable oils and fats will also be used in religious practices, such as lighting lamps. Given these cultural and practical uses, the demand for oilseeds will continue to rise. This demand will be driven not only by the increasing population but also by the growing purchasing power of consumers, which will allow for greater consumption of oil and oil-based products. As Bhutan’s economy develops and its population expands, the need for locally produced oilseeds will become even more pronounced, emphasizing the importance of boosting domestic production to meet both current and future demand.

The significant reliance on imported edible oil is a major concern for the Ministry of Agriculture and Livestock (MoAL). However, with the country's existing potential for domestic mustard production, this import dependency can be reduced through a well-structured and focused oilseed development program. There is a clear opportunity to expand both the acreage and overall production of mustard within Bhutan. The decision by the Department of Agriculture to elevate the Oilseeds Program to commodity status and provide it with focused attention is a crucial step. This move is expected to address existing gaps in the sector by enhancing the technical capacity of the program, thereby promoting sustainable growth in domestic oilseed production. With such strategic efforts, Bhutan can gradually decrease its reliance on imported edible oils, ensuring greater food security and contributing to the country's economic self-sufficiency.

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Chapter 4

Productivity Enhancement of Oilseed Crops in Maldives

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Introduction

The Maldives, an archipelago in the Indian Ocean, has a distinct agricultural landscape characterized by limited arable land and dependence on coastal ecosystems. Agriculture plays a secondary role to fisheries and tourism, but coconuts remain a staple agricultural product. Coconut palms are cultivated throughout the islands, contributing significantly to the food, culture and economy of the Maldives. Coconut oil, derived from these palms, is a critical product used for cooking, skincare and export.

i. General Introduction of Agriculture

Maldivian agriculture is constrained by sandy soils, limited freshwater and dispersed islands. Key crops include Coconuts, Breadfruit, Bananas and Taro. Among oilseed crops, coconut stands out as the primary source of oil production. Despite the challenges, coconut farming represents a deeply ingrained tradition, sustained by generations of farmers.

ii. Main Oilseed Crop: Coconut

Coconut is the only oilseed crop that is cultivated in Maldives.

Area Coverage: Coconuts are grown across all inhabited islands, with small-scale plantations in homesteads and community lands. Recent surveys estimate that over 30% of agricultural households engage in coconut harvesting.

Productivity Trends: Yield ranges between 4,500 to 5,000 nuts per hectare annually. Productivity has fluctuated due to changing climate conditions, pest infestations and inconsistent farm management practices. Efforts are underway to improve productivity through sustainable farming practices.

Varieties: Traditional tall coconut varieties dominate, with limited availability of high-yielding hybrids. Locally adapted varieties are preferred for their resilience to saline conditions and harsh weather.

iii. Future Demand

The demand for coconut oil in the Maldives is expected to increase, driven by population growth, health trends and its use in skincare and wellness industries.

Export demand for premium-grade coconut oil is also rising. Additionally, the global shift toward organic and natural products presents an opportunity for Maldivian coconut oil to gain a niche in international markets.

iv. Crop Rotations

Crop rotations involving coconuts are rare due to their long growth cycles. Intercropping with Bananas, Papaya or Taro is practiced in some areas to maximize land use. The introduction of agroforestry practices, combining coconuts with other perennial crops, has shown promise in improving land productivity and ecosystem health.

v. Availability of Certified Seeds

Access to certified or hybrid coconut seeds is minimal. Farmers often rely on traditional planting methods using local seed stocks. Expanding the availability of certified seeds and promoting seedling nurseries can significantly enhance planting success rates and long-term yields.

A program was conducted by the Ministry of Agriculture and Animal Welfare to promote coconut productions and multiple varieties of seedlings was distributed to island councils to be planted in the islands.

vi. Farmers' Perception and Needs

Farmers recognize coconuts as economically significant but cite challenges such as declining soil fertility, pest issues and lack of modern tools. They express interest in government and technical support to improve yields and oil recovery. A stronger extension network is needed to deliver technical advice, inputs and market information directly to farmers.

Fig. Pest in Coconut Palms that effect the Yield of Seeds

vii. Main Hurdles

- Limited access to high-yielding varieties.
- Labor-intensive harvesting methods.
- Soil salinity and water scarcity.
- Inadequate processing facilities for oil extraction.
- Limited awareness of sustainable farming practices.

viii. Seed Availability and Purity

Traditional propagation methods lead to inconsistent seedling quality. Improved germplasm is necessary to maintain productivity and withstand environmental challenges. Establishing a centralized seed bank or germplasm repository could help preserve valuable genetic diversity while improving access to quality planting materials.

Research & Development

i. High-Yielding Varieties

Ongoing research focuses on developing coconut varieties resistant to pests, diseases and salinity. However, these efforts are limited by resource constraints. Collaboration with regional agricultural research centers could accelerate the development of resilient varieties tailored to Maldivian conditions.

Coconut Seedling Nursery

This Nursery is in an uninhabited Island Near L. Maandhoo called L. Baresdhoo which is a commercially leased island for Agricultural use by the Government and the only crop grown in this field is Coconut Palms.

ii. Crop Management Practices

Studies are being conducted to improve soil health through organic composting and optimize water usage in coconut farming. Research into biofertilizers and natural pest control methods is gaining attention as sustainable alternatives to chemical inputs.

Fig. Coconut Crop Management Practices in *L. Baresdhoo*

iii. Farmer Training

Training programs, often led by non-governmental organizations (NGOs), aim to teach efficient oil extraction techniques, pest control and value addition for coconut products. The Ministry of Agriculture and Animal Welfare also provides farmers with training under the Coconut Rehabilitation Program started in 2022. Expanding these initiatives and incorporating digital platforms for knowledge dissemination can enhance farmer outreach.

Fig. Highlights from Farmer Training Programs

Trends in Oilseed Supply and Demand

i. Production Trends

Coconut oil production remains stable but is vulnerable to climate variations and pest outbreaks. Diversifying income sources through value-added coconut products can reduce dependence on raw oil production.

ii. Consumption Trends

Domestic consumption is high due to its use in cooking, skincare and traditional medicine. Growing export demand for organic and cold-pressed coconut oil has also been noted. Rising awareness about the health benefits of coconut oil is further driving its demand.

iii. Production Requirements

To meet future demand, production must be scaled through improved varieties, better farm management and efficient processing technologies. Increased collaboration between farmers and private sector stakeholders can facilitate investments in production infrastructure.

iv. Oil Recovery Efficiency

Traditional oil extraction methods yield 30-35% recovery. Introducing mechanized methods could raise efficiency to 50-60%. Establishing community-level processing units can make advanced technologies more accessible to small-scale farmers.

Machinery Issues

i. Availability of Suitable Machinery

Farmers lack access to machinery for harvesting, de-husking and oil extraction, relying on manual labour instead. Introducing affordable, easy-to-use machinery tailored to smallholder needs can significantly reduce labour intensity and improve efficiency.

ii. Quality and Value Addition

Modern machinery for cold-press extraction can enhance oil quality, allowing Maldivian coconut oil to compete in premium export markets. Establishing certification standards and quality assurance systems will further bolster market confidence.

Marketing Issues

- **Domestic Market**: Small-scale production due to the high demand for coconut fruit for local use limits the consistent supply needed for larger markets.
- **Export Challenges**: Lack of branding, packaging and certifications (e.g. organic or fair trade) reduces competitiveness. Efforts to establish a national brand for Maldivian coconut oil can address this gap.
- **Logistics:** The dispersed geography of the Maldives complicates transportation and marketing of coconut products. Investments in a coordinated supply chain infrastructure are essential to improve efficiency.

Government Policy

i. Existing Strategies

The government prioritizes coconut production for self-sufficiency under the Coconut Rehabilitation Program but has limited programs targeting oil extraction efficiency or export promotion. Policy interventions focused on financial support, technological adoption and market linkages can address key bottlenecks.

ii. Public-Private Partnerships

Collaborations with private entities could enhance marketing, processing infrastructure and value addition for coconut oil. Engaging private investors in establishing export-oriented processing units can unlock the full potential of the coconut sector.

Way Forward

i. Enhancing Productivity and Recovery Efficiency

- Promote the use of high-yielding, disease-resistant coconut varieties.
- Support farmers in adopting mechanized oil extraction methods.

ii. Scaling Up Production

- Establish centralized processing units for efficient oil extraction and packaging.
- Foster inter-island collaboration to consolidate production and market supply.

iii. Government Support

- Provide financial incentives, capacity-building programs and loans for farmers and entrepreneurs.
- Invest in R&D for resilient coconut varieties and modern processing techniques.

iv. Branding and Product Diversity

- Position Maldivian coconut oil as a premium product in global markets, emphasizing its organic and artisanal qualities.
- Develop diversified products such as virgin coconut oil, skincare products and infused oils.

v. Scaling and Marketing

- Develop export-oriented policies and improve market access through certifications and trade agreements.
- Enhance logistics and distribution networks to connect farmers with buyers efficiently.

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Chapter 5

Productivity Enhancement of Oilseed Crops in Nepal

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Abstract

This country paper highlights the importance of enhancing oilseed crop productivity in Nepal, a critical component of the nation's agricultural sector. Despite growing demand for edible oils, domestic production remains insufficient, leading to significant import dependency. The paper aims to analyze the status of oilseed production, identify key challenges and propose actionable strategies for achieving sustainable productivity growth. The study reviews the production trends of major and minor oilseed crops, including rapeseed, mustard, sarsoon, soybean, groundnut, sesame, niger, linseed and sunflower. Key challenges include limited access to improved varieties, suboptimal agronomic practices, prevalence of pests and diseases and inadequate post-harvest management. Data were collected through national agricultural reports, farmer surveys and stakeholder consultations, providing a comprehensive overview of the sector. Findings reveal that adopting high-yielding varieties, implementing integrated pest and nutrient management practices and promoting mechanization could significantly enhance productivity. Strengthening market linkages, developing oilseed value chains and improving post-harvest handling were identified as critical to bridging the production-consumption gap. The paper concludes that enhancing oilseed productivity in Nepal requires a coordinated effort among research institutions, policymakers and farmers. Prioritizing the dissemination of advanced technologies, capacity-building initiatives and supportive policy frameworks is essential for reducing import dependency and achieving self-sufficiency in oilseed production. Such efforts will not only improve food security but also strengthen rural livelihoods, contributing to the overall economic growth and sustainability of Nepal's agricultural sector.

Keywords: Mechanization, Nepal, Oilseed, Productivity, Value chain

Introduction

Agriculture in Nepal

Agriculture is the backbone of Nepal's economy, engaging over 60% of the population and contributing around 24% to the national GDP (MoALD, 2023). The sector is diverse, with a mix of staple crops such as rice, wheat and maize, as well as high-value crops like potatoes, tea, coffee, cardamom and ginger. Despite this diversity, agricultural productivity faces constraints, including limited irrigation, reliance on traditional farming methods, fragmented landholdings and vulnerability to climate change. The livestock sector also plays a crucial role, especially in rural areas where households depend on cattle, buffaloes, goats and poultry for food security and income. Efforts to modernize the sector focus on expanding irrigation, improving value chains for high-value crops and enhancing market linkages and financial access.

Oilseed crops, including rapeseed, mustard, soybean, sesame, sunflower and groundnut, are vital to Nepal's economy due to their high demand, export potential and role in providing diversified income and nutrition. Despite this, oilseed production remains underdeveloped, with issues such as improper fertilization, micronutrient deficiencies, disease pest infestation and poor plant populations leading to decreased yields (Subedi et al., 2023). While oilseeds can thrive on marginal land and contribute to food security, their productivity lags major cereal crops and the demand for edible oils is often met through imports. To enhance oilseed production, it is crucial to develop high-yielding, climate-resilient technologies and promote diversified cropping systems. With oilseeds contributing approximately 3% to agricultural GDP, increasing their production can significantly boost Nepal's food, nutrition and economic security (Subedi, 2023).

Trend of area, production and productivity

The Commonly grown oilseed crops in Nepal are rapeseed, mustard, sesamum, linseed, groundnut niger and sunflower.

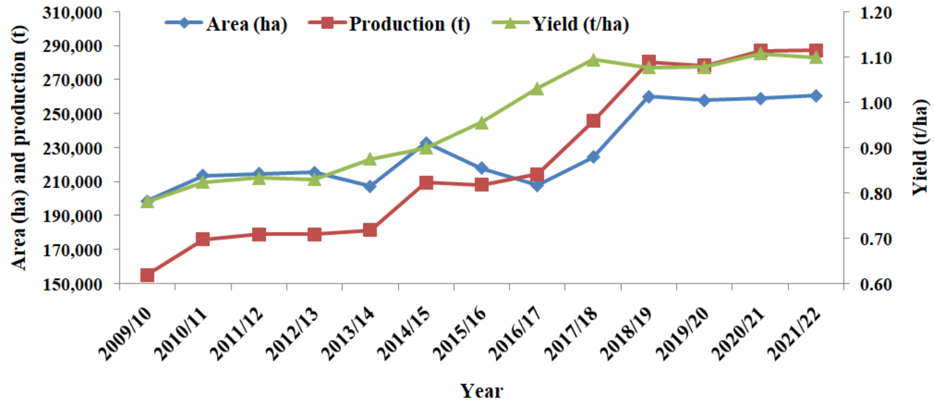


Fig 1. Trend of oilseed crops production in terms of area, production and yield in Nepal

Over the past decade, oilseed cultivation in Nepal has shown considerable growth in terms of area, production and productivity (Figure 1). Data from 2000-2010 reveals a decrease in the compound growth rate of oilseed area and production, while the current decade (2010-2020) has seen an increase in both. Specifically, the area under oilseeds has expanded by approximately 0.053 million hectares, with production rising by 0.13 million tons and productivity increasing by 0.3 tons per hectare. During the current decade, oilseed productivity growth has stabilized and the growth rate has improved (Joshi et al., 2021). Oilseeds are cultivated across all seven provinces of Nepal, with oilseed crops covering 260,645 hectares, ranking fifth in crop area after rice, maize, wheat and millet. Among cash crops, oilseeds occupy the first rank in area, followed by potatoes and sugarcane. In the 2021/22 agricultural year, Nepal's oilseed cultivation covered 260,645 hectares, producing 287,344 metric tons with an average yield of 1.10 tons per hectare (Table 1). The distribution of oilseed cultivation is led by Lumbini Province, which accounts for 25.06% of the total area, followed closely by Madhesh Province (25.00%) and Koshi Province (17.92%). The remaining provinces contribute smaller shares, with Sudurpaschim at 11.54%, Bagmati at 11.27%, Karnali at 5.50% and Gandaki at 3.71%. A similar trend is observed in production, with Lumbini contributing 25.01%, Madhesh 24.45% and Koshi 18.74%, followed by the other provinces in descending order (Table 2). Rapeseed dominates oilseed cultivation, covering 76.34% of the area and contributing 76.84% of the production, followed by minor crops like sarsoon, linseed, rayo, sesame, groundnut, sunflower and niger (MoALD, 2023).

Rapeseed cultivation in Nepal has shown steady increases in area, production and yield from 2011-12 to 2021-22, although these metrics plateaued from 2019 to 2022 (Figure 2). Mustard followed a similar pattern, with consistent growth from 2012-13 to 2016-17, but experienced a significant decline in area, production and yield in 2017-18 and 2018-19. From 2019-20 to 2021-22, mustard saw exponential growth in area and production, while yield remained stable (Figure 3). Sarsoon showed continuous growth in area and production during the same period, but yield has been declining (Figure 4). Linseed, on the other hand, saw an initial increase in area from 2012-13 to 2014-15, followed by a steady decline from 2016-17 to 2021-22. Despite this, linseed's yield has shown a steady increase throughout this period (Figure 5).

Table 1. Area (ha), production (mt) and yield (mt/ha) of various oilseeds in Nepal, 2021-22

Crops	Area (ha)	Production (mt)	Yield (t/ha)
Rapeseed	198,985	220,784	1.11
Sarsoon	20,956	22,542	1.08
Rayo	8,375	8032	0.96
Sunflower	4,217	5525	1.31

Crops	Area (ha)	Production (mt)	Yield (t/ha)
Groundnut	4,243	5757	1.36
Sesame	9,198	9831	1.07
Linseed	12,856	12923	1.01
Niger	1,814	1950	1.07
Total	**260,645**	**287,344**	**1.10**

Table 2. Area, production and average yield of oilseed crops by Province basis, 2021-22.

Province	Area(ha)	Production(mt)	Yield (t/ ha)
Koshi	46,704	53,850	1.15
Madhesh	65,149	70,244	1.08
Bagmati	29,384	32,014	1.09
Gandaki	9,666	10,012	1.04
Lumbini	65,327	71,852	1.10
Karnali	14,343	15,929	1.11
SudurPaschim	30,073	33,443	1.11
Nepal	**260,645**	**287,344**	**1.10**

Groundnut cultivation exhibited constant growth in area, production and yield from 2011-12 to 2021-22, although there was a slight decline in area and production in 2021-22 compared to the previous year. Groundnut is predominantly grown in districts like Jhapa, Sarlahi, Nawalparasi, Rupandehi and others (Figure 6). Sesame showed stable trends in area, production and yield from 2011-12 to 2017-18, with a gradual increase in the following years. Its yield increased in 2013-14 but fluctuated in the following years before stabilizing at 1 t/ha from 2020-21 to 2021-22 (Figure 7). Sunflower cultivation fluctuated in area, production and yield, with a peak between 2016-17 and 2018-19, followed by a decline and stabilization from 2019-20 to 2021-22. It is primarily grown in districts like Jhapa, Morang and others (Figure 8). Niger cultivation showed fluctuating trends in area, production and yield, with steady increases from 2012-13 to 2015-16, followed by a decrease and stabilization (ORP, 2021). The major niger-producing districts include Jhapa, Morang, Sindhuli and Nawalpur-east (Figure 9).

Future demand for oilseed crops in Nepal

The demand for oilseed crops in Nepal is expected to rise significantly due to population growth, changing dietary habits and expanding industrial uses for oil products. With per capita oil consumption growing steadily, currently at 8-10 kg annually and projected to double by 2030, Nepal will face a growing import dependency unless local production increases. Currently, about 90% of Nepal's edible oils are imported, primarily from India (MOF, 2022). Key oilseed crops include rapeseed, mustard, sarsoon, soybean, groundnut and sunflower, with rapeseed/mustard dominating production (85%).

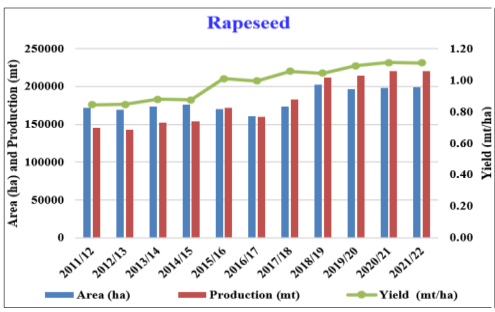


Fig 2. Trend in area production and yield of Rapeseed in Nepal from 2011-12 to 2021-22

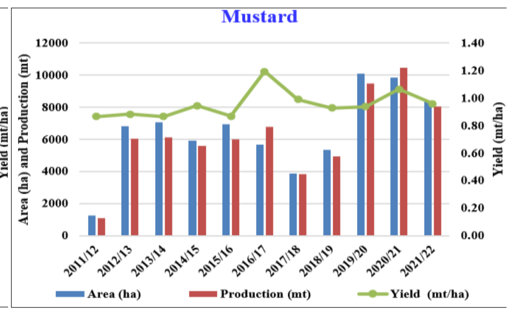


Fig 3. Trend in area production and yield of Mustard in Nepal from 2011-12 to 2021-22

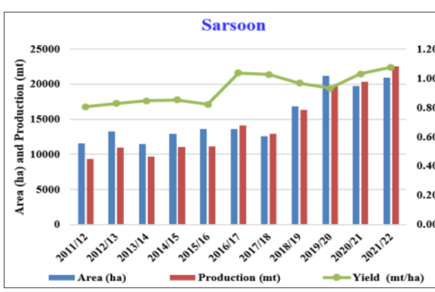


Fig 4. Trend in area production and yield of Sarsoon in Nepal from 2011-12 to 2021-22

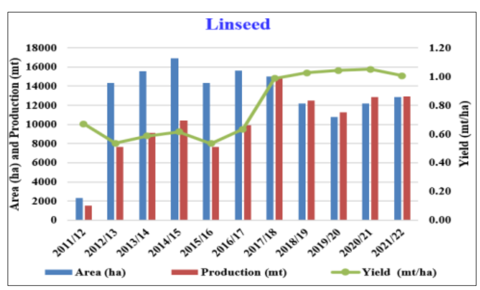
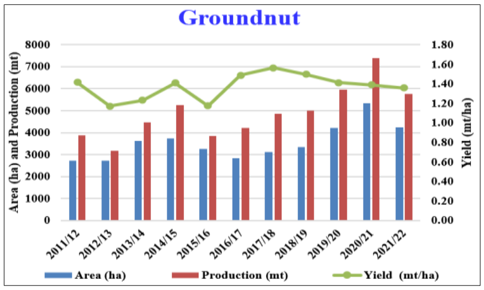


Fig 5. Trend in area production and yield of Sarsoon in Nepal from 2011-12 to 2021-22



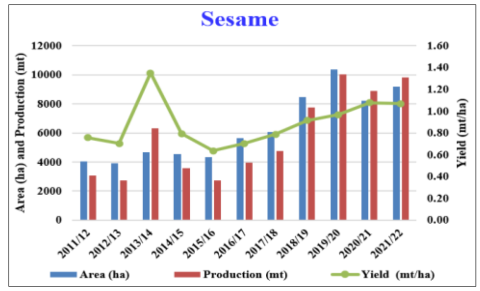
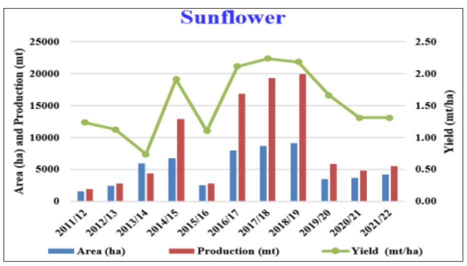


Fig 6. Trend in area production and yield of Groundnut in Nepal from 2011-12 to 2021-22

Fig 7. Trend in area production and yield of Sesame in Nepal from 2011-12 to 2021-22



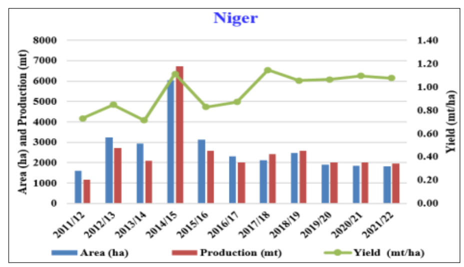


Fig 8. Trend in area production and yield of Sunflower in Nepal from 2011-12 to 2021-22

Fig 9. Trend in area production and yield of Niger in Nepal from 2011-12 to 2021-22

However, domestic production meets only half of the demand and demand for rapeseed/mustard oil is projected to grow by 4-5% annually. Soybean and groundnut cultivation are limited but have potential for expansion to reduce imports, especially as awareness of their health benefits increases. Sunflower oil, almost entirely imported, is projected to see a 6-8% annual rise in demand (MOF, 2022), creating an opportunity to boost domestic cultivation and reduce reliance on imports.

Main crop rotations involving oilseed crops in the country

Oilseed crops play a crucial role in crop rotations, enhancing soil fertility, controlling pests and boosting farm productivity, particularly in regions focused on sustainable agriculture in Nepal. Key oilseeds crop like rapeseed, mustard, soybean, groundnut, sesame, linseed and occasionally sunflower, are integral to rotations, with soybean and groundnut enriching soil nitrogen levels when rotated with cereals like wheat and maize. These rotations help break pest and disease cycles while offering economic benefits through marketable products and oil for household use. Common rotations include rice-rapeseed/mustard-maize in the

Terai, rice-soybean-wheat in the Mid-Hills and Terai, maize-groundnut-wheat in the Mid-Hills and Inner Terai, rice-sunflower-fallow in the Terai and maize-rapeseed/mustard-fallow in high-altitude areas (ORP, 2017). These rotations utilize seasonal planting efficiently, improve soil health and diversify farm income, especially as demand for oilseed crops like groundnut and sunflower rises.

Availability of the certified seeds of different oilseed crops in the country

The availability of certified seeds for oilseed crops in Nepal is a significant challenge, limiting domestic production of key crops like rapeseed, mustard, soybean, groundnut and sunflower. Certified seeds are essential for higher yields, disease resistance and crop uniformity, yet domestic production remains insufficient, with about 78% of seeds sourced informally. Certified rapeseed/mustard seeds cover only 30-40% of demand, soybean seeds 15-20% and groundnut, sesame and linseed seeds less than 10%. Sunflower seed availability is even more limited, covering less than 5% of the total need. Most farmers rely on uncertified seeds, resulting in inconsistent quality and productivity. The shortfall in certified seed availability is compounded by limited domestic production, weak extension services and the high cost of imported seeds (Subedi, 2023). Expanding domestic seed production, improving distribution systems and raising awareness about the benefits of certified seeds are crucial for improving oilseed crops productivity, reducing import dependency and enhancing farmers' incomes.

Farmer's perception and their needs regarding oilseeds crops productivity enhancement in different ecological zones

Farmers in Nepal, across the Terai, Mid-Hills and High Hills, have differing perceptions and needs regarding oilseed crop productivity, shaped by their unique agro-ecological conditions. In the Terai, farmers view oilseeds like rapeseed, mustard, groundnut, sesame and soybean as valuable but face challenges such as limited access to modern inputs and they require improved, pest-resistant seed varieties, better irrigation infrastructure and enhanced extension services for pest management and soil fertility. In the Mid-Hills, where smallholder farming is common, oilseeds are seen as beneficial for soil fertility and income, but farmers struggle with limited land, poor seed quality and market access. They need quality seeds, training in sustainable farming practices and improved market linkages. In the High Hills, oilseeds like rapeseed/mustard are crucial for winter cropping, but low productivity due to harsh climates and limited resources remains a challenge. These farmers need cold-tolerant varieties, better post-harvest support and assistance with soil health management (ORP, 2021). Addressing these region-specific needs with targeted interventions, such as access to high-quality seeds, irrigation support, financial assistance and training, can enhance oilseed crops productivity, improve rural incomes and strengthen food security across Nepal.

Main hurdles being faced by the farmers for adoption of oilseed crops on large scale

Nepalese farmers face numerous challenges in adopting oilseed crops on a large scale, despite growing demand for edible oils. Limited access to high-yield, disease-resistant seeds and inputs reduces productivity and resilience, while inadequate irrigation infrastructure, with only 40% of arable land fully irrigated, hampers reliable crop cultivation. A lack of technical knowledge, limited extension services and low awareness of modern oilseed practices further discourage large-scale adoption. Market access is restricted by transportation issues, price volatility and uncertainty, while high input costs, including fertilizers, pesticides and irrigation equipment, are prohibitive for smallholders. Pest and disease pressures, along with fragmented land holdings, also make oilseed farming less appealing. Additionally, climate vulnerability, including droughts, floods and erratic rainfall, coupled with insufficient financial support and credit access, creates further barriers for farmers looking to invest in oilseed crops (Subedi, 2023). These challenges limit the widespread cultivation of oilseeds in Nepal, despite their potential economic and agronomic benefits.

Seed availability and purity of different oilseed crops

Seed availability and purity remain critical challenges for Nepal's oilseed crops, including rapeseed, mustard, soybean, groundnut, sesame and sunflower. Certified seed supply is insufficient, with rapeseed/mustard seeds meeting only 30% of demand, soybean 15-20%, groundnut and sesame less than 10% and sunflower under 5%. Purity levels are often compromised, ranging from 50-80% for locally sourced seeds, significantly below the 90-95% ideal standard (SQCC, 2023). This affects yields, disease resistance and crop uniformity. Contributing factors include limited domestic seed production, reliance on expensive imported seeds, underdeveloped quality control systems and inadequate farmers awareness due to weak extension services. Addressing these issues through investments in seed production, quality control and farmer education can boost oilseed productivity, reduce dependence on imports and support rural livelihoods.

Research and development

Nepal's agriculture sector has prioritized research and development (R&D) to enhance the productivity of oilseed crops, addressing challenges like low yields, pest susceptibility and climate change. The focus is on developing high-yielding, pest-resistant and climate-resilient oilseed crops varieties to meet the rising demand for edible oils and reduce dependency on imports.

Key Institution driving Oilseed Research and Development in Nepal

Oilseed Research Program (ORP)

The Oilseed Research Program (ORP), established as the National Oilseed Development Program in April 1976 (2nd Baishakh, 2033 BS) at Netraganj VDC-6, Nawalpur, Sarlahi, focuses on research and development of oilseed crops across Nepal's agro-ecological zones. After the inception of the Nepal Agricultural Research Council (NARC) in 1990 (2048 BS), it was renamed ORP and is now one of eight crop commodity research programs under NARC, tasked with generating technologies to enhance oilseed production and productivity. Located in Lalbandi Municipality-1, Nawalpur, Sarlahi, along the East-West Highway at 27°03'86" N latitude and 85°35'52" E longitude at an elevation of 144 meters orP conducts research, develops national guidelines, conserves local oilseed varieties and produces and distributes source seeds. The farm's sandy loam soil has low nitrogen, medium potassium, high phosphorus and organic matter content of 1.34%, with pH ranging from 4.5 to 6.0. Mandated crops include winter oilseeds (rapeseed, mustard, sarsoon, linseed) and summer oilseeds (groundnut, sesame, niger, sunflower). Despite an approved strength of 25 personnel, the program currently operates with only nine staff members, supported by a structured organizational framework (ORP, 2023).

Ongoing Research and Development Programs in Oilseed Crops

The Oilseed Research Program (ORP) undertakes varietal improvement and development of both winter and summer oilseed crops, focusing on germplasm collection, observation nurseries, initial evaluation trials, coordinated varietal trials and coordinated farmers' field trials for crops like rapeseed, mustard, sarsoon and groundnut, alongside screening genotypes against major diseases and pests. It emphasizes varietal maintenance and conservation for crops such as rapeseed, sarsoon, linseed, niger, sesame and sunflower through characterization and preservation. ORP also develops agronomic packages, evaluating factors like crop establishment methods, nutrient levels, tillage practices, weed management and crop diversification to enhance yield and minimize challenges like Orobanche infestation. Fungicidal efficacy against Alternaria blight in rapeseed and mustard is assessed through culture preservation, yield loss assessment and fungicide trials. Participatory technology verification includes the validation of integrated crop, nutrient and pest management (ICM, INM, IPM), participatory varietal selection (PVS) on rapeseed and mustard and community-based foundation seed multiplication. Additionally, ORP focuses on farm management projects such as establishing field gene banks organizing farmer-level training and workshops, celebrating thematic days, conducting progress reviews, and producing breeder and foundation seeds for key oilseed crops (ORP, 2021).

National Research Achievements in Oilseed crops

Varietal Research Achievements

The Oilseed Research Program (ORP) has successfully released eight varieties of rapeseed and three varieties of mustard (rayo) to date, including the recently developed Nawalpur Tori-4 (ICT 2001-35) and Morang Rayo (ICJ 9704) (Table 3). Promising genotypes demonstrating excellent productivity and resistance to biotic and abiotic stresses are in the pipeline, signaling the need to expedite the variety release process (Subedi, 2023). The selection and improvement of other genotypes must continue using advanced breeding methodologies, especially in the context of climate change and stress adaptation. Such efforts aim to enhance national oilseed productivity and improve the livelihoods of marginalized farming communities.

Table 3. List of released varieties and recommendation domain in winter oilseed crops

Sl. No	Varieties	Year	Origin	Yield (mt/ha)	DM	Recommendation Domains
Rapeseed (Tori)						
1	Preeti	2005		2.6	83	Irrigated Terai/Inner terai
2	Unnati	2005		2.2	86	Terai/Inner terai
3	Pragati	1996		1	99	Terai/Inner terai,Midhills
4	Lumle tori 1	1996	Nepal	0.9	89-153	Midhills/High hills
5	Bikash	1989	India	1	85-90	Terai/Inner terai
6	T-9	1980	India	0.8	100	Terai/Inner terai (Denotified)
7	Morang tori 2	2013	Nepal	1.6	83	Terai/Mid hills
8	Nawalpur Tori 4	2020	Nepal	1.02	80-114	Terai/Inner terai,Midhills
Mustard (Rayo)						
1	Krishna	1998	India	1.1	115	Terai/Inner terai
2	Pusa bold	1988	India	0.9	110-115	Terai/Inner terai
3	Morang rayo	2017	Nepal	1.3	102-120	Terai/Inner terai

Over the four years from 2019/20 to 2022/23, significant research achievements have been documented. Promising rapeseed genotypes such as ICT 2002-11 (1066 kg/ha), ICT 2002-16 (1065 kg/ha) and Acc# 5738 (1033.8 kg/ha) have shown great potential (Table 4). Similarly, mustard genotypes (Table 5) like Pusa

Jaganath (1138 kg/ha), ICJ01-56 (1121 kg/ha) and ICJ01-11 (1121 kg/ha), along with sarsoon genotypes (Table 6) such as Binoy (1188.6 kg/ha) and Haripur Local (1075.9 kg/ha), have demonstrated promising results. Additionally, linseed genotypes ACC#96-002, TN#09 and ACC# (1-ICLI-2002-1) have emerged as potential candidates for further development.

Table 4. Research achievements under rapeseed- varietal investigation

Trial Name	2019-20	2020-21	2021-22	2022-23
OBN	ICT 2009-2 (858 kg/ha), NGRC 2800 (745 kg/ha), SR 08 (740 kg/ha), ICT 2001-7 (738 kg/ha), SR 02 (730 kg/ha)	Morang -2 (795kg/ha), ICT 2010-10 (730 kg/ha), Preeti (722 kg/ha), SR 08 (714 kg/ha)	ICT 2012-22 (988 kg/ha), ICT 2001-35 (926 kg/ha), ICT 2012-101 (922 kg/ha)	Bikash (1106 kg/ha), Morang-2 (1006 kg/ha), ICT 2001-20 (989 kg/ha), ICT 2001-35 (922 kg/ha)
IET	ICT 2003-4(729 kg/ha), ICT 2012-100 (714 kg/ha)	ICT 2012-120 (984.45kg/ha), ICT 2010-14 (953.33kg/ha), ICT 2012-101 (902.22 kg/ha)	ICT 2010-17 (704 kg/ha), ICT 2006-3(698 kg/ha), ICT 2012-120 (583 kg/ha)	ICT 2003-9 (537 kg/ha), ICT 2012-120 (528 kg/ha)
CVT	ICT 2002-11(958 kg/ha), ICT 2002-16 (920 kg/ha), ICT 2001-2 (913 kg/ha)	ICT 2002-11 (1066 kg/ha)	ICT 2001-41 (1025 kg/ha), ICT 2003-24 (933kg/ha)	ICT 2002-16 (1065 kg/ha), Acc# 5738(1033.8 Kg/ha)

Table 5. Research achievements under mustard-varietal investigation

Trial Name	2019-20	2020-21	2021-22	2022-23
OBN	ICJ-01-35 (1061 kg/ha), ICJ E-Roye (989 kg/ha), ICJ-9742 (978 kg/ha) T-59 (900 kg/ha),	ICJ01-2-2 (1025 kg/ha), 9612* Pusa (950 kg/ha), Early Divya (900 kg/ha), Banarasi Raja (875 kg/ha), B4*96154-1 (875 kg/ha)	ICJ-01-2-2 (1242 kg/ha), 9612* Pusa (1152 kg/ha), Early Divya (1091kg/ha), SAARC EN 102 (1061 kg/ha	ICJ-9708 (1000 kg/ha), ICJ-9601-B (938 kg/ha), Krishna (813 kg/ha), ICJ-01-16 (813 kg/ha)
IET	ICJ 9711(864kg/ha) ICJ 9665 (859 kg/ha) ICJ03-1 (796 kg/ha)	ICJ 9665 (1167 kg/ha), ANKUR (1133 kg/ha), ICJ 9716 (1125 kg/ha)	ICJ 9716 (1196kg/ha), ICJ9665 (1167kg/ha), ICJ01-69 (1117kg/ha)	ICJ 96126-1 (1154 kg/ha), ICJ01-35 (1121 kg/ha)
CVT	RH8113 (1157 kg/ha), ICJ9701 (1119 kg/ha), ICJ01-40 (901 kg/ha) Rohini (888kg/ha) PusaJaganath (864 kg/ha)	PUSA JAGANATH (1138 kg/ha), ICJ 0156 (1121 kg/ha)	PusaJaganath (1138 kg/ha), ICJ01-56 (1121 kg/ha)	ICJ 01-11(1121 kg/ha), ICJ 9708 (1067 kg/ha)

Table 6. Research achievements under sarsoon- varietal investigation

Trial Name	2019-20	2020-21	2021-22	2022-23
CVT	Bari-15 (630 kg/ha) Tested genotypes: 16 Yield Range: 191-432 kg/ha	Binoy (903.8 kg/ha) Tested genotypes: 16 Yield Range: 193- 635 kg/ha	Bari-16 (1139 kg/ha) Binoy (1042kg/ha) Ragini (630 kg/ha)	Binoy (1188.6 kg/ha), Haripur local (1075.9 kg/ha)

Extensive varietal investigation trials have been conducted to identify high-yielding genotypes across multiple years. For rapeseed, outstanding performers in different trials include ICT 2009-2, Morang-2, ICT 2001-35, ICT 2012-120 and ICT 2002-16. For mustard, ICJ-9708, ICJ01-35 and ICJ 9665 have shown consistent performance, while Binoy and Haripur Local were exceptional among sarsoon varieties. These findings highlight the potential of selected genotypes for further development and inclusion in future variety release programs.

To date, eight varieties of groundnut, one variety of sesame and one variety of niger have been released among summer oilseed crops (Table 7). The most recently released variety of groundnut, Nawalpur Badam-1 (ICGV 97079), demonstrates notable productivity. Numerous promising and pipeline varieties of oilseed crops have shown excellent performance in terms of productivity and resistance to biotic and abiotic stresses. These genotypes should be prioritized for inclusion in the variety release process. Simultaneously, efforts to select and improve other competent genotypes must continue, utilizing proper breeding approaches and methodologies to address the evolving challenges of climate change and associated stresses. Such advancements are crucial to enhancing national oilseed productivity and improving the livelihoods of marginalized farming communities (Mishra and Koirala, 1995).

Major research achievements of the Oilseed Research Program (ORP) from 2020/21 to 2022/23 include identifying promising genotypes based on their performance. For groundnut, the top-performing genotypes were ICGV 98184 (3969 kg/ha), ICGV 07222 (3046 kg/ha) and ICGV 95358 (2367 kg/ha) (Table 8).

In sesame, out of 42 genotypes, the most promising were EC 376383W (1283.33 kg/ha), Kanchanpur-3 (937.50 kg/ha), ACC# 5337-4 (858.33 kg/ha), DN-7-20 (820.83 kg/ha) and DN 6 (808.33 kg/ha). For niger, among 62 genotypes, ICN Lumle 3000 (1050 kg/ha), G30 (1012 kg/ha), G25 (1005 kg/ha), G31 (1002 kg/ha) and ACC 5631 (1001 kg/ha) showed superior performance.

Varietal investigation trials demonstrated significant progress, with notable entries in different maturity categories of groundnut, including ICGV 98184, ICGV 07213 and ICGV 06319. Research across multi-year trials emphasized early maturity (EMG) and medium maturity (MMG) groundnut genotypes with exceptional yield potential and adaptability (Table 8).

Table 7. List of released varieties and recommendation domain in summer oilseed crops

Sl. No	Varieties	Year	Origin	Yield (mt/ha)	DM	Recommendation Domains
Groundnut (Badam)						
1	Baidehi	2005		3.3	115	Terai/Inner terai
2	Rajarshi	2005		2.8	115	Terai/Inner terai
3	Jayanti	1996		2.2	115	Terai/Inner terai, Midhills
4	Jyoti	1996		2.0	137-153	Terai/Inner terai, Midhills
5	Janak	1989	India	2.5	145	Terai/Inner terai, Midhills
6	B4	1980	India	1.5	140	Terai/Inner terai, Midhills
7	Sambriddhi	2019	India	3.1	135	Terai/Inner terai, Midhills
8	Nawalpur Badam 1	2023	India	2.8	125-130	Terai/Inner terai, Midhills
Sesame (Til)						
1	Nawalpur Khairo Til-1	2000	India	0.9	110-115	Terai/Inner terai
Niger (Jhuse til)						
1.	Nawalpur Jhuse Til-1	2000	India	0.9	100	Terai/Inner terai

Table 8. Research achievements under groundnut-varietal investigation

Trial	2020-2021	2021-2022	2022-2023
OBN	ICGV 95358 (4400kg/ha) ICGV 07213 (3567 kg/ha) ICGV 05174 (3133 kg/ha)	ICGV 98184 (2875 kg/ha), CGV 07243 (2575 kg/ha), ICGV 05174 (2500 kg/ha),	ICGV 92201 (2500 kg/ha), ICGV 98184 (1917 kg/ha), ECN-001 (1792 kg/ha)

Trial	2020-2021	2021-2022	2022-2023
IET	EMG: ICGV 07213 2189 kg/ha, ICGV 05155 (1968 kg/ha MMG: ICGV 06211 (2127.0 kg/ha), ICGV 98184 (2044.4 kg/ha)	EMG: ICGV 06319 (1666 kg/ha), ICGV 91114 (1571 kg/ha) MMG: ICGV 98184 (2359 kg/ha), ICGV 06211 (2083 kg/ha)	EMG: ICGV 05155 (2333.33 kg/ha), ICGV 97125 (2079.37 kg/ha), ICGV 06319 (2044.44 kg/ha) MMG: ICGV 07243 (2603 kg/ha), ICGV 98184 (2533 kg/ha)
CVT	EMG: ICGV 06319 (2124 kg/ha), MMG: ICGV 07222 3460 kg/ha, ICGV 07220 (3270 kg/ha	EMG: ICGV 99089 (1873 kg/ha), ICGV 95358 (1870 kg/ha) MMG: ICGV 07222 (2632 kg/ha), ICGV 07247 (2590 kg/ha)	EMG: ICGV 07214 (3066.67 kg/ha), ICGV 06319(2870.00 kg/ha), ICGV 07213 (2526.67 kg/ha) and ICGV 05155 (2513.33 kg/ha), ICGV 99089 (2092.06 kg/ha) MMG: ICGV 95412 (2362 kg/ha), ICGV 97171 (2197 kg/ha)
CFFT	EMG: ICGV 87885 (2660 kg/ha) ICGV 91058 (2345 kg/ha) MMG: ICGV 97079(2645 kg/ha), ICGV 00441 (2155 kg/ha)	EMG: ICGV 91058 (2923 kg/ha), ICGV 87885 (2500 kg/ha) MMG: ICGV 97079(2460 kg/ha), ICGV 00441 (2080 kg/ha)	EMG: ICGV 07240 (2658 kg/ha), ICGV 95358 (2367 Kg/ha) MMG: ICGV 98184 (3969 kg/ha), ICGV 07222 (3046 kg/ha)

Note: EMG = Early Maturity Groundnut & MMG = Medium Maturity Groundnut

Pathological Research on Disease Resistance

Pathological research has focused on identifying genetic resistance in winter oilseed crops, particularly rapeseed, mustard and sarsoon, against alternaria blight disease. Moderate resistance was observed in several genotypes across different years. For rapeseed, genotypes like ICT 2009-2, SRO 2 and ICT 2004-1 exhibited promising results. Mustard genotypes such as NRCHB-506, Pusa Kranti and ICJ-9708, along with sarsoon genotypes like Gold Sarsoon, Haripur Local and ICJ-01-35, demonstrated moderate resistance (Table 9). These findings provide a solid foundation for breeding programs focused on disease-resistant varieties.

Table 9. Research achievements under winter oilseed pathological investigation.

Crops	2019-20	2020-21	2021-22	2022-23
Rapeseed	ICT 2009-2	MR genotypes= 0	ICT 2006-6, ICT 2001-7, ICT 2010-9	SRO 2, ICT 2004-1, ICT 2010-7, NGRC 2798
Mustard	NRCHB-506, PusaKranti, ICJ-9601-B, ICJ-1-56	MR genotypes= 0	ICJ E-Roye, ICJ-9642,	PusaKranti, ICJ-9708, Rohini, ICJ E-Roye, Synthetic, PusaAgrani, RH 8113, ICJ-9642, ICJ-9710
Sarsoon	FTPYS	MR genotypes= 0	Binoy, Ulta Sarsoon, Haripur local	Gold Sarsoon, Haripur Local, Krishna, ICJ-01-35

Table 10. Research achievements under summer oilseed pathological investigation

Crops	2020-2021	2021-2022	2022-2023
Groundnut	ELS: ICGV 97079, ICGV 05184 LLS: ICGV 05184, TMV 2, ICGV 06285, ICGV 06279, ICGV 97079	ELS: ICGV 99052, ICGV 05198, ICGV 06233, ICGV 93125, ICGV 99036, ICGV 97079, TMV 2 LLS: ICCGV 05182, ICGV 05198, ICGV 99036, ICGV 99057, ICGV 06285	ELS: ICGV 06233, ICGV 05184, ICGV 93125, ICGV 97079 LLS: ICGV 99036, ICGV 99057, ICGV 06285, ICGV 97079

Note: ELS- early leaf spot and LLS- late leaf spot

Pathological research focused on identifying genetic resistance to early leaf spot (ELS) and late leaf spot (LLS) diseases in groundnut. While none of the evaluated genotypes were completely disease-free, several exhibited moderate resistances. Over three years (2020/21-2022/23), genotypes such as ICGV 97079, ICGV 05184, TMV 2 and ICGV 06285 consistently showed resistance to ELS and LLS (Table 10). These findings contribute to developing resistant varieties and enhancing disease management strategies for summer oilseed crops.

Crop Management and Outreach Research

Crop management trials have evaluated the impact of production factors on rapeseed yields. The treatment using 125% RDF (75:50:25 NPK kg/ha) produced the highest yield of 1296 kg/ha, followed by treatments with RDF plus sulphur (20 kg/ha) and RDF combined with five tonnes of poultry manure.

Research on sunflower crop management highlighted the impact of nitrogen and sulphur under varying tillage practices. Conventional tillage combined with the application of 60 kg/ha of nitrogen and 25 kg/ha of sulphur resulted in the highest plant population (50), head diameter (17 cm) and grain yield (1422 kg/ha). Similarly, weed management and moisture conservation practices significantly influenced sunflower yield. The highest grain yield (983.3 kg/ha) was achieved using oxyfluorfen at 200-250 g/ha as a pre-emergence herbicide and Linuron at 0.5 kg/ha as a post-emergence herbicide 30 days after sowing. This was followed by a plot using black plastic mulch and irrigation at the buttoning stage, yielding 776.7 kg/ha. These findings provide effective strategies for improving sunflower productivity under diverse conditions in Nepal.

Table 11. Research achievements under outreach research activities of winter oilseed crops

Trial Name/Crop	2019-20	2020-21	2021-22	2022-23
CFFT Rapeseed	ICT 2001-35 (ORP, ABD, HRS)	ICT 2001-35 (ARS, Belachapi& RARS, Parwanipur Acc# 9109 (ABD, Khumaltar; ARS, Surkhet)	ACC#9118 (HRS, ARS, Belachapi) ACC# 9109 (ORP, DoARLumle, DoAR, Parwanipur)	ACC#9109 (ARS, Belachapi, DoAR, Lumle) ACC# 9118 (ORP, Sarlahi)
CFFT Mustard	Krishna (764kg/ha),	Morang Rayo (622.2kg/ha), Pussajaganath (527.2 kg/ha)	PusaJaganath (680 kg/ha) (ORP), Krishna (649 kg/ha) [DoARParawanipur]	Krishna (970 kg/ha)

Trial Name/Crop	2019-20	2020-21	2021-22	2022-23
Micronutrient Trial/ Rapeseed	Improved practice + Sulphur 15 kg/ha) Yielded (1185 kg/ha)		Improved practice (IP) + Sulphur 15 kg/ha (1276 Kg/ha)	Sulfur 15 kg/ha (1055 kg/ha)
Integrated Crop Management/ Rapeseed	Improved practice (1100 kg/ha)		Improved Practice (IP) (1100 Kg/ha)	IP (RDF + 2 spray of D M 45 and insecticide Imidacloprid at 45 and 65 days of seeding) yielded 1185 kg/ha)
Integrated Pest Management / Rapeseed	Improved Practice (1065 kg/ha)		RDF + 2 spray of Dithane M45 and insecticide Imidacloprid at 45 and 65 days of seeding (1011 Kg/ha)	IP (2 sprays of Dithane M45 and insecticide Imidacloprid at 45 and 65 days of seeding) yielded 1270 kg/ha)
Integrated Nutrient Management (INM) Rapeseed	Improved practice (1110 Kg/ha)		Improved practice (1211 Kg/ha)	IP (N: P2O5:K2O 80:40:20 kg/ha + 2 spray of Dithane M45 and insecticide Imidacloprid at 45 and 65 days of seeding) yielded (1183 kg/ha)

Outreach research activities were conducted across four sites: Barahathawa-Sarlahi, Nijgadh-Bara, Santapur-Rautahat and Khairahani-Chitwan, along with farmer field trials in collaboration with other research stations. Prominent findings include the superior performance of genotypes such as ICT 2001-35 and ACC#9109 in rapeseed trials and Krishna, Pusa Jaganath and Morang Rayo in mustard trials. Furthermore, micronutrient trials revealed that improved practices combined with sulfur application significantly increased rapeseed yields, with results reaching up to 1276 kg/ha (Subedi et al., 2024). Integrated crop management practices also demonstrated consistent yield improvements, underscoring their importance in enhancing oilseed productivity (Table 11).

Germplasm Conservation and Maintenance

The conservation and maintenance of oilseed crops germplasm in Nepal is critical for safeguarding genetic diversity and supporting sustainable agricultural development. As of now, the National Agriculture Genetic Resource Center (NAGRC) has preserved a total of 197 oilseed germplasm accessions, ensuring their availability for future breeding and research purposes. Additionally, the Oilseed Research Program (ORP) has conducted evaluations on 495 oilseed germplasm accessions (ORP, 2021), focusing on their potential for improvement in yield, disease resistance and adaptability to various agro-climatic conditions (Figure 10).

Domain-Specific Spread of Rapeseed Varieties

The distribution of oilseed crop varieties across Nepal varies by region, reflecting adaptation to local agro-climatic conditions. In the Eastern Region, varieties such as Preeti, Bikash and Morang-2 are predominantly cultivated due to their suitability for the area. Similarly, in the Central Region, farmers primarily grow Preeti, Bikash and Nawalpur-4, which perform well in the region's conditions. The Western Region favors varieties like Unnati and Pragati, known for their adaptability and productivity. Meanwhile, in the Surkhet Valley, the locally adapted variety Surkhet Local is widely grown, reflecting its resilience and alignment with local farming practices. Lumle Tori-1 is popular in hill and midhill areas (ORP, 2021).

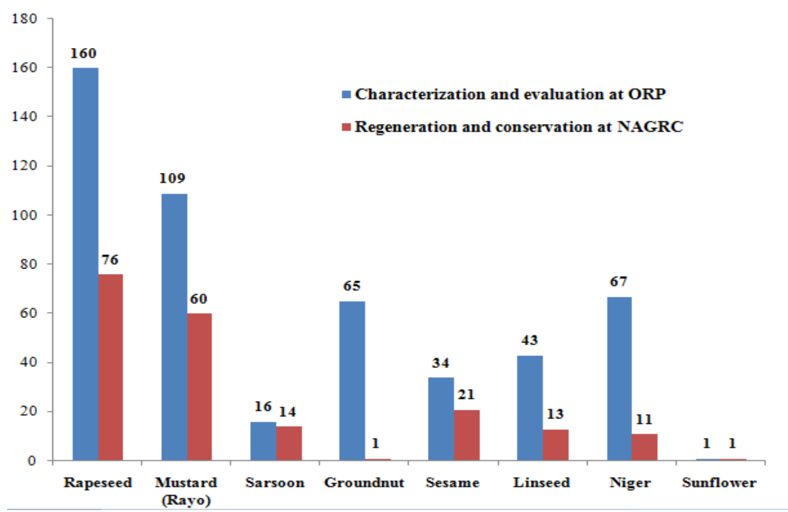


Fig. 10. Germplasm conservation of oilseed crops in Nepal

Recommended Cultivation Technologies for Oilseed Crops

For rapeseed, recommended varieties include Bikash, Pragati, Preeti, Unnati, Morang Tori-2 and Nawalpur Tori-4, while mustard varieties include Krishna, Pusa Bold, Pusa Jagannath, Morang Rayo and Divya. For sarsoon, Binoy and Ulta Sarsoon are suggested. The seed rate is 6-7.5 kg/ha, with a spacing of 30 x 10 cm for rapeseed and 40 x 10 cm for mustard and sarsoon. Fertilizer application should be 60:40:20 NPK kg/ha with 10 tons/ha of FYM for rapeseed and 80:40:20 NPK kg/ha plus 10 tons/ha of FYM for mustard and sarsoon. Treat seeds with Bavistin at 2.5 g/kg before planting. Rapeseed and sarsoon are planted between late Ashwin and early Kartik, while mustard is sown during the first fortnight of Kartik. Incorporating 4-6 bee hives per hectare aids pollination. Mixed cropping is recommended, such as mustard with chickpea (2 kg mustard + 48 kg chickpea/ha) or sarsoon with wheat (1 kg sarsoon + 120 kg wheat/ha). Irrigation is critical, with one application during pre-flowering for rapeseed and two (pre-flowering and pod filling stages) for mustard and sarsoon. To manage pests, apply Imidacloprid (1.5 ml/L water) as needed for aphid control. For Alternaria blight, spray Mancozeb (3 g/L water) three times at 15-day intervals, starting 45-50 days after sowing (ORP, 2023).

Groundnut varieties suitable for cultivation include Janak, Jyoti, Jayanti, Baidehi, Rajershi, B-4, Sambriddhi and Nawalpur Badam-1. Use 60 kg seed or 100 kg pods for small-seeded types and 70 kg seed or 120 kg pods for confectionery types, with spacing of 40 x 20 cm for spreading types and 30 x 20 cm for bunch types. Treat seeds with Carbendazim (2.5 g/kg). Fertilizer application should be 20:40:20 NPK kg/ha as basal. Planting is recommended during Baisakh/Jestha (May/June) in mid-hills and Jestha/Ashadh (June/July) in the Terai. For disease management, spray Carbendazim (2 g/L water) for leaf spots and Chlorothalonil for rust and leaf spot control.

Sunflower requires a seed rate of 10 kg/ha with a spacing of 60 x 25 cm. Treat seeds with Carbendazim (2.5 g/kg) and apply fertilizer at 60:40:20 NPK kg/ha. Planting is done in winter (Ashwin/Kartik) or spring (late Magh to early Falgun). Irrigation is necessary at flowering and grain filling stages. Control pests like caterpillars and sucking insects with Imidacloprid (1.5 ml/L water) and foliar diseases with Mancozeb (3 g/L water). Bird management is essential from flowering to harvest.

For niger, the variety Nawalpur Jhusetil-1 is recommended, with a seed rate of 6 kg/ha and spacing of 30 x 10 cm. Fertilizer application should be 40:30:20 NPK kg/ha. Planting time is Shrawan/Bhadra in the Terai and Jestha to Bhadra in mid-hills (Mishra and Ghimire, 2020). Caterpillar control can be achieved with Imidacloprid (1.5 ml/L water).

Sesame cultivation is best with the variety Nawalpur Khairotil-1 (Ghimire, 2000), using a seed rate of 5-6 kg/ha and spacing of 30 x 10 cm. Apply 40:30:20

NPK kg/ha fertilizer and plant during Shrawan/Bhadra. Pests like caterpillars can be controlled using Imidacloprid (1.5 ml/L water). For foliar diseases, use Mancozeb or copper oxychloride sprays**.**

Trends in Oilseed Supply and Demand

Import/Export trend of oilseeds in Nepal

The oilseeds imports and export scenario in Nepal over the past three fiscal years highlights a significant trade imbalance in this sector. In the fiscal year 2021/22, Nepal's oilseed imports amounted to NRs 32.91 billion, while exports were much lower at NRs 1.73 billion, resulting in a trade loss of NRs 31.18 billion. The following year, 2022/23, saw a reduction in imports to NRs 24.28 billion, with exports slightly rising to NRs 1.91 billion, reducing the trade loss to NRs 22.36 billion. In 2023/24, imports further declined to NRs 21.18 billion, while exports remained stable at NRs 1.92 billion, resulting in a trade loss of NRs 19.27 billion (MOF, 2023). This trend clearly indicates Nepal's continued dependence on oilseed imports and its minimal export capacity, leading to persistent trade deficits in the oilseed sector (Figure 11).

In terms of quantity, Nepal imported 370.53 million kilograms of oilseeds in 2021/22, while exports were limited to only 34.68 million kilograms, underscoring the country's heavy reliance on imported oilseeds. In 2022/23, imports decreased to 230.47 million kilograms and exports showed a small decline to 33.67 million kilograms, resulting in a slight improvement in the trade balance. However, in 2023/24, imports slightly rose to 246.49 million kilograms, while exports fell sharply to just 10.71 million kilograms, further exacerbating the trade gap between imports and exports (MOF, 2023). This data reflects Nepal's ongoing struggle with balancing oilseed trade and highlights the sector's reliance on imports (Figure 12).

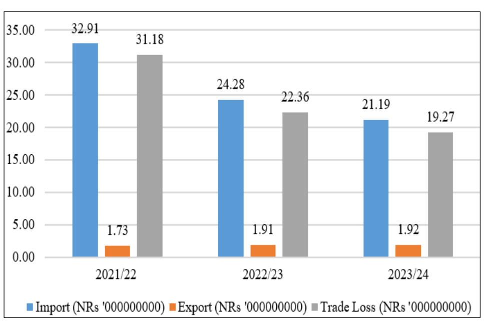


Fig 11. Import and export value of oilseed crops in Nepal

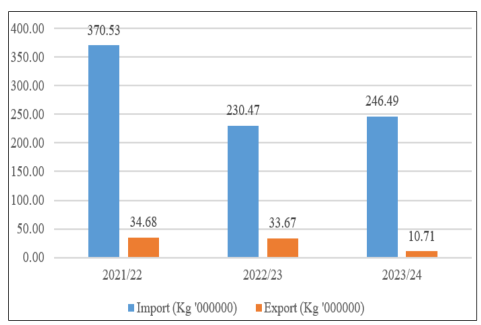


Fig 12. Import and export quantity of oilseed crops in Nepal

Trends in oilseed consumption in Nepal

Oilseed consumption in Nepal has been significantly shaped by population growth, changing dietary habits and an increasing preference for edible oils in cooking. As Nepal's population grows at an annual rate of around 2%, the demand for edible oils continues to rise. Urbanization has also contributed to this increase, as more people adopt urban lifestyles that involve greater use of packaged and refined oils in daily cooking. Additionally, higher disposable incomes have led to a greater reliance on oil-rich processed foods, further driving up oilseed consumption. Despite the rising demand, Nepal faces challenges in meeting this demand with domestic production, which has struggled to keep pace.

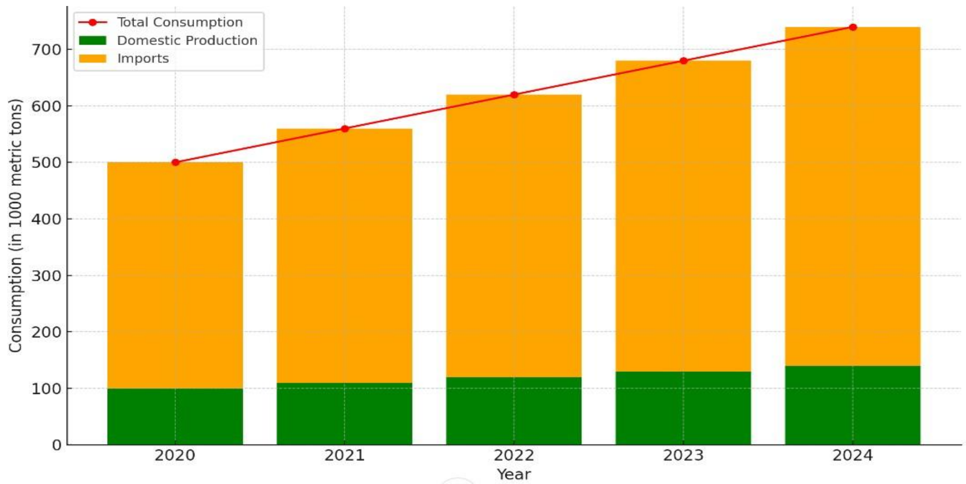


Fig 13. Trends in Oilseed production, imports and consumption in Nepal

Nepal relies heavily on imports to fulfill its oilseed needs. While locally produced oilseeds such as mustard, sunflower, sesame and soybean are available, the country imports a significant portion of its edible oils, primarily palm oil and soybean oil. Imported oils account for 70-80% of total consumption and import volumes have been steadily increasing over the years. Domestic oilseed production, including mustard, groundnut and linseed, has been inconsistent due to factors such as small landholdings, limited access to improved seeds and fertilizers and pest and disease outbreaks. As a result, domestic production meets only about 20-30% of the national demand (MOF, 2023) for edible oils (Figure 13).

In terms of regional preferences, rapeseed/mustard oil remains a staple in rural areas due to its traditional use and local availability. In contrast, urban areas have seen an increasing demand for refined oils like soybean oil and sunflower oil, which are viewed as healthier and more versatile for modern cooking. The per capita consumption of edible oil in Nepal is around 10-11 kg per year, which is lower than the global average, but it is steadily increasing as diets diversify and access to markets improves.

Global market trends also play a crucial role in influencing edible oil consumption in Nepal. The prices and availability of oils like palm oil and soybean oil are subject to fluctuations in the global market, which are often affected by trade agreements, import restrictions and crises such as the COVID-19 pandemic. Looking ahead, there is a growing awareness of health and nutrition, which is expected to drive the consumption of locally produced, cold-pressed oils such as mustard and linseed. Furthermore, increasing investments in domestic oilseed production, along with government policies promoting self-sufficiency, may help stabilize consumption trends in the long run and reduce the country's dependency on imports.

Oilseed Crop Production Requirement and Projection in Nepal

Nepal's growing population and changing dietary preferences have significantly increased the demand for edible oils. To reduce its reliance on imports, boosting domestic oilseed production is crucial. Currently, the demand for edible oil in Nepal is approximately 250,000 metric tons (MT) annually. However, domestic oilseed production stands at around 200,000-220,000 MT, which yields approximately 70,000-80,000 MT of oil after processing (MoALD, 2023). More than 70% of the country's edible oil demand is met through imports, creating a significant dependency on foreign sources. To meet the domestic edible oil demand of 250,000 MT, Nepal would need to produce sufficient oilseeds, considering an average oil recovery rate of 40-50%. This means that Nepal would require approximately 555,000 MT of oilseed production annually to fulfill the current demand.

$$\text{Oilseed Requirement} = \frac{\text{Edible Oil Demand}}{\text{Average Recovery Rate (0.45)}} = \frac{250,000}{0.45} \approx 555,000\,\text{MT}$$

The future projections indicate that by 2030, Nepal will need about 625,000 MT of oilseed production to meet the projected increase in edible oil demand. To bridge the gap between current production and future requirements, several strategies must be adopted. These include expanding the cultivation area of oilseed crops from the current 200,000 hectares to at least 250,000 hectares, improving yields by increasing productivity from the current 1.0-1.1 MT per hectare to 1.5 MT per hectare through better farming practices and high-yielding varieties and promoting mechanization in sowing, harvesting and oil extraction to enhance efficiency and recovery rates. Additionally, focusing on research and development to create climate-resilient, pest-resistant oilseed varieties will be essential (Yadav et al., 2020). Providing supportive policies such as subsidies for quality seeds, fertilizers and mechanization tools, along with improving market infrastructure, will further help. These initiatives are crucial for Nepal to achieve self-reliance in edible oil production and reduce its dependency on imports.

- **Projected Edible Oil Demand by 2030**:

$$\text{Future Demand} = 250,000 \times (1 + 0.02)^6 \approx 281,000\,\text{MT}$$

- **Required Oilseed Production by 2030**:

$$\text{Oilseed Requirement} = \frac{281,000}{0.45} \approx 625,000\,\text{MT}$$

Oil recovery efficiency

The oil recovery rate refers to the percentage of oil extracted from oilseeds during processing and in Nepal, these rates vary significantly. For example, rapeseed and mustard seeds typically have an oil recovery rate of 35% to 40%, while soybean oil recovery ranges from 20% to 25%. These rates are relatively low compared to global standards, where oil extraction rates can exceed 45% with advanced processing technologies. The lower recovery rates in Nepal can be attributed to the traditional methods used in oil extraction, such as expeller pressing, which are commonly employed by small-scale processors using outdated machinery. These outdated techniques do not optimize oil extraction, resulting in substantial oil losses during processing. Moreover, the availability and use of modern extraction technologies, such as cold-press and solvent extraction methods, are limited in Nepal. Although these technologies could significantly improve recovery efficiency, they require substantial investment and technical expertise, which many local farmers and small businesses lack.

The efficiency of oil recovery is also influenced by the oil content of different oilseed varieties. Varieties with higher oil content typically yield better extraction results, making the development of high-yield and high-oil-content varieties through research and development essential for improving recovery rates. Additionally, effective post-harvest management practices, including proper drying and storage, play a crucial role in maximizing oil recovery. Poor handling can lead to spoilage and degradation of oil quality, which impacts the overall extraction process. A lack of training and knowledge among farmers regarding modern oil extraction techniques and best practices further contributes to lower recovery rates. Capacity-building initiatives to educate farmers on effective oilseed processing could significantly enhance recovery efficiency.

The technological upgradation is critical for improving oil recovery rates in Nepal. Investing in modern oil extraction technologies and introducing state-of-the-art machinery could raise extraction rates, reduce production costs and improve product quality. Public-private partnerships (PPP) can also be instrumental in mobilizing resources and expertise to enhance oil recovery efficiency. Collaborative efforts can lead to the establishment of better processing facilities and training programs for farmers and processors. Furthermore, the Nepalese government can play a pivotal role in supporting the oilseed sector by providing financial incentives, facilitating access to modern technologies for local processors and promoting research and development in oilseed genetics and processing technologies. These initiatives are vital for improving oil recovery rates and advancing the oilseed industry in Nepal.

Machinery Issue

Availability of suitable machinery for the harvesting and processing of oilseed crops

The limited availability of suitable machinery for the harvesting and processing of oilseed crops significantly impacts efficiency, crop quality and profitability. Oilseed crops like rapeseed, mustard, soybean and sunflower are still predominantly harvested manually, which is labor-intensive, time-consuming and results in increased labor costs and harvest delays in Nepal. For instance, rapeseed/mustard harvesting is often done by hand, as mechanized harvesting equipment specific to oilseeds is scarce. According to the Ministry of Agriculture and Livestock Development's 2022 data, less than 5% of oilseed farmers have access to mechanized harvesting tools and those available are often unsuitable for Nepal's terrain and crop conditions. Additionally, many oilseed processing units rely on outdated equipment, such as traditional expeller presses, which are inefficient compared to modern extraction technologies like solvent extraction systems. These traditional methods typically yield around 70-80% of the oil content from mustard seeds, while modern equipment can achieve over 90% extraction efficiency. A 2023 study by the Federation of Nepalese Chambers of Commerce and Industry (FNCCI) noted that most processing facilities in Nepal operate below capacity due to outdated technology.

Nepal's heavy reliance on imports for agricultural machinery, including oilseed processing equipment, further exacerbates the issue. The high cost of imported machinery, along with limited technical support for maintenance, makes advanced equipment inaccessible to small- and medium-scale farmers and processors. Import duties, transport costs and logistical hurdles contribute to machinery being 20-30% more expensive in Nepal than in neighbouring India, as reported by the Nepal Agricultural Machinery Entrepreneurs' Association (NAMEA). Additionally, Nepal has minimal local manufacturing capacity for agricultural machinery and the machinery that is produced is often designed for rice, maize and wheat, not oilseeds like rapeseed, mustard, groundnut and niger. This lack of oilseed-specific equipment hinders farmers and processors from fully optimizing their operations. Furthermore, smallholder farmers, who dominate the oilseed sector, face challenges in accessing affordable, smaller machinery suited to their needs. Larger, commercial-scale equipment is not appropriate for small-scale operations and mini-oil expellers or hand-held harvesters, which could enhance value addition at the community level, are rarely available in local markets.

Even when machinery is available, the lack of proper training and technical support for its use and maintenance is a significant barrier. Many farmers lack experience with oilseed-specific machinery and without adequate training programs, they struggle to operate and maintain the equipment. The Nepal Agricultural Research Council (NARC) has identified this gap, but demonstration programs remain limited in reach. Financial constraints also hinder the adoption of modern machinery, as the upfront cost is prohibitive for many small and medium-sized enterprises (SMEs) involved in oilseed production and processing. Agricultural loans are limited and machinery financing is underdeveloped, with agricultural machinery loans making up less than 3% of total agricultural credit in 2023, according to the Nepal Rastra Bank.

To address these challenges, a comprehensive effort is needed to increase access to suitable, affordable and small-scale machinery through subsidies or financing schemes. There is also a need to develop local manufacturing or adapt existing machinery to suit Nepal’s unique agricultural conditions. Promoting training and technical support for oilseed farmers and processors is essential to improve the efficient operation and maintenance of equipment. Facilitating partnerships with neighbouring countries with established agricultural machinery sectors could help ease the import process or enable technology transfers tailored to oilseed crops. By improving machinery access, oilseed farmers and processors in Nepal could increase productivity, reduce labour costs and enhance the quality and profitability of their oilseed products.

Quality of Oil and Value Addition

The quality and value addition in the oilseed sector of Nepal are constrained by inconsistent production practices, inadequate quality control and reliance on traditional processing methods. Approximately 30% of locally produced rapeseed/mustard oil fails to meet the purity and quality standards set by the Nepal Bureau of Standards and Metrology. This inconsistency is due to the lack of proper quality control measures, resulting in variations in taste, purity and nutritional value. Additionally, about 20% of oils sold in local markets are adulterated with cheaper oils such as palm or soybean oil, which further reduces the quality and consumer trust. However, there is a growing demand for premium oils, such as cold-pressed and organic options, particularly in urban areas where consumers are more health-conscious, creating a market gap for high-quality, locally produced oils.

Most of Nepal's oilseed processing still relies on expeller pressing, which is less efficient than modern techniques like solvent extraction. This traditional method extracts only about 80% of the oil from seeds, compared to solvent extraction systems that can yield an additional 10-15%. Cold-press technology, which preserves higher nutritional content, is expensive and used by only a few urban processors, limiting the availability of high-nutrient oils such as cold-pressed mustard and sunflower oil. Despite these challenges, Nepal has significant potential for diversification into high-value oils, such as flaxseed, sesame and niger oil. However, the export of these oils is currently limited, with Nepal's sesame oil export accounting for less than 1% of the global market in 2023. Certification and processing limitations hinder the growth of this sector.

The packaging of oil products also presents an issue, as approximately 60% of locally produced oils are sold in basic plastic packaging, which allows exposure to light and air, leading to oxidation and quality degradation. Upgrading packaging materials to airtight and UV-resistant types could increase shelf life by 20-30%, improving both quality and consumer perception. Branding and consumer appeal also play a role, as oils packaged in high-quality containers that highlight health benefits and origin can command a price premium of up to 25%. Unfortunately, many local producers lack the resources or awareness to invest in such branding efforts.

The government has introduced some support measures, including subsidies on seeds and grants for equipment, but financial assistance for advanced processing equipment remains limited. Expanded support could significantly enhance the sector's ability to improve quality control and value addition. Collaboration with research institutions, like the Nepal Agricultural Research Council (NARC), has led to the development of improved mustard seed varieties that have increased oil yield by up to 15%. Scaling these findings to larger production could benefit the oilseed industry and help meet domestic demand.

Economically, Nepal imports approximately 90% of its edible oils, valued at over $200 million annually. This reliance on imports highlights the potential economic benefits of improving local oilseed production. By focusing on value addition, Nepal could reduce its import bill and develop a more sustainable oilseed industry. With proper certification and quality control, Nepalese oils, particularly oils like sesame and flaxseed, have strong export potential in health-conscious markets in the United States, Japan and Europe. However, the export of Nepalese oilseeds remains limited, but there is considerable potential for growth with investments in processing technology and quality improvement.

Improving the quality and value of oilseed products in Nepal offers significant opportunities for economic growth, reduced import dependency and the expansion of export markets. Addressing challenges in processing technology, packaging and certification can elevate domestic production, allowing Nepal to meet growing consumer demand for high-quality oils and position its oilseed sector toward a more sustainable and profitable future.

Marketing Issue

Marketing oilseed crops and their products in Nepal faces several significant challenges that hinder the growth of the sector and reduce profitability for farmers. One of the primary issues is the underdeveloped market infrastructure, particularly in rural areas where most oilseed crops are cultivated. A 2022 report by the Ministry of Agriculture and Livestock Development revealed that over 60% of rural areas lack proper storage facilities and only 25% of agricultural markets have basic storage. This lack of infrastructure results in high post-harvest losses, especially for oilseeds like rapeseed/mustard and soybean, which have a shorter shelf life in humid conditions. Consequently, farmers are often forced to sell immediately after harvest when prices are low, reducing profitability.

Another significant challenge is the inconsistent supply and quality of oilseeds. The production of mustard seeds, Nepal's most widely grown oilseed crop, dropped by 15% between 2021 and 2023 due to adverse weather and pest infestations, as reported by the Department of Agriculture. This fluctuation makes it difficult for producers to secure steady contracts with processors or buyers and variations in quality impact consumer trust. A 2020 study found that only 30% of Nepali mustard oil met standard quality parameters, compared to 80% in India, resulting in a preference for imported oils. Nepal also faces a lack of processing facilities, with the country importing about 80% of its edible oil. There are approximately 200 oil processing units in Nepal, which are insufficient to meet domestic demand, according to a 2023 report by the Federation of Nepalese Chambers of Commerce and Industry (FNCCI). This limited processing capacity leads to the export of raw oilseeds at low prices rather than value-added processed oil products, which could command higher market prices. Furthermore, access to market information remains limited for Nepali farmers, particularly smallholder farmers. The National Agricultural Market Information System (NAMIS) provides data on prices, but its coverage and accuracy can be unreliable. A 2022 survey by the Nepal Agriculture Research Council found that 70% of farmers do not have timely access to current market prices, restricting their ability to make informed decisions about when and where to sell their produce.

The Nepali market is also heavily influenced by imported oils, especially soybean, sunflower and rapeseed/mustard oils from India and other countries, which dominate due to their lower prices and consistent quality. Domestic consumer awareness of the health benefits of locally grown oilseeds, such as mustard and sunflower, is limited, which affects demand. Local brands struggle to compete, as imported oils are often perceived as better quality and come at lower prices. Additionally, limited access to credit and investment restricts farmers and processors from investing in improved technologies for production, storage and processing. A 2022 report by Nepal Rastra Bank revealed that only 12% of small-scale farmers in Nepal had access to formal credit, which stifles innovation and prevents the adoption of high-yield seeds, efficient irrigation and pest management solutions.

Lastly, policy and regulatory constraints, such as high import taxes on raw oilseeds and refined oils, create an uneven playing field. Refined oils from India benefit from low import duties due to trade agreements, making them more affordable compared to locally produced oils. In contrast, locally grown oilseeds are subject to a 13% VAT, making it difficult for Nepali producers to compete. The lack of clear and coherent regulatory policies for quality standards also affects consumer confidence. The Ministry of Agriculture's 2023 assessment identified these policy issues as major barriers to the development of the oilseed sector in Nepal.

Addressing these challenges will require a diverse approach, including improving market infrastructure, supporting quality control in production, expanding local processing facilities, providing timely market information, increasing access to credit and reforming regulatory policies to make local oilseed products more competitive.

Government Policies

Existing and Future Strategies for Enhancing Oilseed Crop Production

The Government of Nepal has been actively pursuing strategies to enhance oilseed crop production, aiming to improve food security, reduce reliance on imports and strengthen rural livelihoods. Existing initiatives focus on increasing productivity through the promotion of high-yielding, disease-resistant varieties of oilseeds like rapeseed, mustard, soybean and sunflower, with support from the Oilseed Research Program (ORP) under the umbrella of Nepal Agricultural Research Council (NARC). The government provides subsidies for seeds, fertilizers and pesticides to reduce input costs, while also promoting mechanization through small-scale oilseed threshers and seed drills under Prime-minister Modernization Agriculture Project (PMAMP). Plans include expanding research to cover more oilseed crops, such as niger, sesame and sunflower and offering additional subsidies for machinery and processing units to modernize oilseed production. The government also aims to increase access to finance for farmers, develop better pest and nutrient management practices and enhance rural infrastructure, including processing facilities, to reduce post-harvest losses and improve market access. These efforts are designed to boost the sector's competitiveness, particularly through initiatives like organic oilseed production and the establishment of local collection centers for more efficient processing.

Nepal's strategy involves reducing dependence on imported edible oils by fostering domestic production through expanded cultivation and improved yields. The government has set ambitious targets to increase oilseed production by 30% over the next five years and is considering price support mechanisms, such as a minimum support price (MSP), to stabilize farmer incomes and encourage greater production. Furthermore, plans to incentivize private sector investment in oilseed processing and strengthen market linkages, including through cooperative marketing structures and online platforms, are key to ensuring better returns for farmers. As these strategies unfold, they are expected to enhance both the quantity and quality of oilseed crops, positioning Nepal as a more self-sufficient and sustainable producer, thereby reducing the nation's reliance on imports while fostering economic growth and agricultural sustainability.

Possible role of public-private partnership in the promotion of oilseed crops

Public-private partnerships (PPPs) have significant potential to promote oilseed crops in Nepal, a country that relies heavily on imports for edible oil despite favorable conditions for oilseed cultivation. By leveraging investments, infrastructure development and market access, PPPs can contribute to reducing import dependency and boosting the local economy. One primary role of PPPs is to facilitate investment in infrastructure, particularly in establishing processing facilities for oilseed extraction. Private sector involvement can bridge the capital gap, improve the quality of locally produced oil and make it competitive with imports. The Government of Nepal has recognized this need and promotes policies encouraging private investment in agricultural infrastructure such as storage, processing and distribution.

Furthermore, PPPs enhance market access by developing direct supply chains between farmers and markets, reducing post-harvest losses and ensuring fair pricing for farmers. The Agriculture Development Strategy (ADS) highlights the importance of connecting farmers to markets, with private companies playing a key role in creating efficient distribution channels. PPPs also foster research and development (R&D) collaborations between private agricultural firms and institutions like the Nepal Agricultural Research Council (NARC). These collaborations focus on developing high-yield, disease-resistant oilseed varieties and modern agricultural techniques, such as precision farming, which optimize resource use and boost productivity in oilseed.

In addition, PPPs can provide essential financial services, such as credit facilities and crop insurance, by partnering with financial institutions. These services encourage farmers to invest in oilseed production, supported by government subsidies and guarantees. Value addition through local processing is another crucial aspect, with PPPs helping to establish facilities that convert raw oilseeds into refined oil and by-products. This increases farmers' income potential and creates jobs in rural areas. Finally, PPPs offer opportunities for capacity building and knowledge transfer, with private companies providing training on improved farming techniques and management practices, leading to better-quality produce and increased competitiveness.

PPPs offer a comprehensive strategy to promote oilseed crops in Nepal, by facilitating infrastructure development, improving market access, supporting R&D, providing financial services and enhancing value addition. These partnerships can transform the oilseed sector, reduce import dependency and contribute to the broader economic and agricultural development goals of Nepal.

Way Forward

To enhance oilseed productivity and scale up production in Nepal, it is essential to adopt advanced agricultural practices, including high-yield, disease-resistant oilseed varieties and modern techniques like integrated pest management (IPM) and precision agriculture. Training programs for farmers on these practices can boost yields and oil recovery. Additionally, investment in modern oil extraction technologies, such as cold-press and expeller methods, will improve oil recovery rates and quality. To further increase productivity, efforts should focus on improving soil health through regular testing and appropriate fertilizer application. Expanding the variety of oilseed crops, such as introducing niger and groundnut alongside traditional rapeseed/mustard and sesame, can improve resilience to market fluctuations. Investment in rural infrastructure, including roads and storage facilities, is crucial for reducing post-harvest losses and improving market access. Encouraging cooperative models for farmers will help pool resources, enhance marketing power and facilitate better access to inputs.

Government support is key to scaling up oilseed production, with increased financial resources allocated for agricultural research, extension services and the development of capacity-building programs for farmers, extension workers and processors. Financial incentives such as low-interest loans, subsidies for equipment and crop insurance schemes can encourage investment in oilseed production and processing. To improve market recognition, a national branding strategy for Nepali oilseed products can build consumer trust and open new market segments, including products like organic oils and oil cakes for animal feed. Public-private partnerships (PPPs) should be fostered to facilitate technology transfer, infrastructure development and better market access. Additionally, long-term research and development efforts should focus on creating climate-resilient oilseed varieties. Expanding market access and promoting exports, particularly to neighboring countries, will help ensure the success of Nepal's oilseed sector. By implementing these strategies, Nepal can reduce its dependence on oilseed imports, support rural economies and boost self-sufficiency in edible oil production.

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Chapter 6

Productivity Enhancement of Oilseed Crops in Pakistan

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Introduction

Ensuring food and nutritional security has been a fundamental objective of Pakistan's policies, programs, and strategies since its independence. Pakistan's economy is a mixed one, comprising agriculture, industry and services sectors. However, as an agrarian country, the development of the agricultural sector is crucial for achieving food and nutritional security.

Edible oil, a critical component of the human diet, plays a significant role in supporting proper bodily functions and development. For a balanced and healthy life, approximately one-third of total caloric intake should come from oils and fats. Vegetable oils, which are primarily derived from seeds and fruits, such as palm and olive, serve as essential sources of nutrition.

In Pakistan, edible oil is predominantly extracted from oilseed crops, including cottonseed, rapeseed, mustard, canola and sunflower (Figure 1). These crops are the third most significant group in the agricultural sector after cereals and sugar crops. However, these are categorised as minor (other) crops. Wheat, rice, cotton, sugarcane and maize are categorised as major ones (important crops).

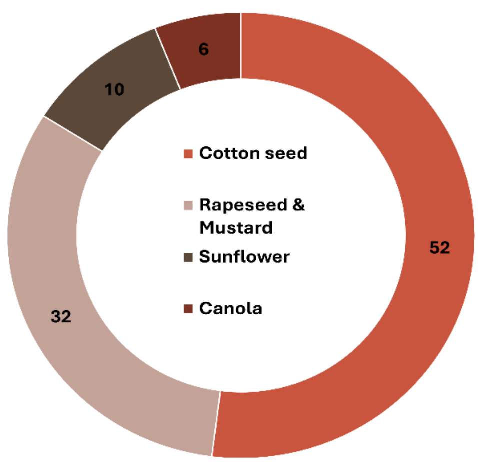


Fig 1. Share (in %age) of Domestic Edible Oil Extraction

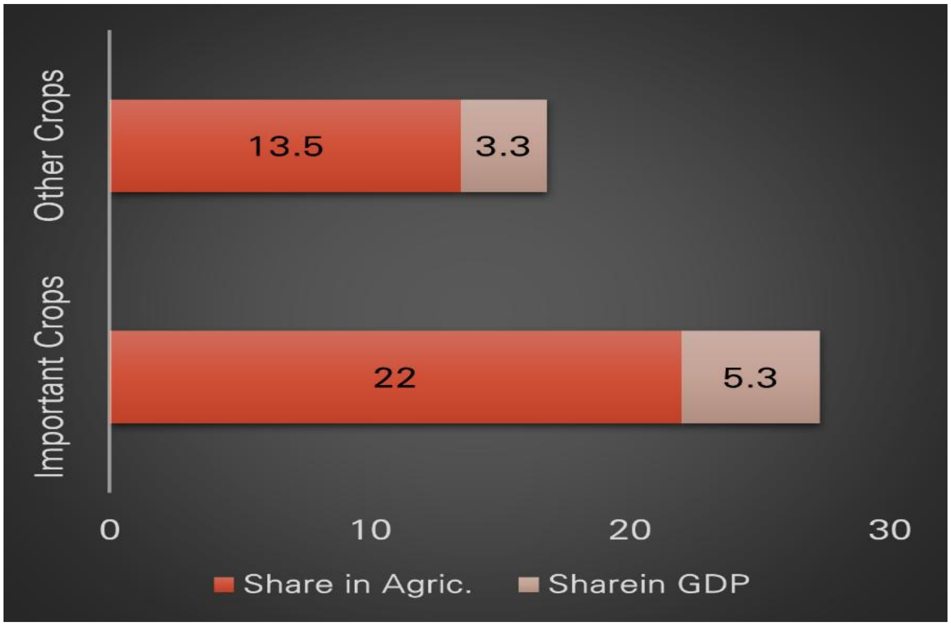


Fig 2. Economic Performance (GDP growth in %) of Agriculture Sector - Crops sub-sector (FY 2023-24)

Pakistan's economy is underpinned by a diversified base, with agriculture contributing 24% to GDP and employing 37.4% of the workforce. The sector's predominance emphasizes its critical role in driving economic growth, generating employment and alleviating poverty, given its strong linkages with other sectors.

The agriculture sector demonstrated strong performance in 2023-24, achieving an overall growth of 6.25%. Crop production surged by 11.03%, marking a significant improvement over the previous year. Within this sub-sector, major crops recorded an impressive 16.82% growth, reflecting solid recovery and increased production. Other crops exhibited modest growth of 0.90%, contributing to stability but playing a smaller role in overall growth. These cops exhibited 22% contribution towards agricultural value addition and ~5% direct contribution towards GDP (Gross Domestic Product).

Despite their importance, the production of oilseed crops (excluding cotton) in Pakistan has consistently fallen short of domestic demand (Figures 4-6). As a result, the country relies heavily on imports to meet its edible oil requirements.

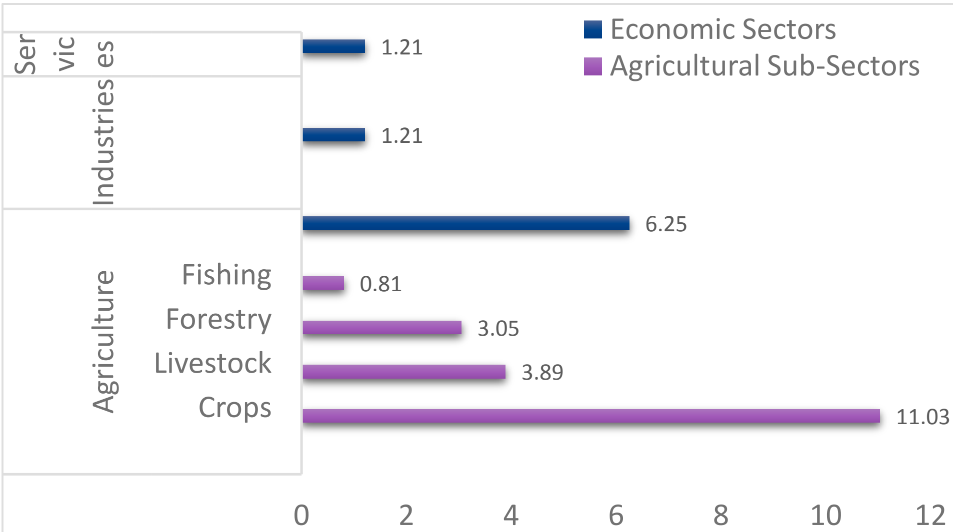


Fig 3. GDP Growth (in %) of Economic Sectors (FY 2023-24)

Rapeseed and mustard are important oilseed crops in Pakistan, contributing significantly to the production of edible oils. These crops are predominantly grown during the Rabi season (winter), typically between October and March, under varying agro-climatic conditions across the country. They provide 30-40% oil content, making them a major source of edible oil in Pakistan. The extracted oil is rich in omega-3 fatty acids and vitamins E and K, contributing to a balanced diet. The oilcake (residual seed meal) after oil extraction is rich in protein and is commonly used as livestock feed. These crops are well-suited to areas with limited water availability, making them important for dryland farming.

Sesame, locally known as Til, is an important oilseed crop in Pakistan. It is valued for its high oil content, nutritional benefits and adaptability to various agro-climatic conditions. Although, sesame cultivation is not as extensive as other oilseed crops, it has significant potential to contribute to the edible oil industry and export earnings. Sesame seeds contain 45-55% oil, which is of excellent quality, rich in unsaturated fatty acids and antioxidants like sesamin and sesamol. Sesame is a drought-resistant crop, making it suitable for arid and semi-arid regions of Pakistan with minimal water availability. It is a high-value crop, providing farmers with substantial returns. It is also an export commodity, particularly in Middle Eastern and Asian markets.

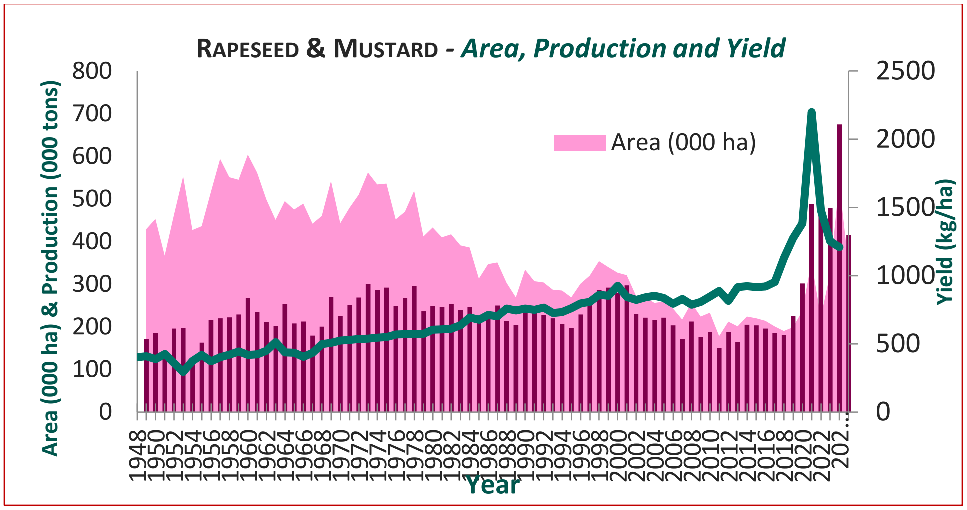


Fig 4. Domestic Statistics of Oilseed Crops -Categorized as Minor Crops

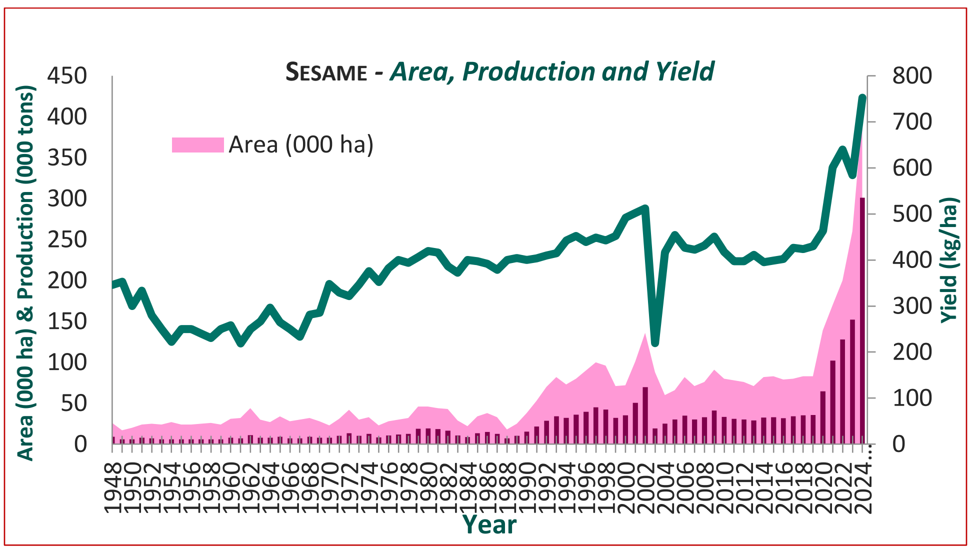


Fig 5. Domestic Statistics of Oilseed Crops -Categorized as Minor Crops

Sunflower is an important oilseed crop in Pakistan due to its high oil content, short growth duration and adaptability to diverse agro-climatic conditions. It serves as a key crop for reducing the country's dependency on edible oil imports, contributing to food security and the agricultural economy.

Sunflower seeds contain 40-50% oil, which is rich in unsaturated fatty acids, particularly linoleic acid, making it a healthier cooking oil option. With a crop period of just 90-120 days, sunflower is ideal for double cropping or as an intercrop. It provides higher returns per unit area compared to traditional crops, making it attractive to farmers. Sunflower grows well in a variety of climatic and soil conditions, from arid to irrigated regions.

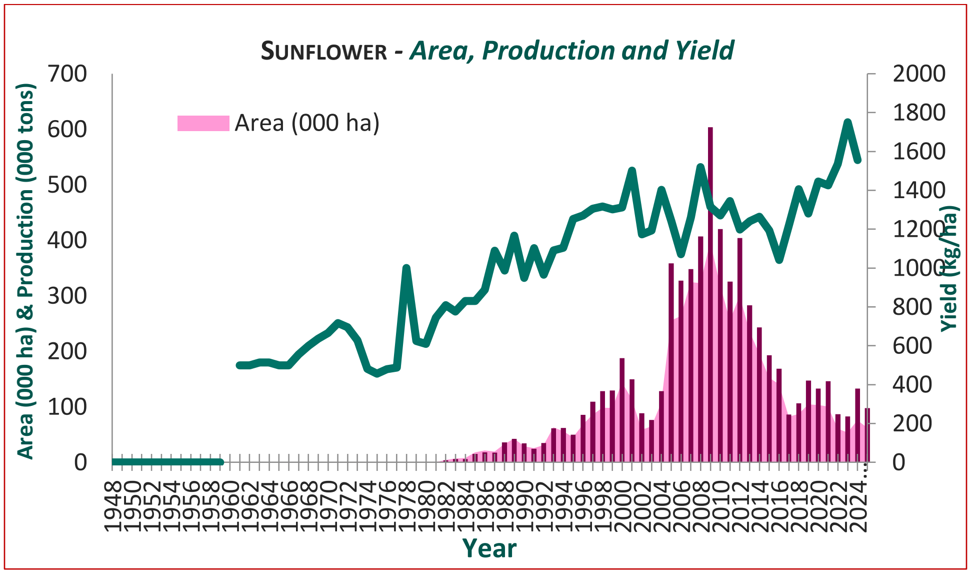


Fig 6. Domestic Statistics of Oilseed Crops -Categorized as Minor Crops

Edible oil is Pakistan's largest food import commodity, ranking third in the import list after petroleum, petrochemicals and machinery. Pakistan was self-sucient in edible oil until early 60's. Import of Palm oil was started in 1963 and remained modest during 70's and 80's. From mid-90's import was increased exponentially and now Pakistan is the third largest edible oil importer of the world after China and India.

Due to the increase in population of the country and changes in dietary habits, per capita consumption of edible oil has increased from 6 kg per annum to 18 kg per annum during last two decades (Figure 7). This trend can be attributed to rapid urbanization, rising income levels, enhanced use of roasted fast food and hoteling fashion. Due to low price and high stability during deep frying, Palm oil is preferred in fast food centers resulting in serious health hazards especially high blood pressure & cardiovascular problems even in the young generation.

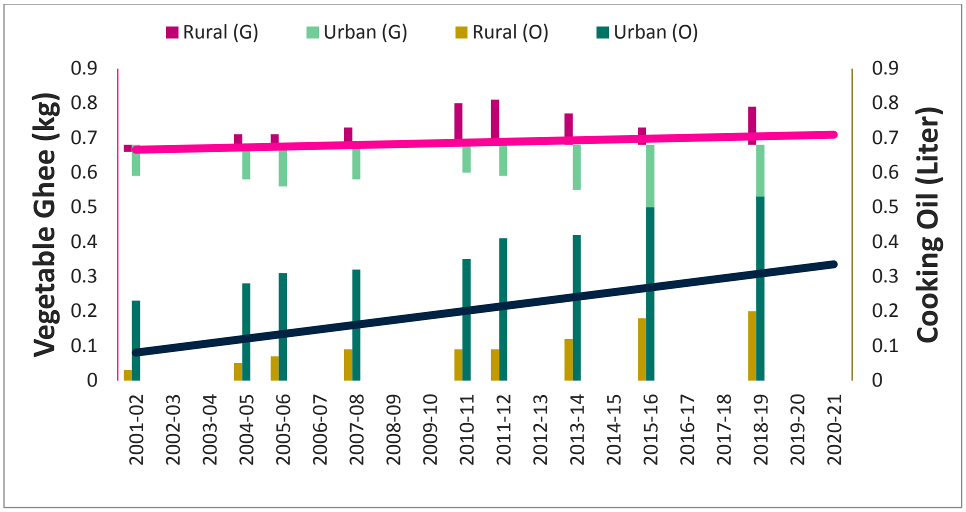


Fig 7. Trends in Monthly per Capita Consumption of Edible Oil in Pakistan

Despite efforts to expand oilseed cultivation, challenges remain intact owing to this increasing trend in per capita consumption and population. This highlights the need for enhanced agricultural strategies to improve self-sufficiency in edible oil production. Major challenges that the oilseed sector faces are as follows:

- **Low Productivity**: Oilseed crops in Pakistan suffer from low productivity due to inadequate technology, poor seed quality, and lack of access to modern farming practices. This results in lower per-acre yields compared to other oilseed-producing countries (Figure 8).
- **Limited Cultivation Area**: The area dedicated to oilseed crops is small compared to other major crops like wheat, rice and cotton. In some cases, farmers prioritize food crops or cash crops over oilseeds due to higher perceived profitability. Moreover, the crop(s) also faces competition with other major crops in particular agro ecological zone(s) (Figure 9).
- **Dependency on Imports**: Pakistan imports a significant amount of edible oil, with over 80% of its edible oil needs being met through imports. This creates a heavy financial burden and trade imbalance. In recent years, Pakistan has been importing edible oils like palm oil and soybean oil from countries like Malaysia, Indonesia and the United States. Pakistan's edible oil import bill is significant $4-5 billion annually). This import dependency on edible oil contributes to Pakistan's trade deficit, making it an economic challenge. This reliance underscores the need to improve domestic oilseed production to reduce foreign exchange expenditure.
- **Water Scarcity**: Oilseed cultivation, LLike other crops, faces challenges related to water scarcity. The country's water resources are under stress and oilseed crops often compete for water with more traditional crops.

- **Climate Conditions**: Oilseed crops like sunflower and soybean are sensitive to climatic conditions, and irregular weather patterns, such as droughts or floods, can significantly affect yields.

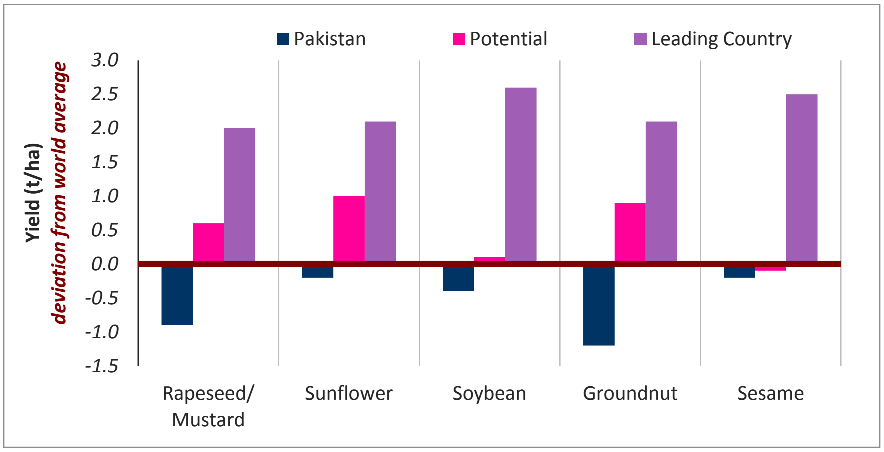


Fig 8. Agro-ecological Zones of Pakistan

The government of Pakistan has been encouraging oilseed cultivation through enhanced involvement of private sector and introduction of subsidies on seed, fertilizers and pesticides. There are also efforts to improve seed quality and provide training to farmers. Moreover, provincial and federal level institutions and private sector is working to develop higher-yielding and drought-resistant oilseed varieties with a focus on improving the overall production and quality of oilseed crops.

Research & Development:

Research and Development (R&D) in oilseed crops have been prioritized in Pakistan to address the challenges of productivity enhancement and improve domestic production. Major focus areas of oilseed research include:

Development of High-Yielding Varieties

Research institutions have been working on developing high-yielding and disease-resistant varieties of oilseed crops such as sunflower, canola, soybean and rapeseed. These varieties are aimed at improving productivity and resilience against biotic and abiotic stresses.

Adapting to Climatic Conditions

With Pakistan's diverse agro-ecological zones, research is focused on breeding oilseed varieties that are well-suited to the local climatic conditions, ensuring better adaptation to drought, salinity and temperature variations.

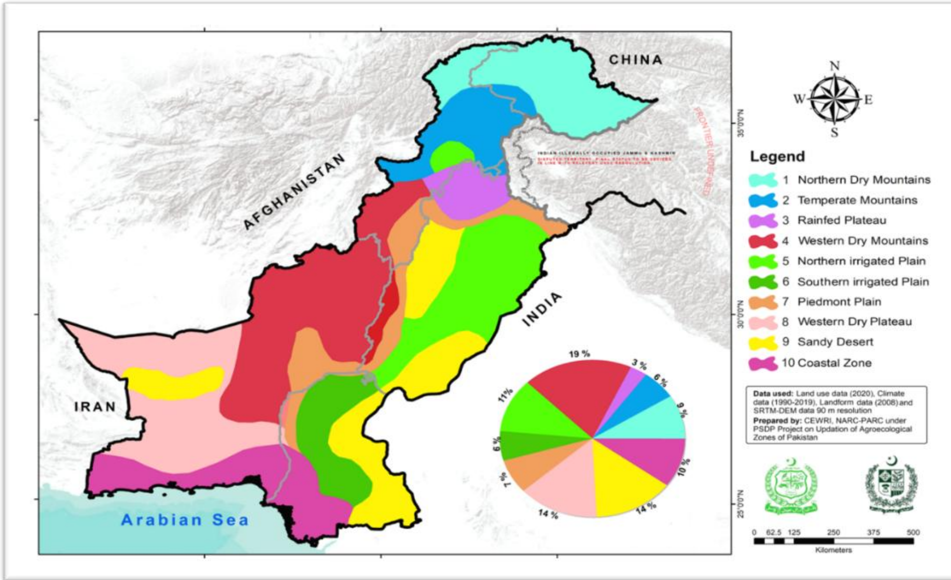


Fig 9. Productivity Perspective of Major Oilseed Crops in Pakistan

Enhancing Oil Content

Scientists are striving to increase the oil content in seeds to maximize yields from existing cultivated areas. This includes introducing hybrid varieties and improving oil extraction efficiency.

Crop Management Techniques

Research is also focused on agronomic practices such as optimized planting techniques, efficient irrigation methods, integrated pest management and soil fertility improvement to enhance oilseed crop productivity.

Post-Harvest and Processing Technology

Improving post-harvest handling and processing technology is a key area of research to reduce losses and improve the quality of extracted oil.

Pakistan Agricultural Research Council (PARC) has established the National Coordinated Research Programs (NCRPs) on crops as a mechanism to coordinate research efforts in the country. It started with research programs on major crops in collaboration with all concerned provincial and federal institutions and the private sector as participating units. The NCRPs provide the most effective mechanism for joint planning of agricultural research with a view to eliminate redundancy and repetition of research efforts and to improve the utilization of research resources. At present, there are seven Coordinated Crop Research Programs operated by the PARC viz. Wheat, Rice, Maize-Sorghum-Millet and other Fodders, Sugar crops, Pulses, Horticulture and Oilseed crops. Each program is headed by a National Coordinator and is based at PARC, whereas the coordinating units in the provinces are headed by the provincial senior scientists. The core activities assigned to be carried out by the National Coordination Research programs are:

i. Germplasm acquisition, evaluation and distribution

ii. National Uniform Yield Trials (NUYT)

iii. Annual Planning Meeting

iv. Traveling Seminar

National Coordinated Research Programmes have shared more than one million germplasm (accessions/lines) of Indigenous as well as exotic sources with the partners of coordinated research programs for use in their breeding programs. This germplasm helped the plant breeders of the National Agricultural Research System (NARS) to tailor the new varieties according to desired traits.

Various NARS stakeholders at federal and provincial levels as well as from the private sector are involved in a variety development activities. The major institutions involved are given in table 1.

Table 1. Major Public Sector Institutions Involved In Oilseed Research & Development Activities

Sl No	Institution	Status	Focus
1	Oilseed Research Program (ORP), Crop Sciences Institute (CSI), National Agricultural Research Center (NARC), Islamabad	Federal (Islamabad)	Rapeseed/Mustard/Canola, Sunflower, Soybean, Sesame, Groundnut
2	Oilseed Research Institute (ORI), Ayub Agriculture Research Institute (AARI), Faisalabad	Provincial (Punjab)	Rapeseed/Mustard/Canola, Sunflower, Soybean, Sesame
3	Barani Agricultural Research Institute (BARI), Chakwal	Provincial (Punjab)	Rapeseed/Mustard/Canola/ Taramira, Groundnut
4	Barani Agricultural Research Station (BARS), Fatehjang	Provincial (Punjab)	Rapeseed/Mustard/Canola/ Taramira, Groundnut
5	Oilseed Research Station (ORS), Khanpur	Provincial (Punjab)	Rapeseed/Mustard/Canola
6	Regional Agricultural Research Institute (RARI), Bahawalpur	Provincial (Punjab)	Rapeseed/Mustard/Canola
7	Groundnut Research Station (GRS), Attock	Provincial (Punjab)	Groundnut
8	Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad	Federal (Punjab)	Sesame, Soybean

Sl No	Institution	Status	Focus
9	National Institute for Biotechnology and Genetics Engineering (NIBGE), Faisalabad	Federal (Punjab)	Sesame, Soybean
10	University of Agriculture Faisalabad (UAF)	Provincial (Punjab)	Soybean
11	University of Sargodha (UOS)	Provincial (Punjab)	Sunflower
12	Oilseed Research Institute (ORI), Agriculture Research Institute (ARI) Tarnab Peshawar	Provincial (KP)	Rapeseed/Mustard/Canola, Sunflower, Soybean
13	Nuclear Institute for Food and Agriculture (NIFA), Peshawar	Federal (KP)	Rapeseed/Mustard/Canola
14	Agriculture Research Institute (ARI), Swat	Provincial (KP)	Rapeseed/Mustard/Canola, Soybean
15	Nuclear Institute of Agriculture (NIA), Tandojam	Federal (Sindh)	Rapeseed/Mustard/Canola
16	Oilseeds Research Institute (ORI), Agriculture Research Institute (ARI), Tandojam	Provincial (Sindh)	Rapeseed/Mustard/Canola, Soybean, Sesame, Sunflower
17	Agriculture Research Institute (ARI), Quetta	Provincial (Baluchistan)	Soybean
18	University of Agriculture Peshawar (UAP)	Provincial (KP)	Rapeseed/Mustard/Canola

Testing of potential elite lines/candidate varieties of crops across the country in the National Uniform Yield Trials at multilocation is the most important core activity of the NCRP on Oilseeds.

The candidate lines are evaluated in the NUYT for their yielding ability, adaptation to the environment, disease resistance, quality traits and other agronomic characteristics of economic importance.

The data of NUYT forms the basis of recommendations by the Variety Evaluation Committee (VEC) regarding the approval or rejection of these candidate varieties and their release in the country for commercial cultivation (Table 2). A summary (in numbers) for the received proposals (Pro) and VEC recommended candidate lines (Rec) of the last 5 years (2020-2024) is presented in Table 3.

Table 2. List of Registered/Released Oilseeds Varieties in Pakistan

Sl No	Crop	Variety Name	Breeding Institution	Year of Release
1	Groundnut	BARD 479	PARC, Islamabad	1992
2		BARI 89	BARI, Chakwal	1992
3		Chakori	BARI, Chakwal	1992
4		BARD 699	PARC, Islamabad	1993
5		Swat phali 96	ARS, Swat	1996
6		BARI 2000	BARI, Chakwal	2000
7		Golden Chakwal	BARI, Chakwal	2002
8		Fakhar-i-Swat SP-2004	ARS, Swat	2004
9		BARI-2011	BARI, Chakwal	2011
10		BARI-2016	BARI, Chakwal	2016
11		Pothowar	PARC, Islamabad	2017
12		NARC-2019(PG-1090)	PARC, Islamabad	2019
13		Fakhar-e-Chakwal	BARI, Chakwal	2021
14		Attock-2019	GRS, Attock	2021
15	Rapeseed / Mustard / Canola	Pela Raya	ORI-AARI, Faisalabad	1985
16		Altex	ARS, Swat	1986
17		Torch	ARS, Swat	1986
18		Tower	ARS, Swat	1986
19		Anmol 87	ORI-AARI, Faisalabad	1988
20		BARD 1	PARC, Islamabad	1990
21		Pak cheen	ARS, Swat	1990
22		Agaiti Sarhein	ARI, Tandojam	1991
23		Shiralee	PARC, Islamabad	1992
24		Chakwal Raya	BARI, Chakwal	1994
25		Abasin 95	NIFA, Peshawar	1996
26		Bulbul 98	ARI, Tarnab	1997
27		Khanpur Raya	ORI-AARI, Faisalabad/ORS Khanpur	2000
28		Zafar 2000	Tarnab, Peshawar	2000
29		Chakwal Sarson	BARI, Chakwal	2002

Sl No	Crop	Variety Name	Breeding Institution	Year of Release
30		Bahawalpur Raya	RARI, Bahawalpur	2003
31		NIFA Raya	NIFA, Peshawar	2003
32		Takwara	ARI, DI Khan	2004
33		Durr-e-Nifa	NIFA, Peshawar	2005
34		Punjab Canola	ORI-AARI, Faisalabad	2009
35		FAISAL CANOLA	ORI- AARI, Faisalabad	2011
36		Hasnain-2013	Hazara University	2013
37		NIFA Gold	NIFA, Peshawar	2013
38		SURHAN-2012	NIA, Tandojam	2013
39		Zahoor-2013	UAP, Peshawar	2015
40		AARI-Canola	ORI-AARI, Faisalabad	2016
41		Rohi Sarsoon	ORS, Khanpur	2016
42		Super Raya	ORS, Khanpur	2016
43		Super Canola	ORI-AARI, Faisalabad	2018
44		Sandal Canola 2019	ORI-AARI, Faisalabad	2019
45		Rokhana	UAP, Peshawar	2020
46		Dalaj	UAP, Peshawar	2020
47		Mehran Raya	ORI, Tandojam	2020
48		Sindh Raya	ORI, Tandojam	2020
49		11CBN006 (Barani Canola)	BARI, Chakwal	2021
50		Khanpur Canola (KN-279)	ORS, Khanpur	2021
51		Rachna Canola (RBN-13016)	ORI-AARI, Faisalabad	2021
52		Barani Sarson (14CBN009)	BARI, Chakwal	2021
53		NIFA-Sarson T-20	NIFA, Peshawar	2021
54		Mingora-I	ARI, Sawat	2022
55		IBGE Sarson	UAP, Peshawar	2022
56	Sesame	Til 89	ORI-AARI, Faisalabad	1990
57		TS 3	ORI-AARI, Faisalabad	2000
58		TH-6	ORI-AARI, Faisalabad	2009
59		TS-5	ORI-AARI, Faisalabad	2011

Sl No	Crop	Variety Name	Breeding Institution	Year of Release
60		NIAB Sesame 2016	NIAB, Faisalabad	2016
61		NIAB Pearl 2017	NIAB, Faisalabad	2017
62	Soybean	Swat 84	ARS, Swat	1984
63		NARC I	PARC, Islamabad	1992
64		NARC II	PARC, Islamabad	1992
65		Kharif 93	ARS, Swat	1993
66		Wahab 93	ARI, Tarnab, Peshawar	1993
67		Faisal	ORI-AARI, Faisalabad	1996
68		Malakand 96	ARS, Swat	1996
69		AARI Soybean (95-1-14)	ORI-AARI, Faisalabad	2021
70	Sunflower	C 206	Monsanto (Cargill), Lahore	1990
71		SF 100	Monsanto (Cargill), Lahore	1990
72		NK 265	Sandoz, Karachi	1992
73		P 6480	Pioneer, Lahore	1992
74		SF 187	Monsanto (Cargill), Lahore	1992
75		Aritar 93	ARI, Tarnab Peshawar	1993
76		PARC 92 E	PARC, Islamabad	1993
77		Peshawar 93	ARI, Tarnab, Peshawar	1993
78		RS-96	ARS, Mingora, Swat	1996
79		Gulshan 98	PODP, Tarnab, Peshawar	1997
80		FH-331 (Hybrid)	ORI-AARI, Faisalabad	2009
81		ORISUN-648 (FH-648)	ORI-AARI, Faisalabad	2021
82		ORISUN-701(FH-701)	ORI-AARI, Faisalabad	2021
83		ORISUN-675(FH-675)	ORI-AARI, Faisalabad	2021

Table 3. List of Recent VEC Recommended Oilseed Varieties of Pakistan

Sr No	Crop	Variety Name	Mode Yield (kg/ha)	Breeding Institution	Year of Release
1	Sunflower	GulBahar-436 F1	2300	Green Gold Agri Seeds	2022
2		ORISUN-701	2500	ORI-AARI Faisalabad	2022
3		ORISUN-751	2500	ORI, AARI Faisalabad	2022
4		ORISUN-741	2500	ORI, AARI Faisalabad	2022
5		NARC-Sun-2020	2300	PARC, Islamabad	2022
6		REYNA	2400	Seethi Seeds	2022
7		Diamond-2033	2100	Suncrop	2022
8		Tahafuz-4033	2200	Sungro	2022
9		Ali Sun 93	2400	Innovative Seed	2023
10		HSF-352C	2400	Certus Seed	2023
11		HSF-351B	2400	Certus Seed	2023
12		Sirena	2300	Seethi Seed	2023
13		HYSUN-60	2400	LCI	2024
14		HYSUN-55	2300	LCI	2024
15		HYSUN-50	2300	LCI	2024
16		HSF-353D	2300	Certus Seed	2024
17		HSF-354E	2500	Certus Seed	2024
18		Tipu Gold	2500	V-Gro Seed	2024
19	Soybean	NARC Golden Soy	1600	PARC, Islamabad	2023
20		ESB-390A	2000	Certus Seed	2023
21		Super Soybean	2100	ORI, AARI Faisalabad	2024
22		NIBGE-Soy-2	2400	NIBGE Faisalabad	2024
23	Sesame	Faisalabad Till	600	ORI, AARI Faisalabad	2024
24		NIAB Sesame 786	800	NIAB Faisalabad	2024
25		NIAB Sesame-7	700	NIAB Faisalabad	2024
26		NS-407	500	NIAB Faisalabad	2024
27	Rapeseed / Mustard / Canola	AS-207	2100	Afson Seeds Corporation	2022
28		M-11	1800	Baba Fareed Seed Corporation	2022
29		MM-VEGEOILA	1800	Dharti Mala	2022
30		MM-22OILA	1700	Dharti Mala	2022
31		YG-SOLO-SUPER	2000	Fair Seed Corporation	2022
32		Cazola	1800	Four Brothers Seed Corp.	2022
33		MS-555	1800	Maarij Agro Seed Corporation	2022
34		7860	1900	Mercury Seeds Company	2022
35		NX-888	1900	Nature Explore Seeds	2022
36		Yellow Queen RA-	1700	Rachna Agri-business	2022

Sr No	Crop	Variety Name	Mode Yield (kg/ha)	Breeding Institution	Year of Release
		3051			
37		Abbasi Raya	2000	RARI, Bahawalpur	2022
38		SD-3024	1800	Sohni Dharti	2022
39		SD-40S50	1700	Sohni Dharti	2022
40		TS-3435	1500	Turab Seed Corporation	2022
41		VX-111	1900	Vertex Seed	2022
42		ZS-4445	1900	Zaitoon Seeds Company	2022
43		86M45	1800	Zhongzhi Seeds Company	2022
44		HC-025D	1800	Certus Seeds	2022
45		FBS-101	1700	Four Brothers Seed Corp	2022
46		TM-Canola	1700	ORI-AARI Faisalabad	2022
47		RGT CAPACITY TT	2300	Seethi Seeds	2022
48		MSC-2029	1800	Mabroom Seed	2023
49		Supreme Mustard	1900	PARC, Islamabad	2023
50		NARC Raya	1900	PARC, Islamabad	2023
51		Kissan Sarson	1900	ORI, AARI, Faisalabad	2023
52		NIA Toria Gold	1900	NIA Tandojam	2024
53		HMU-1621B	1700	Certus Seed	2024
54		SD-40-S-35	1700	Sohni Dharti	2024
55		EPL-55	1700	Empire Seed	2024
56		ZS-4446	1700	Zaitoon Seed	2024
57		PS-48	1700	Pakpattan Seed	2024
58		LG-160	1600	LA grain Seed	2024
59		Z-996	1600	Zhongzhi Seed	2024
60		Cazola Gold	1700	Four Brother Seed	2024
61		Cazola Super	1600	Four Brother Seed Corp	2024
62		HC-027F	1600	Certus Seed	2024
63		NIFA-Raya-24	2100	NIFA, Peshawar	2024
64	Groundnut	NARC Nawaz	2800	PARC, Islamabad	2023

Table 4. Summarised Data (in Numbers) of Evaluated (Pro) and VEC Recommended (Rec) Oilseed Varieties in the Country

Crop	Year									
	2020		2021		2022		2023		2024	
	Pro	Rec	Pro	Rec	Pro	Rec	Pro	Rec	Pro	Rec
Rapeseed	3	1	7	6	4	4	1	1	5	1
Mustard	1	1	17	12	22	17	8	3	18	11
Sunflower	5	4	2	2	8	8	5	4	8	6
Groundnut	1	1	2	2	-	-	1	1	-	-
Sesame	1	1	3	3	-	-	3	0	5	4
Soybean	-	-	2	2	-	-	5	2	4	2
Total	11	8	33	27	34	29	23	11	40	24

Trends in Oilseed Supply and Demand:

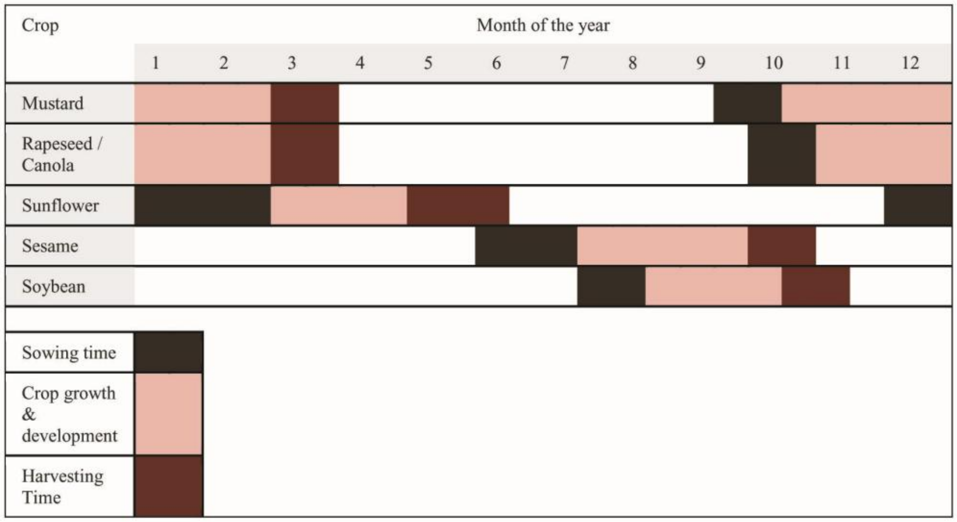
Trends in Oilseed Crops Production

Oilseed crops are an essential component of Pakistan's agricultural economy, providing raw materials for edible oil production and livestock feed. Despite their importance, oilseed crop production in Pakistan has faced fluctuating trends over the years due to a combination of climatic, economic and policy-related factors.

Oilseed crops such as mustard, canola, sunflower, sesame, soybean and rapeseed are grown in Pakistan, but the production is relatively low compared to the country's total edible oil consumption. The most widely cultivated oilseed crop in Pakistan is canola and used for producing canola oil. The domestic canola production is still not enough to meet the domestic demand.

Sunflower is another significant oilseed grown in Pakistan. It is widely cultivated in the provinces of Punjab and Sindh. However, production is limited and often lower than the demand.

Table 5. Crop Calendar of Oilseed Crops in Pakistan



Although soybean is not widely cultivated, there is growing interest in expanding its production due to its potential for oil extraction and as a high-protein crop for livestock feed.

Rapeseed production is also part of the oilseed sector, but it faces competition from other crops (Table 4) and has been less commercially viable than canola or sunflower.

Pakistan’s edible oil consumption has been steadily increasing due to population growth and changing dietary preferences. Domestic oilseed production has not kept pace, leading to a reliance on imports to fulfill over 80% of edible oil demand. The area under oilseed crops has shown inconsistent growth due to competition with major crops like wheat, rice and sugarcane. Yield per hectare for oilseed crops remains below global averages due to the use of traditional varieties, poor farming practices and limited access to inputs. There has been an increasing focus on promoting non-traditional oilseed crops like sunflower and canola, which have shorter crop cycles and higher oil content. Traditional crops like rapeseed-mustard and cottonseed still dominate but with fluctuating production trends. The adoption of hybrid sunflower and canola varieties has improved yields in some regions. However, the lack of widespread availability and affordability limits their use.

By addressing these challenges and capitalizing on emerging opportunities, Pakistan can improve its oilseed production, enhance farmer incomes and reduce its dependency on imported edible oil.

Trends in Oilseed Consumption

Oilseed consumption in Pakistan has been steadily rising due to increasing population, urbanization, changing dietary patterns and growing demand for edible oil and livestock feed. However, the country relies heavily on imported oilseeds and edible oil to meet domestic demand.

Edible oil is an integral part of staple food in Pakistani households. The annual per capita edible oil consumption is estimated at 18-20 kg, above the global average of around 13 kg. Total edible oil consumption in Pakistan has grown at a compound annual growth rate (CAGR) of 3-4% over the last two decades. With urbanization and changing lifestyles, there has been a shift from traditional cooking fats like desi ghee to processed cooking oils like canola, sunflower and soybean oil. There is a growing preference for healthier oils, such as sunflower and canola, due to their lower saturated faty acid content and perceived health benefits.

Edible oil consumption is price-sensitive in Pakistan. Rising global prices of palm oil and soybean oil have impacted affordability, especially for lower-income groups. Palm oil remains the most consumed oil due to its lower price and wide availability.

By addressing challenges like low domestic production and heavy import reliance, Pakistan can stabilize its oilseed consumption trends and work toward self-reliance in edible oil production.

Requirements of Oilseed Crops Production

The successful cultivation of oilseed crops in Pakistan requires an integrated approach involving suitable climatic conditions, proper soil management, timely availability of inputs and supportive policies. Below are the essential requirements for oilseed crop production:

i. Agro-Climatic Conditions

a. Oilseed crops require specific temperature ranges for optimal growth at specific crop growth stage. Generally, it varies between 25-35°C depending upon the crop type and crop growth stage.

b. Rainfed conditions are suitable for drought-tolerant crops like sesame and rapeseed-mustard, but crops like sunflower and soybean require supplemental irrigation.

ii. Soil Requirements

a. Oilseed crops grow well in a variety of soils, but sandy loam to clay loam soils with good drainage are preferred.

b. Most oilseed crops prefer a neutral to slightly acidic soil pH (6.0-7.5).

c. Oilseed crops respond well to fertile soils with sufficient organic matter and balanced nutrients.

iii. Fertilizer Requirements

a. Oilseed crops need balanced nutrients for optimum yield that includes Nitrogen (vegetative growth and seed formation), Phosphorus (root development and seed quality), Potassium (resistance to drought and disease) and Micronutrients (Zinc, boron, and sulfur are critical for flowering and seed development).

b. The recommended doses vary by crop and agro ecology. However, Sunflower generally requires 100-120 kg/ha of N, 60-80 kg/ha of P, and 60-80 kg/ha of K. Similarly, for Canola/Rapeseed-Mustard, it varies between 90-100 kg/ha N, 40-50 kg/ha P, and 30-40 kg/ha K and for sesame it is around 50-70 kg/ha N, 40-50 kg/ha P, and 20-30 kg/ha K.

iv. Seed Requirements

a. Certified seeds of high-yielding, disease-resistant, and climate-adapted seed varieties are essential for better productivity.

b. Optimal seed rates ensure proper plant density. For sunflower, it varies between 5-6 kg/ha, 4-6 kg/ha of canola/rapeseed/mustard, 50-60kg/ha of soybean, and 3-4 kg/ha of sesame.

c. Timely sowing ensures proper growth and development. It varies with the agro-ecological zone and cropping pattern.

v. Weed and Pest Control

- Weeds compete with oilseed crops for nutrients, water, and light. Timely weeding or the application of selective herbicides is necessary.

Oil Recovery Efficiency

Oil recovery efficiency refers to the percentage of oil extracted from the total oil content present in oilseeds. It is a critical factor in assessing the economic and industrial viability of oilseed crops. Several factors influence oil recovery efficiency, including seed quality, oil content, extraction methods, and processing technology.

Different oilseeds have varying levels of oil content, which directly affects the recovery efficiency.

- Sunflower: 40-45% oil content
- Canola/Rapeseed: 35-40% oil content
- Soybean: 18-22% oil content
- Sesame: 45-50% oil content
- Cottonseed: 15-20% oil content

Proper cleaning, drying, and handling of seeds enhance recovery efficiency by reducing impurities. The traditional method involves the mechanical crushing of seeds. Oil recovery efficiency varies between 65-80% with seed type and pressing conditions. Residual oil remains in the seed cake, and is often used as livestock feed.

The ideal seed moisture content for maximum oil recovery is 8-10%. Excess moisture can lead to lower efficiency and increased oil loss in the seed cake.

In Pakistan, oil recovery efficiency varies widely due to the predominance of small-scale and traditional oil mills, which often rely on mechanical pressing methods.

The lack of advanced processing technologies, along with inefficient practices, contributes to high residual oil losses.

Machinery Issue:

The cultivation and processing of oilseed crops in Pakistan rely on a variety of machinery and tools to enhance efficiency, improve yields, and reduce manual Labor. However, the level of mechanization varies across different regions and depends on the scale of farming operations.

Most of the oilseed crops pose tremendous postharvest losses. This is because of non-availability of proper machinery and where it is available is beyond the purchase power of the small farmer. Therefore, proper, planting, harvesting and threshing machinery needs to be designed.

Marketing Issue:

The marketing of oilseed crops in Pakistan involves various stakeholders, including farmers, middlemen, oilseed processors, and exporters. Effective marketing plays a crucial role in ensuring profitability for farmers, stabilizing domestic oilseed supply, and reducing dependence on imported edible oil.

Marketing oilseed crops faces several challenges that include:

Price Volatility: Prices of oilseeds are subject to fluctuations based on international edible oil markets. Farmers often receive lower returns due to uncertain pricing.

Dependence on Middlemen: Farmers rely heavily on middlemen for market access, who often exploit them by offering low prices.

Lack of Infrastructure: Inadequate storage facilities lead to post-harvest losses and distress sales by farmers.

Quality Issues: Poor seed cleaning, grading, and packaging reduce the market value of oilseeds. Moreover, limited adoption of modern post-harvest technologies impacts export potential.

Import Dependency: The availability of cheaper imported edible oil discourages local oilseed production, affecting farmer incomes.

Low Farmer Awareness: Many farmers lack knowledge about market trends, quality standards, and better marketing practices.

By addressing the challenges and implementing effective strategies, Pakistan can create a more efficient and equitable marketing system for oilseed crops. This will not only benefit farmers but also reduce the country's edible oil import bill and strengthen the agricultural sector's contribution to the economy.

Government Policies:

During 2018-19, the Prime Minister's task force on agriculture has taken a holistic view of the issues faced by the agriculture sector and has made some sound recommendations for improving the productivity of agriculture sector. Under this Program, several projects have been initiated. One of them is the "National Oilseeds Enhancement Program" developed under the Prime Minister's Agriculture Emergency Program. This project has a cost of Rs.10,176 million over a period of 05 years. The key interventions identified for enhancing productivity and increasing profitability are:

- Registration of oilseed growers for grant of subsidy
- Subsidy of Rs. 5,000 per acre, maximum up to 20 acres
- Fifty percent subsidy on purchase of oilseed machinery
- Ensure hybrid seed availability through national and multi-national seed companies
- Establishment of Procurement Centre in collaboration with All Pakistan Solvent Extractors Association (APSEA) under the monitoring of government representatives
- Arrangement of demonstration plots in oilseed growing areas

The government is striving hard to increase oilseed production in the country. M/o NFS&R has proposed the first-ever comprehensive National Oilseed Policy, which will be submitted to the competent forum for approval. The policy will focus on enhancing the production of edible oils and reducing dependence on imports, improving the profitability of the oilseed growers, access to the credit facility, availability of good quality sowing seed at reasonable prices, and dissemination of the latest approved production technology to the oilseed growers.

Another key feature of the policy is to recommend measures for improving the quality of edible oils to protect people's health and rationalize consumption.

Furthermore, a new project to introduce soybean production in the country is being prepared to meet our poultry industry and edible oil requirements. M/o NFS&R is also considering extending the National Oilseed Enhancement Programme (NOEP) to sustain the momentum gained during the last four years in enhancing the area and production of the oilseed in the country.

Way Forward

Oilseed production in Pakistan remains underdeveloped and unable to meet the country's needs, leading to a heavy dependence on imports. Despite challenges such as limited land area, low productivity and water scarcity, there are opportunities to expand and modernize oilseed farming through research, government support and private investment. By increasing domestic production, Pakistan can reduce its reliance on imports, improve its trade balance and create economic opportunities for farmers in rural areas. Hence, the way forward will be:

Adoption of Modern Techniques: To improve productivity, there is potential for adopting modern farming practices such as precision farming, better irrigation techniques and pest management.

Diversification: There is also potential to diversify oilseed production by introducing alternative crops such as safflower, groundnut and mustard, which could help reduce reliance on imports.

Sustainability: Emphasis on sustainable agricultural practices, such as organic farming, crop rotation and water conservation, could help mitigate some of the challenges posed by climate change.

Private Investment: There is increasing private sector interest in the development of oilseeds and more investment in processing facilities and research could help increase local production and reduce the import gap.

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Chapter 7

Productivity Enhancement of oilseed crops in Sri Lanka

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Introduction

Oilseeds can be categorized in to two groups, as edible seed oil which is used for edible purposes and industrial oilseeds which are used for industrial purposes. Major world sources of edible seed oils are soybeans, sunflowers, rapeseed, cotton and peanuts. Seed oils from Flax (Linseed) and castor beans are used for industrial purposes.

Sri Lanka is an island situated in the Indian Ocean with the land area of 6.55 million ha. Based on the rainfall there are three prominent climatic zones - wet zone (1.52 million ha), intermediate zone (0.86million ha) and dry zone (4.17 million ha). Sri Lanka receives bimodal pattern of rainfall during two monsoons which determine the cultivating season which known as from October to March as Maha season and that through South West monsoon lies from April to September is the dry season and commonly refer as *Yala* season.

The agricultural land use in Sri Lanka can be categorized in to two main objective-based sectors, which is the sectors involve in feeding the nation and sectors mainly targeting export market. Here, rice is the staple food of the country and field crops including grain legumes and oil crops, fruits and vegetables are mainly catering the needs of the country. On the other hand, export-oriented crops are tea, rubber, coconut and various spices in which are having very big demand due to the unique qualities of such export crop products.

Sri Lankan coconut oil is the 100% natural, best quality cooking oil extracted from dried kernel of the coconut fruit (copra). Sesame, Groundnut, Mustard and Sunflower are grown as oilseed crops. Sesame is being cultivated in Sri Lanka since ancient times. In present day context, sesame is a crop that shows higher export demand and the one and only significantly exporting oil crop as seed in Sri Lanka. It is mainly used for snacks and confectionaries. Rather than that it is used in oil extraction, indigenous medicine and industrial purposes. Mustard is an important oilseed crop which is used as a condiment in Sri Lanka. Farmers traditionally cultivate mustard as a mixed crop with finger millet.

Trends in edible oil consumption in Sri Lanka

Total edible oil supply during 2020 was 263, 621 MT both from local production (44, 326 MT) and imports (219,295 MT) (CDA,2020). Almost 63% of this supply is being utilized for industrial needs while other 23% is consumed for household needs. About 8% of local oil production is generating from coconut sector while another 9 % is supplied by existing palm tree plantations.

Average household consumes around 1.6 liters of fats and oils / month in which main source is the coconut oil (HIES, 2016). Large portion (i.e. 50% of the production) of coconut produced is used as fresh coconut consumption in the country, while the remaining is used for the oil production and exporting (https://www.cda.gov.lk). Although Sri Lanka has initiated palm oil cultivations, but recently government has banned further expansion of cultivation of oil palm due to environmental concerns. But it is found to be a huge drawback for the country's edible oil industry.

Present status of cultivation of annual oilseed crops in Sri Lanka.

Groundnut and Sesame are the major annual oilseed crops cultivated in Sri Lanka. However, mustard and Sunflower are also cultivated on small areas. The main reason for the limited extend and low production is that country is heavily dependent on coconut for their edible oil needs. Still, there is no significant improvement in any oil industry through these annual oilseed crops.

Table 1. Cultivated extent and production of Groundnut and Sesame in Sri Lanka

Year	Groundnut		Sesame	
	Extent (ha)	Production (Mt)	Extent (ha)	Production (Mt)
2015	17716	28500	17841	13300
2016	19975	24200	14044	14900
2017	12639	22475	9065	7800
2018	15752	27602	11872	8589
2019	14527	26922	6035	6085
2020	19508	36375	11654	8223
2021	18536	36946	17228	11999
2022	16656	27181	16222	10230

Source: AgStat, DOA and www.statitics.gov.lk

Table 1, shows how the production of groundnut and sesame varied in the recent years. Groundnut is mainly cultivated in dry and intermediate zones of Sri Lanka. It is mainly used as a snack in the country where several confectionary based industries have evolved. Sesame which was traditionally grown as a chena crop (shifting cultivation) in dry zone has now become an economically important oil seed crop in Sri Lanka due to the higher domestic and export demand. Country's productivity in groundnut is fluctuating between 1.5-2.0 MT/ha while in sesame it is around 0.6-0.8 MT/ha. Recently, with the involvement of private sector, there was some discussion for the initiating castor cultivation in the island. However, up to now there is no commercial scale cultivations of castor in Sri Lanka.

With the involvement of Department of Agriculture in Sri Lanka, several oil crop varieties have been developed to cater the needs of the country (Table 2). Considering the regional crop improvement of oil crops, Sri Lanka is still behind especially due to lack of genetic resources to work with.

Table 2. Recommended Oil Seed Crops varieties in Sri Lanka

Crop	Variety	Year of release	Duration (Days)	Avg. Yield Kg/ha	Oil %
Groundnut	Tissa	1993	90-100	2000	42
	ANKG 1	2011	90-100	3000	
	ANKG 2	2015	105-110		
	ANKGN 3	2019	105-115	4400	
	ANKGN 4	2020	90-100	4200	
Sesame	Uma	1994	70-75	1700	50
	Malee	1994	80	1800	53
	ANKSE 3	2020	90-95	1400	
Castor	JX-6		5-6 months	1000-1500	

Source: DoA, Sri Lanka

Key issues of oil crops sector in Sri Lanka

The main point to highlight is that country is mainly dependent on coconut oil and we do not have proper plans to initiate oil industry though other alternative crops. The decision for the band of expanding oil palm cultivation was a mistake. However, no policy decision was yet taken to rectify this issue. Limited availability of land is an issue as there are many crops to be cultivated in a limited arable land. However, the productivity can be still improved in the lands with some improvement in the agricultural system. Another key related issue is high cost of production as usage of appropriate machinery is very limited in oilseed crops cultivation. Lack of appropriate technologies (varieties and adaptable cultural practices) when compare with other regional countries can be highlighted as an issue which require assistance from the regional countries. Overall, there should be a plan for the next several years to improve the oil crop sector with a proper plan with a wholistic approach considering environmental, economic, social and health aspects of the nation.

Research and development of oilseed crops sector in Sri Lanka

Considering the seasonal oilseed crops such as groundnut, Sesame and mustard, Department of Agriculture in Sri Lanka is responsible for the research and development programs. Currently, a comprehensive crop improvement program is ongoing for those mentioned crops considering key issues related to these crops. In groundnut, the main breeding objectives are high yield, physical quality traits, drought tolerance and tolerance to major diseases. Seed color, yield and tolerance to biotic stresses are the main considerations in sesame crop improvement. Mainly the conventional breeding techniques and mutation breeding techniques are being practiced at present crop improvement programs. Other than that, there are studies to improve the existing technical package specially targeting productivity improvement by the means of agronomic practices. Special seed production programs are being implemented through government funding to increase the seed availability. Technology dissemination is mainly done through the agricultural extension system of Department of Agriculture.

Machinery issue in oilseed crops sector

Lack of application of proper machinery solutions for main cultural operations in oilseed crops cultivation has been a problem for decades in expanding cultivation in Sri Lanka. In groundnut, recently several machines were introduced for threshing and other post-harvest operations. However, adoption of such technologies is very slow since most of the farmers do not have financial capabilities. The solution would be creating farmer societies or farmer communities and provide machinery to those communities. For sesame, there were very limited efforts to introduce appropriate machinery to main cultural operations. Overall, there is a severe need of proper machinery to improve the oilseed crops sector in the country and the improvements are too slow to cater the demand.

Government policies related to oilseed crops sector

The decision for the band of expanding oil palm cultivation was a mistake. However, no policy decision was yet taken to rectify this issue. The policies related to oilseed crops sector were not stable considering past decade or so.

However, with the economic crisis during recent past, importation of several oilseed crops was temporally halted. It had an impact on the prices of commodities and indirectly expansion of cultivation. Those decisions were made not considering the sector improvement and later government decided to import several oilseed crops based on the requests of the private sector. We do need a stable policy framework on oilseed crops sector in the country, though there are fragmented policy initiatives considering only temporal issues. In crops such as castor, government needs to take firm decisions on cultivation, considering the financial value and food security in the country as lands are a limiting factor.

The way forward in oilseed crops sector and the SAARC collaboration

The research and development of annual oilseed crops sector need some support when we think about the future. Specially, country need some kind of collaboration in crop improvement and introducing modern technical aspects for the cultivation. Here, exchange programs for new germplasm, which initiated earlier needs to be continue. Further, considering the mechanization we suggest there should be a collaboration in the SAARC countries experts and then we may able to interact and introduce proper machinery solutions for each country, including Sri Lanka. The oil extraction industry of Sri Lanka needs to be improved further considering the scale of expansion in oilseed crops sector. It will support the improvement of the oilseed crops sector, while diversification of edible oil consumption will be expanded. Public-private partnerships need to be look in to as other potential oilseed crops such as sunflower, mustard and soybean are still not be cultivated up to commercial scale. With steady policy decisions coupled with strong action plan, Sri Lanka’s oilseed crops sector can go a long way.

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Chapter 8

Nutritional Importance of Cooking Oil for Human Health & an overview of use of edible oil in Bangladesh

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Introduction

Edible oil is a vital component of every cuisine culture. The sources of edible cooking oils are both plants and animals. Edible oils got from oilseed crops are crucial in the human diet as the primary source of energy. These are also getting the spotlight because of their nutritional benefits and versatile applications. These are unsaturated and rich in natural nutrients. These are also considered important for a balanced and healthy diet. The consumption of this type of oil is associated with health benefits. For example, it can support in reduction of LDL cholesterol, which is considered bad (https://www.ecycle.com). Research published by the American Heart Association (https://vglobo.globo.com) shows that adding food with vegetable oil can prevent the risk of strokes and other diseases. EPOs (Edible plant oils) are important raw materials in our daily consumption of food, as well in food processing. They not only provide heat energy and essential fatty acids for human beings but also bestow food with a pleasant flavour and in addition to containing the necessary nutrients in EPOs, the flavour is also a major factor that is considered when choosing an EPO (Tekaya et al., 2018). Flavour substances are one of the important indicators of the sensory quality of EPOs (Fujikawa et al.,2002) and the unique flavour of different EPOs is not formed by one or several compounds but is formed by the synergy of various components (Zhang et al., 2012; Yang et al., 2015; Liu et al., 2017). Global demand for edible oils is increasing with the growth of the human population. Therefore, there is a need to increase oilseed crop production to enhance productivity while minimizing environmental impact. To fulfil the global demand for edible oils from the oilseed crops, experts in nutrition health, food production, agronomy, economy, sociology and governments need to work together with the common goal of maximum production of oilseed crops according to the future requirements. To ensure the safety of edible oil production, in each stage of the edible oil industry, strict monitoring of environmental conditions is required to provide a good and safe environment for the cultivation to processing and ultimately to ensure the safety of edible oil production under environmentally friendly conditions. Detail of different types of edible oils is given below:

Edible Oil

Edible oil is an essential ingredient in any cuisine culture. Besides being cooking ingredient, edible oils also add to calories intake. Requirement of edible oil does not arise as a primary source of calorie, but to complete the process of protein intake from food.

Functions of Edible Oils

- **Energy Source:** Fats are a concentrated source of energy, providing 9 calories per gram, which is more than twice the amount provided by carbohydrates and proteins.
- **Carrier of Fat-Soluble Vitamins:** Oils help in the absorption of fat-soluble vitamins like vitamins A, D, E and K.
- **Flavor and Texture:** Oils add flavor and texture to food, making it more enjoyable.
- **Satiety:** Fats can help us feel full for longer periods, reducing overall calorie intake.

Chemical Composition of Cooking Oil

Cooking oils are made up of a variety of compounds, including:

- **Triacyl glycerides (TAGs):** The main component of cooking oils, making up about 96% of their composition. TAGs are esters of glycerol and fatty acids.
- **Other lipids:** Cooking oils may also contain phospholipids and sterols.
- **Minor compounds:** Cooking oils may also contain free fatty acids, phytosterols, tocopherols, antioxidants and waxes.
- **Energy Source:** Fats are a concentrated source of energy, providing 9 calories per gram, which is more than twice the amount provided by carbohydrates and proteins.
- **Carotenoids:** Some cooking oils contain carotenoids, which are precursors to vitamin A.

Sources of Cooking Oil

Cooking oil comes from a variety of seeds, beans and fruits, including:

Canola oil

A versatile oil with a neutral flavour, high smoke point and smooth texture. It's derived from rapeseed and is popular for cooking and baking.

Corn oil

Also known as maize oil, this oil is extracted from the germ of corn. It has a high smoke point, making it a good choice for frying.

Soybean Oil

A versatile oil with a neutral flavor, it's high in polyunsaturated fats and can help lower cholesterol.

Sunflower oil

Pressed from the seeds of the sunflower plant, this oil contains high amounts of linoleic acid, an essential fatty acid.

Safflower oil

A stable vegetable oil that can be used for cooking, soap, candles, massage oils and more. High-oleic safflower oil has a high level of monounsaturated fats.

Sesame oil

Derived from sesame seeds, this oil has a distinctive nutty aroma and taste. It's used for cooking and as a flavor enhancer in many cuisines.

Avocado oil

Produced by extracting the pulp from avocados, this oil has a neutral taste and works well for salad dressings, browning roasts and searing.

Palm oil

Obtained from the fruit and kernels of the oil palm tree, this oil is used for cooking and frying. RBD palm stearin is used for shortening, margarine, vegetable ghee and more.

Mustard oil

The essential oil results from grinding mustard seed, mixing the grounds with water and isolating the resulting volatile oil by distillation. It can also be produced by dry distillation of the seed.

Animal Based Sources of Cooking Oil

Butter: Derived from milk, it's used for cooking, baking and spreading.

Lard: Rendered from pig fat, it's used for frying and baking.

Ghee: A clarified butter, it's used in Indian cuisine for cooking and frying.

The type of oil used depends on its intended use, its smoke point and its nutritional profile.

Fish Oil

Fish oil is derived from oily fishlike mackerel, herring and cod liver. It is primarily used as a dietary supplement rather than a cooking oil. It is rich in omega-3 fatty acids, which are essential for heart health, brain function and reducing inflammation.

While fish oil is not typically used for cooking, it can be consumed directly in capsule form or added to food as a supplement.

Most Popular Cooking Oil in Bangladesh: Mustard Oil

Mustard oil is the most popular cooking oil in Bangladesh. It's widely used due to its distinct flavor, aroma and numerous health benefits. The essential oil results from grinding mustard seed. It can also be produced by dry distillation of the seed. Pressed mustard oil is used as cooking oil in some cultures, but sale is restricted in some countries due to high levels of Erucic acid. Mustard oil and seeds rich in essential fatty acids, vitamins and minerals. The predominant fatty acids found in mustard oil are monounsaturated fats, polyunsaturated fats and omega-3 fatty acids.

Mustard Oil Nutritional Value per 100g

Nutrients	Amount /100gm
Calories	884
Saturated fat	5-12 gm
Selenium	9.96 mg
Magnesium	49 gm
Sodium	1120 mg
Protein	1.88 gm
Vitamin E	34 mg
Vitamin A	3%
Vitamin C	5%
ω-3	0.20 mg
Nicotinic acid	0.60 mg
Calcium	38.92 mg
Potassium	151 mg
Zinc	0.44 mg
Dietary fibers	1.08 mg

Source: Agricultural marketing information network and USDA network data base (2004).

Positive Aspects of Mustard Oil

Rich in Healthy Fats: It's a good source of monounsaturated and polyunsaturated fatty acids, which can help lower bad cholesterol and reduce the risk of heart disease.

Anti-inflammatory Properties: Contains compounds with anti-inflammatory properties, which may help alleviate pain and inflammation.

Antimicrobial: It has antimicrobial properties, making it effective in fighting infections.

Hair and Skin Benefits: Often used in hair and skin care due to its nourishing and moisturizing properties.

Negative Aspects of Mustard Oil

Erucic Acid: Some types of mustard oil, especially the older varieties, contain erucic acid, which can be harmful if consumed in large quantities. However, modern processing techniques have significantly reduced the erucic acid content in commercial mustard oil.

High Smoke Point: While a high smoke point is beneficial for cooking, it's crucial to avoid overheating the oil, as it can produce harmful compounds.

Other Popular Oils in Bangladesh:

While mustard oil is the most popular, other oils are also commonly used:

Soybean Oil: A versatile oil with a neutral falovor, it's high in poly unsaturated fats and can help lower cholesterol.

Sunflower Oil: Another popular choice, it's rich in vitamin E and has a high smoke point, making it suitable for high-temperature cooking.

Palm Oil: Widely used in cooking and food processing, palm oil is high in saturated fats and can raise bad cholesterol levels.

It's important to choose cooking oils wisely and use them in moderation. While mustard oil is a healthy choice, a balanced diet and lifestyle are crucial for overall well-being.

Mustard Oil vs. Soybean Oil: A Comparison

Feature	Mustard Oil	Soybean Oil
Origin	Mustard seeds	Soybeans
Taste	Strong, pungent flavor	Mild, neutral flavor
Smoke Point	High	High
Fatty Acid Profile	High in monounsaturated and polyunsaturated fats.	High in polyunsaturated fats, especially omega-6 fatty acids.
Health Benefits	Heart health, anti-inflammatory properties, potential antimicrobial benefits.	Heart health, brain health and reduced inflammation.
drawbacks	Older varieties contained erucic acid, which is harmful in large quantities. Modern processing techniques have significantly reduced this content.	May contribute to an imbalance of omega-6 and omega-3 fatty acids if consumed excessively.
Culinary Uses	Bangladeshi cuisine, especially for tempering and frying.	Widely used for cooking, frying and salad dressings.

Bad effect of oil on human health:

Oil spills can have a significant impact on human health, both in the short and long term. Here's a breakdown of the bad effects:

Short-Term Effects:

Respiratory Problems: Exposure to oil fumes can irritate the lungs, leading to coughing, difficulty breathing and other respiratory issues.

Skin Irritation: Direct contact with oil can cause skin rashes, irritation and even chemical burns.

Eye Irritation: Oil in the eyes can cause severe irritation, pain and temporary vision problems.

Nausea and Vomiting: Exposure to oil fumes or ingesting contaminated food can lead to nausea and vomiting.

Long-Term Effects

Cancer Risk: Some components of oil, such as benzene, are known carcinogens and can increase the risk of certain cancers.

Neurological Damage: Exposure to certain chemicals in oil can damage the nervous system, leading to problems with memory, concentration and coordination.

Reproductive Problems: Some studies suggest that exposure to oil can affect fertility and increase the risk of birth defects.

Immune System Suppression: Oil Exposure can weaken the immune system, making individuals more susceptible to infections and diseases.

Rising trend in consumption of oils and fats in Bangladesh: An Overview

Total consumption of oils and fats in 2019:

- 2019: 3.04 million tones
- 2018: 2.97 million tones

This shows a **2.97%** increase in total consumption from 2018 to 2019.

- **Average per capita consumption of oils and fats:** Approaching 18.7 kg.
- **Steady increase in per capita consumption:** Over the last couple of years.
- **High dependence on imports:** 90-92% of annual requirements are met through imports.
- **Dominance of Palm oil:** It's the leading edible oil in terms of consumption and import since 2003.

Bangladesh is a country of about 170 million people and annually consumes about 3.0 million tons of oils and fats, which include both edible and inedible. As revealed from the statistics of Oil World - 2019, globally recognized source of information on oils and fats, consumption of oils and fats in Bangladesh shows an increasing trend, which is highest among the developing countries.

In 2019, total consumption of oils and fats was 3.04 million tons which is about 2.97 per cent higher compared to 2018. The average per capita consumption of oils and fats is seen approaching 18.7 kgs.

As per Oil World, during last couple of years, average per capita consumption of oils and fats in Bangladesh has increased steadily.

Consumption of oils and fats, in general, is on a growing trend keeping in pace with population growth, economic development and increase of purchasing power of the general consumers.

Bangladesh is experiencing steady economic growth during recent times, which is contributing greatly in increase of purchasing power of the consumers vis-à-vis increase of consumption of oils and fats.

It is worth mentioning that due to insufficient indigenous production, Bangladesh is mostly dependent on import to meet up the requirements of oils and fats.

About 90 to 92 per cent of the annual requirements of oils and fats are met through import. Presently there are three major edible oils consumed in the country, namely, palm oil, soyabean oil and rapeseed / canola oil and import shares of which were at a ratio of 58:37:5 respectively, as per 2019 statistics.

Choose the Right Oil: Select oils with a high smoke point for frying and those with lower smoke points for other cooking methods.

Use in Moderation: While oils are essential, excessive consumption can lead to weight gain and other health issues.

Store Properly: Store oils in airtight containers in a cool, dark place to prevent oxidation and rancidity.

Be Aware of Trans Fats: Limit your intake of trans fats, which are harmful to heart health.

By understanding the nutritional value of different oils and using them wisely, you can make healthy choices that benefit your overall well-being.

Trans fatty acids & Nutrition

Trans fatty acids, also known as trans fats, are a type of unsaturated fat that can be found in small amounts in some animal-based foods and in larger amounts in some processed foods. From these two types, natural trans fats are safe in moderation, but artificial ones may lead to health issues.

Common Sources of Trans Fats

Fried foods: French fries, doughnuts, fried chicken

Baked goods: Cookies, cakes, pastries

Margarine and shortening

Processed foods: Crackers, microwave popcorn

Trans fatty acids: Effects on Health & Nutrition

Unlike other fats, our bodies don't metabolize trans fats well. Consuming them can have several negative health consequences:

- Increased Risk of Heart Disease.
- Increased Risk of Type 2 Diabetes.
- Increased Risk of Inflammation.
- Obesity.

Oil Fortification Rules in Bangladesh to Address Malnutrition

The National Micronutrient Survey 2011-12 has identified vitamin A deficiency as a major threat to public health. One in every five children in the country was identified as vitamin A deficient.

To mitigate vitamin A deficiency issues in the marginal population, Bangladesh has enacted the Fortification of Vitamin A in Edible Oil, 2013 Act.

The fortification program covers the larger population groups besides children 6-59 months of age who are under the coverage of Vitamin A capsule.

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Chapter 9

Rapeseed and mustard

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Rapeseed and mustard

Rapeseed and mustard are important oilseed crops cultivated in Pakistan. These crops are a rich source of oil, containing 40-46% oil content. Additionally, their meal comprises 38-40% protein with a complete amino acid profile, including lysine, methionine and cystine. However, non-Canola varieties of rapeseed and mustard have high levels of Erucic acid in their oil and Glucosinolates in their meal, which are harmful to human and animal health (Rakow & Getinet, 1998).

Canola

Rapeseed and mustard varieties with less than 2% Erucic acid in their oil and less than 30 µmoles per gram of Glucosinolates in their oil-free meal are classified as Canola. Canola-quality rapeseed and mustard oils are highly suitable for human consumption due to their superior nutritional properties, including a healthier Fatty acid profile with low levels of harmful compounds. Moreover, the meal derived from these varieties serves as an excellent protein-rich feed for livestock and poultry, as it is free from antinutritional factors like high Glucosinolate content, which can impair growth and metabolism in animals (Khattak et al., 2021).

The development of Canola-quality rapeseed and mustard cultivars have significantly expanded the utilization of these crops. The oil is now widely used in cooking, frying and food processing, thanks to its light flavor, low saturated fat content and heart-healthy benefits. Similarly, the meal has become a preferred choice for animal feed, especially for poultry, due to its complete amino acid profile, which supports growth, productivity and overall health in birds and other livestock (Ali et al., 2022). This advancement has not only improved the economic value of rapeseed and mustard but has also contributed to addressing the nutritional needs of both humans and animals. It represents a critical step toward enhancing food security and reducing dependency on imported edible oils and protein meals.

Genetic background of Erucic acid

The regulation of Erucic Acid (EA) content in *Brassica napus* is controlled by multiple genes, with significant findings from recent genomic studies. Research indicates that at least 654 genes are associated with EA variation, with a focused subset of 23 genes identified as having a substantial impact on EA levels in seeds (Xu et al., 2024). Notably, the fatty acid Elongase 1 (FAE1) gene plays a critical role, with two functional homologous copies located on chromosomes A08 and C03, which are essential for EA synthesis (Liu et al., 2022; Tian et al., 2011). Additionally, specific mutations in the *FAE1* gene have been linked to low Erucic acid traits in various cultivars (Wu et al., 2015).

Key Genes Involved

FAE1 Genes: Two homologous copies (BnaA08.FAE1 and BnaC03.FAE1) are crucial for EA synthesis.

BnaGPAT9 Genes: Four homologous genes contribute to functional divergence affecting EA content (Liu et al., 2024).

Genetic Variations

Mutations: Various mutations in *FAE1*, such as single-base transitions and deletions, have been identified as responsible for low Erucic Acid (EA) traits in cultivars (Wu et al., 2015). While the focus has been on specific genes, the complex interplay of multiple genetic factors suggests that Erucic acid regulation is a multifaceted trait influenced by various genetic mechanisms (Liu et al., 2022; Xu et al., 2024). This complexity highlights the potential for further research into the genetic architecture of EA in *Brassica napus*, especially through integrated genomics and functional analyses to uncover novel regulatory elements and gene networks involved in EA biosynthesis.

Genetic background of Glucosinolates

The genetic control of glucosinolates (GSLs) in Brassica napus involves multiple genes and quantitative trait loci (QTLs). Recent studies have identified a total of 78 loci associated with GSL traits, with 15 reliable QTLs specifically linked to seed GSL content. Notably, four QTLs qGSL.A02.2, qGSL.C02.1, qGSL.A09.2 and qGSL.C09.1 are crucial for low seed GSL levels (Tan et al., 2021 & Liu et al., 2020). Additionally, 36 candidate genes have been implicated in GSL biosynthesis, with specific genes like BnaA3.MYB28 and BnaC02.GTR2 playing significant roles in regulating GSL accumulation in leaves and seeds (Liu et al., 2020 & Lu et al., 2014).

Key Genetic Loci

QTLs Identified: 15 reliable QTLs linked to seed GSL content.

Candidate Genes: 36 genes inferred to be involved in GSL biosynthesis.

Functional Roles of Genes

BnaA3.MYB28: Responsible for high leaf/low seed GSL content.

BnaC02.GTR2: Positively regulates seed GSL accumulation.

Despite the focus on reducing GSL content for improved nutritional value, some studies emphasize the importance of GSLs for plant defense and human health, suggesting a balanced approach to breeding strategies (Liu et al., 2020 & Lu et al., 2014).

History

Canola's history begins in the 1970s in Canada, where scientists developed it, as a healthier alternative to traditional rapeseed. Traditional rapeseed, used primarily for industrial purposes, contained high levels of Erucic acid and Glucosinolates, which made it unsuitable for human consumption. Through conventional plant breeding, researchers significantly reduced these compounds, creating a new crop known as "canola," short for “Canadian oil, low acid” (Rakow & Woods, 2022; Shah et al., 2021). This innovation revolutionized the global edible oil market and provided a valuable source of healthy oil and high-protein meal for human and animal consumption.

Canola quickly gained popularity for its heart-healthy oil, low in saturated fat and high in omega-3 and omega-6 fatty acids. It is now one of the world's leading oilseed crops, grown in countries like Canada, the United States, Australia and Europe. In addition to its use in cooking oil, canola is a key source of biofuel and livestock feed, contributing to its economic and agricultural significance globally (Rakow & Woods, 2022; Shah et al., 2021).

The history of canola in Pakistan dates to the 1980s, when efforts were made to introduce it as an alternative oilseed crop to reduce the country's heavy reliance on edible oil imports. Initially, the crop was promoted due to its high oil content, health benefits and adaptability to local agro-climatic conditions by the Pakistan Agricultural Research Council (PARC), Islamabad and Pakistan Oilseeds Development Board (PODB), along with provincial research systems (Ahmad et al., 2020; PARC, 2022).

The Oilseeds Research Institute (ORI) at Ayub Agricultural Research Institute (AARI), Faisalabad initiated Canola breeding program in 1996. This initiative marked a significant milestone in Pakistan's efforts to enhance the quality and productivity of oilseed crops, particularly rapeseed and mustard. The program aims to develop high-yielding, disease-resistant and climate-resilient varieties of Canola-quality rapeseed and mustard that meet international standards for oil and meal quality.

Since its inception, the Canola breeding program has focused on reducing undesirable compounds such as Erucic acid in the oil and Glucosinolates in the meal. The program also emphasizes selecting traits that ensure better adaptability to Pakistan's diverse agro-climatic conditions, addressing challenges such as drought, heat stress and climate change. These improvements have made the oil more suitable for human consumption and the meal an excellent feed for livestock and poultry.

By developing superior Canola-quality cultivars, the program has contributed significantly to reducing the country's reliance on imported edible oils and protein meals. It also promotes sustainable agricultural practices by encouraging farmers to adopt Canola-quality rapeseed and mustard varieties, which offer higher economic returns and better market opportunities.

The initiative by ORI, AARI, continues to play a pivotal role in strengthening Pakistan's agricultural sector, enhancing oilseed crop productivity and contributing to national food security goals (Aftab et al., 2021).

Canola commercial cultivation was introduced in Pakistan during 2005-06 with the launch of Canola hybrids imported by multinational seed companies. Despite its potential, the adoption of canola faced challenges, including limited awareness among farmers, competition with traditional crops like wheat and mustard and insufficient marketing infrastructure. However, over the years, government initiatives, subsidies and awareness campaigns have gradually increased its cultivation. Today, canola contributes to Pakistan’s edible oil production, though efforts are ongoing to expand its acreage and reduce the country’s dependency on imported edible oils further.

Brassica triangle (u’s triangle) and its importance

The Brassica Triangle, also known as U’s Triangle, is a classical genetic model proposed by Japanese scientist Woo Jang-choon (Nagaharu U) in 1935 to explain the genetic relationships among six species of the genus *Brassica*. The triangle illustrates how three diploid species *Brassica rapa* (AA, 2n=20), *Brassica nigra* (BB, 2n=16) and *Brassica oleracea* (CC, 2n=18) combine through natural hybridization and chromosome doubling (polyploidy) to form three allotetraploid species: *Brassica juncea* (AABB, 2n=36), *Brassica napus* (AACC, 2n=38) and *Brassica carinata* (BBCC, 2n=34) (U, 1935; Prakash et al., 2011). This model remains foundational in Brassica genetics, breeding and evolutionary studies.

Brassica Species

a. Diploid Species:

- Brassica rapa (AA, 2n = 20)
- Brassica nigra (BB, 2n = 16)
- Brassica oleracea (CC, 2n = 18)

b. Allotetraploid Species (derived through hybridization):

- Brassica juncea (AABB, 2n = 36) - Indian mustard
- Brassica napus (AACC, 2n = 38) - Canola / rapeseed
- Brassica carinata (BBCC, 2n = 34) - Ethiopian mustard

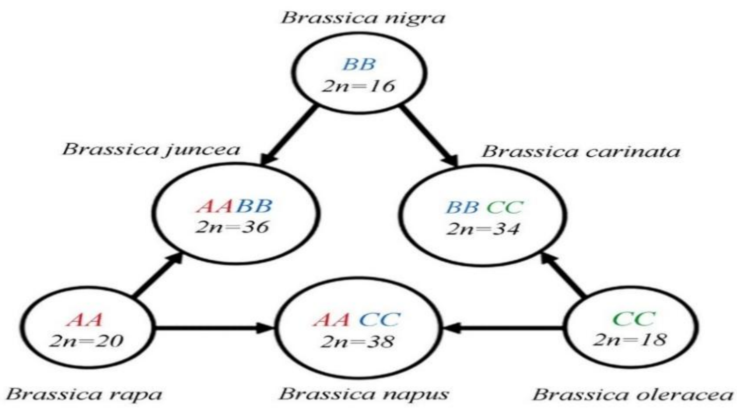

Fig 1. Brassica Triangle (U's Triangle)

Importance of the Brassica Triangle

i. Understanding Genetic Relationships:

The triangle provides a framework to study the genetic and evolutionary relationships among *Brassica* species, aiding in taxonomic classification.

ii. Crop Improvement:

Knowledge of genetic compatibility allows breeders to transfer beneficial traits (e.g., disease resistance, stress tolerance and higher oil content) between species.

iii. Hybrid Development:

The model supports the development of hybrids and new varieties by facilitating interspecific crosses. For example, creating more productive or resilient canola varieties (*B. napus*).

iv. Genomic Studies:

It serves as a foundation for genomic mapping and marker-assisted selection to enhance breeding efficiency.

v. Sustainable Agriculture:

Improved understanding of *Brassica* genetics contributes to sustainable farming by enabling the development of resilient crops suitable for diverse environments. The Brassica Triangle remains a cornerstone in agricultural science, guiding both fundamental research and practical applications in crop breeding.

Variety development in canola

Canola breeding is a specialized field of plant breeding focused on developing improved canola (*Brassica napus*) varieties with desirable traits. The primary goals of canola breeding include enhancing yield, oil quality, disease resistance, stress tolerance and adaptability to various climatic and soil conditions. Recent advancements in canola breeding have emphasized the development of cultivars with high yield potential and improved oil quality. Breeding programs aim to enhance traits such as oil content, fatty acid composition and meal quality to meet market demands and nutritional standards. Disease resistance is another critical focus area. Breeders are working to develop canola varieties resistant to major diseases like White rust and Alternaria black spot, which can significantly impact yield and oil quality. The breeding process typically involves the following key steps:

a. Trait Identification and Selection

Desired traits like high oil content, low Erucic acid, low Glucosinolates, disease resistance (e.g., to Blackleg and Sclerotinia) and environmental adaptability are identified.

b. Parent Selection and Crossbreeding

Elite parental lines are selected and crossbred to combine favorable traits. Techniques such as traditional crossbreeding, hybridization and molecular breeding are commonly used.

c. Hybrid Development

Hybrid canola varieties are developed by combining genetically diverse parent lines to produce vigorous plants with higher yields and uniform performance.

d. Genetic Improvement

Modern tools like CRISPR-Cas9, marker-assisted selection (MAS) and genomic selection are used to accelerate breeding cycles and enhance precision.

e. Disease and Stress Resistance

Breeding for resistance to diseases (e.g., Blackleg) and abiotic stresses (e.g., drought, heat, salinity) ensures better crop performance in challenging environments.

f. Testing and Evaluation

Candidate varieties undergo rigorous field trials to assess their agronomic performance, adaptability, oil quality and resistance to diseases and pests in different agro ecological zones across the province / country.

i. Release and Commercialization

After two years of rigorous evaluation of new Canola strains under the National Uniform Yield Trial (NUYT), candidate varieties that demonstrate superior performance in terms of yield, quality and agronomic adaptability are presented to the Variety Evaluation Committee (VEC) for assessment. The VEC reviews the comprehensive trial data, including yield performance, oil content, Erucic acid levels, Glucosinolate content and resistance to biotic and abiotic stresses.

Following the committee's recommendation, the cases are submitted to the respective Provincial Seed Councils for final approval. Upon approval, the variety is officially released for commercial cultivation, enabling widespread adoption of improved Canola-quality varieties by farmers. This process ensures that only varieties meeting stringent agronomic, quality standards and resilient to climate change are introduced into the agricultural system, enhancing productivity and economic returns.

Canola breeding is crucial for meeting the rising demand for edible oil and adapting to climate change challenges. Continuous research and innovation in breeding techniques ensure the development of sustainable, high-performing canola varieties worldwide.

Canola Research in Pakistan

Several research institutes in Pakistan are actively engaged in Canola development programs aimed at improving its productivity, quality and adaptability to diverse agro-climatic conditions. The prominent institutes are:

1. Oilseeds Research Institute (ORI), Faisalabad
2. National Agricultural Research Centre (NARC) Islamabad
3. Regional Agricultural Research Institute (RARI), Bahawalpur
4. Barani Agricultural Research Institute (BARI), Chakwal
5. University of Agriculture, Faisalabad (UAF)
6. Nuclear Institute for Food and Agriculture (NIFA), Peshawar
7. Nuclear Institute of Agriculture (NIA) Tandojam

The Oilseeds Research Institute (ORI), Faisalabad, is a leading institution dedicated to the development of high-yielding, disease-resistant Canola varieties and the promotion of oilseed cultivation through research and outreach initiatives. The institute has successfully released open-pollinated (00) Canola varieties in the rapeseed and mustard, characterized by high yield potential and excellent adaptability to local climatic conditions. Notable varieties include Punjab Canola (2009)**,** Faisal Canola (2011)**,** AARI Canola (2016)**,** Super Canola (2018)**,** Sandal Canola (2019)**,** Khanpur Canola (2021)**,** Rachna Canola (2021) and TM Canola (2023) (Mustafa et al., 2024; Mustafa et al., 2022; Mahmood et al., 2019)**.** During 2016 orI achieved a significant milestone by releasing Pakistan's first (00) Canola-quality variety in *Brassica juncea L.* AARI Canola, a standout variety, is a short-duration crop (110 days) and is particularly well-suited for intercropping with sugarcane sown in September and for maize-growing areas. This variety exhibits several exceptional traits, including 00, high omega-3, earliness, tolerance to pod shattering and drought resistance, making it increasingly popular among brassica growers. The seeds of these Canola varieties are distributed through the Punjab Seed Corporation and private seed companies, ensuring widespread availability to farmers and contributing to the enhancement of Pakistan's oilseed sector- (Mustafa et al., 2018**;** Mahmood et al., 2017).

In Pakistan, Mustard (*Brassica juncea* L.) dominates oilseed cultivation, accounting for approximately 70% of the total area under oilseed crops. Canola (*Brassica napus* L.) occupies about 20% of the cultivated area, while Toria (*Brassica rapa* L.) is grown on the remaining 10%. This distribution reflects the adaptability of mustard to diverse agro-climatic conditions, particularly in arid and semi-arid regions, as well as its resilience to drought and heat stress. Conversely, Canola's share is steadily increasing due to its superior oil quality and higher economic returns, while Toria, despite its shorter growing season and early maturity, remains a less preferred choice due to its lower yield potential and oil quality.

Table 1. Characteristics of Canola varieties

Sl.No	Variety Name	Year of release	Yield Potential (kg/ha)	Salient characters
1.	TM Canola	2023	3550	Short duration (130 days), Long silique, bold seed Frost tolerant
2.	Rachna Canola	2021	3550	High Omega-3 (9.3%) High Omega-9 (72%)
3.	Khanpur Canola	2021	3670	High oil content (46%) Heat tolerant
4.	Barani Canola	2021	3280	drought tolerant Suitable for rainfed areas

Sl.No	Variety Name	Year of release	Yield Potential (kg/ha)	Salient characters
5.	Sandal Canola	2019	3970	Long silique Heat tolerant
6.	Super Canola	2018	3888	Lodging tolerant High number of siliques Frost tolerant
7.	AARI Canola	2016	3276	00 mustard Short duration Shattering tolerant High omega-3 (14%)
8.	PARC Canola (Hybrid)	2014	2800	00 Canola hybrid Frost tolerant Bold seed
9.	Faisal Canola	2011	2875	Frost tolerant Heat tolerant
10.	Punjab Canola	2009	2550	1st canola variety Heat tolerant

In sugarcane-growing regions, intercropping rapeseed and mustard with September-sown sugarcane offers an opportunity to enhance oilseed production and boost farmers' profitability. Both rapeseed and mustard cultivars possess distinct advantages and limitations based on their adaptability to specific regional conditions, soil types, water requirements and seed shattering tendencies during harvesting.

Rapeseed (Canola) cultivars are characterized by their low Erucic acid content in oil, making them suitable for high-quality edible oil production. They perform best in fertile soils and thrive in regions with mild climates. However, they are prone to seed shattering at maturity, which can lead to yield losses during harvesting.

Mustard cultivars, on the other hand, contain higher levels of Erucic acid in their oil but are better adapted to loamy soils. They demonstrate superior drought tolerance, can withstand higher temperatures and exhibit a lower tendency for seed shattering, making them more resilient under challenging environmental conditions.

Selecting the appropriate cultivar for cultivation depends on the specific agro-climatic and soil conditions of the region, as well as the farmer's priorities regarding oil quality, resilience and harvesting efficiency.

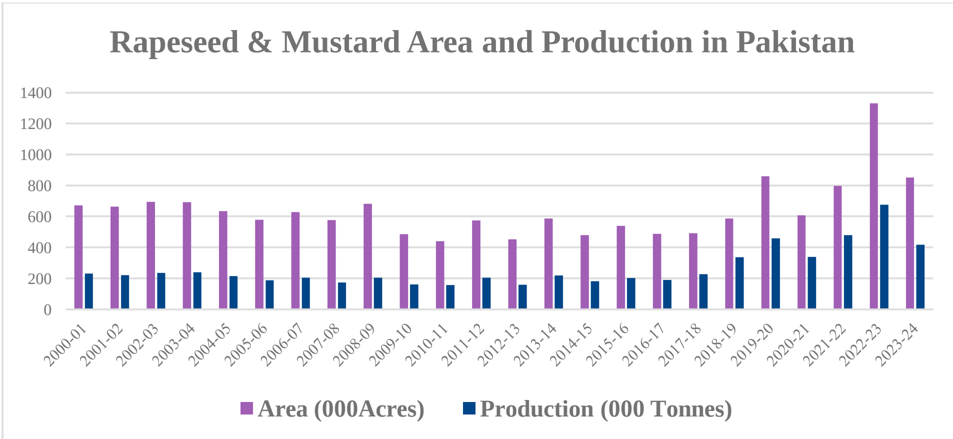

Fig 2. Trends in Area and Production of Rapeseed and Mustard in Pakistan

Source: Economic Survey of Pakistan

The data above indicates that, due to the prioritization of oilseed cultivation in the country, the area and production of rapeseed and mustard have shown continuous growth from 2017 to 2023. Notably, Punjab has made a significant contribution to the increase in both the area under cultivation and the production of rapeseed and mustard during this period.

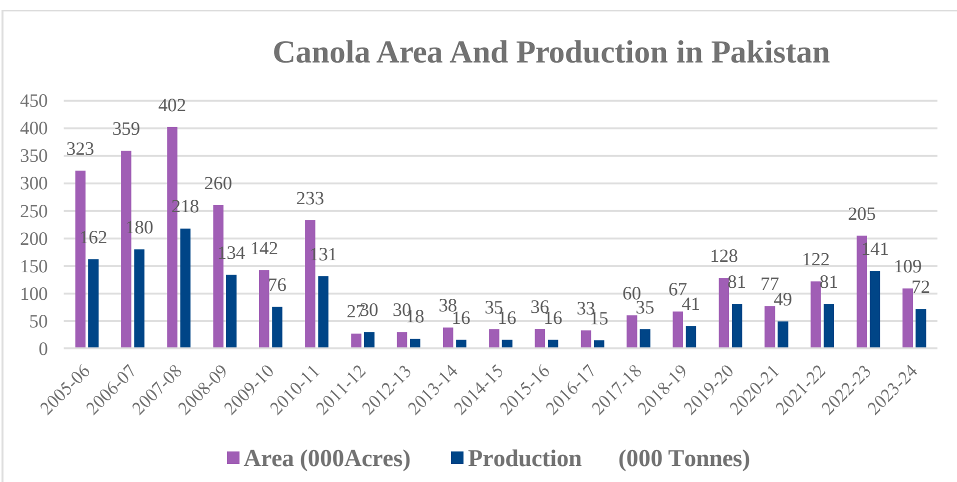

Fig 3. Trends in Area and Production of Canola in Pakistan

Source: Economic Survey of Pakistan

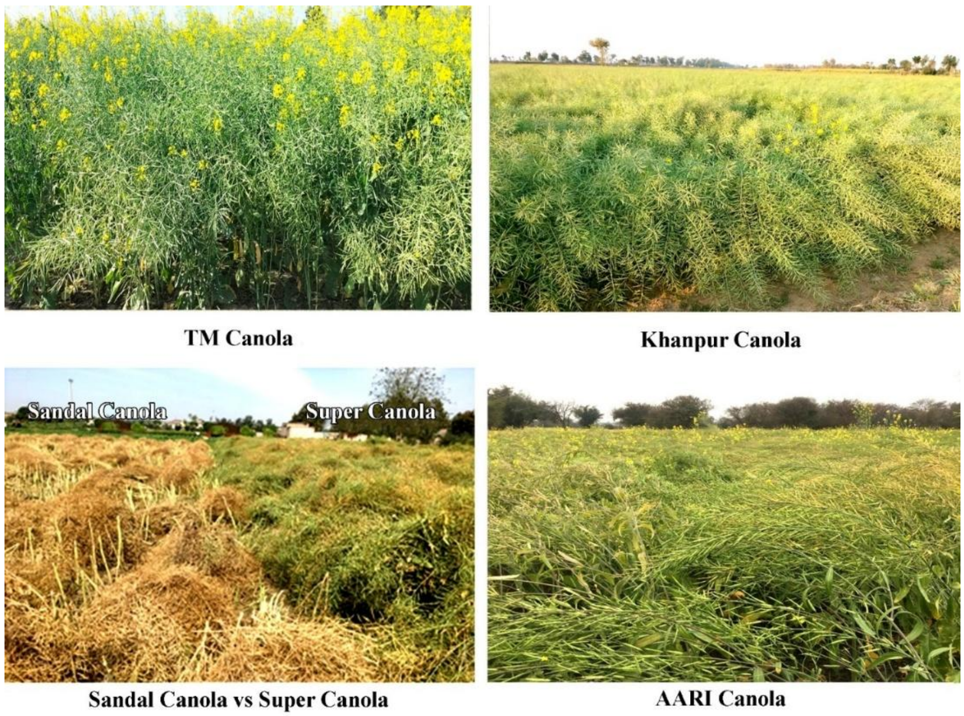

Fig 4. Latest Approved Varieties of Canola

Canola Production Technology

Effective canola production technology involves a series of agronomic practices designed to maximize yield, improve oil quality and ensure sustainable cultivation. Key components include:

i. Variety Selection

- Choose high-yielding, disease-resistant and climate-adapted varieties suitable for the local agro-ecological zone. Always use good quality certified seed for optimum production.

ii. Land Preparation

- Ensure a fine, firm seedbed for uniform seed placement and optimal germination.
- Conduct deep plowing followed by leveling to retain soil moisture.

iii. Sowing Time

- Ideal sowing time:
  - **Irrigated areas**: Early October to end October.

- **Rainfed areas**: Late September to mid-October.

Timely sowing is critical to avoid the effect of climate change especially frost, heat stress during flowering and seed filling stages. The sowing in 1st week of October will also helpful to avoid aphid attack. The sowing time can be managed considering regional climatic condition and rainfall pattern.

iv. Seed Rate and Spacing

- **Seed Rate**: 4-5 kg per hectare for optimal plant population.
- **Spacing**: 45-60 cm row spacing and 10-15 cm between plants for better air circulation and light penetration.

v. Fertilizer Application

- Apply balanced fertilizers based on soil tests:
  - **Nitrogen (N)**: 80-120 kg/ha (split application: ½ at sowing, ½ at flowering).
  - **Phosphorus (P)**: 60-80 kg/ha.
  - **Potassium (K)**: 30-40 kg/ha.
- Supplement micronutrients like sulfur and boron to enhance oil quality.

vi. Irrigation Management

- Canola requires 3-4 irrigations depending on climatic conditions:
- Critical stages: germination, flowering and seed formation.
- Avoid waterlogging to prevent root diseases.

vii. Weed Control

- Use pre-emergence herbicides @ 800 ml per acre (e.g., S- metolachlor, Pendimethalin) or post-emergence herbicides (e.g., Quizalofop for grassy weeds).
- Manual weeding may also be necessary for effective control.

viii. Pest and Disease Management

- Common Pests: Aphids, cutworms, Painted bug and flea beetles.

Use integrated pest management (IPM) techniques, including natural predators and selective insecticides.

- Common Diseases: Sclerotinia stem rot, Blackleg, White rust and Alternaria blight.

Grow disease-resistant varieties and rotate crops to break disease cycles.

ix. Harvesting and Threshing

- Harvest when 70-80% of the pods turn yellow and seeds are firm.
- Use a combine harvester or manual methods, ensuring minimal seed loss.

x. Post-Harvest Handling

- Dry seeds to 8-10% moisture for safe storage.
- Store in cool, dry conditions to maintain oil quality and prevent spoilage.

Advantages of Adopting Modern Canola Production Technology

- **Increased Yield**: Efficient practices can boost yield to 2-3 tons/ha.
- **Improved Oil Quality**: Balanced fertilization and timely harvesting enhance oil content and reduce impurities.
- **Sustainability**: Better resource management ensures long-term soil fertility and water use efficiency.

By adopting advanced production technology, farmers can achieve higher profitability and contribute to reducing edible oil imports in countries like Pakistan.

Table 2. Brief Canola crop production technology.

Sl. No	Operation	Recommendations
1.	Sowing time	Ist October to 20th October, preferably grow in 1st week of October to escape Aphid attack
2.	Land preparation	2-3 ploughings followed by planking
3.	Seed Rate	2 kg /acre
4.	Fertilizer	a. Urea = 1 bag/acre b. DAP = 1 bag/acre c. SOP = 1 bag/acre
5.	Irrigations	3-4
6.	Plant population	60,000 to 80,000/acre
7.	Weeds management	Pre-Emergence spray (Weedicide) Dual Gold 800 ml / 120 L of water just after sowing at good wattar condition

Sl. No	Operation	Recommendations
8.	Insect / pest & disease management	Insects: Aphid, Mustard Saw fly, Painted bug Diseases**:** Alternaria blight, White Rust, Stem Rot, Powdery Mildew Control before Economic threshold level
9.	Harvesting time	March

Table 3. Estimated cost of production for canola production

Operations	Cost per acre (PKR.)
Land preparation	10,000
Seed & Cultivation	12000
Fertilizer	30,000
Intercultural operation	7000
Irrigation (Canal)	7000
Plant Protection	6000
Harvesting/Threshing	15000
Land rent & management (6 month)	50,000
Total Cost	**137,000**
Average Production	1000 kg
Total Income	Rs. 200,000@ Rs. 8000/40kg
Net Profit	**Rs. 74,000**

Constraints in Canola Production:

- Climate change
- Competition with other winter crops like wheat
- Non adoption of recommended production technology
- Less availability of quality seed
- Use of imbalance fertilizers
- Lack of specific harvesting & threshing machines.
- Uncertain market price

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Chapter 10

Rapeseed-Mustard Crop Productivity Enhancement in Bangladesh

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Introduction

Rapeseed-mustard is the second most significant oilseed crop globally, following soybean and oil palm (Zheng and Liu, 2022). In Bangladesh, it plays a crucial role economically, agriculturally and nutritionally. These crops, particularly mustard, are widely cultivated by small-scale farmers, especially in the northern regions and serve as a vital source of income (Arafat et al., 2022). Mustard oil, a staple cooking oil in Bangladeshi households, contributes substantially to the domestic edible oil market, reducing dependence on imported oils and saving foreign currency (Sumon et al., 2024). Mustard's compatibility with the cropping cycle, especially between Aman and Boro rice seasons, optimizes land use, making it an important crop in Bangladesh's agricultural landscape.

Mustard oil, rich in monounsaturated fats and omega-3 fatty acids, supports heart health and offers antibacterial and anti-inflammatory benefits. Widely used in cooking, frying and pickling, it holds cultural and medicinal significance in Bangladesh (Shah et al., 2022). With growing demand for edible oils and government incentives, mustard cultivation is expanding, presenting an opportunity for greater self-sufficiency in edible oil production. Rapeseed and mustard, which are often collectively referred to as "mustard" in Bangladesh, are dual-purpose crops, both used for oil and seed production (Arafat et al., 2022). While Bangladesh grows both rapeseed and mustard, the terms “Shet,” “Rai,” and “Tori” are commonly used to refer to different mustard and rapeseed varieties. Despite challenges like high population density and limited arable land, the importance of mustard cultivation for food security and rural economic development remains undeniable. Modern, short-duration mustard varieties fit seamlessly into the existing cropping patterns, particularly after the harvest of T. Aman rice, offering minimal input requirements and low-risk cultivation.

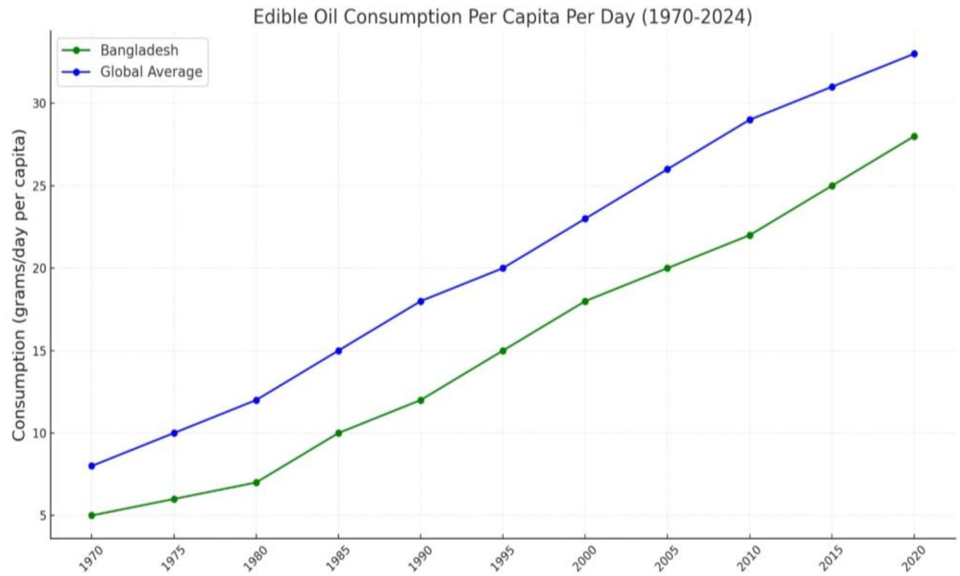

Fig 1. Per Capita Daily Edible Oil Consumption in Bangladesh Compared to the Global Average.

Mustard seeds are rich in protein (23-30%), oil (29-40%) and carbohydrates (12-18%) and their distinctive nutty and somewhat sharp flavor varies depending on the type. Mustard seeds are also a source of antioxidants and preservatives. Despite its importance, mustard production faces challenges, including the lack of good-quality seeds and the insufficient adoption of improved production technologies, leading to low yields. From 1970 to 2024, per capita daily edible oil consumption in Bangladesh steadily increased from around 5 grams to 20 grams but remained below the global average, which rose from 10 grams to over 30 grams (Figure 1). Despite significant growth, the widening gap highlights Bangladesh's lag in dietary patterns and potential nutritional disparities. With the current edible oil production falling short of domestic demand, Bangladesh imports a significant portion, contributing to foreign exchange expenditures (DAE, 2022). In 2022-23, Bangladesh utilized 33,060.78 hectares for mustard cultivation, yielding 409,659 metric tons with an average yield of 1.24 MT per hectare. This gap in supply and demand highlights the potential for increased production through the adoption of short-duration, high-yielding mustard varieties, which could not only boost farmer incomes but also reduce the country's dependence on imported edible oils.

To achieve balanced nutrition and increase farmers' income, agricultural diversification must be prioritized and mustard plays a key role in this strategy. Despite the decline in the area cultivated with oilseeds, mustard cultivation has shown a consistent upward trend since 2010. While significant progress has been made in research and development, the adoption of improved varieties at the farmer level remains a challenge. Government initiatives and financial support for oilseed research are crucial to enhancing production. Through the adoption of high-yielding varieties like BARI mustard-14, BARI mustard-15, BARI mustard-16, BARI mustard-17 and BINA-mustard-4, the country can strengthen its oilseed production capacity. However, understanding and addressing the barriers to the adoption of these varieties is essential for improving mustard production, boosting yields and enhancing food security in Bangladesh.

Research and development of rapeseed/mustard in Bangladesh

Efforts to enhance the production of oilseed crops, particularly mustard and rapeseed, are a key focus of research in Bangladesh. The Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Institute of Nuclear Agriculture (BINA) are leading initiatives to develop high-yielding varieties tailored to diverse agro-ecological zones. These programs aim to boost production by improving yield potential, disease resistance and adaptability to local conditions. For example, BARI has released short-duration, high-yielding mustard varieties such as BARI Mustard-14, BARI Mustard-15, BARI Mustard-17 and BARI Mustard-20, which are well-suited for cultivation after T. Aman rice. These varieties are designed to fit within existing cropping patterns, enabling efficient land use while reducing input costs. The rapeseed-mustard yield in Bangladesh has shown a consistent upward trend from 1970 to 2024 (Figure 2). In 1970, the yield was approximately 0.80 tons per hectare, which steadily increased over the decades. By 2000, the yield reached about 1.00 ton per hectare, showing notable progress in mustard production. This growth continued and by 2024, the yield surpassed 1.15 tons per hectare. The sustained improvement indicates advancements in agricultural practices, technology and possibly the adoption of higher-yielding mustard varieties.

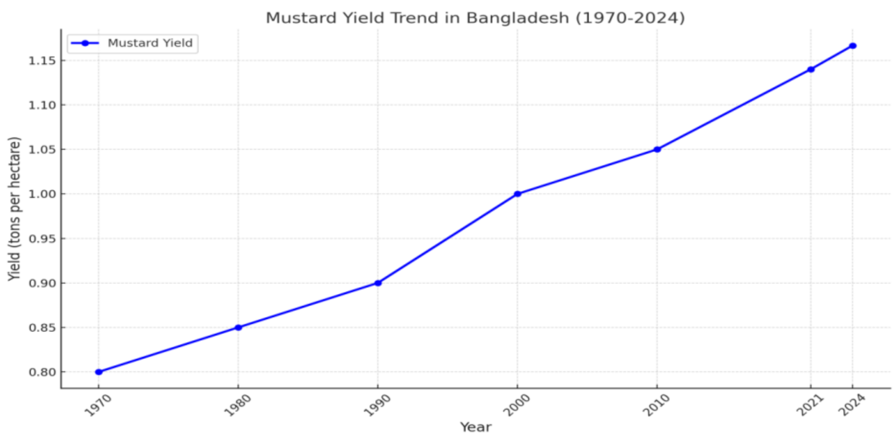

Fig 2. Average Seed Yield of Major Rapeseed-Mustard Varieties in Bangladesh

To address the growing demand for high-quality oilseeds, research integrates traditional breeding with modern biotechnological approaches, including molecular marker-assisted selection and genetic modification. Emphasis is placed on improving oil content, seed quality, pest and disease resistance. Short-duration and drought-tolerant varieties are gaining prominence to tackle challenges posed by climate change and water scarcity. Beyond variety development, significant research focuses on optimizing agronomic practices for mustard and rapeseed cultivation. Studies explore soil fertility management, irrigation scheduling, pest and disease control and nutrient optimization to ensure maximum yield and quality. Improved seedbed preparation, timely sowing, proper plant spacing and the use of quality inputs like fertilizers and biocides have been identified as critical factors for boosting productivity. Crop rotation systems incorporating mustard and rapeseed are being examined to promote soil health and sustainability.

Integrated pest management (IPM) strategies are being tested to minimize chemical pesticide usage while maintaining effective pest control. These strategies include the deployment of resistant varieties, biological control agents and eco-friendly pesticides. Additionally, climate-smart practices, such as water-efficient irrigation methods and organic fertilizers, are being evaluated to enhance the resilience of oilseed crops under changing climatic conditions. A vital aspect of these efforts is farmers training and capacity building. BARI, BINA and the Department of Agricultural Extension (DAE) conduct training sessions, workshops and field demonstrations to promote the adoption of improved varieties and cultivation techniques. These programs cover topics like the benefits of high-yielding varieties, modern crop management practices, pests and diseases control and efficient inputs usage. Farmers gain hands-on experience through demonstration plots, while extension officers receive technical training to support oilseed growers. Additionally, seed producers, agricultural technicians and agribusiness stakeholders are included in these programs to strengthen the entire oilseed value chain. Government and non-government organizations also play a crucial role in raising awareness of the economic and food security benefits of oilseed crops. Mass campaigns highlight the importance of increasing domestic production to reduce dependency on imported edible oils. Through collaborative research, development and extension initiatives, Bangladesh aims to improve the livelihoods of farmers, achieve self-sufficiency in oilseed production and enhance national food security.

Challenges in rapeseed-mustard breeding in Bangladesh include the need for developing short-duration, high-yielding and stress-tolerant varieties to combat diseases like Alternaria blight, white mold and club root, as well as pests like *Spodoptera litura* and aphids. Additional challenges include limited climate-smart varieties, high crop competition, unpredictable weather and a pest- and disease-favourable environment. Breeding strategies focus on germplasm evaluation, interspecific hybridization and developing hybrid and double-low (canola) varieties with improved yield, stress tolerance and adaptability. Key Brassica species exhibit diverse oil contents, with B. rapa (38-45%), B. napus (35-50%), B. juncea (30-40%) and others like Raphanus sativus and Rorippa indica offering unique traits but facing challenges such as disease susceptibility, low yields or nutritional limitations.

In 2023-24, rapeseed-mustard was cultivated on 1.10 million hectares, producing 1.61 million tons, contributing significantly to Bangladesh's total oilseed production of 2.04 million tons from 1.36 million hectares. Integration into fallow periods of major cropping patterns like Boro Rice-Fallow-T. Aman (2.0 million ha) highlights its potential for diversification. Popular cropping systems such as Mustard-Boro-T. Aman and Sesame-T. Aman-Mustard have increased productivity, with innovations like the Mustard-Cowpea mixed system boosting mustard equivalent yields by 27%. In flood-prone areas like Manikganj, cropping patterns such as Mustard-Boro Rice-Fallow enhance rice equivalent yields by 20%, while Sylhet’s Laishak-Patshak-T. Aus-T. Aman system achieves an 80% yield increase.

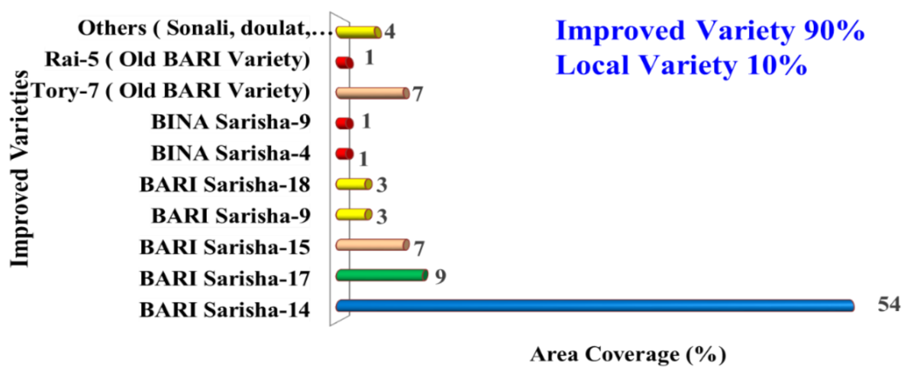

Fig.3. Adoption rate of Rapeseed-Mustard varieties developed by research institutes in Bangladesh

Breeding efforts have developed 48 rapeseed-mustard varieties in Bangladesh, including 22 by BARI, 12 by BINA and others by BAU and SAU (Figure 3). Notable varieties include BARI Sarisha-14 (saline-tolerant, 1.4-1.6 t/ha), BARI Sarisha-18 (canola type, 2.0-2.5 t/ha) and BINA Sarisha-12 (Alternaria-tolerant, 1.9 t/ha). Adoption rates show improved varieties account for 90%, with BARI Sarisha-14 (54%) being the most preferred. Technology pipelines include high-yielding and early-maturing varieties with enhanced stress tolerance, such as those with 94-98-day durations yielding 3.1-3.5 t/ha. These advancements, coupled with improved cropping systems, have significantly increased oilseed productivity and profitability, as evidenced by higher yields and economic returns in regions like Pabna, Barind and Cox’s Bazar.

Trend of Mustard Production in Bangladesh

In Bangladesh, rapeseed and mustard production has seen significant growth. For the 2023/24 market year, the harvested area for rapeseed and mustard expanded to approximately 1.1 million hectares, with a production forecast of 1.6 million metric tons, reflecting a 50% increase in area and a 43% increase in production compared to the five-year average (Figure 4). This rise can be attributed to improved cultivation practices and higher yields of around 1.5 tons per hectare, surpassing the long-term average.

Rapeseed-mustard has experienced fluctuating production trends in Bangladesh over the years. While mustard is the most widely cultivated oilseed crop, rapeseed (locally known as "Tori") is also grown, though it occupies a smaller area in comparison. In the 2021-2022 fiscal year, mustard accounted for about 610 (000 hectares) of cultivated area, producing approximately 822 thousand metric tons. Despite this, the overall oilseed production in the country is still below the required levels to meet domestic demand.

Over the past decade, there has been a steady increase in mustard production, attributed to the development and dissemination of high-yielding varieties, such as BARI Mustard-14, BARI Mustard-15 and BARI Mustard-16, which have improved the yield potential of this crop. The adoption of improved crop management practices, such as better seed quality, irrigation and pest control, has contributed to this upward trend in production. However, challenges such as limited arable land, climatic variability and insufficient input use still affect the overall growth of mustard and rapeseed production in Bangladesh.

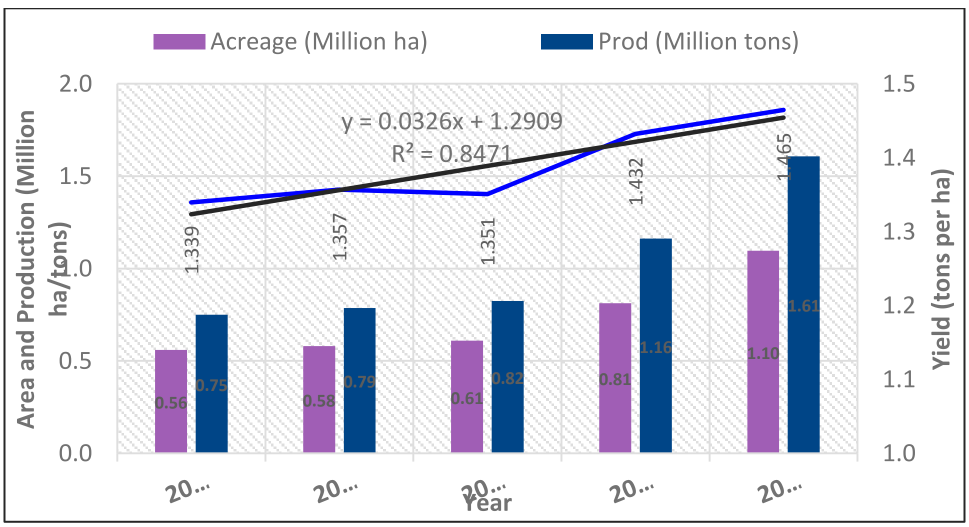

Fig. 4. Trends of rapeseed-mustard cultivation area, production and yield in Bangladesh (Source: DAE, 2024)

Cultivated Area of Oilseed Crops

The cultivated area is the term used to describe the total amount of land in which seeds were sown for producing crops. A total area of almost 500.08 thousand ha was bought under oil crop cultivation in 2021-2022. The percent shares of cultivated areas by major oilseed crops are presented in Table 1. The demand for edible oils, particularly mustard oil, has been steadily increasing in Bangladesh. Mustard oil is a staple cooking oil, highly valued for its flavour, health benefits and culinary versatility. It is used for frying, pickling and flavouring traditional dishes, making it an essential part of daily consumption. Additionally, mustard oil's health benefits, including its rich content of monounsaturated fats and omega-3 fatty acids, have contributed to its growing popularity among consumers.

Table 1: Area & production of different oilseed crops during 2023-24 in Bangladesh.

Crop	Area (Million ha)	Production (Million tons)	Yield (tons/ha)
Rapeseed-mustard	1.10	1.61	1.46
Groundnut	0.09	0.18	2.05
Sesame	0.07	0.08	1.18
Soybean	0.09	0.17	1.84
Sunflower	0.02	0.03	1.65
Total	1.36	2.04	1.50

Bangladesh faces significant challenges in meeting the growing demand for mustard oil due to high population density, limited arable land and insufficient domestic production, which has led to a heavy reliance on imports. The increasing demand, driven by population growth, changing dietary habits and urbanization, underscores the need to boost mustard production through the adoption of high-yielding varieties, improved seed quality and modern agricultural practices such as efficient crop management, irrigation and pest control. Land constraints necessitate crop diversification strategies like intercropping and rotation with high-value crops, while investments in farmer training, resources and inputs are essential for improving yields. Enhancing storage and processing infrastructure is critical to reducing post-harvest losses and increasing oil recovery rates, which currently stand at 30-40% due to reliance on traditional pressing methods. Advancing extraction technologies, such as cold pressing and solvent extraction, alongside breeding efforts to develop pest-resistant and climate-tolerant mustard varieties with higher oil content, can further improve productivity and profitability. Addressing these challenges through improved practices, better infrastructure and research-driven innovations will help Bangladesh achieve self-sufficiency in mustard oil production, reduce imports and enhance farmer livelihoods.

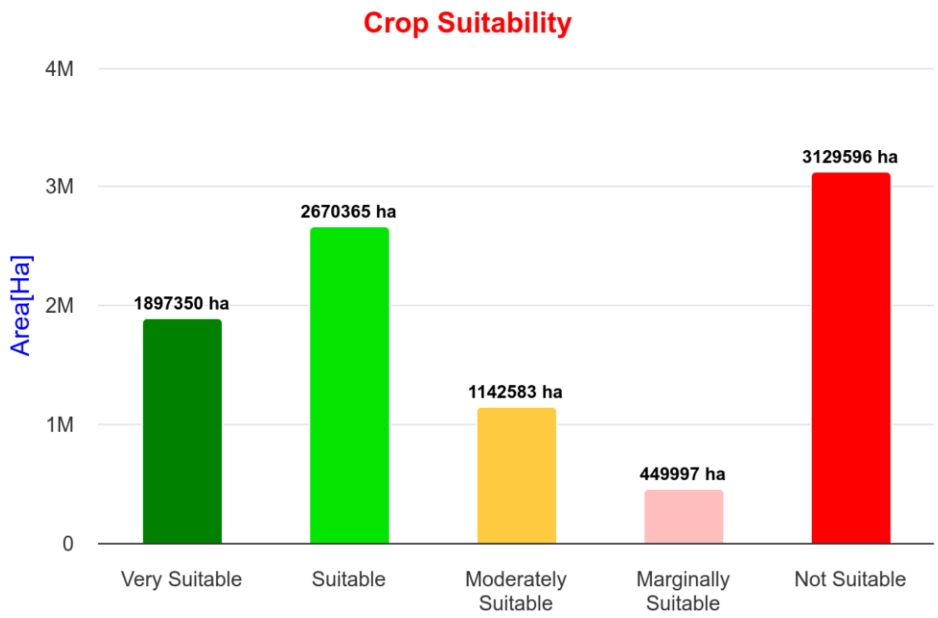

Fig 5. Crop suitability of rapeseed/mustard production area in Bangladesh.

HYV of Rapeseed and Mustard Released by BARI

Table 2. shows the history of mustard and rapeseed HYVs developed and released by the Bangladesh Agricultural Research Institute (BARI). It provides valuable information for farmers choosing the most suitable mustard/rapeseed variety for their needs. Generally, shorter-duration varieties (e.g., Tori-7) are suitable for areas with shorter growing seasons or double cropping (planting two crops in a year). Longer duration varieties (e.g., BARI Mustard-11, BARI Mustard-16) might produce higher yields but require more time for growth. Higher yield varieties (e.g., BARI Mustard-6, BARI Mustard-10, BARI Mustard-18) are preferable for maximizing production. Varieties with higher oil content (e.g., Sonali, BARI Mustard-15) are more profitable as they produce more oil per unit of seed. There seems to be a general trend of increasing yield potential over time. Newer varieties like BARI Mustard-18 offer significantly higher yields compared to the earlier released varieties Rai-5. While some longer-duration varieties exist, there seems to be a focus on developing shorter-duration varieties in recent years (e.g., BARI Mustard-14, BARI Mustard-17). The oil content remains relatively stable across most varieties, ranging from 39 to 52%.

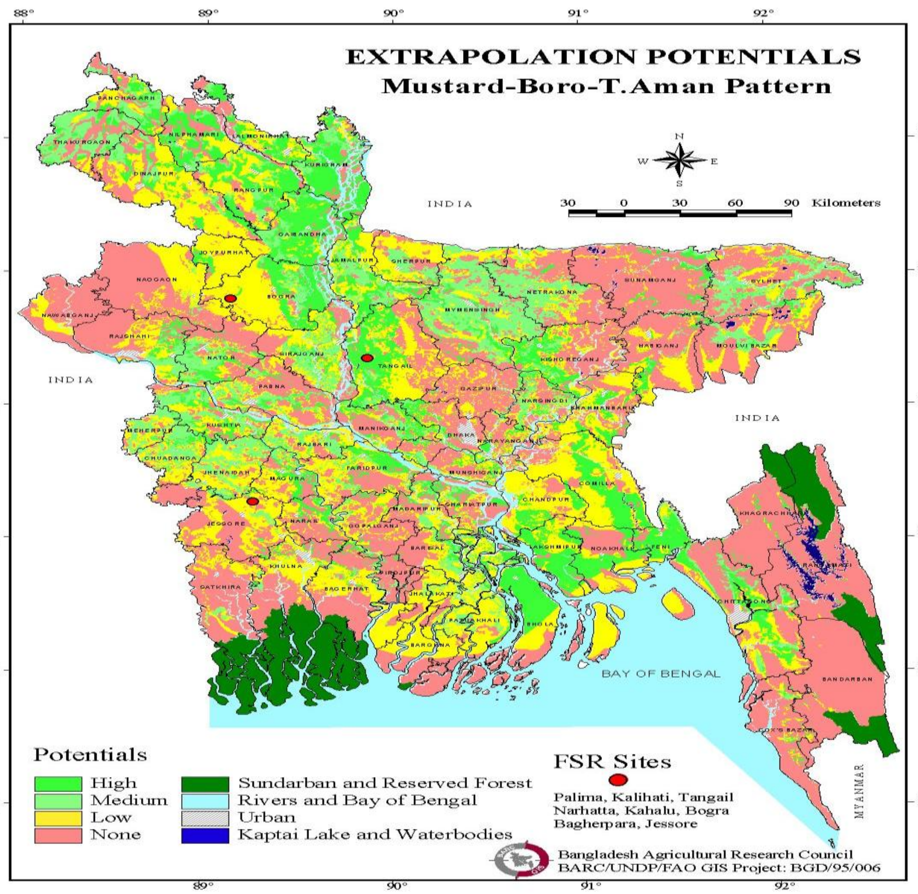

Fig 6. Spatial distribution of Mustard-Boro-T.Aman cropping pattern suitability in Bangladesh.

Table 2. Rapeseed- Mustard Released by BARI, BINA, BAU, BSMRAU and SAU

Oilseed Crops	**Variety Released by different Organizations**					**Total**
	BARI	BINA	BAU	BSMRAU	SAU	
Rapeseed & Mustard	22	12	9	1	4	48

Variety	Release year	Crop duration (days)	Yield (t/ha)	Oil content (%)
BAARI Sarisha-1 (Tori-7)	1976	75-80	1.6-2.0	38-41
BAARI Sarisha-2 (Rai-5)	1976	110-120	1.0-1.2	39-40
BAARI Sarisha-3 (Kallyani (TS-72))	1979	80-85	1.2-1.4	40-42
BAARI Sarisha-4 (Sonali (SS-75))	1979	90-100	1.8-2.0	44-45
BAARI Sarisha-5 (Daulat (RS-81))	1988	90-100	1.3-1.5	39-40
BARI Sarisha -6	1994	90-100	2.1-2.5	44-45
BARI Sarisha -7	1994	90-100	2.0-2.5	42-45
BARI Sarisha -8	1994	90-100	2.1-2.4	43-45
BARI Sarisha -9	2000	80-85	1.2-1.4	43-44
BARI Sarisha -10	2000	85-90	2.2-2.8	42-43
BARI Sarisha 11	2001	105-110	2.0-2.5	40-42
BARI Mustard-12	2001	80-85	1.2-1.4	43-44
BARI Sarisha -13	2004	90-95	2.2-2.8	42-43
BARI Sarisha -14	2006	75-80	1.4-1.6	40-45
BARI Sarisha -15	2006	90-85	1.4-1.7	48-52
BARI Sarisha -16	2009	105-110	2.2-2.3	40-42
BARI Sarisha -17	2013	82-86	1.7-1.8	40-42
BARI Sarisha-18	2021	90-95	2.2-2.9	40-42
BARI Sarisha-19	2021	90-105	1.7-2.5	40-41
BARI Sarisha-20	2022	80-85	1.7-2.0	40-42
BARI Sarisha-21	2024	95-110	1.5-2.5	43-44
BARI Sarisha-22	2024	84-85	1.9-2.1	40-41

Bangladesh Agricultural Research Institute (BARI); Bangladesh Nuclear Agricultural Research Institute (BINA); Bangladesh Agriculture University (BAU); Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU); Sher-e-Bangla Agricultural University (SAU)

Source: BARI, 2024

Growth Rate of Yield and Cultivated Area of Mustard

Table 3. shows that up to fiscal year 2020-21 percentage area brought under mustard cultivation was continuously decreasing but in recent years it has increased at a considerable rate. The yield of mustard is also enjoying a positive change because of better HYV seeds and modern agricultural practices. In 2021-22, cultivation area increased by 0.36% & yield increased by 2.87% from the year 2020-21. Cultivation areas have also increased continuously in the last couple of years since mustard farmers are getting fair prices. This is very encouraging for Bangladesh for self-sufficiency in food.

Table 3. Growth rate of yield and cultivated area of Rapeseed/Mustard

Year	Yield (kg/acre)	Area ('000' acre	Yield increase (%)	Area change (%)
2016-17	437	831	-	-
2017-18	463	760	5.94	-9.34
2018-19	467	667	0.86	-13.94
2019-20	469	764	0.42	12.67
2020-21	487	814	3.83	-13.94
2021-22	501	817	2.87	0.36

Source: BBS, 2022

Machinery issues

The BARI Seeder is an advanced agricultural implement designed for single-pass tilling, line seeding and seed covering, offering significant efficiency in crop establishment. It supports multi-crop seeding, including wheat, maize, oilseeds, pulses, jute and sesame and effectively utilizes residual soil moisture, making it suitable for resource-limited conditions. The seeder saves 20% of seeds and reduces costs by 67%, while minimizing the turnaround time between crops by 7-9 days. Priced at Tk. 65,000 (US$ 800) without a power tiller, it provides an affordable solution for farmers seeking efficiency and cost savings. Additionally, the BARI Mobile Oil Expeller facilitates small-scale oilseed crushing, handling 40-50 kg per hour with an oil extraction rate of 30-35%. It allows farmers to process small quantities (5 kg) of oilseeds, promoting local oil production and value addition. The expeller, priced at Tk. 1,25,000 (with a vehicle), is a versatile tool for enhancing oilseed utilization and farmer profitability.

Government policy

Bangladesh has achieved notable progress in edible oil self-sufficiency, with local production increasing from 12.43% in 2021-22 to a projected 40.24% in

2024-25, driven by advancements in domestic oilseed production (Figure 7). Mustard, along with sunflower and sesame, thrives in unfavourable ecosystems, making it ideal for diverse regions across the country. In Charland (0.8 million ha), BARI Sarisha-14, 17, 18 and 20 are well-suited, while Coastal Areas (0.9 million ha) support BARI Sarisha-14, 17, 18 and 20 in non-saline regions and BARI Sarisha-11, 18, 19 and 21 in saline conditions. Similarly, the Barind Tract (0.3 million ha) and Haor Areas (0.25 million ha) are favorable for BARI Sarisha-14, 17, 18 and 20, while Hilly Areas (1.6 million ha) accommodate BARI Sarisha-14, 18, 20, 21 and 22. These varieties maximize the productive use of underutilized lands. Incorporating mustard into existing cropping patterns, particularly the 1.3 million hectares under four-crop sequences, can enhance land utilization and sustainability.

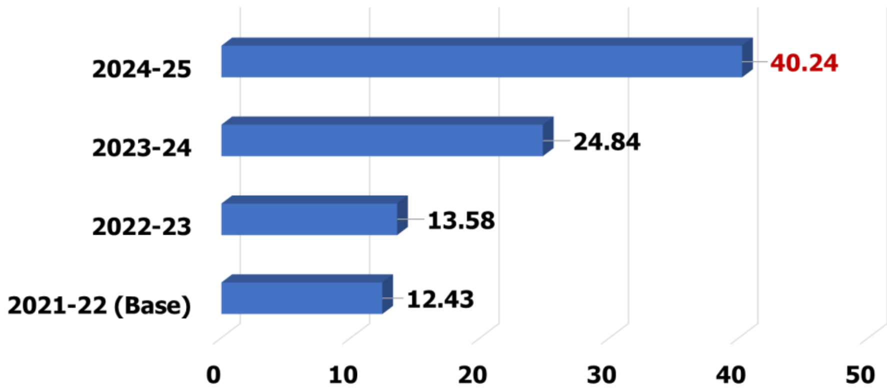

Fig 7. Government policy for enhancing self-sufficiency in edible oil through local production

Bangladesh's six agricultural hotspots salinity (1.06 million ha), drought (3.5 million ha), waterlogging (2.6 million ha), charland (0.75 million ha), haor (0.86 million ha) and hilly areas (1.81 million ha) comprise 60% of the country's land under unfavourable ecosystems, with a cropping intensity of 133%, significantly below the national average of 214%. These regions face challenges such as soil salinity, drought, seasonal flooding, erosion and nutrient-poor soils, limiting productivity in 30.2 lakh hectares of land. Addressing these challenges through the adoption of stress-tolerant varieties, conservation agriculture, improved soil and water management and farmer training programs can boost cropping intensity and productivity. To increase rapeseed-mustard production, it is essential to replace traditional varieties with high-yielding ones, establish "Sarisha Gram" for technology dissemination and expand cultivation into fallow and marginal lands. Reducing yield gaps through proper management practices and ensuring the timely availability of quality seeds can further optimize production, improve farmer livelihoods and contribute to national self-sufficiency in edible oil.

Way Forward

To enhance rapeseed-mustard production in Bangladesh, it is crucial to replace traditional varieties with high-yielding, climate-smart varieties that are resilient to drought, pests and various environmental stresses. These improved varieties should be carefully developed to ensure they are adaptable to different agro-ecological zones and have the potential to increase productivity under changing climatic conditions. In addition to breeding high-yielding varieties, reducing the existing yield gap through better management practices is vital. This includes selecting the right seeds, ensuring optimal planting density, efficient irrigation techniques and effective pest and disease control measures. Integrating rapeseed-mustard into the existing cropping systems, such as between Aman and Boro rice seasons, will make better use of available land, enhancing the overall productivity of agricultural systems. A timely and adequate supply of quality seeds will ensure that farmers can access the best planting material for optimal yields. Furthermore, developing hybrid varieties of rapeseed-mustard will provide more diverse genetic options, improving resistance to environmental stresses and pests. The introduction of omics-based research, including genomics and biotechnology, will further improve breeding efficiency and help in the development of varieties with enhanced yield potential, oil content and resistance to biotic and abiotic stresses. Strengthening research facilities to address the challenges posed by unfavourable ecosystems will be essential for developing varieties suited to specific regions. Moreover, capacity building through farmer training and the dissemination of modern technologies will empower farmers with the knowledge and tools they need to implement best practices in cultivation. Ultimately, a combined effort of improved varieties, better management practices, timely seed supply and capacity-building initiatives will promote increased rapeseed-mustard production, improve food security and contribute to the country's self-sufficiency in edible oil.

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Chapter 11

Rapeseed-mustard Scenario in India

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Introduction

Brassicaceae (Cruciferae) is of great economic significance as plants of this family are used as vegetables, condiments and edible oils. It contains over 3,700 species in 338 genera, having significant genetic diversity (Demeke et al. 1992; Hayward 2012). Crop Brassicas including six *Brassica* species distributed around the world and used for various purposes. *Brassica carinata* (Ethiopian mustard), *B. napus* (Gobhi sarson) and *B. juncea* (Indian mustard) are amphidiploids originated through natural hybridization between the diploid species *B. rapa*, *B. nigra* and *B. oleracea* (U 1935). Species under genus *Brassica* having diverse morphology and uses. *B. carinata*, *B. juncea*, *B. napus* and the diploid *B. rapa*, are naturally oliferous species. These species have good combination of saturated and unsaturated fatty acids along with secondary metabolites, glucosinolates in moderate to high amount in seed oil and erucic acid and protein content in the seed meal in moderate to high proportions. *B. nigra* is mainly used as condiments and *B. oleracea* is cultivated for vegetable purpose due to its enormous morphological diversity. Other genera in Brassicaceae are valued for condiments (*Sinapis*, *Eruca*), vegetable (*Eurca*, *Raphanus*, *Diplotaxis*), industrial uses (*Eruca*, *Crambe*, *Sinapis*, *Lepidium*, *Camelina*, *Thlaspi*) and food / fodder (*Orychophragmu*, *Eruca*) (Dixon 2007; Warwick et al. 2009).

Table 1. Some crop species of the Brassica.

Scientific name	Common name / description	*n*
Brassica rapa subsp. campestris (L.) A.R. Clapham	Summer turnip rape, wild turnip rape	10 (A)
Brassica rapa subsp. oleifera (DC.) Metzg.	Winter turnip rape	10 (A)
Brassica rapa var. brown sarson	Brown Sarson	10 (A)
Brassica rapa var. toria	Toria	10 (A)
Brassica rapa var. yellow sarson	Yellow sarson	10 (A)
Brassica nigra (L.) W.D.J. Koch	Black mustard, Banarasi rai	8 (B)
Brassica oleracea L.		9 (C)

Brassica juncea (L.) Czern.	Indian mustard, brown mustard	18 (AB)
Brassica napus L.	Rapeseed, canola	19(AC)
Brassica napus subsp. Oleifera (Delile) Sinskaya	Summer oilseed rape, Canola	19 (AC)
Brassica napus f. biennis (Schübl. & G. Martens) Thel	Winter oilseed rape, Winter canola	19 (AC)
Brassica carinata A. Braun	Abyssinian mustard, Ethiopian mustard,	17 (BC)
B. tournefortii	African mustard, Sahara mustard	10 (T)
Eruca sativa Mill	Garden rocket, Rocket salad	11 (E)
Sinapis alba	White mustard	12(Sal)

Source: Sharma et al. (2022)

Rapeseed-mustard production statistics in India

India is cultivating nine oilseed crops under the diverse agro-ecosystems, among which rapeseed-mustard stands first in terms of production (Rapeseed-mustard production during 2023-24=131.61 Lakh Tonnes) followed by soybean (Soybean production during 2023-24=130.54 Lakh Tonnes) and groundnut (production= 102.89 Laksh tonnes) (Agricultural statistics briefly, 2023). The major rapeseed-mustard species cultivated in India includes; Brassica juncea, B. rapa, B. napus *and* B. carinata (used for edible oil) and B. oleracea *and* B. nigra (for seed condiments). Among these, Indian mustard [B. juncea (L.) Czern], holding sizable contribution in terms of area and production of oilseeds and edible oils. In past, brown mustard (*B. rapa var. brown sarson*) was the dominant oilseed brassica crop in India, however, today it is dominated by Indian mustard (*B. juncea*) (90% acreage). The different landraces of Brassica species have different ecological niches and developed the varieties as per their agro-ecological suitability. Indian mustard (*B. juncea*) is predominantly cultivated in western to central parts of North India and in some non-traditional areas of southern India. Yellow mustard (*B. rapa var. yellow sarson*) and toria (*B. rapa var. toria*) are short-duration crops and cultivated in north-eastern India as catch crop. Taramira/rocket salad (*Eruca sativa*) is a drought-tolerant species grown in the drier parts of northwest India. Gobhi mustard (*B. napus*) and Ethopian mustard/Karan rai (*B. carinata*) are the new emerging oilseed crops having a limited area under cultivation in northern India (Jat et al., 2019). Indian mustard oil contains low amount of saturated fatty acids (palmitic acid and stearic acid) (8%) and a high amount of monounsaturated fatty acids (oleic, eicosenoic and erucic acids) (70%) and polyunsaturated fatty acids linoleic and linolenic acids

(22%). The mustard oil is high in omega-3, free from cholesterol and trans fats and have a very low N-6 to N- 3 ratio) compared to other oils. Indian mustard oil is blended with other vegetable oils (sunflower, soybean, corn, etc.) improve their fatty acid profile. However, with the increasing awareness about health and wellness, the demand of mustard oil is increasing globally as to be used for direct consumption and other value-added products (Kumar, 2015; Jat et al., 2019).

A quantum jump in production of Rapeseed-mustard was recorded from a mere 0.76 million tonnes in 1950-51 to 13.16 million tons in 2023-24 (Fig. 1). Similarly, productivity levels increased from 368 kg/ha in 1950-51 to 1444 kg/ha in the year 2023-24 (Anonymous, 2023). The percent increase in total oilseeds area, production and productivity in the country is +181, +669 and +173% in 2023-24, respectively over the base period of 1950-1951. During the same period, the rapeseed-mustard area, production and productivity also increased by +346, +1644 and +294%, respectively. The compound annual growth rate (CAGR) in area, production and yield levels of oilseed brassica is +2.06%, +3.99% and +1.89% during 2023-24 over 1950-51 which is higher than total oilseeds (+1.42%, +2.83% and +1.38%), respectively. Rapeseed-mustard share was highest (33.42%) in total oilseeds production followed by soybean (32.92%) during 2023-24, however, stand first in edible oil production in the country (Agril. statistics at a glance, 2023).

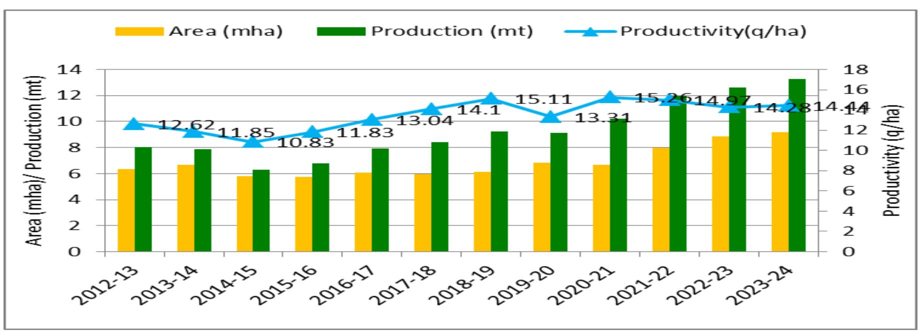

Figure 1. Production trend in oilseed and rapeseed-mustard since 1950

Despite of significant progress achieved in the oilseeds production in India, increasing population and changing lifestyle of the people leads to increase in demand and import of vegetable oils in India. Since 2010-11 the import of edible oil increased from 7.24 million tonnes to 16.5 million tonnes in 2022-23 (Fig. 2). During the last 20 years, the total consumption has been increased (+198%) from 9.7 million tonnes in 2000-01 to 28.92 million tonnes in 2022-23 (Fig. 2). During the same period, the production of edible oils from all sources increased (%) from 5.5 million tonnes in 2000-2001 to 12.42 million tonnes in 2022-23. This gap between consumption and production is just met out through import which has increased (+292%) from 4.2 million tonnes in 2000-2001 to 16.50 million tonnes in 2022-23 (Agricultural statistics at a glance, 2023).

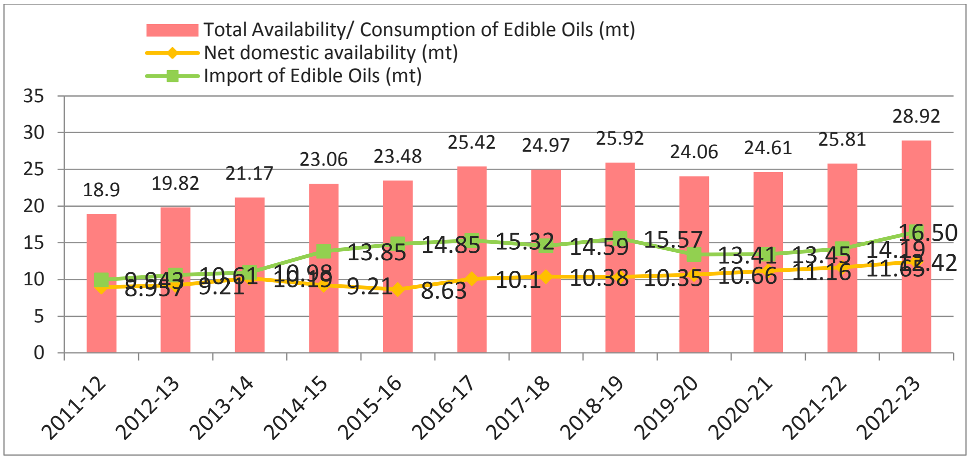

Fig 2. Domestic production and import of edible oil in India (Source: Agricultural statistics at a glance, 2023)

At present, vegetable oils hold 50% share (in terms of value) in the total import of the country and drain significant quantum of revenue to the foreign countries. It is a stern apprehension to the national economy while fulfilling the domestic edible oils requirement simultaneously. India is mainly importing the refined edible oil from other countries against the negligible export. The situation will be more challenging with rising consumption up to 2030 with the projected population and thereafter may increase at a decreasing rate with declining population growth rate. The limited and steadily declining natural resources (land and water) and competition from agriculture and non-agricultural sector, jeopardized the scope to increase the acreage under oilseeds. In such a situation, increase in yield levels through translational scientific interventions is a conceivable alternative to increase the production and edible oil availability. Rapeseed-mustard is grown all over India; however, it dominates in five states (Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana and West Bengal) which contributes 85% area and 88% production with a maximum in Rajasthan (45% area and 46% production) (Fig. 3). Eco-regional variations are mainly noted due to biophysical fittingness of the crop.

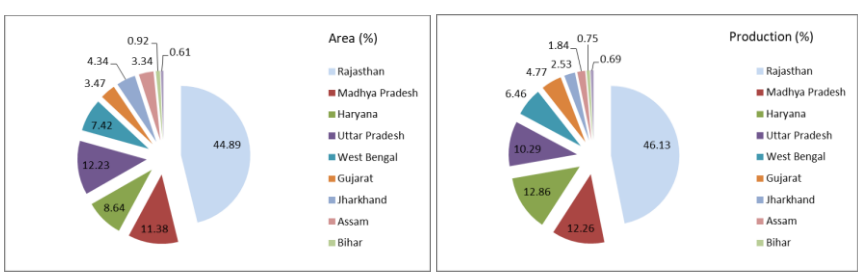

Fig 3. Share of states in Rapeseed-mustard production during 2023-24 (Source: Agricultural statistics at a glance, 2023).

Rapeseed-mustard breeding in India

The research work on the improvement of rapeseed mustard started with start of 20th century at Pusa (Bihar), the then Bengal Presidency through the collection and purification of land races. The initial scientific work for varietal improvement of rapeseed-mustard in India started at Layallpur (now Faisalabad in Pakistan), (NRCRM, 2000) which led to the development of Indian mustard variety RL 18 (Raya Layallpur 18), in 1937 and yellow sarson variety L1 through selection. Indian mustard strain RT 11 from Uttar Pradesh was released in 1936. During the course of about two decades (1947- 67), a number of high-yielding varieties of mustard (Laha 101, Varuna, Durgamani, Patan Mustard), toria (Abohar, BR 23, M 27, T 9, ITSA, T 36, DK 1), brown sarson (BSA, BSG, BSH 1, BS 2, BS 65, BS 70), yellow sarson (T 151, Patan sarson, YSPb 24, T 42) and taramira (ITSA) were developed (NRCRM, 2007). In April 1967, Indian Council of Agricultural Research (ICAR) launched All India Coordinated Research Project on Oilseeds (AICORPO) including five major crops namely, groundnut, rapeseed-mustard, sesame, linseed and castor. However, Project Coordinator (Rapeseed-Mustard) was established on 28 January 1981 at Haryana Agricultural University, Hisar, Haryana. To provide a strong leadership to the rapeseed-mustard research activities in the country, ICAR established National Research Centre on Rapeseed-Mustard on 20 October 1993 at Bharatpur (Rajasthan) bringing under its umbrella, the All India Coordinated Research Project on Rapeseed-Mustard with 19 research centres across the country. In February 2009, the National Research Centre on Rapeseed-Mustard was redesignated as Directorate of Rapeseed-Mustard Research (DRMR) (Chauhan et al., 2006, Chauhan et al., 2011).

Initially Exotic germplasm has been utilized in Indian breeding programme to develop 21 varieties of rapeseed-mustard, especially for oil and seed meal quality characters. Two varieties of brown sarson and 10 varieties of gobhi sarson, 09 of Indian mustard and one in karan rai were developed. Until 1970, pure line and mass selection were the only breeding methods, employed to develop 26 varieties. Later, hybridization was followed to develop varieties. All the varieties developed before the inception of AICRPO/ AICRP-R&M were the selections from the local germplasm (Chauhan et al., 2006, Chauhan et al., 2011). Till June 2023, 304 rapeseed-mustard varieties were identified/ released from which 246 varieties were notified by Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agriculture Crops (Table 2). First notified variety was ITSA of toria (*B. rapa*) in 1973. The list of trait specific varieties is presented in Table 3.

Table 2. Total number of Rapeseed-mustard varieties developed (1936-2023).

Crop	Notified	Not notified	Total Identified/released	Notified varieties Recommended by	
				CVRC	SVRC
Indian mustard	150	24	174	95	55
Karan rai	5	3	8	2	3
Black mustard	1	0	1	0	1
Brown sarson	8	6	14	2	6
Toria	33	13	46	7	26
Yellow sarson	21	8	29	13	8
Gobhi sarson	19	2	21	6	13
Taramira	9	2	11	6	3
Total	246	58	304	131	115

Source: Rai et al., 2023.

Indian mustard oil contains high amount of erucic acid (40-57% of total fatty acids) which is not considered good for human health. Its seed meal contains high glucosinolate which is harmful for non-ruminant animals. Hence, efforts were made to develop varieties which contain low (< 2%) erucic acid (Pusa Karishma, Pusa Mustard 21, Pusa Mustard 22, Pusa Mustard 24, RLC 1, RLC 2, RLC 3 and PM 32) and double low (low erucic acid and low glucosinolate 30 micro mole/g of defatted seed meal) varieties (PDZ 1 and PDZ 33). The varieties released during the last two decade (2001-21) have been given in Table 4. The varieties have also been developed for various traits like tolerant to biotic (white rust, Alternaria blight, powdery mildew) and abiotic stresses (drought, salinity, high temperature and frost) and better quality for specific growing conditions. Various novel genetic stocks of oilseed brassica (low erucic acid, low erucic acid and low glucosinolates, high oil content, high oleic acid and low linolenic acid, dwarf, earliness, long main shoot, bold seed, yellow seed, tetra locular siliquae, white rust resistance, tolerance to high temperature and salinity, drought, high water use efficiency) were also registered with National Bureau of Plant Genetic Resources (NBPGR), New Delhi for the use in future breeding program.

The major emphasis of varietal improvement program is now on genetic enhancement to widen the genetic basis for seed and oil yield with introgression traits like; early, timely and late-sown conditions to cater the need of diverse agroecological situations of the country, improvement of oil (low erucic acid) and seed meal (low glucosinolate), high omega oil quality, resistance/tolerance against biotic (white rust, Alternaria blight, Sclerotinia rot diseases and aphid and painted bug insects) and abiotic stresses (drought, high temperature, frost and salinity) (Jat et al., 2019).

Table 3. Indian mustard varieties recommended for specific conditions/ specific traits.

Specific trait	Varieties
High temperature tolerant at seedling stage	Kanti, Pusa Agrani, RGN 13, Urvashi, NRCDR 2, Pusa Mustard 25, Pusa Tarak, Pusa mustard 27 (EJ17), Pusa Mustard 28 (NPJ 124), Pant Rai 19, Azad Mahak
Late sown / High temperature tolerant at terminal stage	Ashirwad, RLM 619, Swarnjyoti, Vardan, Navgold (YRN 6), CS 56 (CS-234-2), RGN 145, NRCHB 101, Pusa Mustard 26 (NPJ113), CS 58, Radhika, Brijraj, Sampoorna (OUAT Kalinga Mustard 1)
Intercropping	RG 30, Vardan
Rainfed / drought tolerant	Aravali, Geeta, PBR 97, Pusa Bahar, Pusa Bold, RH 819, RGN 48, Shivani, TM 2, TM 4, RB 50, RH 406, RH 725, RGN 229, Raj Vijay Mustard 1, RVM 2, Pant Rai 20, RGN 298, GM 3 (Gujarat Mustard 3), PBR 378, RH 761, RSPR 69 (MCN 04-35), DRMR 150-35, DRMR 1165-40, Birsa Bhabha Mustard 1(BBM 1), RH 1424
White Rust resistant	Basanti, JM 1, JM 2, Rohini (A4A5)-491 (Rohini WRR 2), Pusa Bold (A4A5)-842 (Pusa Bold WRR 2), Varuna (A4A5)-936-279 (Varuna WRR 2)
Salinity tolerant	Narendra Rai (NDR 8501) CS 52, CS 54, CS 56 CS 58, CS 60, CS 61, CS 62, CS 64
Quality trait (Low erucic acid)	Pusa Karishma, Pusa Mustard 21, Pusa Mustard 22, Pusa Mustard 24, Pusa Mustard 29 (LET 36), Pusa Mustard 30 (LES 43), Pusa Mustard 32 (LES 54), Pusa Mustard 34 (LES 60), RLC 2 (ELM 123), ELM 079 (RLC 1)
Quality trait (Double low)	Pusa Double Zero Mustard 31 (PDZ 1), Pusa Double Zero Mustard 33 (PDZ 11), RLC 3, RCH 1
Hybrid	NRCHB 506*, DMH 1, Coral PAC432, Coral PAC 437, RCH 1*, Kesari Gold, Kesari 5111 (PCJ03 401), SVJH 108

(Source: Rai et al., 2023) *Govt. sector hybrid

Table 4. Recently released varieties of Rapeseed-mustard developed in India (2011-2023)

Crop	Variety
B. juncea	Pusa Mustard 28 (NPJ 124), Coral 437 (PAC 437) (Hybrid), RLC 2 (ELM 123), RGN-229, RH 0406, Divya 33,Pant Rai-19 (PR 2006-1), PBR 378, RH 749, Raj Vijay Mustard 2 (JMWR 08-3), RRN-573, RGN-229, Pusa Mustard 29 (LET-36), Pusa Mustard 30 (LES-43),Giriraj (DRMRIJ 31), RGN-298, RGN-236,Gujarat Mustard-3 (GM-3),Albeli-1, Pant Rai-20, DRMR150-35, PBR 357, Gujarat Dantiwada Mustard 4, Gujarat Dantiwada Mustard 5, Raj Vijay Musatard-1, RLC-3, CS 1100-1-2-2-3 (CS 58), Pant Rai 21 (PRB2008-15), RH 0725, CS 2800-1-2-3-5-1 (CS 60), PDZ-1, Keshri (PRO 5111) (Hybrid), DRMR 1165-40, RH 761,TBM-204, Pusa Mustard 32 (LES 54), Radhika (DRMR 2017-15), Brijraj (DRMRIC 16-38), Azad Mahak [(KMR (E) 15-2)], RCH 1, Pusa Double Zero Mustard 33, TAM 108-1, PHR 126, Birsa Bhabha Mustard 1(BBM1), Trombay Him Palam Mustard 1 (THPM-1), KMR 16-2 (Surekha),TBM 143 (Trombay Bidhan Mustard 143),Jammu Mustard-135 (JM 13-5), RH 1424, RH (OE) 1706 (RH 1706), Rohini (A4A5)-491 (Rohini-WRR 2), Pusa Bold (A4A5)-842 (Pusa Bold WRR 2), Varuna (A4A5)-936-279 (Varuna WRR 2), Pusa Mustard 34 (LES 60), CS 13000-3-2-2-5-2 (CS 61), CS 15000-1-1-1-4-2 (CS 62), CS 2005-143 (CS 64), Pant Rai-22 (PRL-2013-17), Anand Hema (Gujarat Mustard 8), Sampoorna (OUAT Kalinga Mustard 1), Gujarat Mustard 6 (Banas Sona)
B. carinata	PC 6 (BJC 1)
B. napus	GSC 7 (GSC 101), RSPN-25, Him Palam Gobhi Sarson I (AKMS 8141), PGSH 1707, PGSH 1699 (GSH 1699), Jammu Gobhi sarson 123 (JGS 12-3), Shalimar Gobhi Sarson-1 (KGS-32), Him Palam Gobhi Sarson 2 (AKGS 19-8)
B. rapavar. toria	Sushree, TL17, Raj Vijay Toria 1, Pant Hill toria 1 (PT 2006-4), Pant Toria 508 (PTE 20008-2), Tapeshwari, Tripura Toria 1, RSPT-6, Raj Vijay Toria 3, (RTM 08-6), Jeuti (JT 90-1), Azad Chetna (TKM 14-2), Raj Vijay Toria 2 (RMT 08-2), AAU TS 38
B. rapavar. yellow sarson	Pant Sweta (PYS 2007-10), Pant Girija (PYS 2012-6), Sachita (YSWB-2014/2), Anushka (YSWB-2011-10-1), Pant Pili Sarson-2 (PYS-2016-8)
B. rapavar. brown sarson	Shalimar Sarson 1, Shalimar Sarson-2 (KBS-49), KBS-3, HPBS-1, RSPT-6 (TCN 13-9)
Eruca sativa	Vallabh Taramira 1(PUT93-11), Vallabh Taramira 2 (PUT 93-1),Jwala Tara (RTM 1355), Jobner Tara (RTM 1351), Krishna Tara (RTM-1624)

Source: updated from Sharma et al., 2022.

Improved package of practices of rapeseed-mustard production

Table 5. Improved package of practices of rapeseed-mustard production

Land preparation	➢ Under irrigated condition, first ploughing should be done with soil turning plough followed by 3 to 4 harrowing or ploughing and planking after every ploughing. ➢ Under rainfed condition, disc harrowing should be carried out after every effective shower in monsoon to conserve soil moisture. Planking should always follow the harrowing or ploughing to avoid clod formation and moisture loss. Pulverize the soil, using cultivator before sowing.
Sowing time	➢ October 10- 25th is the most appropriate time of sowing. The maximum temperature during sowing should not be more than 32^{o} C. ➢ For yellow sarson, time of sowing is the first fortnight of October. ➢ Toria should be shown during the first fortnight of September.
Seed Rate and spacing	➢ Optimum seed rate is 3.5-4 kg/ha. ➢ Line sowing at 45 cm x 10-15 gives optimum plant population. ➢ In late sown crops a closer inter row 30 cm spacing adopted. ➢ For Toria and Yellow sarson the row to row spacing should be kept at 30 cm. ➢ Seed treatment with Metalaxyl (Apron 35 SD) @ 6g/kg seed can reduce the yield loses due to white rust and downy mildew. For control of soil borne pathogens seed treatment with Trichoderma @ 6g/kg seed is advised
Nutrient management	➢ Apply 15-20 t/ha FYM one month before sowing. ➢ Soil incorporation of 2.5 t/ha mustard straw along with *Sesbania* green manuring increased seed yield of Indian mustard by 45%. ➢ Use of Azotobacter can reduce the nitrogen requirement up to 25-30 kg/ha provided bacterial strain is efficient and soil is rich in organic matter. ➢ Application of N: P: K @ 80:40: 40 kg/ha under timely sown condition and @ 100:50:50 kg/ha under late sown condition along with sulphur @ 40 kg/ha, zinc sulphate @ 25 kg/ha and borax 10 kg/ha. ➢ Half of the nitrogen to applied as basal dose and half at 30-45 DAS at the time of first irrigation. For rainfeed crop

	apply the full-recommended dosages of nutrients at the time of sowing. ➢ Replacing of DAP with single super phosphate (SSP) (250kg/ha) resulting in availability of sulphur. Neem coated urea is recommended to use as source of nitrogen. It is advised that gypsum @ 200 kg/ha should be applied as basal dressing if SSP is not used as the source of phosphorus.
Thinning and weeding	➢ Thinning operation by removing the extra plants should be done at 21-25 days after sowing. ➢ Weeds cause 15-30% yield loses in rapeseed-mustard. Two mechanical weeding using hand held hoe is recommended at 15-20 DAS and 35-40 DAS. ➢ Pendimethalin pre-plant incorporation @ 1kg/ha also found effective.
Irrigation management	➢ Two irrigations, one at pre-flowering stage (35-45 DAS) and at siliqua formation stage. ➢ The mustard crop seed yield increases by 24% using micro sprinkler (irrigation efficiency 60-70%) and by 18 % using drip irrigation (irrigation efficiency 80-90%) over check basin (irrigation efficiency 30-40%).
Harvesting and threshing	➢ The crop should be harvested when 75 per cent of pods turn to golden yellow in colour. ➢ The crop should preferably be harvested in the morning when the pods are damps with night dew, which minimizes the shattering losses. ➢ Threshing should be done preferably by using threshers. Seeds should be sun dried for at-least one week to reduce the moisture content.

Table 6. Integrated insect-pest and disease management

Insect management	
Insect	**Management Practices**
Mustard aphid	➢ Foliar spray of 2% neem oil or 5% Neem Seed Kernel Extract (NSKE). ➢ Use predators such as coccinellids, syrphid and lacewing ➢ Oxydemeton methyl 25 EC @ 1.0 litre dissolved in 700-800 litres of water/ha
Painted bug	➢ Seed treatment with imidacloprid 70WS @ 5g/kg seed. ➢ Conserve bio-control agents *Alophora* spp. (tachinid fly) parasitizing eggs of painted bugs.

Pea leaf miner	➢ Predators: Lacewings, lady bug beetle, spiders, fire ants ➢ Foliar spray of systemic insecticide such as Oxydemeton methyl 25 EC @ 1.0 litres.
Mustard saw fly	➢ Conserve *Perilissus cingulator* (parasitoids of the larvae) and the bacterium *Serratia marcescens* which infect the larvae of sawfly. ➢ Spray the crop with malathion 50 EC @ 500 ml in 500 litre of water/ha. Repeat the spray if population builds up again.
Bihar hairy caterpillar	➢ Dust the crop with Malathion 5% dust @ 25-30 kg/ ha against young caterpillars. ➢ Spray the crop with malathion 50 EC @ 1.0 litre in 500 litre of water/ha.
Cabbage butterfly	➢ Collect and destroy the gregarious form of larvae in 5% kerosenized water. ➢ Spray the crop with malathion 50 EC 1 litre in 600-800 litre of water/ha under severe infestation.
Flea beetle	➢ Spray the crop with malathion 50 EC @ 1 litre / ha in 600-800 litre of water under severe infestation.
Leaf webber	➢ Pluck the infested shoots and inflorescence with larvae and destroy them. ➢ Spray the crop with malathion 50 EC @ 1.0 litre / ha in 600-800 litre of water in severe infestation.
Diamond back moth	➢ *Diadegma insulare* is the most important parasitoid of the diamond back moth. ➢ Application of 4% NSKE ➢ Spray the crop with malathion 50 EC @ 1.0 litre / ha in 600-800 litre of water.
Termites	➢ Entomopathogenic fungi like *Beauveria bassiana* 1kg multiplied in 50 kg FYM/compost can effectively control the termites. ➢ Application of chlorpyriphos 20 EC @ 4 litre/ ha during last ploughing and properly mixing in soil minimize the termite infestation.
Diseases management	
Disease	**Management Practices**
Damping-off and seedling blight	➢ Seed treatment with apron 35 SD 6 g/kg + carbendazim 2 g/ kg @ 0.2%.

Alternaria blight	➢ Iprodione @ 2 g per litres of water or mancozeb (dithane M-45) @ 2.5 kg/ha at 15 days interval normally at 45, 60 and 75 days after sowing or tebuconazole 50%+ trifloxystrobin 25% 1 g /lit of water at 45 and 75 DAS.
Downy mildew and White rust	➢ Treat the seed with Metalaxyl (apron 35 SD) @ 6 g/ kg seed ➢ Spray ridomil MZ 72 WP @ 2 kg/ha dissolved in 800 litres of water soon after the disease appearance at 15 days interval. ➢ Avoid irrigation at pod formation stage.
Sclerotinia stem rot	➢ Irrigation management (no irrigation during 25 Dec-15 Jan) ➢ Seed treatment (ST) carbendazim 50WP 2g/kg seed or with *Trichoderma* 10g/kg seed. ➢ Foliar Spray of carbendazim 2g or tebuconazole @ 1 ml/lt of water or tebuconazole 1 ml /lit of water at 60-70 DAS.
Powdery mildew	➢ Spray of 1 kg dinocap or 2 kg wettable sulphur/ha dissolved in 800 litres of water
Club root	➢ Apply chemical amendment lime @ 3 ton/ha along with compost before sowing in the infested soil to increase the soil pH to 7.2 and save the crop.
Root rot	➢ Seed treatment with carbendazim @2 g/ kg followed by spray on ground level with 0.1% carbendazim could be effective in managing the disease.

Strategies for enhancing rapeseed-mustard production

- Front line demonstrations can be used as an effective tool for creating a multiplier effect of technology and for utilizing FLD data in effective technology dissemination. DRMR should forge links between farmers and private sector for the sale of the good quality crop as a seed so that this spreads faster to many farmers. There is a need for providing a price incentive to the farmers for canola types. The possibility of developing public-private-partnership (PPP) for contract farming and branding quality oil should be explored. This kind of move is consistent with the new guidelines of ICAR on commercialization of technology. It is also important to analyse wide yield gaps in different states/regions.
- Infrastructure support for oil expelling units required for north-eastern states and non-traditional areas.

- Assured buy back polity on MSP to encourage farmers for mustard production.
- To attract the farmers towards oilseeds, in general and rapeseed-mustard in particularly, favourable support price, higher tariff rate on import of edible oil and effective market intervention would have to be looked.
- Quality seeds production in mustard through seed hubs.
- There is a need to further ensure irrigation facilities through irrigation canals, water harvesting structures etc.
- Linkages with KVKs, SAUs, State Department, etc is required for dissemination of already developed technologies of rapeseed-mustard so that it can reach to the farmers.
- There is a need to develop FPO's/Entrepreneurs for quality seed production through HRD activities including trainings, exposure visits.

Future projections, challenges and strategies

At the current trends, 39.2 million tons of vegetable oil will be required to meet the demand of the 1.68 billion population in India by half of the 21st century due to changing lifestyle and dietary preferences of human. Though the production of edible oils increased at a CAGR of 2.83% since 1950-51 to 2023-24. To fulfil oilseed requirement, rapeseed-mustard must contribute 20.5 million tons of production (assuming a contribution at 25% in total oilseeds production) by the year 2050 which is a gigantic task for the scientists and policy makers. To meet out the projected demand of edible oils; area, production and productivity of oilseed brassica should increase at a faster pace. At the present level of contribution of rapeseed-mustard (25%) in total oilseed stock, its area, production and yield must increase to a tune of 8 million ha, 20.51 million tons and 2563 kg/ha by the year 2050 (Anonymous, 2015; Jat el al., 2019).

To reach out at the level of projections in the year 2050, the country must bring 1.22 million ha additional area under cultivation and double the productivity to produce 3-times more rapeseed-mustard at the present figures. Additional area under cultivation for rapeseed-mustard may be explored in rice-fallow system (North-eastern regions) and in non-traditional areas (southern regions) provided with suitable technology and policy interventions. Under present climatic variability, fast depleting natural resources, limitations of food and nutritional security, the realization of these targets will be unimaginable without the path-breaking technological interventions (Jat et al., 2019). However, there is a need to integrate, frontier science research along with ongoing programs for yield improvement, resource use efficiency, diversified products and uses, stakeholders' involvement and viable supply chain and marketing. Significant improvement has been made genetic enhancement of rapeseed-mustard, still there is need to develop varieties for diverse agro-ecological situations in traditional and non-traditional areas, input responsive, climate resilient, tolerant to biotic and abiotic stresses and of high oil content and quality. Use of pre-breeding along with advanced tools like GISH (Genomic In-Situ Hybridization), FISH (Florescence In-Situ Hybridization) to harness the genes from wild and weedy relatives of rapeseed-mustard is required. Identification and development of high heterotic crosses, exploitation of exotic germplasm to enhance the level of heterosis is need of the hour. Effective utilization of genomic tools (transcriptomics, proteomics, metabolomics), gene editing, genetic engineering, maker assisted breeding is very much required for mining, tagging of the novel genes (for biotic, abiotic stress, quality traits, earliness, high photoperiodic responses), theirs functions and transfer into agronomically superior genetic background is very much needed to break the yield barriers in rapeseed-mustard. Further there is a need to freely exchange the trait specific germplasm with international organizations.

Application of proven technologies such as integrated nutrient management, precision agriculture and resource conservation approaches for specific agro-ecology. Yield loss due to insect pest, diseases and parasitic weeds (Orobanche) needs to be address through development of the resistance/tolerant varieties and holistic control measures to reduce the losses. Rapeseed-mustard productivity at national level could be improved by bridging the yield gaps between farmer's field and experimental plots through Farmer-Institution-Industry linkages. Development of double zero varieties has opened new avenues for mustard to be used in development of value added products. All the risk mitigation options like timely availability of inputs (quality seeds, fertilizers) and credit, high MSP and assured procurement, crop insurance, linking farmers to market should be addressed for better oilseed economy of our country.

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Chapter 12

Rapeseed Productivity Enhancement in Nepal

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Abstract

Rapeseed is Nepal's most important winter oilseed crop, contributing over 77% of the country's oilseed area and production. Despite its significance in ensuring food security and reducing import dependency, domestic rapeseed productivity remains low due to a range of agronomic, technical and policy challenges. This paper analyses the status of rapeseed production in Nepal, synthesizing data from national reports, field trials and stakeholder consultations. Key bottlenecks include limited availability of high-yielding varieties, inadequate access to certified seed, nutrient and pest management gaps and weak post-harvest handling. Over the past decade, however, notable progress has been made through research initiatives, including varietal improvements such as Nawalpur Tori-4 as a recently released variety and ACC#9109, ICT 2006-3 and ICT 2010-17 as promising pipelines and adoption of integrated crop, nutrient and pest management practices. Field and outreach trials consistently show that these technologies can boost rapeseed yields up to 40% over farmers' practices. Moreover, the development of domain-specific recommendations and participatory varietal selection has strengthened technology dissemination. The study concludes that improving rapeseed productivity in Nepal requires a coordinated approach emphasizing research investment, seed system strengthening, farmer capacity-building and policy support to achieve self-sufficiency in edible oil production.

Keywords: Integrated Management, Nepal, Oilseed Self-sufficiency, Rapeseed, Productivity, Varietal Improvement

Introduction

Agriculture in Nepal

Agriculture is the backbone of Nepal's economy, employing over 60% of the population and contributing about 24% to the national GDP (MoALD 2023). Among winter crops, rapeseed plays a vital role due to its high domestic demand, export potential and contribution to rural income and nutrition. However, its productivity remains low due to poor fertilization, micronutrient deficiencies, pest and disease pressures and suboptimal plant populations (Subedi et al. 2024). Despite its adaptability to marginal lands, rapeseed continues to lag major cereals and Nepal relies heavily on imports to meet edible oil needs. Strengthening rapeseed production through high-yielding, climate-resilient varieties and improved cropping systems is essential. As oilseeds contribute around 3% to the agricultural GDP, investing in rapeseed can significantly enhance Nepal's food, nutrition and economic security (Subedi 2023).

Trend of area, production and productivity

Over the past decade, rapeseed cultivation in Nepal has expanded steadily in area, production and yield, with a notable increase from 2011/12 to 2022/23, though growth plateaued between 2019 and 2022 (Figure 1&2). Rapeseed dominates Nepal's oilseed sector, accounting for 77.0% of the total oilseed area and 77.1% of production in 2022/23 (MoALD 2024). Nationally, oilseeds were cultivated on 244,046 hectares, producing 270,482 metric tons at an average yield of 1.11 t/ha, with rapeseed contributing the largest share (Table 1). Lumbini, Madhesh and Koshi Provinces led in rapeseed cultivation, both in area and production. While overall oilseed growth has improved since 2010-2020 following a slowdown in 2000-2010 (Joshi et al. 2021), rapeseed remains the principal driver of this upward trend, highlighting its strategic importance in Nepal's agricultural economy.

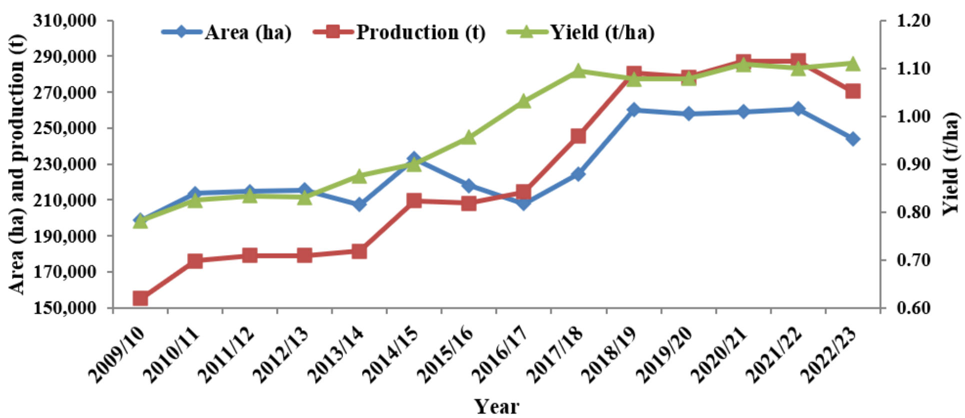


Fig 1. Trend of oilseed crops production in terms of area, production and yield in Nepal

Table 1. Area (ha), production (mt) and yield (mt/ha) of various oilseeds in Nepal, 2022/23

Crops	Area (ha)	Production (mt)	Yield (t/ha)
Rapeseed	187,924	208,542	1.11
Sarsoon	18,226	19,969	1.10
Rayo	9,167	9738	1.06
Sunflower	4,020	5528	1.37
Groundnut	3,950	4965	1.26
Sesame	7,603	8324	1.09
Linseed	11,552	11671	1.01
Niger	1,604	1743	1.09
Total	244,046	270,482	1.11

Table 2. Area, production and average yield of oilseed crops by Province basis, 2022-23

Province	Area(ha)	Production(mt)	Yield (t/ ha)
Koshi	43,197	52,102	1.21
Madhesh	54,068	59,683	1.10
Bagmati	36,238	43,456	1.20
Gandaki	8,662	9,164	1.06
Lumbini	60,567	64,453	1.06
Karnali	17,826	17,720	0.99
SudurPaschim	23,489	23,903	1.02
Nepal	244,046	270,482	1.11

Table 3. Area, production and average yield of winter oilseed crops by Province basis, 2022-23

Crop	Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	Sudur paschim	Total
Rapeseed								
Area (ha)	34754	30411	32286	5814	50103	12220	22336	187924
Production (mt)	42997	33208	39342	5729	53060	11599	22606	208541
Yield (mt/ha)	1.24	1.09	1.22	0.99	1.06	0.95	1.01	1.11
Sarsoon								
Area (ha)	783	7083	1658	1346	6322	964	71	18227
Production (mt)	1111	7562	1701	1760	6816	940	78	19968
Yield (mt/ha)	1.42	1.07	1.03	1.31	1.08	0.98	1.10	1.10
Rayo								
Area (ha)	448	4404	332	77	134	3746	27	9168
Production (mt)	556	4496	372	74	146	4070	24	9738
Yield (mt/ha)	1.24	1.02	1.12	0.96	1.09	1.09	0.89	1.06
Linseed								
Area (ha)	4128	5266	236	458	1199	125	140	11552
Production (mt)	3981	5623	240	511	1061	134	122	11672
Yield (mt/ha)	0.96	1.07	1.02	1.12	0.88	1.07	0.87	1.01
Total area (ha)	40113	47164	34512	7695	57758	17055	22574	226871
Total production (m.t)	48645	50889	41655	8074	61083	16743	22830	249919
Yield (t/ha)	1.21	1.08	1.21	1.05	1.06	0.98	1.01	1.10

Based on Nepal's 2022/23 winter oilseed data, rapeseed overwhelmingly dominated, constituting 77% of the total cultivated area (187,924 ha) and production (208,541 mt). Lumbini province was the largest producer overall winter oilseed (61,083 mt) and for rapeseed specifically (53,060 mt), also holding the largest total area of winter oilseed (57,758 ha). Koshi and Bagmati achieved the highest average yields for both rapeseed (1.24 mt/ha and 1.22 mt/ha) and total oilseeds (1.21 mt/ha each), significantly exceeding the national average yield of 1.10 mt/ha (Table 2 &3).

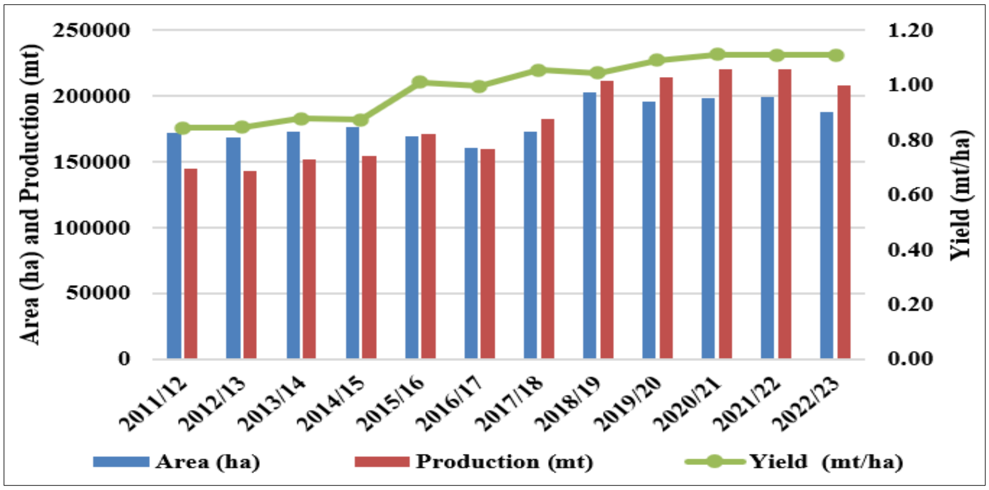


Fig 2. Trend in area production and yield of rapeseed in Nepal from 2011-12 to 2022-23

Future demand for rapeseed crops in Nepal

The demand for rapeseed oil in Nepal is projected to grow by 4-5% annually, driven by population growth, changing diets and increased industrial use (MOF 2022). Per capita edible oil consumption, currently 8-10 kg, is expected to double by 2030, intensifying reliance on imports, which already account for about 90% of total edible oil supply, mainly from India. While rapeseed, mustard and sarsoon together dominate 85% of oilseed production, domestic output meets only half of national demand. Without scaling up local rapeseed production, Nepal's import dependency will deepen, underscoring the urgent need for productivity enhancement and expansion of cultivation (MOF 2022).

Main crop rotations involving rapeseed crops in the country

Oilseed crops play a crucial role in crop rotations, enhancing soil fertility, controlling pests and boosting farm productivity, particularly in regions focused on sustainable agriculture in Nepal. Brassica crops are sown as a pure crop in many parts of Nepal. It is also shown as a mixed crop or as an intercrop. These crops are also grown as a mixed crop with lentil or linseed etc. Sometimes farmers prefer to show the crops as relay crops in rice. The rice crops should be kept clean before sowing them. The important crops rotations are as follows:

For rapeseed (Tori)

- Maize -Tori (for upland condition)
- Maize/Millet- Tori (For upland condition)

- Rice-Tori (Low land condition)
- Rice-Tori + lentil (Low land condition)
- Rice-Tori + lentil + Linseed

Sometimes Tori is sown mixed with lentil + linseed as a relay crop of standing rice crops. But there should not be too much weeds in rice fields. In mid and far western region of Nepal, this practice is common.

For Mustard (Rayo)

- Maize-Rayo
- Rice-Wheat +Rayo are the main crop rotations.

Key winter oilseeds like rapeseed, mustard, sarsoon and linseed are integral to rotations, with lentil enriching soil nitrogen levels when rotated with cereals like wheat and maize. These rotations help break pest and disease cycles while offering economic benefits through marketable products and oil for household use (ORP 2017). These rotations utilize seasonal planting efficiently, improve soil health and diversify farm income, especially as demand for oilseed crops like linseed rises.

Availability of certified seeds of rapeseed crops in the country

Limited availability of certified rapeseed seed remains a major bottleneck to improving productivity in Nepal. Currently, certified rapeseed/mustard seeds meet only 30-40% of national demand, with around 78% of farmers relying on informal sources, leading to inconsistent yields and poor crop performance (Subedi 2023). This shortfall is exacerbated by weak domestic seed production, limited extension support and the high cost of imported seeds. To boost rapeseed productivity and reduce import dependency, it is essential to strengthen domestic seed systems, improve distribution channels and promote awareness of the benefits of using certified seeds (Subedi 2023).

Farmer's perception and their needs regarding rapeseed crops productivity enhancement in different ecological zones

Farmers across Nepal's diverse agro-ecological zones view rapeseed as a valuable winter crop but face region-specific challenges limiting its productivity. In the Terai, key needs include access to improved, pest-resistant seed varieties, irrigation facilities and stronger extension support for nutrient and pest management. Mid-Hill farmers, often smallholders, require better-quality seeds, market access and training in sustainable practices. In the High Hills, rapeseed cultivation is constrained by harsh climates and limited resources, creating demand for cold-tolerant varieties and improved post-harvest and soil management. Addressing these needs through targeted support in seed systems, irrigation, training and finance is vital to boost rapeseed productivity and rural livelihoods (ORP 2021).

Main hurdles being faced by the farmers for adoption of rapeseed crops on large scale

Despite rising demand, large-scale adoption of rapeseed in Nepal is hindered by several challenges. Farmers face limited access to high-yielding, disease-resistant seeds, inadequate irrigation, only 40-50% of land is fully irrigated and weak extension services and technical know-how (Subedi 2023). High input costs, fragmented landholdings and poor market access further constrain expansion. Additionally, vulnerability to climate extremes (droughts, floods) and lack of financial support deter investment in rapeseed cultivation. These systemic hurdles must be addressed to unlock rapeseed's full potential for Nepal's economy and food security (Subedi 2023).

Seed availability and purity of rapeseed crops

Seed availability and purity remain major constraints to rapeseed productivity in Nepal. Certified rapeseed/mustard seeds meet only about 30% of national demand and locally sourced seeds often show low purity levels (50-80%), well below the ideal 90-95% standard (SQCC 2023). This undermines yield, disease resistance and crop uniformity. Key issues include limited domestic seed production, high cost of imports, weak quality control and low farmer awareness. Strengthening seed systems through investment in production, quality assurance and farmer education is essential to enhance rapeseed productivity and reduce import dependency (SQCC 2023).

Research and Development

Nepal's agriculture sector has prioritized research and development (R&D) to enhance the productivity of rapeseed crops, addressing challenges like low yields, pest susceptibility and climate change. The focus is on developing high-yielding, pest-resistant and climate-resilient oilseed varieties to meet the rising demand for edible oils and reduce dependency on imports.

Key Institution driving Rapeseed Research and Development in Nepal

Oilseed Research Program (ORP)

The Oilseed Research Program (ORP), established as the National Oilseed Development Program in April 1976 (2^{nd} Baishakh, 2033 BS) at Netraganj VDC-6, Nawalpur, Sarlahi, focuses on research and development of oilseed crops across Nepal's agro-ecological zones. After the inception of the Nepal Agricultural Research Council (NARC) in 1990 (2048 BS), it was renamed ORP and is now one of eight crop commodity research programs under NARC, tasked with generating technologies to enhance oilseed production and productivity.

Located in Lalbandi Municipality-1, Nawalpur, Sarlahi, along the East-West Highway at 27°03’86” N latitude and 85°35’52” E longitude at an elevation of 144 meters orP conducts research, develops national guidelines, conserves local oilseed varieties and produces and distributes source seeds. The farm’s sandy loam soil has low nitrogen, medium potassium, high phosphorus and organic matter content of 1.34%, with pH ranging from 4.5 to 6.0. Mandated crops include winter oilseeds (rapeseed, mustard, sarsoon, linseed) and summer oilseeds (groundnut, sesame, niger, sunflower). Despite an approved strength of 25 personnel, the program currently operates with only nine staff members, supported by a structured organizational framework (ORP 2023).

Ongoing Research and Development Programs in rapeseed Crops

The Oilseed Research Program (ORP) is actively engaged in enhancing rapeseed productivity through varietal improvement, germplasm collection and multi-location evaluation trials. Core activities include observation nurseries, coordinated varietal trials (CVT, IET, OBN) and farmers’ field testing, along with screening for major pests and diseases, notably *Alternaria* blight (ORP 2021). The program emphasizes varietal maintenance, integrated crop, nutrient and pest management (ICM, INM, IPM) and participatory varietal selection (PVS). ORP also promotes community-based seed multiplication and develops agronomic packages addressing nutrient management, tillage and weed control. Capacity-building efforts include trainings, workshops and breeder/foundation seed production to support rapeseed innovation and adoption (ORP 2021).

National Research Achievements in rapeseed crops

Varietal Research Achievements

The Oilseed Research Program (ORP) has successfully released eight varieties of rapeseed to date, including the recently developed Nawalpur Tori-4 (ICT 2001-35) (Table 4). Promising genotypes demonstrating excellent productivity and resistance to biotic and abiotic stresses are in the pipeline, signaling the need to expedite the variety release process (Subedi 2023). The selection and improvement of other genotypes must continue using advanced breeding methodologies, especially in the context of climate change and stress adaptation. Such efforts aim to enhance national oilseed productivity and improve the livelihoods of marginalized farming communities.

Table 4. List of released varieties and recommendation domain in rapeseed crops

S. N.	Varieties	Year	Origin	Yield (mt/ha)	DM	Recommendation Domains
Rapeseed (Tori)						
1	Preeti	2005		2.6	83	Irrigated Terai/Inner terai
2	Unnati	2005		2.2	86	Terai/Inner terai
3	Pragati	1996		1	99	Terai/Inner terai,Midhills
4	Lumle tori 1	1996	Nepal	0.9	89-153	Midhills/High hills
5	Bikash	1989	India	1	85-90	Terai/Inner terai
6	T-9	1980	India	0.8	100	Terai/Inner terai (Denotified)
7	Morang tori 2	2013	Nepal	1.6	83	Terai/Mid hills
8	Nawalpur Tori 4	2020	Nepal	1.02	80-114	Terai/Inner terai,Midhills

Over four fiscal years (2021/22-2024/25), rapeseed trials (OBN, IET, CVT, CFFT) consistently identified high-yielding genotypes. ACC#9109 demonstrated exceptional performance, yielding 1,155-1,677 kg/ha across multiple years and trial types (CFFT). ICT 2006-3 and ICT 2010-17 also showed multi-year reliability, with yields peaking at 1,405 kg/ha (CVT, 2023/24) and 1,378 kg/ha (CVT, 2024/25), respectively. Yields varied significantly by trial and year, ranging from 890 kg/ha (OBN, 2024/25) to 2,800 kg/ha (OBN, 2022/23), reflecting genotype-environment interactions and trial-specific selection pressures (Table 5).

Table 5. Research achievements under rapeseed-varietal investigation

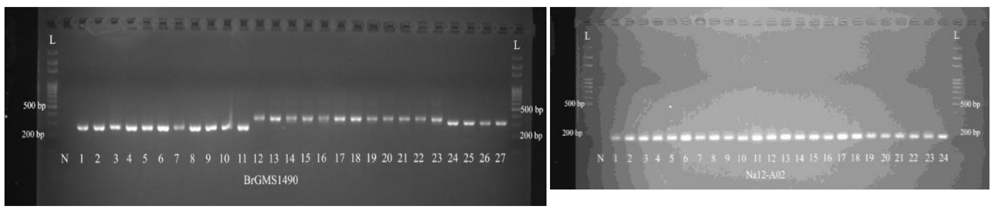
Trial Name	2021-22	2022-23	2023-24	2024-25
OBN	ICT 2001-20 (1067 kg/ha), ICT 2001-35 (1061 kg/ha), NGRC 2751 (1006 kg/ha), SRO 15 (957 kg/ha),	ICT 2012-37 (2800 kg/ha), ICT 2010-6 (2400 kg/ha), ICT 2010-7 (2400 kg/ha), ICT 2010-2 (2200 kg/ha)	ICT 2012-62 (2000 kg/ha), ICT 2012-27 (1900 kg/ha), ICT 2012-86 (1500 kg/ha)	ICT 2006-3 (1056 kg/ha), ICT 2012-81 (1055 kg/ha), ICT 2012-15(945 kg/ha), ICT 2012-97(890 kg/ha)

Trial Name	2021-22	2022-23	2023-24	2024-25
IET	ICT 2003-4 (1270 kg/ha), ICT 2003-9 (1260 kg/ha), ICT 2012-120 (1230 kg/ha), ICT 2006-3 (1140 kg/ha)	ICT 2012-22 (1600 kg/ha), ICT 2010-11 (1575 kg/ha), ICT 2002-9 (1492 kg/ha)	NGRC 2791 (1238 kg/ha), SRO10 (1190 kg/ha), ICT 2012-101 (1142 kg/ha)	NGRC 2791 (1029 kg/ha), ICT 2012-100 (1016 kg/ha)
CVT	ICT 2002-11(1148 kg/ha), ICT 2002-16 (1115 kg/ha), ICT 2001-2 (1088 kg/ha), ACC#5738 (1070 kg/ha)	ICT 2002-10 (1560 kg/ha), ICT 2012-120 (1440 kg/ha), ICT 2003-4 (1360 kg/ha), ICT 2006-3 (1247 kg/ha)	ICT 2010-17 (1407 kg/ha), ICT 2006-3 (1405 kg/ha), ICT 2002-10 (1121 kg/ha)	ICT 2010-17 (1378 kg/ha), ICT 2001-22 (1251 Kg/ha) and ICT 2002-9 (1200 kg/ha)
CFFT	ACC#9109 (1155 kg/ha) and ACC#9118 (1065 kg/ha)	ICT 2002-16 (1406 kg/ha), ACC#9109 (1350 kg/ha), ICT 2002-11 (1241 kg/ha)	ACC#9109 (1677 kg/ha), ICT 2002-11 (1631 kg/ha) and ACC#5738 (1530 kg/ha)	ICT 2002-11(1502 kg/ha), ACC# 5738(1482 kg/ha) and ICT 2002-16 (1444 kg/ha

Extensive varietal investigation trials have been conducted to identify high-yielding genotypes across multiple years. Rapeseed trials consistently identified high-yielding genotypes, with ACC # 9109 excelling in CFFT trials (1,155-1,677 kg/ha) and ICT 2006-3/ICT 2010-17 showing multi-year reliability. Yields varied significantly by trial type and year, reflecting genotype-environmental interactions. These findings highlight the potential of selected genotypes for further development and inclusion in future variety release programs.

DNA fingerprinting of promising genotypes of winter oilseed (rapeseed, mustard and sarson)

This study assessed genetic diversity among 35 Nepalese winter oilseed genotypes (11 mustard, 7 sarson, 17 rapeseed) using 15 SSR markers to establish a DNA fingerprinting database crucial for breeding and conservation. Despite the importance of these crops for Nepal's economy and food security, only one marker (BrGMS1490, PIC=0.56) out of nine scorable markers showed polymorphism, revealing extremely limited genetic variation as evidenced by similar banding patterns across most varieties (Figure 3). This low polymorphism is attributed to factors including the inherent genetic nature of amphidiploid species like *Brassica napus* (known for <45% polymorphism due to low out-crossing), potential limitations in the marker selection and the specific genotypes studied. The findings highlight a concerning lack of diversity and underscore the critical need for future research using expanded marker panels to effectively characterize and conserve genetic resources for sustainable oilseed improvement in Nepal.



(a) BrGMS1490 (b) Na12-A02

Fig 3. Banding patterns created for the varieties of oilseed using labelled SSR-primers BrGMS1490 (a) and Na12-A02 (b).

Crop Protection

Pathological Research

Pathological research has focused on identifying genetic resistance in rapeseed crops against alternaria blight disease. Moderate resistance was observed in several genotypes across different years. Table 9 summarizes genotypes of Rapeseed identified as research achievements through pathological investigation for disease resistance over four consecutive fiscal years (2021/22 to 2024/25). Each year, a range of genotypes underwent screening; Rapeseed consistently had the highest number evaluated (e.g., 12-15 genotypes annually), with ACC#9109, NGRC 2752 and ICT 2003-10 appearing frequently. This table 6 highlights the ongoing evaluation efforts to identify resistant lines for rapeseed crops. These findings provide a solid foundation for breeding programs focused on disease-resistant varieties.

Table 6. Disease-resistant genotypes identified in winter oilseed pathological research

Crops	2021-22	2022-23	2023-24	2024-25
Rapeseed	ICT 2010-12, ICT 2001-40, ICT 2001-20, NGRC 2752, ACC#9109, ACC#9118, ICT 2012-27	ICT 2002-16, ICT 2002-10, ICT 2003-10, ICT 2006-2, NGRC 2766, ICT 2012-10, ACC # 9109, NGRC 2783, NGRC 2775, ICT 2006-3	ICT 2006-3, ICT 2001-25, ACC # 5738, NGRC 2752, ICT 2001-23, ICT 2012-22, ICT 2010-24, ICT 2010-6, ICT 2012-10, ACC # 9109, ICT 2003-10, ICT 2010-9	ICT 2001-20, NGRC 2752, ACC # 9109, ICT 2003-10, ICT 2006-2, NGRC 2766, ICT 2010-24

A field experiment at ORP, Nawalpur, Sarlahi during the 2080 BS winter season evaluated fungicides for controlling Alternaria blight in rapeseed. Tricyclazole (1g/l) application resulted in the lowest disease severity (PDI: 29.50%) and highest yield (1178 kg/ha). Hexaconazole 5% EC (1ml/l) was the next most effective (PDI: 30.42%; Yield: 1133 kg/ha). The untreated control plot showed the highest disease severity (PDI: 46.47%) and lowest yield (850 kg/ha). A yield loss assessment study at the same location and season quantified losses from Alternaria blight. The rapeseed variety 'Nawalpur Tori-4' in unprotected plots suffered a 29.45% yield loss compared to protected plots (seed treatment with Carbendazim 50% WP 2g/kg + two foliar sprays of Mancozeb 75% WP 2.5g/l).

Crop Management and Outreach Research

Crop Management

Crop management trials have evaluated the impact of production factors on rapeseed yields. The treatment using 125% RDF (75:50:25 NPK kg/ha) produced the highest yield of 1296 kg/ha, followed by treatments with RDF plus sulphur (20 kg/ha) and RDF combined with five tonnes of poultry manure.

A field experiment at ORP, Nawalpur, Sarlahi during FY 2021/22 evaluated the effect of sowing dates on yield and yield components of promising and released rapeseed varieties. Variety ACC # 9109 sown on Ashoj 20 produced the highest grain yield (1279 kg/ha).

These findings provide effective strategies for improving rapeseed productivity under diverse conditions in Nepal.

Outreach Research

Outreach research activities were conducted across four sites: Barahathawa-Sarlahi, Nijgadh-Bara, Santapur-Rautahat and Khairahani-Chitwan, along with farmer field trials in collaboration with other research stations. Prominent findings include the superior performance of genotypes such as ACC # 9109 and ICT 2002-16 in rapeseed trials across the seasons. Furthermore, micronutrient trials revealed that improved practices combined with sulfur application consistently and significantly increased rapeseed yields compared to farmers' practice, with yields reaching up to 1245 kg/ha in 2024/25. Integrated crop, pest and nutrient management practices also demonstrated substantial and consistent yield improvements over farmers' practice throughout the four-year period, underscoring their importance in enhancing oilseed productivity (Table 7).

Table 7. Research achievements under outreach research activities of winter oilseed crops

Trial Name/Crop	2021-22	2022-23	2023-24	2024-25
PVS Rapeseed	ACC#9109 (1125 kg/ha) and ACC#9118 (1035 kg/ha) Farmers field of Chitwan (1110 kg/ha) and Rautahat (1075 kg/ha)	ICT 2002-16 (1481 kg/ha) and ICT 2002-11(1317 kg/ha) Farmers field of Chitwan (1291 kg/ha) and Sarlahi (1146 kg/ha)	ICT 2002-16 (1456 kg/ha) and ACC # 9109 (1412 kg/ha) Farmers field of Chitwan (1270 kg/ha) and Sarlahi (1125 kg/ha)	ACC # 9109 (1375 kg/ha) and ICT 2002-16 (1250 kg/ha) Farmers field of Rautahat (1250 kg/ha) and Chitwan (1195 kg/ha)
Micronutrient Trial/ Rapeseed	Improved practice-MN + Sulphur 15 kg/ha) Yielded (1110 kg/ha) compared to farmers Practice (925 kg/ha)	Improved practice-MN + Sulphur 15 kg/ha) Yielded (1223 kg/ha) compared to farmers Practice (975 kg/ha)	Improved practice-MN + Sulphur 15 kg/ha) Yielded (1154 kg/ha) compared to farmers Practice (916 kg/ha)	Improved practice-MN + Sulphur 15 kg/ha) Yielded (1245 kg/ha) compared to farmers Practice (875 kg/ha)
Integrated Crop Management/ Rapeseed	Improved practice-CM RDF + 2 spray of D M 45 and insecticide Imidacloprid at 45 and 65 days of seeding)	Improved practice-CM (1219 Kg/ha) compared to FP (986 kg/ha)	Improved practice-CM (1164 Kg/ha) compared to FP (925 kg/ha)	Improved practice-CM (1275 Kg/ha) compared to FP (975 kg/ha)

Trial Name/Crop	2021-22	2022-23	2023-24	2024-25
	yielded (1071 kg/ha) compared to Farmers Practice (899 kg/ha)			
Integrated Pest Management/ Rapeseed	Improved Practice-IPM (2 sprays of Dithane M45 and insecticide Imidacloprid at 45 and 65 days of seeding) yielded (1083 kg/ha) compared to Farmers Practice (944 kg/ha)	Improved Practice-IPM yielded (1143 kg/ha) compared to FP (995 kg/ha)	Improved Practice-IPM yielded (1200 kg/ha) compared to FP (973 kg/ha)	Improved Practice-IPM yielded (1225 kg/ha) compared to FP (945 kg/ha)
Integrated Nutrient Management (INM) Rapeseed	Improved practice-INM (N: P2O5:K2O 80:40:20 kg/ha + 2 spray of DM45 and insecticide Imidacloprid at 45 and 65 days of seeding) yielded (1105 Kg/ha) compared to FP (963 kg/ha)	Improved Practice-INM yielded (1175 kg/ha) compared to FP (916 kg/ha)	Improved Practice-INM yielded (1239 kg/ha) compared to FP (951 kg/ha)	Improved Practice-INM yielded (1278 kg/ha) compared to FP (913 kg/ha)

Germplasm Conservation and Maintenance

The conservation and maintenance of oilseed crop germplasm in Nepal is critical for safeguarding genetic diversity and supporting sustainable agricultural development. As of now, the National Agriculture Genetic Resource Centre (NAGRC) has preserved a total of 197 oilseed germplasm accessions, ensuring their availability for future breeding and research purposes. Additionally, the Oilseed Research Program has conducted evaluations on 495 oilseed germplasm accessions (ORP 2021), focusing on their potential for improvement in yield, disease resistance and adaptability to various agro-climatic conditions (Figure 4).

Domain-Specific Spread of Rapeseed Varieties

The distribution of oilseed crop varieties across Nepal varies by region, reflecting adaptation to local agro-climatic conditions. In the Eastern Region, varieties such as Preeti, Bikash and Morang-2 are predominantly cultivated due to their suitability for the area. Similarly, in the Central Region, farmers primarily grow Preeti, Bikash and Nawalpur-4, which perform well in the region's conditions. The Western Region favors varieties like Unnati and Pragati, known for their adaptability and productivity. Meanwhile, in the Surkhet Valley, the locally adapted variety Surkhet Local is widely grown, reflecting its resilience and alignment with local farming practices. Lumle Tori-1 is popular in hill and midhill areas (ORP 2021).

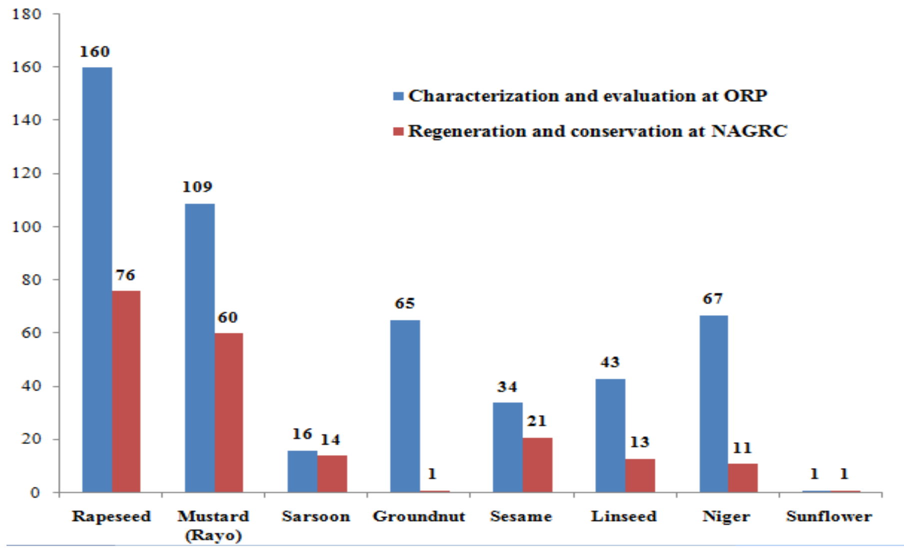


Fig 4. Germplasm conservation of oilseed crops in Nepal

Recommended Cultivation Technologies for Rapeseed Crop

For rapeseed, recommended varieties include Bikash, Pragati, Preeti, Unnati, Morang Tori-2 and Nawalpur Tori-4. The seed rate is 6-7.5 kg/ha, with a spacing of 30 x 10 cm. Fertilizer application should be 60:40:20 NPK kg/ha with 10 tons/ha of FYM. Treat seeds with Bavistin at 2.5 g/kg before planting. Rapeseed is planted between late Ashwin and early Kartik (Mid-October). Incorporating 4-6 bee hives per hectare aids pollination. Mixed cropping is recommended, such as rapeseed with chickpea (2 kg rapeseed + 48 kg chickpea/ha) or rapeseed with wheat (1 kg rapeseed + 120 kg wheat/ha). Irrigation is critical, with one application during pre-flowering for rapeseed. To manage pests, apply Imidacloprid (1.5 ml/L water) as needed for aphid control. For Alternaria blight, spray Mancozeb (3 g/L water) three times at 15-day intervals, starting 45-50 days after sowing (ORP 2023).

Source seed production of winter oilseed crops

Source seed production of winter oilseed crops (Rapeseed, Mustard, Sarsoon and Linseed) at the ORP, Sarlahi over the last five fiscal years (2020/21 to 2024/25) totaled 16,340 kg. Rapeseed dominated production, contributing most of both Breeder seed (1,655 kg) and Foundation seed (13,153 kg), with Foundation seed production peaking in 2024/25 at 4,055 kg. Mustard and Sarsoon had lower but consistent Breeder seed outputs (145 kg and 52 kg total, respectively) and more variable Foundation seed production (689 kg and 334 kg total). Linseed, producing only Foundation seed, showed a noteworthy increase over the period, rising from 5 kg in 2020/21 to 160 kg in 2024/25, totaling 312 kg (Table 8). Overall, Foundation seed constituted the bulk of production across all crops and years.

Table 8: Source seed production of winter oilseed crops (Rapeseed, Mustard, Sarsoon and Linseed) in the last five fiscal years at ORP, Sarlahi

Crop/Seed type	2020-21	2021-22	2022-23	2023-24	2024-25	Total
Rapeseed						
Breeder Seed (kg)	330	330	330	335	330	1655
Foundation seed (kg)	2459	1901	2474	2264	4055	13153
Mustard						
Breeder Seed (kg)	30	30	25	30	30	145
Foundation seed (kg)	122	163	98	102	204	689
Sarsoon						
Breeder Seed (kg)	12	10	10	10	10	52
Foundation seed (kg)	93	28	28	62	123	334
Linseed						
Foundation seed (kg)	5	16	41	90	160	312
Total	3051	2478	3006	2893	4912	16340

Trends in Oilseed Supply and Demand

Import/Export trend of oilseed in Nepal

The oilseed imports and export scenario in Nepal over the past three fiscal years highlights a significant trade imbalance in this sector. In the fiscal year 2021/22, Nepal's oilseed imports amounted to NRs 32.91 billion, while exports were much lower at NRs 1.73 billion, resulting in a trade loss of NRs 31.18 billion. The following year, 2022/23, saw a reduction in imports to NRs 24.28 billion, with exports slightly rising to NRs 1.91 billion, reducing the trade loss to NRs 22.36 billion. In 2023/24, imports further declined to NRs 21.18 billion, while exports remained stable at NRs 1.92 billion, resulting in a trade loss of NRs 19.27 billion (MOF 2023). This trend clearly indicates Nepal's continued dependence on oilseed imports and its minimal export capacity, leading to persistent trade deficits in the oilseed sector (Figure 5).

In terms of quantity, Nepal imported 370.53 million kilograms of oilseeds in 2021/22, while exports were limited to only 34.68 million kilograms, underscoring the country's heavy reliance on imported oilseeds. In 2022/23, imports decreased to 230.47 million kilograms and exports showed a small decline to 33.67 million kilograms, resulting in a slight improvement in the trade balance. However, in 2023/24, imports slightly rose to 246.49 million kilograms, while exports fell sharply to just 10.71 million kilograms, further exacerbating the trade gap between imports and exports (MOF 2023). This data reflects Nepal's ongoing struggle with balancing oilseed trade and highlights the sector's reliance on imports (Figure 6).

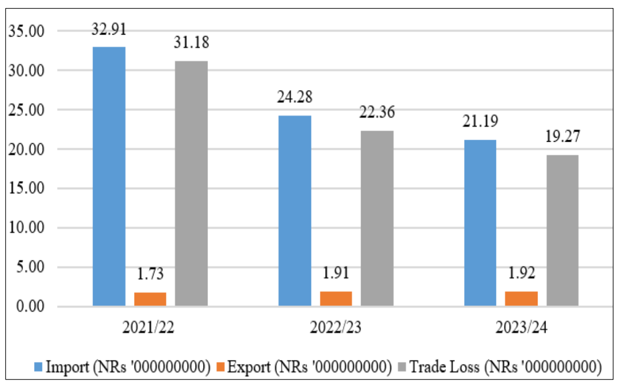


Fig 5. Import and export value of oilseed crops in Nepal

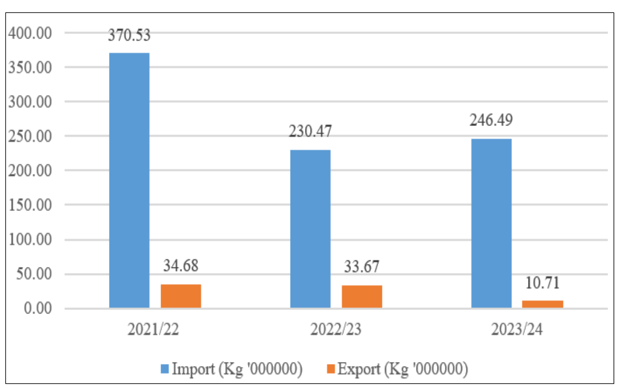


Fig 6. Import and export quantity of oilseed crops in Nepal

Trends in oilseed consumption in Nepal

Rapeseed oil consumption in Nepal is rising, driven by population growth (~2% annually), urbanization and changing dietary habits that favor edible oils in cooking (MOF 2023). While rapeseed/mustard oil remains a staple in rural diets due to tradition and local availability, urban consumers increasingly prefer refined oils like soybean and sunflower. Per capita edible oil consumption stands at 10-11 kg/year, below the global average but steadily increasing (Figure 7).

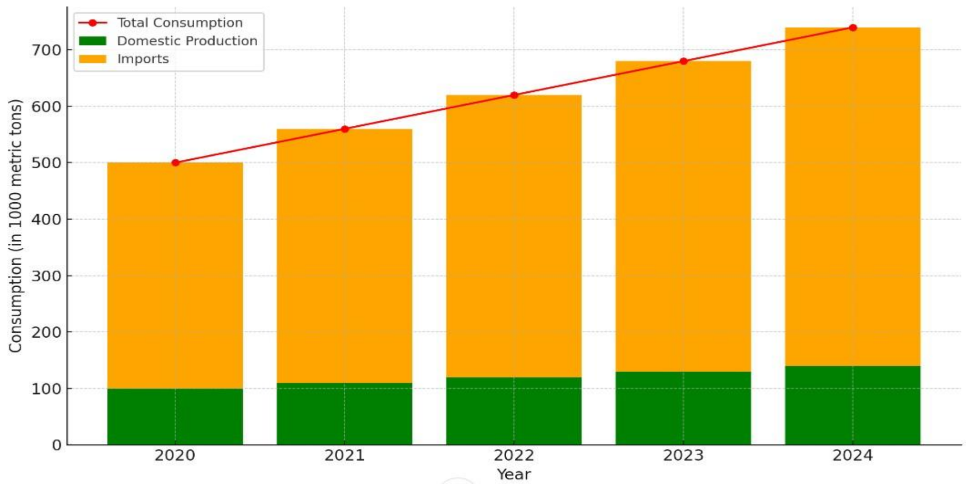


Fig. 7. Trends in Oilseed production, imports and consumption in Nepal

Despite growing demand, domestic rapeseed production meets only 20-30% of national edible oil needs, with the rest mainly palm and soybean oil covered through imports (MOF 2023). Inconsistent local supply is due to small landholdings, limited access to quality inputs and pest and disease pressures. Global market volatility and trade dependencies further affect import reliance.

However, increasing health awareness is shifting interest toward cold-pressed, locally produced oils such as rapeseed/mustard. Strengthening domestic rapeseed production through targeted investment and supportive policies is key to stabilizing consumption trends and reducing Nepal's edible oil import dependency.

Rapeseed Crop Production Requirement and Projection in Nepal

Rapeseed oil consumption in Nepal is steadily increasing, driven by population growth (~2% annually), urbanization and evolving dietary preferences (MOF 2023). It remains a dietary staple in rural areas due to traditional use and local availability, even as urban consumers shift toward refined oils. With per capita edible oil consumption at 10-11 kg/year, below the global average, growing demand presents a strong case for boosting domestic rapeseed production to meet future needs (MOF 2023).

$$\text{Oilseed Requirement} = \frac{\text{Edible Oil Demand}}{\text{Average Recovery Rate (0.45)}} = \frac{250,000}{0.45} \approx 555,000\,\text{MT}$$

By 2030, Nepal will require approximately 625,000 metric tons of oilseeds to meet rising edible oil demand, highlighting the urgent need to boost rapeseed production (Yadav et al. 2020). Key strategies include expanding rapeseed cultivation from 200,000 to 250,000 hectares, raising yields from 1.0-1.1 to 1.5 t/ha through improved practices and high-yielding varieties and promoting mechanization in sowing, harvesting and oil extraction to enhance efficiency. Investment in climate-resilient, pest-resistant rapeseed varieties, along with policy support for inputs, machinery and market access, is vital to achieve self-reliance in edible oil production and reduce import dependency (Yadav et al. 2020).

- **Projected Edible Oil Demand by 2030**:

$$\text{Future Demand} = 250,000 \times (1 + 0.02)^6 \approx 281,000\,\text{MT}$$

- **Required Oilseed Production by 2030**:

$$\text{Oilseed Requirement} = \frac{281,000}{0.45} \approx 625,000\,\text{MT}$$

Oil recovery efficiency

In Nepal, rapeseed oil recovery rates range from 35-40%, significantly lower than the global benchmark of over 45%, primarily due to the widespread use of traditional expeller presses and outdated processing equipment. These low efficiencies result in substantial oil loss during extraction, particularly among small-scale processors lacking access to modern technologies like cold-press or solvent extraction systems. The adoption of such technologies is limited by high costs and a shortage of technical expertise.

Recovery efficiency also depends on varietal oil content, underscoring the need for R&D to develop high-oil, high-yield rapeseed varieties. Additionally, poor post-harvest practices such as inadequate drying and storage further degrade oil quality and reduce extraction rates. Farmer training and capacity-building on processing techniques and handling practices are essential to address these gaps.

Improving oil recovery in rapeseed requires technological upgrades, investment in modern extraction systems and promotion of public-private partnerships (PPP) to establish efficient processing units. Government support through financial incentives, technology access and R&D promotion is crucial to enhance recovery rates, lower production costs and boost the competitiveness of Nepal’s rapeseed sector.

Machinery Issue

The lack of suitable machinery for rapeseed harvesting and processing in Nepal significantly limits efficiency, product quality and profitability. Currently, over 95% of rapeseed is harvested manually, as oilseed-specific mechanized tools are scarce and poorly adapted to local terrain (MoALD 2022). Most processing units rely on outdated expeller presses with 70-80% oil extraction efficiency, compared to over 90% with modern systems, leading to underutilized production capacity (FNCCI 2023). High costs of imported machinery—20-30% higher than in India limited domestic manufacturing and absence of rapeseed-specific tools further constrain adoption (NAMEA 2023).

Smallholders, who dominate rapeseed cultivation, have limited access to affordable, scaled-down machinery such as mini-harvesters or oil expellers, which are rarely available in local markets. Even when equipment is available, lack of training and technical support hinders effective use. Agricultural machinery loans account for less than 3% of total agricultural credit, creating a major financing gap (Nepal Rastra Bank 2023). Addressing these barriers through subsidies, financing schemes, local manufacturing and targeted training is essential to improve rapeseed productivity and value chain competitiveness in Nepal.

Quality of Oil and Value Addition

The quality and value addition of rapeseed oil in Nepal are limited by inconsistent production practices, poor quality control and traditional processing methods. Around 30% of locally produced rapeseed/mustard oil fails to meet national purity standards, while 20% is adulterated with cheaper oils like palm or soybean, eroding consumer trust (MOF, 2023). Despite these issues, rising demand for cold-pressed and organic oils, especially in urban markets, presents a strong opportunity for premium rapeseed products.

Most rapeseed oil is extracted via traditional expeller presses, with ~80% efficiency, while modern solvent extraction yields 10-15% more. Cold-press methods, though nutritionally superior, are underutilized due to high costs and limited adoption. Packaging is another constraint, 60% of rapeseed oil is sold in basic plastic containers, which degrade quality through oxidation. Upgrading to airtight, UV-resistant packaging could extend shelf life by 20-30% and enhance consumer appeal. Branding and improved packaging can boost product value by up to 25%.

Supportive policies exist, including seed subsidies and limited grants, but financing for advanced processing remains inadequate. Collaboration with NARC has led to improved mustard varieties with up to 15% higher oil yield, which if scaled, could greatly benefit rapeseed value chains.

With Nepal importing over 90% of edible oils, enhancing domestic rapeseed oil quality and value addition could significantly cut the $200+ million import bill, improve food security and tap into export markets like the U.S., Japan and Europe. Strategic investment in processing, packaging, certification and branding is crucial to unlock rapeseed's full economic potential.

Marketing Issue

Marketing rapeseed and its products in Nepal faces major challenges, limiting sectoral growth and farmer profitability. A key issue is underdeveloped rural market infrastructure. Over 60% of rural areas lack proper storage, leading to high post-harvest losses and forcing farmers to sell immediately after harvest at low prices (MoALD 2022). Inconsistent supply and quality further hinder market access. Rapeseed/Mustard seed production dropped by 15% between 2021 and 2023 due to pests and adverse weather (MoALD 2023) and only 30% of domestic rapeseed/mustard oil met quality standards, compared to 80% in India, reducing consumer confidence. Limited processing capacity with just 200 units nationwide results in the export of raw rapeseed instead of value-added oil products (FNCCI 2023). Access to reliable market data is also poor; 70% of farmers lack timely price information, restricting informed selling decisions (ORP 2022). Competition from cheaper, consistently available imported oils, especially from India, undermines demand for local rapeseed oil, which also suffers from limited consumer awareness of its health benefits. Moreover, credit access is limited, with only 12% of smallholders receiving formal loans, stalling investment in improved production, storage and processing technologies (NRB 2022). Policy constraints including 13% VAT on local oilseeds and favorable tariffs on refined imports further weaken competitiveness (MoF 2023). To improve rapeseed marketing, Nepal must strengthen infrastructure, expand processing capacity, improve quality control, increase market access and reform fiscal policies. These changes are critical to boosting domestic rapeseed value chains and reducing dependency on imported edible oils.

Government Policies

Existing and Future Strategies for Enhancing Rapeseed Crop Production

The Government of Nepal is actively promoting rapeseed production to enhance food security, reduce edible oil imports and improve rural livelihoods. Through the Oilseed Research Program (ORP) under NARC, efforts focus on developing high-yielding, disease-resistant rapeseed varieties and promoting integrated pest and nutrient management. Support measures include subsidies for seeds, fertilizers, pesticides and mechanization tools like seed drills and threshers under the Prime Minister Agriculture Modernization Project (PMAMP).

To modernize rapeseed production, the government is expanding research coverage, increasing subsidies for processing units and improving rural infrastructure and finance access to minimize post-harvest losses and boost market connectivity. Strategies also emphasize organic production, local collection centres and processing enhancement.

Nepal targets a 25 to 30% increase in oilseed production over five years, considering interventions like a minimum support price (MSP) to stabilize farmer incomes. Additionally, it is encouraging private investment, cooperative marketing and digital platforms to strengthen market linkages. These initiatives aim to boost rapeseed productivity and competitiveness, making Nepal more self-reliant and sustainable in edible oil production.

Possible role of public-private partnership in the promotion of rapeseed crop

Public-private partnerships (PPPs) hold strong potential to boost rapeseed cultivation in Nepal, helping reduce edible oil imports and strengthen the local economy. PPPs can drive investment in processing infrastructure, improving the quality and competitiveness of locally produced rapeseed oil. Recognizing this, the Government of Nepal has introduced policies supporting private investment in storage, processing and distribution facilities.

PPPs also improve market access by building direct supply chains, reducing post-harvest losses and ensuring fair pricing. The Agriculture Development Strategy (ADS) emphasize connecting farmers to markets, where private firms play a crucial role. Collaborations between the private sector and research institutions like NARC foster the development of high-yielding, disease-resistant rapeseed varieties and promote modern technologies, such as precision farming.

PPPs facilitate access to finance and crop insurance, encouraging farmer investment in rapeseed, backed by government subsidies. They also support value addition through local processing, raising farmer income and creating rural jobs. Capacity-building initiatives led by private partners help transfer knowledge on improved practices, enhancing productivity and product quality.

PPPs offer a comprehensive strategy to transform Nepal's rapeseed sector by addressing key gaps in infrastructure, market access, R&D, financing and farmer training, advancing national goals for self-sufficiency and agricultural growth.

Way Forward

To boost rapeseed productivity and scale up production in Nepal, the adoption of high-yield, disease-resistant varieties, along with modern practices such as IPM and precision agriculture, is essential. Farmers training in these techniques can significantly improve yields and oil recovery. Investment in modern extraction technologies like cold-press and advanced expeller systems will enhance both oil recovery rates and quality.

Improving soil health through regular testing and balanced fertilizer use is also critical. Introducing newly released rapeseed varieties alongside traditional ones can strengthen market resilience. Infrastructure upgrades, especially roads and storage, are vital to reduce post-harvest losses and improve market access. Cooperative farming models can help farmers pool resources, increase bargaining power and improve access to inputs.

Strong government support is key, including funding for research, extension services and capacity-building programs. Financial incentives such as low-interest loans, equipment subsidies and crop insurance will further encourage investment. A national branding strategy for Nepali rapeseed oil can enhance consumer trust and open niche markets, including organic oils and oil cakes.

Public-private partnerships (PPPs) should be strengthened to support technology transfer, infrastructure and market linkages. Long-term R&D must focus on developing climate-resilient rapeseed varieties, while expanding export potential to neighbouring countries. These strategies will enhance rapeseed self-sufficiency, reduce import reliance and support Nepal's rural economy.

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Chapter 13

Sunflower: An important Source of Vegetable Oil

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Introduction

Taxonomy of sunflower

Sunflower (*Helianthus annuus* L.) belongs to family Asteraceae, one of the largest plant families, characterized by inflorescences that resemble a single flower but are composed of numerous florets (Judd *et al*., 2016; Bashir *et al*., 2015; Lindstrom *et al*., 2015). The Genus *Helianthus* includes 70 species, both annual and perennial commonly referred to as sunflowers, with the species *Helianthus annuus* being agronomically and economically the most important one. These 70 species are mostly native to North America. The annual species (*Helianthus annuus* L.) is notable for its large, bright yellow inflorescences, which are both visually striking and agriculturally significant being globally a big source of vegetable oil (Adeleke and Babalola, 2020; Balogh, 2008).

Origin, Species and Global Distribution of Sunflower

Helianthus annuus is the most widely cultivated and economically important species (Adeleke et al., 2020) which was domesticated by Native Americans around 3000 BCE (Fernández et al., 2014). In the late 1800s, the species was introduced into the Russian Federation, where it became an important food source as oilseed crop. Russian farmers made significant advancements in sunflower cultivation practices, enhancing its agricultural and economic value (Prajapati et al., 2024). Since its domestication, sunflowers have been utilized for a wide variety of applications worldwide (Giannini et al., 2022). These include ornamental use, medicinal purpose, food sources, animal feed, raw material for fodder, natural dyes for the textile industry, body painting, decorations and many more (Kaya & Miladinovic, 2012).

The cultivated sunflower is an annual herbaceous plant characterized by a rough, hairy stem, which can grow from 3 to 12 feet in height. Its leaves are broad, coarsely toothed and rough, ranging from 3 to 12 inches in length. The plant features circular flower heads that are 3 to 6 inches wide in wild types but can exceed 12 inches in cultivated varieties/hybrids (Galisteo et al., 2024). This flower heads consist of numerous small tubular flowers densely arranged on a flattened receptacle disk. The outer row of flowers, called ray florets, have yellow petals, while the central disk is composed of hundreds of smaller disk flowers, each capable of forming a fruit (called achene) upon maturity (Kaya and Vasilevska-Ivanova, 2021).

Sunflower exhibit significant genetic diversity within the genus *Helianthus* having a basic chromosome number of 17. This genus includes species with a range of ploidies i.e. diploid, tetraploid and hexaploid (Sahin, 2024; Fernández-Luqueño *et al*., 2014). Plant breeders have leveraged this diversity by creating interspecific crosses within the genus, leading to the transfer of valuable traits such as increased oil content (%), cytoplasmic male sterility for hybrid seed production and resistance to diseases and insects. These advancements have significantly enhanced the commercial viability and utility of sunflower crop (Meena and Sujatha, 2022). Today, sunflowers are distributed globally, particularly in temperate and subtropical regions. The plant's adaptability to diverse climates makes it a versatile crop for both oil production and ornamental purposes worldwide (Adeleke and Babalola, 2020).

Sunflower in Pakistan

In Pakistan, sunflower is an important oilseed crop that was introduced as a commercial crop in late 1960s to reduce the country's reliance on imported edible oils (GOP, 2022). The favorable agro-climatic conditions in the country allow sunflower cultivation both in spring and fall seasons in several regions, including Sindh, Punjab and Khyber Pakhtunkhwa. Although sunflower significantly contributes to local vegetable oil production, its full potential remains untapped due to several challenges such as fluctuating market prices, limited farmer awareness and competition with traditionally important staple crops like wheat and rice (Khan, 2003; Rashid and Iqbal, 2003). Despite these obstacles, sunflower cultivation in Pakistan has shown steady growth both in terms of area and total production, driven by government initiatives and the rising demand for domestically produced edible oils.

Sunflower Oil: Composition, Nutrients and Quality

Sunflower oil, extracted from its seeds is valued for its high nutritional content and wide range of culinary applications. The composition and quality of sunflower oil depend on factors such as the sunflower variety, cultivation conditions and processing methods (Maguire, 2007). Sunflower oil is primarily composed of triglycerides, with fatty acids being its main components. The key fatty acids include linoleic acid (Omega-6 fatty acid-accounting for 48-74% of the total fats) which is a poly-unsaturated fatty acid that supports cardiovascular health (Codex Alimentarius, 2019) and oleic acid (Omega-9), comprising 14-40%, a mono-unsaturated fatty acid known for its anti-inflammatory properties (Maguire, 2007). Sunflower oil also contains smaller amounts of saturated fatty acids, including palmitic acid (4-9%) and stearic acid (1-7%). Based on its oleic acid content, sunflower oil is categorized into three types: high-linoleic oil, which is rich in Omega-6 fatty acids; high-oleic oil, containing 80% or more of oleic acid and offering superior oxidative stability (Codex Alimentarius, 2019); and mid-oleic oil, which provides a balanced profile of linoleic and oleic acids. Sunflower oil is also a rich source of essential nutrients. It contains vitamin E (tocopherols), an antioxidant that protects cells from oxidative stress, with concentrations ranging from 35-85 mg/100g (FAO, 2021). Additionally, it is a source of phytosterols, which help lower cholesterol absorption in the intestine and promote heart health (Maguire, 2007), as well as polyphenols, which are natural antioxidants with anti-inflammatory properties (FAO, 2021).

The quality of sunflower oil is influenced by several factors, including its oxidative stability and sensory attributes. High-oleic sunflower oil exhibits excellent resistance to oxidation, making it ideal for frying and extended storage (Codex Alimentarius, 2019). Moreover, its light color and mild flavor enhance its suitability for cooking and food processing applications.

Reducing Edible Oil Imports in Pakistan: The Potential of Sunflower Farming

Edible oil and oilseeds are among the largest food and feed import items in Pakistan, with edible oil imports reaching a record 3.55 million metric tons in 2020/21. This heavy reliance on imports imposes a significant financial burden on the economy, highlighting the urgent need for sustainable solutions to meet domestic demand (USDA, 2020) through indigenization of oilseeds.

Sunflower farming presents a viable opportunity to address this issue, given its adaptability to Pakistan's diverse agro-climatic conditions and its potential for high seed and oil yield. Sunflowers can be cultivated in various regions of the country, including Sindh, Punjab and Khyber Pakhtunkhwa, without significantly disrupting existing cropping systems due to their short growing cycle of around three months. Promoting sunflower cultivation through farmer incentives, subsidies and awareness programs, coupled with investments in high-yield, disease-resistant varieties and efficient processing facilities, can significantly enhance local edible oil production. By expanding sunflower farming, Pakistan can reduce its dependence on costly imports, improve food security and support the livelihoods of local farmers while alleviating the economic strain of importing edible oil.

Major Sunflower Growing Countries of the World

Sunflower is one of the most widely cultivated oilseeds crops globally with Ukraine and Russia being the largest producer. The popularity of specific hybrid and variety of sunflower can vary depending on factors like region, climate and market demand. The global sunflower market is driven by demand for edible oil, birdseed and other industrial products. A general overview of the types of sunflowers grown in each country is described below.

Ukraine

Ukraine is the world's largest producer of sunflower seeds, accounting for over 40% of global production. The country's fertile black soil and favorable climate make it an ideal place for sunflower cultivation and the total yearly sunflower production is over 7 million tons. Ukraine primarily grows hybrid sunflowers, which account for over 90% of the country's sunflower production. Popular hybrid varieties include: Ukrainskyi F_1, NK Brio, NK Ferti, P63LL06 oreal, Pioneer 64H20, Syngenta NK 7904 and Limagrain LG 5430. Some Ukrainian farmers also grow open-pollinated varieties (OPVs) and population varieties but the area under them is quite low.

Russia

Russia is the second-largest producer of sunflowers, with most of its production concentrated in the southern regions. The country's sunflower production is mainly focused on oilseed production. Russia also grows a significant amount of hybrid sunflowers, which account for around 80% of the country's sunflower production. Popular hybrid include: Belochka, Imidzh, Arimi and Immi, Klip**,** Surus, Pioneer 64H20, Syngenta NK 7904 and Monsanto Dekalb 3737. Russian farmers also grow OPVs particularly in the southern region like Karavan, Konditer, Kalibr, Aurelia, Fizalia, Zhemchuzhny, Rumyanets, Agat and Mazhor etc.

China

China is the third-largest producer of sunflowers, with most of its production concentrated in the northeastern provinces. It’s the world's fifth largest exporter of sunflower seeds. China primarily grows hybrid sunflowers, which account for over 95% of the country's sunflower production. Popular hybrid varieties include: Jian Zhang, Jingjing Yang, Like Zhang, Jiang Luo, Changlong Wen etc. Some Chinese farmers also grow OPVs and population varieties, particularly in the northeastern provinces.

Romania

Romania is also an important producer of sunflowers in the European Union, with most of its production concentrated in the eastern and southern regions. The country's sunflower production is mainly focused on oilseed production. Romania grows a mix of hybrid and open-pollinated sunflowers. Popular hybrid varieties include Lemon Queen, Mammoth Sunflower, Chocolate, Firecracker, Teddy Bear, Pioneer 64H20, Syngenta NK 7904 and Limagrain LG 5430.

Turkey

Turkey also grows sunflower on a significant area with most of its production concentrated in the southeastern regions of the country. The country's sunflower production is mainly focused on meeting domestic demand for edible oil. Turkey primarily grows hybrid sunflowers, which account for over 85% of the country's sunflower production. Popular hybrid varieties include: C-207, Hysun-33, T-40, H-OI, Hysun-39, Suncross Gulshin, FH-825, FH-797, FH-784, AGSUN-5270 etc.

United States

The United States of America is also a significant producer of sunflowers, with most of its production concentrated in the Great Plains region. The country's sunflower production is mainly focused on oilseed production and birdseed production. The United States grows a mix of hybrid and open-pollinated sunflowers. Popular hybrid varieties include: American Giant, Nuseed Conoil, Nusun, N4H 161CL, N4H422 CL, Falcon, Camaro II, Panther DMR and Badger DMR etc.

Bulgaria

Bulgaria is a smaller but significant producer of sunflowers in the European Union, with most of its production concentrated in the northeastern regions. The country's sunflower production is mainly focused on oilseed production. Bulgaria primarily grows hybrid sunflowers, which account for over 80% of the country's sunflower production. Popular hybrid varieties include Vokil, Linzi, Krasela, Velko etc. Some Bulgarian farmers also grow OPVs, particularly in the northeastern regions.

Hungary

Hungary is another smaller but significant producer of sunflowers in the European Union, with most of its production concentrated in the eastern regions. The country's sunflower production is mainly focused on oilseed production. Hungary grows a mix of hybrid and open-pollinated sunflowers. Popular hybrid varieties include Heliosmart and Sunfarm. Hungarian farmers also grow OPVs, particularly in the eastern regions e.g. Sunflower Kernels.

Biotic and Abiotic Problems affecting productivity in sunflower

Different biotic and abiotic stresses/problems can significantly impact sunflower seed yield and oil quality. It shows how important the use of integrated pest management and crop management practices is for ensuring high seed yield in sunflower with good quality. Some of the stresses significantly affecting productivity have been highlighted below.

Biotic Problems

Insect Pests

Insects not only damages sunflower stems, leaves and flowers affecting the seed yield and its quality but also provides entry points to different disease-causing pathogens. Some of the important insects are:

1. Aphids: Cause curling and distortion of leaves, reducing plant growth.

2. Whiteflies: Transmit diseases like sunflower yellow vein virus.

3. Bollworms: Damage flower heads, reducing seed yield.

4. Sunflower beetles: Feed on leaves, stems and flower heads.

5. Thrips: Transmit diseases like sunflower ringspot virus.

Diseases

Many diseases attack sunflower crop but some of the important ones are given below:

1. Downy mildew: Causes yellowing and death of leaves.

2. Powdery mildew: Causes white powdery growth on leaves.

3. Sunflower rust: Causes orange or yellow spores on leaves.

4. Sclerotinia head rot: Causes soft, mushy and discolored flower heads.

5. Verticillium wilt: Causes yellowing and wilting of leaves.

Nematodes

1. Root-knot nematodes: Cause galls on roots, reducing plant growth.

2. Cyst nematodes: Cause yellowing and stunting of plants.

Abiotic Problems

Abiotic factors affecting yield in sunflower given in the following lines.

Environmental Factors

1. Drought: Reduces plant growth, seed yield and oil quality.

2. Water logging: Causes root rot, reducing plant growth.

3. High temperatures: Reduces seed yield and oil quality.

4. Low temperatures: Delays plant growth/maturity and reduces seed yield.

Nutrient Deficiencies

1. Nitrogen deficiency: Causes yellowing of leaves, reducing plant growth.

2. Phosphorus deficiency: Causes stunted plant growth, reducing seed yield.

3. Potassium deficiency: Causes yellowing of leaves, reducing plant growth.

Soil Factors

1. Soil salinity: Reduces plant growth, seed yield and oil quality.

2. Soil acidity: Reduces plant growth, seed yield and oil quality.

3. Poor soil structure: Reduces plant growth, seed yield and oil quality.

Economic importance of sunflower

Edible oil is the essential component of our daily food intake but we are producing only 10 to 20% of our domestic needs and the remaining 80-90% are imported to fulfill the local requirement. Keeping in view the factor of population pressure we must increase our local production of edible oil. Sunflower has the potential to enable us to bridge the huge gap between local edible oil production and its total national annual demand due to its high seed yield and over 40% good quality oil. Sunflower is the third most produced oilseed in the world, after soybean and rapeseed. In 2021, Russia and Ukraine produced 55% of the world's sunflower oil.

Economic Benefits of Sunflower

Sunflower is important economically for these reasons given below:

- The leaves can be used as fodder
- The flowers can be used to make a yellow dye
- Sunflower seeds are a good source of vitamin A, B and K.
- Sunflower oil extracted from its seed is considered premium quality vegetable oil.

Breeding Focus of Sunflower

Following traits/parameters needs to be focused while breeding new sunflower hybrids and varieties including:

- Development of short duration hybrids for spring season cropping systems.
- Development of hybrids/varieties with tolerance to drought, terminal stress, high temperature and water logging.
- Overcoming seed setting problem.
- Development of hybrids with resistance to Alternaria, SND and powdery mildew.
- Short duration and dwarf varieties/hybrids for lodging tolerance.
- Development of climate smart resilient varieties/hybrids.

Production technology of sunflower

Soil Type

Heavy soils are most suitable for sunflower cultivation. Sandy and water-logged soils are not desirable for sunflower production.

Seedbed preparation

Sunflower has a well-developed root system, deep ploughing with a moldboard plough is necessary. Deep ploughing is necessary to break the hard pan. Laser land leveler should be used to level the field.

Time of Sowing

Timely sowing of sunflower is necessary to get more yield. In case of late sowing, oil content decreases and yield losses occur. In Pakistan sunflower is being grown in two seasons: spring and summer.

Spring sunflower crop

1st January to end of February

Summer sunflower crop

1st July to 10 August

Seed rate

Seed rate depends upon soil type, germination percentage, time of sowing and method of sowing.

2-2.5 kg of hybrid seeds having germination percentage more than 90% should be used per acre.

Planting Pattern

Sunflower can be planted through planter, dibbling, single row cotton drill and Kera method. Row to row distance should be 2.-2.5 feet and plants within rows should be 9 inches apart in case of irrigated areas and 12 inches apart in case of rain-fed areas.

Fertilizer requirement

Fertilizer requirement of sunflower is 32 kg/acre nitrogen, 23 kg/acre phosphorous and 25 kg/acre potassium. But optimal level of these macronutrients depends upon the fertility level of the soil and should be decided based on the lab. Analysis of the soil.

Irrigation requirement

Four to five irrigations are required for the crop but it also depends upon weather conditions especially soil type, temperature and wind speed. First irrigation should be given 20 days after emergence, second 20 days after first irrigation, third at head formation, fourth and fifth at grain formation.

Thinning

Thinning is one of the operations essential to maintain the desired plant population. For this purpose, weak or abnormal seedlings should be uprooted before the application of first irrigation.

Weed control

Control of weeds during the first eight weeks after emergence is crucial. Weed control can be done through hoeing and pre/post emergence herbicide application.

Insects of sunflower

Jassid, Whitefly, Aphid, Cutworm, Armyworm and Mealy bugs are the major insects causing problems. Instead of chemicals application, biological control should be used to control these insects.

Diseases of sunflower

Charcoal rot, Head rot, Leaf blight, Downy mildew, Powdery mildew are the diseases affecting this crop. Seed treatment with fungicides can be helpful in controlling fungal diseases.

Harvesting and storage

Sunflower crop matures when back of flower head turns yellow and the leaves become grayish white and moisture content of seed is 30-35%. For storage, the seed moisture content should be 8-10%.

Future Breeding Focus for Sunflower Crop

Vegetable oils are a key component of human dietary need and health worldwide. Oil quality of sunflower is better than all others because of the higher percentage of the linoleic acid that is the most appropriate character missing in all other oilseed crops. Changing climate and extreme weather events are making crop highly vulnerable and threatening global food security (Arshad et al., 2020).

Breeding Objectives

Most breeding objectives change only slowly but a few changes rapidly, because of a new requirement, a new product quality, a new resistance to disease or a change in the economic situation of the crop or because new techniques make possible studies that could not be undertaken in the past. In recent years, there have been many changes in research techniques, in particular, the possibility of determining the genotype of a plant and not just its phenotype. Seed yield, oil content, protein content and hull ability, fatty acids, minor constituents are major breeding objectives.

Pest and Disease Resistance

With climate change altering growing conditions, new pests and diseases are emerging and existing pathogens are evolving. Breeding sunflowers with broad-spectrum disease resistance can help protect against multiple pathogens simultaneously. Downy Mildew, Broomrape, Sclerotinia and some others minor ones should be controlled through genetic improvement and management practices (Vear, 2016).

Sunflower Modeling

Development and applications of crop growth models is an effective tool for sustainable agricultural planning and decision-making process. Outdated experimental approaches are overpriced, time-consuming and not resourceful to adopt with changing climatic condition. Modelling of sunflower (*Helianthus annuus* L.) is stimulating because the crop species combines high harvest potential with excessive adaptability. Crop modelling might be an advantageous tool for identifying appropriate and economical management practices for sunflower, particularly climate change vulnerable regions worldwide (Arshad et al., 2020).

Climate Smart Traits

Crop adaptation to regional climate is often highly dependent on flowering time and its sensitivity to environmental signals. Flowering time is a critical agronomic and quantitative trait. Development of more productive and drought-tolerant lines in breeding programs requires the knowledge of root traits and functions and their effect on sunflower productivity, as depth-efficient roots for more water uptake are one of the indicators of physiological drought tolerance (Miladinović et al., 2019). Selection for heat resistance is an integral part of many breeding programs and cultivation of sunflowers in conditions of high temperature caused by climate change can be achieved by avoiding adverse conditions or by breeding varieties and species with increased resistance to heat shocks. drought is the most restraining factor in sunflower production worldwide, severely reducing yield, oil volume, oil quality and other important yield traits (Hladni et al., 2018). Therefore, it is important to identify the physiological, molecular and genetic components of sunflower hybrids resilience to environmental variation, with a special focus on water stress in the context of climate change. Global warming is seen as one of the causes of an increase in floods as well as their unexpected occurrences, regimes and localizations (El- Khoury et al., 2014). Waterlogging affects 10% of the global land area and it is one of the most important constraints imposed on agricultural crop production (Patel et al., 2015).

Nutrient-Water Use efficiency

Climatic changes affect the absorption and metabolism of nutrients in sunflower, which is reflected in seed yield and oil content and quality. The impact of atmospheric CO_2, heat and stress due to drought affect the development of sunflower plants and their productivity. However, the interaction between these abiotic factors and their effect on photosynthesis, the development of plants and transpiration are still insufficiently unexplored in sunflower (Debaeke et al., 2017).

Sunflower water requirements can be divided into two phases. The first phase is before the flowering (pre-anthesis) and water deficit is mainly reflected by the small leaf area index and withered leaves. The second phase, which, after flowering (post-anthesis), combines groups of factors such as accelerated aging of the leaves, withering and the reduction of the stoma (Connor and Hall, 1997). Although the lack of water affects all development phases of the sunflower, the maximum yield reduction occurs when in drought during the reproductive phase (Reddy et al., 2003).

Edible Oil Scenario in SAARC Countries

The production and import/export of edible oil in the South Asian Association for Regional Cooperation (SAARC) countries are influenced by a variety of factors, including agricultural resources, domestic demand and global market conditions. Here's an overview of edible oil production and imports in these countries:

Afghanistan

Afghanistan has potential for oilseed production from sunflower and cottonseed, but overall production is low and insufficient for domestic needs. Afghanistan produces around 300 metric tons of edible oil which makes 10% of total need hence while the rest of the needs are met through imported oil.

Bangladesh

Bangladesh produces edible oils from mustard, sunflower and soybean cultivation. However, the production is not enough to meet the growing demand. During 2022-23, Bangladesh produced 1416 thousand tons of edible oil meeting only 20-25% of total demand (USDA, 2024).

Bhutan

Bhutan produces some mustard oil but the production is not sufficient to meet domestic needs. According to an estimate, Bhutan imported 67 shipments of edible oil in 2023-24.

India

India is one of the largest producers of edible oil in the world but still heavily reliant on imports to meet its domestic demand. The country produced 11.65 MT edible oil during 2021-22 which was not sufficient, so India imported 14.19 MT of edible oil which is 55% of its total needs (GOI, 2023).

Maldives

Maldives produces very little edible oil locally and that is too dominated by coconut oil. Major part of the edible oil needs is fulfilled by imports.

Nepal

Nepal produces edible oil from mustard and soybeans. However, the total production was estimated 239 thousand tons in 2023 whereas total consumption turned out to be 330 thousand tons so the country imported 28% of its total edible oil needs.

Pakistan

Pakistan produces edible oils primarily from canola, cottonseed and sunflower, soybean and palm. However, total annual domestic oil production falls way shorter of its needs. During 2021-22, Pakistan produced 460 thousand tons of edible oil making 15% of total need whereas imported 2754000 tons (GOP, 2022).

Sri Lanka

Sri Lanka is a major producer of coconut oil, which is widely used in the country. However, production from other sources like palm oil and soybeans is minimal. Sri Lanka produced 9 thousand tons of edible oil in 2023 making 25% of the total edible oil need in the country.

Sunflower as a solution to edible oil deficiency in the region

Sunflower oil is very widely used in every household for gastronomy because of its affordability and neutral taste. In industrial processing, sunflower oil is normally subjected to dewaxing (winterization) and refining. Refined sunflower oil finds widespread utility in the food, pharmaceutical and cosmetic industries and culinary practices globally. In culinary contexts, refined sunflower oil serves as a staple for cooking and baking endeavours. With its neutral taste profile and high smoke point, it proves ideal for frying and deep-frying. Cold-pressed oil (CPO), with a light nutty flavor, is more of a specialty suitable for cold cooking. On the market, the above types of oils can also be found as products of controlled organic farming (organic quality). The oil is extracted from the seeds of the common sunflower (*Helianthus annuus* L.). In the contest of SAARC countries, Bangladesh imports sunflower oil almost around 1 % its total imports. India imports sunflower oil making 15 % of its total edible oil import. Pakistan and Sri Lanka also import about 1% sunflower oil of their total edible oil imports (Nakonechna et al., 2024; Sahibzada et al., 2021). Improving sunflower productivity in the SAARC region with improved hybrids/varieties having wide adaptabilities with good yield potential for seed and oil can help bridge up the huge gaps between productions and local needs in the counties of this region.

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Chapter 14

Oil Palm (*Elaeis guineensis* Jacq.)

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Abstract

Oil palm, a highly efficient oilseed crop, plays a significant role in the global vegetable oil industry, contributing 32% of the world's supply of oils and fats from just 5% of the cultivated oilseed area. Originating from West Africa, it has successfully expanded to regions such as Southeast Asia, South America and India. Despite India's high oilseed production, the demand for edible oils far exceeds domestic supply, leading to significant reliance on imports, with palm oil constituting 60% of total imports. The Indian government is actively promoting oil palm cultivation to bridge this gap through initiatives like the National Mission on Edible Oils-Oil Palm (NMEO-OP), which emphasizes sustainable cultivation, farmer support and technological advancements.

This paper highlights the history of oil palm in India, current cultivation practices and the contributions of ICAR-IIOPR in advancing oil palm research. Achievements include the development of high-yielding hybrids, molecular markers and innovative crop management techniques. Sustainable cultivation practices and government support have led to significant growth in India's oil palm production area, currently spanning 0.47 million hectares. Challenges such as climate variability, disease management and the need for high-quality planting material are discussed alongside potential solutions, including drought-tolerant hybrids, precision farming technologies and breeding for disease resistance. By addressing these challenges, India can harness the full potential of oil palm to achieve self-sufficiency in edible oil production while ensuring environmental sustainability.

Introduction

Oil palm, with its remarkable efficiency in producing oil on a relatively small land footprint, stands as one of the most significant global crops today. This versatile crop yields two types of oil, widely utilized in cooking, cosmetics, lubricants, sanitizers and cleaning agents. Additionally, the by-products of palm oil production find applications in areas such as livestock feed, biofuels and water purification, demonstrating its multifaceted value. Originating from the humid tropics of West Africa, the crop has successfully expanded to diverse regions, including the semi-arid tropics of Southeast Asia, where it thrives in countries like Indonesia, Malaysia, Thailand and India.

Globally oil palm is cultivated in 23.98 Mha with an estimated production of 77.28 million metric tons of oil (USDA 2023). This accounts to 5 per cent of global vegetable oil acreage and 32 per cent of global supply of oils and fats. Majority of oil palm area is concentrated in Southeast Asia (18.69 Mha) followed by South and Central America (1.43 Mha), Africa (1.0 Mha) and the Pacific (0.14 Mha). The countries with notable area of production include;

Southeast Asia: Indonesia, Malaysia, Papua New Guinea are leading producers.

Africa: Prominent cultivation occurs in Nigeria, Ivory Coast, Ghana, Liberia, Sierra Leone, Cameroon, Republic of Congo and Zaire.

South America: Countries like Costa Rica, Panama, Colombia, Guyana, Peru, Ecuador, Venezuela and Brazil also contribute significantly to global production.

Indonesia (44%), Malaysia (26%), Thailand (5%), Columbia (2%) and, Nigeria (2%) occupies the top position in production of palm oil. India is a prominent player in the global oilseed industry, ranking as the fourth-largest producer worldwide, after the United States, China and Brazil. The oilseed sector holds a crucial position in the country's agricultural landscape and economic framework, contributing significantly to rural livelihoods and overall food security. With its extensive cultivation areas and substantial production of various oilseeds, India showcases its potential in the global arena. Despite its production capacity, India is one of the largest consumers of edible oils globally, driven by a rapidly growing population, rising income levels, evolving dietary patterns and increasing industrial applications of vegetable oils. These factors have created a widening gap between domestic production and consumption, resulting in heavy reliance on imports. India currently meets over 50% of its edible oil demand through imports, making it the second-largest importer of edible oils after China.

Table 1. Vegetable oil scenario in India

Year	Domestic availability (Mn T)	Total consumption (Mn T)	Gap (Mn T)	Percentage gap
2018-19	10.95	25.97	15.02	57.83
2019-20	11.63	26.33	14.70	55.83
2020-21	12.13	25.50	13.37	52.43
2021-22	12.55	26.62	14.07	55.13
2022-23	12.42	28.17	15.75	55.91

The rising population, increasing income levels, improved living standards and higher per capita consumption, coupled with industrial applications of vegetable oils, have significantly widened the gap between demand and domestic supply in India. This shortfall is primarily addressed through imports, making India the second-largest importer of edible oils after China. Palm oil holds a dominant position among imported oils in India, accounting for approximately 60% of the total edible oil imports**.**

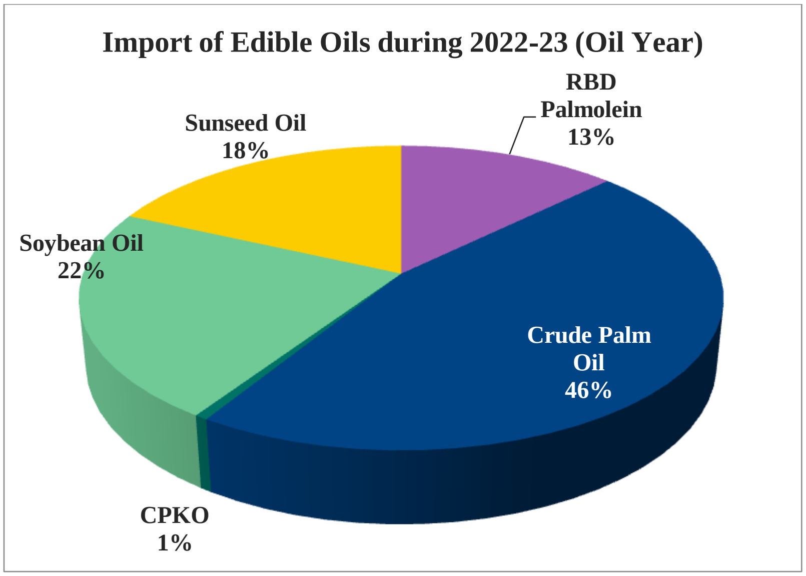

Fig 1. Import scenario of edible oils during year 2022-23

This dependency on imports has economic and strategic implications, including a strain on foreign exchange reserves and vulnerability to global market fluctuations. Addressing this challenge requires a dual strategy focused on boosting domestic oilseed production and promoting efficient consumption.

- To address the growing gap between the demand and supply of vegetable oils in India, the Government of India is actively promoting the cultivation of oil palm, because of the following advantages.
- Oil palm is the most productive oilseed crop, yielding 4-6 tonnes of oil per hectare annually**,** far exceeding the productivity of other crops like soybean and sunflower. Its high land productivity ensures efficient use of agricultural space, while its low water requirements per unit of oil produced make it an environmentally efficient option.
- Oil palm is a perennial crop with a productive life of 25-30 years, providing farmers with a long-term income source. Additionally, it has low greenhouse gas (GHG) emissions when grown sustainably and possesses a high carbon sequestration capacity, contributing positively to climate change mitigation.

- Oil palm cultivation requires minimal labor compared to other crops due to reduced planting and maintenance activities after the initial establishment phase, making it cost-effective for farmers.
- With proper care, including optimized irrigation, fertilization and pest management, oil palm offers high yields and stable productivity, making it an attractive crop for systematic farming practices.
- Farmers do not need to invest in storage facilities for fresh fruit bunches (FFB**)**, as these are directly harvested and sent for processing, reducing post-harvest losses and costs.
- Government and industry support for oil palm ensures steady market demand. Processing units for crude palm oil (CPO) and palm kernel oil (PKO) often enter into agreements with farmers, offering stable prices and dependable buyers.
- Unlike seasonal crops, oil palm provides year-round harvests of FFB, ensuring a consistent and reliable income stream for farmers.
- In the early stages of oil palm cultivation, intercropping with short-duration crops like legumes, vegetables or grains is possible, allowing farmers to maximize land use and generate additional income before the palms mature.
- Oil palm experiences fewer pest and disease issues compared to many other crops, reducing the need for frequent pesticide applications and lowering cultivation costs.

By combining its economic benefits**,** environmental advantages and low resource requirements**,** oil palm stands out as a sustainable and profitable crop for farmers. Further, in India, oil palm cultivation is promoted on cultivated lands and unused areas, rather than by clearing existing forests. This approach ensures that its growth does not contribute to deforestation or disturb biodiversity. By avoiding the destruction of natural ecosystems, the cultivation of oil palm in India is considered sustainable and environmentally friendly, aligning with ecological preservation goals while addressing the demand for vegetable oils. These features make it a critical component of India's strategy to reduce edible oil imports while ensuring long-term agricultural and environmental sustainability.

History

Oil palm was first introduced to India as an ornamental plant, being planted in the National Botanical Garden, Kolkata in 1886. Later, between 1971 and 1984, large-scale plantations were established by the Plantation Corporation of Kerala Limited in Kerala and subsequently in the Andaman and Nicobar Islands. In 1983, oil palm cultivation as an irrigated crop began in Andhra Pradesh, marking a significant shift toward commercial production. To identify suitable areas for oil palm cultivation, the Government of India appointed several committees over time. The most recent study, conducted by Reddy et al. (2020), identified a potential area of 2.79 million hectares across 22 states in India for oil palm cultivation. Recognizing the crop's potential to boost domestic edible oil production and reduce import dependency, the government has introduced several schemes to promote oil palm cultivation, including financial incentives and technical support for farmers. These initiatives aim to strengthen India's position in edible oil production while ensuring sustainable agricultural practices.

Oil palm Research in India

Research on oil palm in India began in 1976 at the Regional Centre of the ICAR-Central Plantation Crops Research Institute (CPCRI), located in Palode, Kerala. Recognizing the need for focused research on this important crop, a dedicated National Research Centre for oil palm was established in 1995. To further strengthen research efforts, it was upgraded to the Directorate of Oil Palm Research (DOPR) in 2009.

As the significance of oil palm cultivation continued to grow, the DOPR was elevated to the status of a full-fledged Indian Institute of Oil Palm Research (IIOPR) in 2014. This progression highlights the increasing importance of oil palm in India's agricultural landscape and the government's commitment to advancing research, development and technology dissemination to promote sustainable cultivation of the crop.

Major achievements

The ICAR-Indian Institute of Oil Palm Research (IIOPR) has achieved significant advancements in oil palm research and development. Here is a summary of its key contributions:

Development of Hybrids: Through conventional breeding, ICAR-IIOPR has developed three oil palm hybrids: Godavari Swarna, Godavari Ratna and Godavari Gold (Mathur et al., 2021).

Godavari Swarna (NRCOP-4): With high fresh fruit bunch yield (26.87 t/ha/yr) and high mesocarp oil yield (5.71 t/ha/year). Suitable for coastal ecosystem with moderate humidity and temperature under assured micro-irrigation system recommended for cultivation in Andhra Pradesh.

Godavari Ratna (NRCOP-2): With a fresh fruit bunch yield of 22.44 t/ha/yr average bunch weight of 18.31kg, high sex ratio (0.70), high mesocarp oil yield (5.36 t/ha/year) and high oil/bunch ratio (24.1), suitable for high rainfall and assured irrigated conditions of coastal region of Maharashtra and Goa States.

Godavari Gold (NRCOP-17): It has special traits such as high fresh fruit bunch yield (27.23 t/ha/yr), more bunches/palm (11.74), high sex ratio (0.72), mesocarpnoil yield (5.79 t/ha/year) and oil/bunch ratio (21.28); suitable for coastal Tamil Nadu region under assured irrigated conditions.

Molecular Marker Innovations: A CAPS marker was developed for differentiating fruit types: dura, pisifera and tenera, ensuring genetic purity and timely distribution of high-yielding tenera sprouts.

- SSR markers were identified to distinguish between tall and dwarf genotypes. One marker, validated via association mapping and bioinformatics analysis, was linked to asparagine metabolism, which influences dwarfing in plants.

Clonal Propagation: A protocol for indirect somatic embryogenesis was developed, enabling large-scale production of homogeneous, high-yielding oil palm plants within a shorter time frame.

Germplasm Collection:

- A total of 176 germplasm was collected from various countries.
- 63 indigenous germplasm were registered to broaden the genetic base.

Innovative Pollination Technique:

A novel insect-assisted pollination technique was developed and patented, ensuring uniform and effective fruit set.

Fertigation Protocol:

A fertigation protocol was developed and successfully validated in farmers' fields.

Suitability Mapping:

- Suitability maps for irrigated and rainfed cultivation of oil palm were developed using RS (Remote Sensing) and GIS (Geographic Information Systems) with MCDA modeling.
- A Decision Support System (DSS) was created for micro-level evaluation of site suitability for oil palm cultivation.

Nutrient and Irrigation Management:

- A site-specific nutrient management system was developed through soil and leaf analysis.
- DRIS indices and critical leaf nutrient levels were established for eight states.
- A mobile app-based irrigation management system, using PET (Potential Evapotranspiration), was developed for three states.

Quality Seedling Production:

Protocols for producing high-quality seedlings were standardized.

Crop Management Practices:

- Sustainable practices such as in-situ mulching, intercropping and improved field management were developed.
- Models incorporating perennial ornamental, spice, medicinal and aromatic plants as intercrops were designed to enhance productivity.

Soil and crop Studies:

- Growing Degree Days (GDDs) were estimated for different growth stages under irrigated conditions.
- Boron fractions in oil palm soils were analyzed, including adsorption and desorption behaviours and kinetics.

Harvesting Mechanization:

A 3-in-1 engine-operated machine for ablation and harvesting operations was developed.

Pest and Disease Management:

Good Agricultural Practices (GAPs) were standardized for managing key pests and diseases, including Rhinoceros beetles, bagworms, bud rot and wet rot.

Support for planting material production through seed garden concept:

The institute provides the parental material and technical guidance.

Training and Capacity Building:

- The training needs of farmers and agricultural officers are assessed.
- Need-based training programs are regularly conducted to enhance knowledge and skill sets related to oil palm cultivation.

These advancements collectively aim to enhance productivity, sustainability and farmer profitability in oil palm cultivation across India.

Policy support

The National Mission on Edible Oils-Oil Palm (NMEO-OP)**,** introduced in 2021, is a key initiative by the Government of India to enhance domestic edible oil production and reduce the nation's dependency on imports. The mission aims to promote oil palm cultivation across 6.5 lakh hectares by 2025-26, with a focus on regions like the Northeastern states and the Andaman & Nicobar Islands, which have high potential for cultivation. The program supports farmers through subsidies for planting materials, fertilizers and irrigation infrastructure and includes a viability gap funding mechanism to protect against price fluctuations in Fresh Fruit Bunches (FFBs). It also emphasizes sustainable agricultural practices, research and development and close collaboration with state governments to identify suitable areas for oil palm cultivation. By boosting productivity and ensuring environmental sustainability, NMEO-OP seeks to achieve self-sufficiency in edible oils, reduce import dependency and improve farmer incomes across India. NMEO-OP represents a significant step towards achieving self-sufficiency in edible oil production and supporting the economic well-being of farmers while maintaining ecological balance.

Thanks to robust government policies and extensive research support from ICAR-IIOPR, the area under oil palm cultivation in India has expanded significantly, reaching approximately 0.47 million hectares during 2023-24. This growth reflects the combined impact of strategic interventions, research-driven advancements and farmer-oriented initiatives aimed at boosting edible oil production and reducing import dependency.

With the present status of research achievements and the farmer friendly policies of Indian government, oil palm productivity is marching towards a good uptrend aiming to meet the domestic needs of edible oil in the country.

Table 2. State wise production of Crude Palm Oil (metric tons) during last 10 years.

State	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Andhra Pradesh	127570	161566	170478	193562	190999	234696	232938	208359	237900	295075
Karnataka	1770	1736	2176	2538	2051	2224	2280	2184	2734	10068
Tamil Nadu	1035	820	1019	1222	1115	938	1017	553	429	
Gujarat								NA		
Odisha	443	558	557	618	NA					
Goa	372	371	388	581	437	379	411	309	305	353
Kerala	7378	6303	6515	7015	5929	5191	4609	4825	4281	318
Mizoram			365	496	603	648	625	535		6775
Telangana	6825	9373	10012	12499	8947	27275	37205	38050	26690	48141
Total	145393	180727	191510	218531	210081	271351	279085	254815	272339	360729

However, the full potential of the crop can be realized by concentrating on the following aspects in research front combined with need based supportive government policies and of course in combination with these challenges highlight the importance of research, sustainable practices and infrastructural support to fully realize the potential of oil palm cultivation.

Production of High-Quality Planting Materials to Meet Area Expansion Targets: To ensure the rapid expansion of oil palm cultivation, the production of high-quality planting material such as improved hybrid seeds is critical. Efforts must focus on enhancing production capacity to meet the growing demand for oil palm saplings in both new and existing cultivation areas.

Development of drought-Tolerant Hybrids: With climate variability and water scarcity being significant challenges, the development of drought-tolerant oil palm hybrids is essential. Such varieties can ensure stable yields in water-deficient regions and enhance the crop's adaptability to diverse agro-climatic conditions.

Breeding for Dwarf Palms with Compact Canopy: Breeding programs should aim to develop dwarf oil palm varieties with a compact canopy. These traits not only facilitate easier harvesting and reduced labor requirements but also allow for better sunlight penetration and efficient spacing.

Hybrids with Improved Oil Quality: To enhance the economic value of oil palm, breeding efforts must focus on developing hybrids that produce oil with superior quality, such as higher oleic acid content or reduced saturated fat levels, making it more appealing for both domestic and industrial uses.

Hybrids Tolerant to Basal Stem Rot (BSR) Disease: Basal Stem Rot caused by *Ganoderma* fungi is a major threat to oil palm productivity. Developing disease-resistant hybrids through advanced breeding techniques or genetic interventions is critical to ensure plantation sustainability.

Sensor and IoT-Based Precision Water and Nutrient Management: Leveraging advanced technologies like sensors and IoT can enable precise management of water and nutrients. These technologies can monitor soil moisture, plant health and nutrient levels in real time, reducing wastage and ensuring optimal resource utilization.

Systems Approach for Higher Net Profit: To maximize profitability, a systems-based approach that integrates oil palm cultivation with other compatible agricultural components such as intercropping or livestock management can be implemented. This holistic approach increases resource use efficiency and generates additional income streams.

Periodic Assessment of Suitable Areas Under Changing Climatic Scenarios: With climate change altering the suitability of regions for oil palm cultivation, periodic reassessment using tools like remote sensing, GIS and climate models is essential. This ensures accurate identification of areas best suited for oil palm, minimizing risks and promoting sustainable expansion.

These strategic interventions will contribute to the sustainable development of the oil palm sector in India, improving productivity, profitability and environmental outcomes.

Conclusion

Oil palm is a globally significant crop known for its unmatched productivity, yielding 4-6 tonnes of oil per hectare annually. It is cultivated on 23.98 million hectares worldwide, with Southeast Asia dominating production. India, despite being a major oilseed producer, remains heavily dependent on imports to meet its growing edible oil demand, driven by rising population, industrial applications and per capita consumption. Palm oil accounts for 60% of India's edible oil imports.

Recognizing the need to enhance domestic production, the Government of India has introduced the National Mission on Edible Oils-Oil Palm (NMEO-OP). The program aims to expand oil palm cultivation to 6.5 lakh hectares by 2025-26 through farmer incentives, sustainability measures and research advancements. India’s oil palm cultivation has grown to 0.47 million hectares, supported by ICAR-IIOPR's contributions, including hybrid development, molecular markers, nutrient management protocols and innovative mechanization.

Challenges such as water scarcity, disease threats and climate variability require strategic interventions, including drought-tolerant and disease-resistant hybrids, compact canopies for efficient harvesting and precision agriculture technologies. Sustainable practices, intercropping and regular reassessment of suitable cultivation areas are essential for long-term success. By addressing these challenges, oil palm cultivation in India holds immense potential to reduce import dependency, ensure farmer profitability and promote ecological balance.

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Chapter 15

Soybean (*Glycine max*)

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Introduction

Soybean (*Glycine max*), often referred as the "miracle bean" possess a unique combination of approximately 20% oil and 40% protein, while also enhancing soil fertility by adding nitrogen to the soil. Globally, this crop plays a significant role, contributing 25% to the production of edible oil and 65% to animal feed. In India, soybean is the second most significant crop in terms of vegetable oil economy, following rapeseed-mustard. This versatile crop has firmly established itself as a key rainy season agricultural staple within the rainfed agro-ecosystems of central and peninsular India. Cultivated soybean, scientifically classified as Glycine max (L.) Merr. belongs to the genus Glycine in the tribe Phaseoleae**,** under the subfamily Papilionaceae of the family Leguminosae. Soybean is not only a crop of oil production; it has great therapeutic and nutritional potential. High protein content (40%) of soybean seeds is great source of vegetable protein to eradicate the curse of malnutrition in developing countries. KTI, an anti-nutritional factor present in soybean, causes hindrance to direct use of soybean seeds for food purpose. Food grade soybean varieties (e.g., NRC 142) free from such anti nutritional factor- KTI for commercial cultivation has been developed in India. Soybean has other undesirable flavors which cause soy food products (Soya Paneer, Soya Milk) less attractive to consumers. Success has been achieved by developing soybean varieties NRC 142 by removing undesirable factors like LOX genes causing beany flavour from soybean. The protein content of soybeans is 36-42% of the dry weight. The fat content is approximately 18% of the dry weight mainly polyunsaturated and monounsaturated fatty acids, with small amounts of saturated fat. Being low in carbohydrate, whole soybeans are very low on the glycemic index (GI). This low GI makes soybeans suitable for people with diabetes. Soybeans contain a fair amount of both soluble and insoluble fiber. Soybeans are rich in various bioactive plant compounds, including (Isoflavones, Phytic acid and saponin). Isoflavones a family of antioxidant polyphenols have a variety of health effects. Phytic acid (phytate) impairs the absorption of minerals like zinc and iron. One of the main classes of plant compounds in soybeans, saponins have been found to reduce cholesterol in animals. In 1970, soybeans covered a mere 30,000 hectares, producing 10,000 quintals. However, at present 2022, soybean cultivation has expanded to a staggering 12 million hectares, yielding 13.9 million metric tons. Soybean cultivation in India is concentrated in three states: Madhya Pradesh, Maharashtra and Rajasthan, which contribute significantly to both area and production. The continuous increase in global soybean production is closely tied to the development of new cultivars, which have played a pivotal role in enhancing yields.

Origin

The cultivation and use of soybean could be traced back to the beginning of China's agricultural age. Chinese medical compilations, dating back 6000 years, mention its utilization for human consumption (Krishnamurthy and Shivashankar,1975). To the populace of China, Japan, Korea, Manchuria, Philippines and Indonesia, for centuries, soybean has meant meat, milk, cheese, bread and oil. This could well be the reason, why, in these countries it has earned epithets like 'Cow of the field' or 'Gold from soil' (Hovarth,1926). Owing to its amino acids composition, the protein of soybean is called a complete protein. Its nutrition value in heart disease and diabetes is well known. It is significant that Chinese infants using soybean milk in place of cow's milk are practically free from rickets. Today USA, Brazil, Argentina are the “Big-3” producers of the world. Versatility of soybean was recognized in the west quite recently. Around 1921, China produced about 80 percent of the world's soybean (Bisaliah, 1988). In India Soybean was introduced from China in 10^{th} century A.D. through the Himalayan routes and brought in via Burma (now Myanmar) by traders from Indonesia. As a result, soybean has been traditionally grown on a small scale in Himachal Pradesh, the Kumaon Hills of Uttar Pradesh (now Uttaranchal), eastern Bengal, the Khasi Hills, Manipur, the Naga Hills and parts of central India covering Madhya Pradesh. It has also been reported that the Indian continent is the secondary centre for domestication of the crop after China (Hymowitz, 1990; Khoshoo, 1995; Singh and Hymowitz, 1999).

Plant architecture

In general, cultivated soybean is a bushy herbaceous erect annual that can attain height up to 150 cm. It has three types of growth habits *viz*., determinate, semi-determinate and indeterminate, but determinate and semi-determinate types are preferred by Indian farmers. In soybean, primary leaves are unifoliate and ovate; and the secondary leaves are compound trifoliate in general and four, five or more leaflets are to be present occasionally. Pod bearing nodes range from 3 to 14 and number of pods per cluster range from 3 to 9. The root system contains a tap root with strong nodulation system for N_2 fixation. Soybean is a self-pollinating and photo-sensitive short-day crop. Latitude and sowing dates considerably affect its adaptability and yield. Late sowing due to delayed onset of monsoon will result in reduction in biomass and yield. Days to flowering in Indian soybean varieties range from 30 to 60 days and the maturity range from 85 to 130 days. The cultivated soybean is an annual, generally exhibiting an erect, sparsely branched, bush-type growth habit with pinnately trifoliate leaves. Purple or white flowers are borne on short axillary racemes on reduced peduncles. The pods are either straight or slightly curved, usually hirsute. The one to three seeds per pod are usually ovoid to sub-spherical in shape. The seed coats range in colour from light yellow, olive green and brown to black. It is a self-pollinated species propagated commercially by seed. It has complete flower, having 10 stamens arranged around the pistil. The stigma is receptive to pollen about one day before pollen is shed from anthers of the same flower. Flower initiation is controlled by photoperiod, temperature and genotype. Soybean stem growth and flowering habit are of two types: indeterminate and determinate. In case of indeterminate, apical meristem continues vegetative activity during most of the growing season. The inflorescences are axillary racemes and pods are produced rather uniformly on the stem. The determinate type is characterized by vegetative development which ceases when the apical meristem becomes an inflorescence, both axillary and terminal racemes exist and pods are borne rather uniformly along the stem except for cluster of pods at the terminal racemes. The flowering period and the time of overlap of vegetative and reproductive growth is greater for the indeterminate than determinate type.

Climate

Soybean originated in sub temperate region of northern China however, now its cultivation extends to sub-tropics and temperate climates. The profitable soybean production is between 25^0 and 45^0 N latitude at altitudes of less than 2000 m. Soybean is relatively tolerant to very low and high temperature but growth decreases above 35^0C and below 18^0C. Minimum temperature for growth is about 10^0C and maximum rate of development between planting and flowering ensues at 30^0C. Day length influences the rate of development of crop. In short day plants, increased day length may result in the delay of flowering and taller plants with more nodes. Short days hasten flowering, particularly for late maturing varieties. The critical photoperiod for bud initiation is around 14 hrs. Subsequent photoperiods influence blossoming. At 16 to 18 hrs, soybean flowers do not open but maximum floral blossoming occurs at 10 to 13 hrs photoperiod. Night temperatures also influence floral initiation. Soybean in India is often cultivated during *kharif*, however, supplemental irrigation to overcome long dry spell is generally practiced. Soybean can come up well in areas with rainfall varying from 600 to 1000 mm. Distribution of rainfall during the crop season is more important than the total amount.

Soil

Soybean can be grown in variety of soil types. However, a well-drained, sandy loam to clay soils with medium water holding capacity, rich in organic carbon and levelled fields with near neutral pH is ideal for harnessing maximum soybean yield. Soil with excessive salts / sodium, acidic and poorly drained soil are not suitable for soybean. It is noteworthy that the crop is predominantly grown under black cotton areas. In India, soybean cultivation in the hilly regions of the Himalayan states has a rich history dating back centuries.

Global Production Status

113 countries Produced 395.12 MT Soybean in 2023-24. (USDA). 5 Countries produced 89% of world's total soybean. India ranked fifth in total production. 113 countries produced 395.12 MT Soybean in 2023-24. (USDA). 5 Countries produced 89% of world's total soybean. Brazil, USA, Argentina, China and India are the major soybean producers with production of 120.7, 116.9, 43.8, 20.3 and 12.9 million metric tons and productivity of 2951, 3330, 2763, 1980 and 1069 kg/ha (FAOSTAT, 2022). These five countries produced 89% of world's total soybean production. In India, a record 14.98 mt soybean production was achieved during 2022-23 from 12.1 mha acreage.

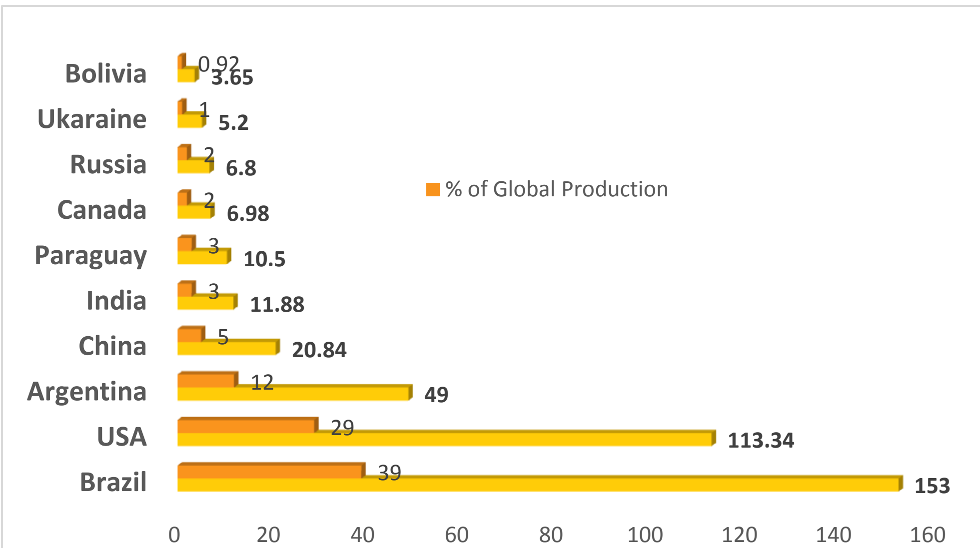

Fig: Top 10 Soybean Producing Countries, 2023

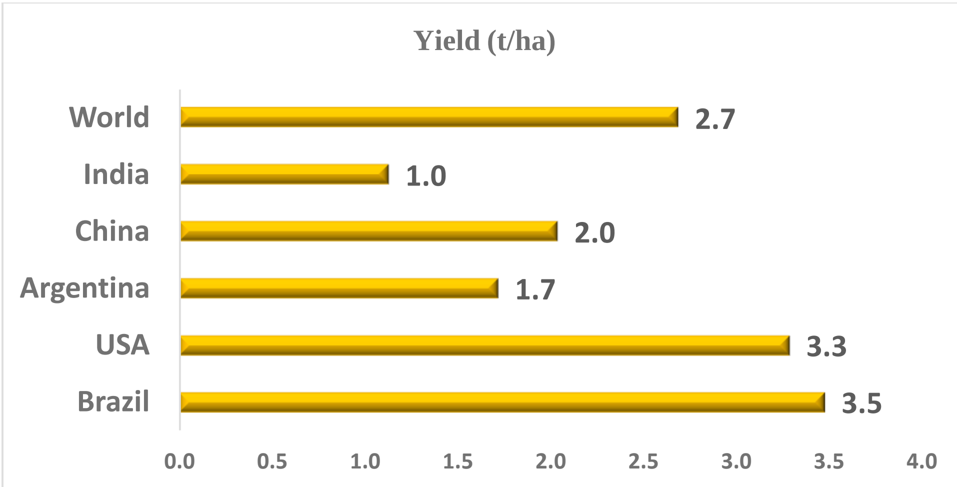

Fig 2. Productivity in major soybean countries.

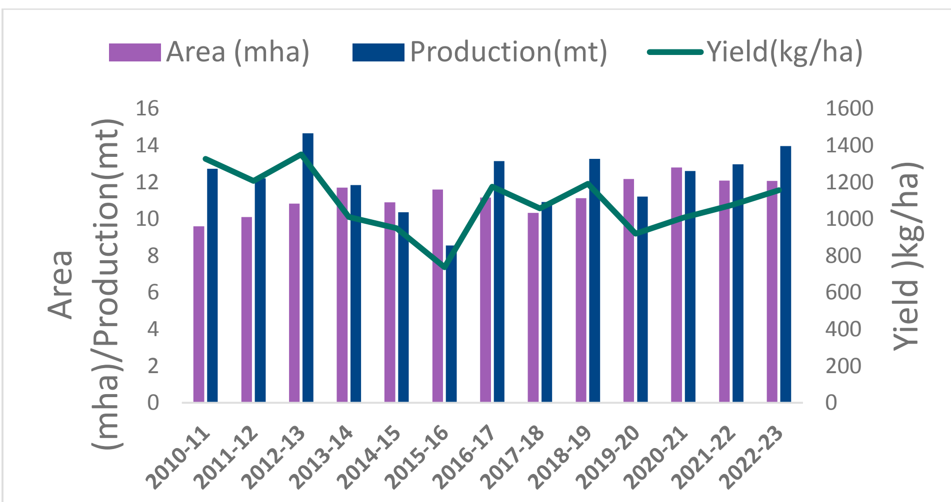

Fig 3. Trends of Area, Production and Yield of soybean in India during last decade.

Source: Various issues of Area and Production of "Principal Crops in India" Department of Extension and Statistics, Government of India: Agricultural Statistics at a Glance

Soybean growing region in India are mainly concentrated in 3 states, Madhya Pradesh, Maharashtra and Rajasthan contributing 45, 38 and 10.0% to area and 42, 42 and 7% to production, respectively. The average yield in India is about 11-12 q/ha.

Crop Improvement

In soybean breeding programs, both classical (traditional) breeding methods like phenotypic selection and controlled crosses are used alongside molecular breeding techniques like marker-assisted selection (MAS), genomic selection and genetic transformation to identify and incorporate desirable traits into new cultivars, significantly accelerating the breeding process and enhancing genetic improvement potential.

Classical (traditional) breeding methods

Phenotypic selection: Selecting plants based on visible traits like yield, maturity time and disease resistance etc.

Controlled crosses: Deliberately crossing specific parent lines to combine desired traits.

Pedigree selection: Tracking the genetic lineage of plants to identify superior lines. A breeding method that involves selecting plants with desired traits.

Single seed descent: A hybridization technique that involves crossing parental lines and selecting progeny over multiple generations. A hybridization technique that involves crossing parental lines and selecting progeny over multiple generations.

Backcrossing: A hybridization technique that involves crossing parental lines and selecting progeny over multiple generations.

Molecular Breeding methods

Marker-assisted selection (MAS): Using molecular markers linked to specific genes to identify desirable genotypes early in the breeding process.

Genomic selection (GS): Predicting the genetic merit of individuals based on their whole-genome marker profiles.

QTL mapping: Identifying chromosomal regions associated with quantitative traits.

Genetic transformation: Introducing new genes into a plant's genome to confer specific traits like pest resistance.

Genome editing: Precisely modifying specific genes within the genome using techniques like CRISPR-Cas9

Speed breeding: Artificial control of photo thermal conditions: A method that involves using artificial control of photo thermal conditions to advance generation advancement.

Objectives of Breeding

High yield: Breeding programs aim to develop varieties that produce more soybeans per hectare.

Disease resistance: Breeding programs aim to develop varieties that are resistant to diseases like Pod blight, Charcoal rot, Rhizoctonia Arial Blight, Frog eye leaf spot, Leaf rust, Soybean Mosaic Virus (SMV), Soybean rust and Bacterial blight.

Pest resistance: Breeding programs aim to develop varieties that are resistant to pests like Stem fly, Girdle beetle, Bihar hairy caterpillar etc.

Food: Food grade variety free from anti nutrient compound and vegetable soybean variety with yield & nutritional value.

Quality traits: High oil content, high oleic acid content, high protein quality and seed size.

Stress tolerance: Breeding programs aim to develop varieties that can tolerate, Drought, flood (excess moisture) and high temperature etc.

Early maturity: Breeding programs aim to develop varieties that mature early.

Wider adaptability: Breeding programs aim to develop varieties that can grow in a wider range of conditions.

Benefits of combining classical and molecular breeding in soybean

Increased efficiency: Molecular markers allow for faster identification of desired genotypes, accelerating the breeding process.

Improved accuracy: Molecular markers provide more precise information compared to phenotypic selection alone, leading to better selection decisions.

Broader genetic diversity: Accessing genetic variation from a wider range of germplasm through molecular techniques.

Development of complex traits: Combining classical and molecular approaches enables the improvement of traits controlled by multiple genes.

The Remarkable Journey of Soybean Cultivation in India

Improved varieties, in any crop are essential for achieving higher productivity. Unlike, traditional varieties, these varieties are developed with specific characters like higher yields, tolerance to various biotic and abiotic stresses and suitable maturity duration for a particular crop rotation. Soybean is a short-day plant and is highly sensitive to day length. This results in narrow adaptability of individual soybean varieties across latitudes and planting times. The history of development of soybean varieties in India is comparatively new. The introduction of soybean started in 1963 with trials conducted at Pantnagar and Jabalpur agricultural universities, using varieties from USA. Promising varieties in these trials like Bragg, Clark 63 were released for cultivation. During 1980-90, these varieties were used as parent to develop further improved varieties for Indian conditions. The varieties developed after 1990 utilized breeding lines and indigenously developed varieties in hybridization programmes. Some of these varieties are land races or selections from them and have been known since long. These are (a) a pool of black seeded indigenous varieties such as *Bhat* or *Bhatmash* which represent the habitat of northern hill region but are also cultivated in scattered pockets of central India under the names such as *Kalitur* and *Kala Hulga*, (b) yellow seeded pool of northern or Tehri-Garhwal region presently represented by JS 2 and (c) a pool of indigenous varieties with small and yellow-seeded varieties represented by Type 49. In Kumaon hills, black soybean locally known as bhat, was grown while in North Eastern India viny type yellow seeded cultigens were grown. These land races have given rise to three varieties viz., Kalitur, JS-2 and Type-49. This includes central as well as state releases. Most Indian varieties have been developed using exotic parents. Depending on their breeding history, the Indian varieties can be grouped into two. The first group comprises varieties viz. Bragg, Lee, Improved Pelican, Hardee, Monetta, Shilajeet, Co 1, Gujarat Soy 1, Gujarat Soy 2, VL Soy 2 and JS 71-05 which owe their evolution to direct selection from exotic and indigenous material. The second group comprises a bulk of the Indian varieties which were developed through hybridization and mutation in/among the varieties of the first group. The traditional breeding techniques have been used for improvement to yield and other traits. In India, selection cycle 1 cultivars (developed by selection in exotic introduced material) registered 4 times higher yield and harvest index than local variety Kalitur (Karmakar and Bhatnagar. 1996). Selection cycle 2 cultivars (developed from hybridization among exotic and local material) had 19 and 16% higher yield and harvest index, respectively over selection cycle 1 cultivars. Assessment of yield gain in Indian varieties for 1969 to 2008 revealed 103% yield improvement @2.6% per year.

The ideal soybean plant for high yield should have determinate or semi determinate growth habit (suited to short growing season), erect and non-lodging, long juvenile period, broad leaves for maximum light interception, rapid LAI development and seed fill duration and maturity duration of 95-100 days. Faster rate of LAI development allows for maximum light interception and curtails weed growth. Most of the improved varieties can yield 3-4 t/ha. The important yield contributing characters are high number of pods per unit area, seeds/pod and seed size. Major drivers for yield increase in soybean varieties have been increased number of seeds per area, number of seeds per pod, number of pods per area, reduced lodging. At present the total number of released/notified varieties in India is 187.

Indian Soybean Varieties: A Breakthrough in Crop Productivity

The development of improved crop varieties has revolutionized the agricultural landscape in India. By incorporating specific traits, Indian breeders have successfully created advanced soybean cultivars that outperform traditional varieties. These refined varieties boast enhanced yields, improved tolerance to biotic and abiotic stresses and optimized maturity durations tailored to specific crop rotations.

Food Grade Soybean Varieties

Notably, Indian breeders have achieved significant success in developing food grade soybean varieties that are free from anti-nutritional factors such as kunitz trypsin inhibitor and lipoxygenase, which are responsible for off-flavors in soybeans. Some notable food grade varieties include: NRC 127, NRC 132, NRC 142, NRC 147, NRC 150, NRC 152, NRC 181, NRC 197 & MACS NRC 1667.

Vegetable Type Soybean (Edamame)

In addition to food grade varieties, vegetable type soybean, commonly known as Edamame has been released for cultivation. Some notable vegetable type soybean varieties are: Swarna Vasundhara (for Jharkhand), Karune (KBVS 1) (for southern region) and NRC 188 (for central zone).

Disease-Resistant Varieties

To address regional disease concerns, Indian breeders have developed disease-resistant soybean varieties, including:

Rust Resistant Varieties: DSb 23, DSb 34, KDS 753 and KDS 726 (for southern zone)

Yellow Mosaic Disease Resistant Varieties: SL 958, SL 979, NRCSL 1, SL 1028 and SL 1078 (for northern zone).

Charcoal Rot Resistant Varieties: JS 20-69, AMS 100-39, AMS 5-18 and JS 20-98.

Rhizoctonia Aerial Blight Resistant Varieties: NRC 150, JS 20-69, PS 1347 and JS 20-98.

Indian Bud Blight Resistant Varieties: NRC 128 and RSC 10-46.

Early maturing varieties

The soya state of India Madhya Pradesh farmers demands early maturing varieties (90 days) so that they can grow three crops each year. To cater to the demand for early maturing varieties in Madhya Pradesh, Indian breeders have developed several options, including: NRC 150, NRC 130, NRC 131, NRC 138, JS 95-60, JS 20-34, JS 22-12, JS 22-16, JS 23-03, JS 23-09, NRC 165 and NRC 157 etc. These early maturing varieties have an average yield ranging from 15-19 quintals per hectare. Indian breeders have also developed varieties that can withstand drought and excessive moisture stress conditions, including :1. drought tolerant variety: NRC 136 (for eastern zone and Madhya Pradesh).2. Excessive moisture stress tolerant varieties: JS 97-52, NRC 128.

High Yielding Varieties

To meet the demand for high yielding soybean varieties, Indian breeders have developed several options, including, NRC 142, JS 20-69, JS 20-98, JS 22-12, NRC 150, RVS 24, JS 21-72, JS 22-16, RVSM 2011-35, RSC 10-46, RSC 11-07, JS 23-03, JS 23-09 etc. These refined, Indian soybean varieties have the potential to significantly enhance crop productivity, making them an attractive option for farmers and agricultural stakeholders in India.

Table. Latest Indian soybean varieties recommended for different zones of India

States	Recommended Varieties
Madhya Pradesh	NRC 131, NRC 136, NRC 157, JS 20-69, JS 95-60, Raj Soya 18 (RVS-18), JS 20-29 and RVS 2001-4.
Madhya Pradesh, Bundelkhand region of Uttar Pradesh, Rajasthan, Gujarat, North-West region of Maharashtra	NRC 150, NRC 165, JS 23-03, JS 23-09, JS 22-12, JS 22-16, NRC 181, NRC 188, NRC 152, Him Palam Soya (Himso 1689), JS 21-72, RVSM 2011-35 (RVSM-35), NRC 138 (Indore Soya -138), AMS 100-39 (PDKV Amba), RVS 76 (Raj Vijay Soybean), NRC 142 (Indore Soya-142), MACS 1520, NRC 130 (Indore Soya- 130), RSC 10-46, RSC 10-52, AMS-MB-5-18(Suvarna Soya), JS 20-116, JS 20-94, JS 20-98, NRC 127, NRC 86, JS 20-34 and JS 97-52.
Chhattisgarh, Jharkhand, Bihar orissa and West Bengal	RSC 11-35, MACS 1407, MACS 1460, NRC 132, NRC 147, NRC 128, NRC 136, NRCSL 1, RSC 11-07, RSC 10-46, AMS 2014-1 (PDKV Purva), DSb 32, JS 20-116, KDS 753 (Phule Kimaya) and Kota Soya-1 (RKS 113).
Punjab, Haryana, Delhi, North Eastern Plains of Uttar Pradesh, Plains of Uttarakhand and Eastern Bihar	PS 1670, SL 1074, SL 1028, NRC 128, SL 979, SL 955, Pant Soybean 26 (PS 1572), PS 1477, SL 958, Pusa 12, PS 1347 and SL 688.
Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Southern Part of Maharashtra	MACS NRC 1667, Karune (KVBS-1), NRC-142 (Indore Soya 142), MACS 1460, AMS 2014-1, RSC 11-07, NRC 132, NRC 147, DSb 34, KDS 753 (Phule Kimaya), DSb 28 (DSb 28-3), KDS 726 (Phule Sangam), AMS 1001 (PKV Yellow Gold), MAUS 612, KS 103, DSb 23 (DSb 23-2), MACS 1281, KDS 344 (Phule Agrani), DSb 21, MAUS 162 and MACS 1188.
Maharashtra	MAUS 725, Phule Durva (KDS 992), AMS 1001 (PKV Yellow Gold) and MAUS 158.

Telangana	ALSB-50 (Adilabad Indore Soya Chikkudu-1) and Basar.
Karnataka	KBS 23 and DSb1.
Himachal Pradesh and Hill region of Uttarakhand	VL Soya 99 (VLS 99), Pant Soybean 25 (PS 1556), VL Soya 89, VL Soya 59 and VL Soya 63.
Jammu and Kashmir (J&K)	Shalimar Soybean-1, Shalimar Soybean-2 and (SKUAWSB-101).
Uttarakhand	Black Soybean (Bhat 202), PS 1521, Pant Soybean 23 (PS 1523), Pant Soybean 21 (PS 1480), PS 1368, VL Bhat 201, VL Soya 77 and VL Soya 65.
Meghalya	Umiam Soybean-1.
Jharkhand	Birsa Soya 4, Birsa Soya 3 (BAUS 40) and Swarna Vasundhara.
Chhattisgarh	RSC 11-15 and Chhattisgarh Soya 1.

Existing Technologies

- 9 Novel food grade biofortified varieties identified and released i.e., Null KTI & Lox2 i.e., NRC 127, NRC 132, NRC 142, NRC 147, NRC 150, NRC 152, NRC 181, NRC 197 and MACSNRC 1667.
- In situ moisture conservation technology and related mechanization for soybean-based cropping system (BBF, FIRBS R&F) have been developed and commercialized.
- For the management of Charcoal rot disease, seed treatment with Thiophanate Methyl 450 g/l + Pyraclostrobin @ 3g/kg of seed followed by foliar spray with Tebuconazole + Sulphur @ 1000 g/ha at 45 and 60 days after sowing was most effective.

Farm equipment/machinery developed/introduced

- Broad bed furrow (BBF) Seed drill
- Furrow irrigated raised bed system (FIRBS)
- Subsoiler
- Sweep seed drill
- Ridge fertilizer drill cum seed planter
- Broad bed furrow (BBF) planter
- Soybean Seed planter
- Single ridge seed planter
- Soybean seed drill cum planter two in one

Cultivation Practices

Land preparation

Deep ploughing is essential during summer, after harvesting the *rabi* crops. This facilitates exposing the hibernating insects to extreme heat and predatory birds as well as movement of nutrients and infiltration of soil water. Therefore, one deep ploughing once in 3-4 years, otherwise one normal ploughing in summer followed by 2 crisscross harrowing or cultivation for breaking of soil clods will make ideal seed bed for a good soybean cultivation is recommended. Also, sub-soiling operation once in 4-5 years at an interval of 10 meter, break the compactness of the sub-soil and facilitate infiltration of rainwater which is useful for un-interrupted crop growth even during drought period also. Soon after arrival of monsoon, the land may be prepared by harrowing followed by planking to level the field. If soybean is planted in low laying area, make the drainage channel for drain out the excess water from field.

Conservation / Reduced / Minimum tillage

Crop residue management has recently received amplified consideration in the quest for sustainable agriculture and its impending influence to soil fertility and health. The efficiency of conservation tillage to improve water storage is comprehensively recognized. No-till practices and conservation tillage for soybean are wide-spread in areas of highly-erodible soil and research has shown that soybean yields remain the same or increase with decreased tillage Conservation tillage (< 30% crop residue left on the soil surface) is a popular compromise, especially in herbicide tolerant soybean production. The minimum tillage system in a soybean-based cropping system brought improvement in physical, hydro-physical, nutrients solubility equilibrium and biological properties of soil was observed, together with the rebuilt of structure and increase of water permeability of soil which resulted in more productive soil, better protected against wind and water erosion and needing less fuel for preparing the seed bed. Similarly, minimum/reduced found suitable for soybean and soybean-based cropping systems without compromising yield levels with reduced cultivation cost and higher energy use efficiency and more sustainable than conventional tillage. A resource efficient crop establishment technology i.e. Permanent broad bed furrow technology (PBBF) for soybean-based cropping systems developed by ICAR- Indian Institute of Soybean Research, Indore which entails the permanent broad bed furrow (PBBF) crop establishment method with residue (50% soybean and chickpea residue retained during *winter* season and 30% for wheat and maize residue retained during *rainy* season) and without residue retention is the sustainable technology to improve the crop productivity under changing climate scenario for soybean-wheat and soybean-maize cropping systems in India. Direct sowing of soybean in *rainy season*, wheat and maize in *winter* season through broad bed furrow (BBF) machine enhances crop productivity, reduced the cost of cultivation and improves soil health.

Seed germination test

Farmers are advised to check germination status of seed purchased/available seed with them before sowing. To ensure optimum plant population and thereby good yield, minimum 70% germination is essential. This can be done through sowing of 400 seeds in 4 m x 4 m plot and it is kept moist. From 5-8 days' emergence is counted everyday till the count is stabilized. The germination test can also be done by placing seeds on sand in a tray soaked with 50% water and keep it moist up to 7-8 days.

Table. Indian Minimum Seed Certification Standards for Soybean

S.No.	Item		Foundation	Certified
1.	Pure seed	Minimum	98%	98%
2.	Inert matter	Maximum	2.0%	2.0%
3.	Other crops	Maximum	Nil	10/kg
4.	Weed seed	Maximum	5/kg	10/kg
5.	Other variety of same crop	Maximum	10/kg	40/kg
6.	Germination including hard seed	Minimum	70%	70%
7.	Moisture	Maximum	12%	12%
8.	Moisture (for vapour) proof containers	Maximum	7%	7%

Seed treatment and seed inoculation

Seed treatment is very important operation in soybean considering number of fungal, bacterial and viral diseases which causes considerable reduction in plant population and thereby yield. Hence, farmers are advised to treat soybean seed at the time of sowing using premixed fungicides like Azoxystrobin 2.5% + Thiophanate Methyl 11.25% + Thiamethoxam 25% FS (10 ml/kg seed) or Penflufen + Trifloxystrobine 38 FS (1 ml/kg seed) or Fluxapyroxad 333 g/L FS (1 ml/kg seed) or Carboxin 37.5 + Thiram 37.5 (3g/kg seed) or Trichoderma viride @ 8-10 g/kg seed. Once the seed treatment with fungicides and insecticide is done, farmers are advised to inoculate the treated seed with bio-inoculants like *Bradyrhizobium japonicum* and Phosphate Solubilizing Micro-organism (PSM) each @ 5 g/kg seed immediately before sowing. If the soybean is grown in non-traditional/new area, they should increase the quantity of bio-inoculants to at least 10-15 g/kg seed. Farmers are also advised to follow correct sequence of seed treatment with recommended fungicides followed by insecticide and seed inoculation (FIR). Similarly, seed treatment with fungicides as well as seed inoculation in mixed form simultaneously should be avoided as the micro-organisms present in the culture are destroyed. However, if *Trichoderma viride* must be used, all the three bio-agents can be used in one go after seed treatment with insecticide.

Sowing time, spacing and seed rate for soybean

Soybean being a photosensitive crop, hence time of planting is very important feature for achieving the decent yield. Too early planting promotes high vegetative growth, whereas late planting restricted the vegetative growth and in both the cases yield declines**.** Since soybean is a rainfed crop grown during *kharif* season, it should be sown only after the arrival of monsoon and sow the crop only after 100 mm rainfall is received to ensure germination and development of the plant till next spell of rains. Appropriate sowing time in India is between 15 June -5th July.

Seed rate

Soybean seed rate and germination percentage are inversely proportional to seed size. The small seeded varieties are excellent in germination compared to bold seeded varieties. Therefore, the seed rate should be modified accordingly to achieve optimum plant population and yield. The recommended seed rate for soybean varieties having small seed size (<10 g) is 60 to 65 kg/ha, medium seed size is 65 to 70 kg/ha while for bold seed (> 12 g) varieties), the seed rate should be increased to 75 kg/ha.

Spacing

The optimum row to row (inter row spacing) is of 30 cm (for short duration and dwarf / short stature varieties) and for medium and long duration varieties, it is 45 cm and plant to plant spacing (intra row spacing) of 5-10 cm with 3 cm sowing depth. The bold seeded varieties be placed at shallow depth. The narrow row spacing (30 cm) showed an edge over wider row spacing (45 cm) with respect to seed yield.

Plant population

The recommended 'row to row' and 'plant to plant' spacing should be followed. The seed is a living entity and should be properly grown to be able to develop a new healthy plant in the next generation. If the plant population is not maintained or uniform plant spacing is not followed there will be competition for nutrient for growth and seed development. Scarcity of nutrient may cause deficiencies of important and critical biological units e.g. enzymes and mineral co-factors of enzymes with cause failure of germinability of seed produced. The optimum plant population for a virtuous harvest of soybean is about 0.4 to 0.45 million plants/ha for indeterminate varieties and 0.55 to 0.60 million plants/ha for determinate varieties.

Spacing

The optimum row to row (inter row spacing) is of 30 cm (for short duration and dwarf / short stature varieties) and for medium and long duration varieties, it is 45 cm and plant to plant spacing (intra row spacing) of 5-10 cm with 3 cm sowing depth. The bold seeded varieties be placed at shallow depth. The narrow row spacing (30 cm) showed an edge over wider row spacing (45 cm) with respect to seed yield. The sub-or super-optimal plant population is one of the major restraints for poor soybean yield. Present day improved machineries for soybean seed are developed like soybean seed drill or soybean seed planter where desired plant spacing is achieved properly. Such machines should be utilized for sowing of seed production plots. Proper spacing of plants is not only desirable for proper seed development, it also helps in management of insects and diseases.

Sowing techniques

With increased mechanization and availability of tractor drawn seed drills, use of multi-crop seed drills having adjustable row-to-row distance and seed rate as per the requirement of the crops. Normally these seed drills have provisions of flat sowing 5-9 rows of soybean crop with adjustable row to row distance of 14-18 inches. Looking to the prevailing climatic aberrations and erratic rainfall, following methods can be used to mitigate the adverse climate.

a) **Broad Bed Furrow planting:** The BBF seed drills have a provision of opening the irrigation channels after an interval of 4-5 rows. The furrow mechanism is fitted on both the ends of BBF seed drills.

b) **Ridges & Furrows planting (FIRB (furrow irrigated raised bed):** Seed drills are now available for sowing each row/paired rows on ridges.

Nutrient management

Soybean being a protein rich and oil yielding crop requires effective nutrient management. Soybean is moderately exhaustive crop. Vertisols of central India under soybean-wheat system are largely deficient in N, P, S and Zn. Balanced nutrients application ensures better yield performance of soybean. The integration of Farm Yard Manure (5-10 t/ha) or Compost (5 t/ha) or Poultry manure (2.5 t/ha) along with the basal application of Nitrogen, Phosphorus, Potash and Sulphur generally provides balanced nutrition for harnessing the yield potential. In soybean, use of fertilizers is recommended only as basal application placement at 5 cm in the soil. The micronutrients (Zn and Fe) play significant role in soybean yield enhancement. Therefore, under micronutrients deficit soil application of $ZnSO_4$ $7H_2O$ + $FeSO_4$ $7H_2O$ @ 25 + 50 kg ha^{-1} as basal to soil at the time of sowing. Further, foliar application of $ZnSO_4$ $7H_2O$ + $FeSO_4$ 7 H_2O (0.50% + 1.0%) at before flowering, maximum flowering and seed filling stage can be used as corrective measure to reduce micronutrient deficiency in soybean with enhanced seed yield.

Water management

Adverse climatic events like delayed monsoon arrival, long dry spells, rainfall of high intensity and rains during maturity stage have been increasingly experience during recent years. The drought or moisture stress particularly during critical growth stages like seedling, flowering and pod filling causes significant yield losses in soybean. Farmers are advised to sow the crop using BBF/Ridge Furrow methods facilitating dual advantage of moisture conservation/drainage.

Weed management

Weeds are considered one of the most detrimental pests in soybean (Vivian et al. 2013). About, 37% of global soybean production is affected by weeds (Oerke and Dehne 2004). Uncontrolled weeds in soybean causes about 25-85% yield losses. Further, yield loss up to 68% has been reported depending on time of weed occurrence, duration of weeds presents in the field, nature and intensity of weeds in soybean (Billore et al. 1999). Weed density, type of weeds and growing conditions are factors that affect the degree of competition between weeds and the crop.

This can be done using mechanical, agronomical and chemical weed control. The critical period for weed control in soybean is from sowing to 40-45 days after sowing (Dhakad et al. 2022). Therefore, the weeds should be managed during this period. Two hand weeding at 20 and 40 days after sowing (DAS) or intercultural operation (Hand hoe/*Dora/Kulpa*) using bullock drawn/tractor drawn implements during critical period is found beneficial. *In situ* mulching of weeds at 30 DAS is also beneficial for controlling weeds as well as to conserve soil moisture and add the organic matter in the soil. The weed management during critical period through manual and physic-mechanical methods are not feasible due to continuous rains particularly in vertisols, then one can opt for chemical weed control. For soybean crop, herbicides are recommended into three categories based on time of application includes (1) pre-plant incorporation (PPI) herbicides, (2) pre-emergence (PE) herbicides and post-emergence (PoE) herbicides. The detailed information about the time of application, active ingredient and quantity is given in Table Select any one of the recommended herbicides considering the type of weeds (monocot/dicot) prevalent in field. Pre-mix formulations are also recommended for broad spectrum weed control in soybean. Instead of using same herbicides every year, herbicide rotation is desirable. Carry out inter-culture operation (*dora/kulpa*) at 20-25 DAS where PPI/PE herbicides are used. To control the weeds effectively, it is very necessary to make the appropriate spraying solution and its uniform spray on entire area/weed foliage. Hence, use 500 litre of water per hectare along with recommended quantity of herbicides using *Flat Fan* or *Flood Jet nozzle*.

Table. Commonly used herbicides in Soybean.

Type of herbicide	Chemical Name	Dose (ha)	Quantity (per ha)	Targeted weeds
Pre-Plant Incorporation (PPI)	Pendimethalin 30% EC + Imazethapyr 2% EC	750-50 g to 900+60g	2.5-3 l	G+BLW
Pre-emergence (PE)	Diclosulum 84 WDG	22 g	26 g	BLW
	Sulfentrazone 48 SC	360 g	750 ml	G+BLW+S
	Pendimethalin 30 EC	1 kg	3.25 l	G+BLW
	Metribuzin 70WP	0.025	0.75- 1 kg	G+BLW
	Sulfentrazone (39.6%) + Clomazone (50%) EC	725 ml	2.5 l	G+BLW
	Pyroxasulfone 85 WG	127 g	150 g	G+BLW
Early Post emergence (EPOE)-10-12 DAS	Chlorimuron ethyl 25 WP+ Surfactant (0.2%)	9 g	36 g	BLW+S
	Bentazone 48 SL	960 g	2.0 l	BLW+S
Post emergence (POE)- 15-20 DAS	Imazethapyr10 SL	100 g	1.00 l	G
	Quizalofop-ethyl 5 EC	50 g	1.00 l	G
	Quizalofop-p-ethyl 10 EC	37.5 - 45 g	375-450 l	G
	Haloxyfop R Methyl 10.5 EC	105 - 131.5 g	1-1.25 l	G
	Imazethapyr 70% WG + Surfactant	70 g	100 g	G+BLW
	Fomesafen 11.1% + Fluazifop-p-butyl 11.1 W/w Sl	-	1-1.25 l	G
POE Pre-mix formulations (15-20 DAS)	Imazethapyr (35%) + Imazamox (35%) WG	70	100 g	G+BLW
	Propaquizafop (2.5%) + Imazethapyer (3.75%)	50-75g	2.0 l	G+BLW
	Sodium Aceflourofen (16.5%) + ClodinafopPropargyl (18%) EC	-	1.0 l	G+BLW

Note: G: Grasses, BLW: Broad Leaved Weeds and S: Sedges

Application of pre-emergence or pre-plant incorporation herbicides or post emergence herbicides and two hand weeding at 20 and 40 DAS were found equally effective to overcome the weed problem in soybean (Billore et al. 1999). Soybean is smothering crop which take care of weeds after critical period. The smothering effect depends on the plant stature.

Integrated weed management

Integrated weed management involves a combination of control methods in a view to minimize the use of herbicides and their adverse impact on the environment. It is always advantageous to combine whichever method used with cultural practices that favour soybean growth, making the crop more competitive against weeds (da Silva et al. 2013). The crop rotation, deep ploughing in summer followed by one harrowing before sowing and need based recommended dose of herbicide use either PPI or PE herbicides (cyclic selection) and one inter-culture operation at 20 to 25 days after sowing (DAS) found beneficial to effective weed control in soybean. Further, pre-emergent herbicide followed by one hand weeding at 40 DAS is also recommended as integrated weed control measures in soybean.

Strategies to mitigate drought/long dry spells in soybean

Soybean is, by and large, grown as a rainfed crop during kharif season. Since last few years, the distribution of rainfall was found to be uneven and erratic. Farmers are advised to use BBF or Ridge and Furrow for soybean planting to mitigate the climatic adversities. In case of flat sowing, if there is a long dry spell, particularly during critical growth stages affect the yield adversely. Hence, farmers are also advised to apply lifesaving irrigation during these critical stages to sustain yield levels. Farmers should also spray the crop with anti-transparent like potassium nitrate (1%) or Magnesium Carbonate/glycerol (5%) during long dry spells to save the crop from drought. Alternatively, farmers can use crop straw @ 5 t/ha after emergence of soybean crop for mitigating the adverse effect of drought.

Plant Protection

Soybean crop suffers from diseases at pre and post emergence as well as later stages of crop growth till maturity, which are caused by fungi, bacteria, viruses, nematodes and mycoplasma. The average losses from these diseases are about 12-20%. Some major soybean diseases and their control measures are described below.

Anthracnose or Pod blight

Disease is caused by *Colletotrichum truncatum* and occurs in severe form under high temperature and humidity. It is a major disease distributed throughout the India and can cause 16-25% damage but sometimes loss in yield can be up to 100%. Pathogen survives in seed and in crop residues. Crop is attacked at all stages of growth but symptoms are evident in the early reproductive stage on stems, petioles and pods.

Control measures

i. Cultivation of resistant varieties

ii. Seed treatment with Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed or Carbendazim 25% + Mancozeb 50% WS @3g/kg seed or Penflufen 13.28% w/w + Trifloxystrobin 13.28% w/w FS @ 1 ml/kg seed.

iii. At initiation of disease, symptom like veins necrosis on lower side of upper leaves appears. During this stage spraying of Thiophanate methyl @ 2 g/L of water or Tebuconazole @ 1.25 mL/L of water

Rhizoctonia aerial blight

Rhizoctonia solani causes aerial blight of soybean. In addition, it also causes seed rot, seedling rot, root and stem rot. Disease is favoured by continuous wet conditions and is a major disease all over the India. Severity of disease increases with monoculture of soybean. Pathogen is soil and seed borne and sclerotia serve as primary inoculum.

Control measures

i. Cultivation of disease resistant/tolerant varieties

ii. Avoidance of excess plant population.

iii. Seed treatment with Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed or Carbendazim 25% + Mancozeb 50% WS @3g/kg seed or Penflufen 13.28% w/w + Trifloxystrobin 13.28% w/w FS @ 1 ml/kg seed.

iv. One spray of Carbendazim or Thiophanate methyl (0.1%) is found very effective.

Charcoal rot

It is soil as well as seed borne disease, caused by *Macrophomina phaseolina*. dry conditions, less soil moisture and temperature ranging from 25 to 35 ºC favour the disease.

Control measures

i) Seed treatment with Carbendazim 25%+ Mancozeb 50% WS @ 3 ml/kg seed or Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed.

ii) Irrigation during low soil moisture (drought condition) especially at the time of flowering to pod-fill stage.

iii) Crop rotation with cereals or mixed cropping. Balanced use of fertilizers and proper seed rate.

iv) Use of tolerant varieties.

v) Sowing at raised bed or broad bed with basal application of Zinc Sulphate @ 25 kg/ha along with Boron @ 0.5 kg/ha reduces the infection of charcoal rot.

Rust: *Phakopsora pachyrhizi* is the causal organism of Rust. This disease is severe at the temperature range of 22-27^{o}C accompanied with 80-90% relative humidity and leaf wetness. A yield loss ranging from 40 to 80% has been reported from recent rust epiphytotics in India. Pathogen survives mainly in collateral hosts but also in crop residues remain with the seed.

Control measures

i. Deep ploughing during summer.

ii. No summer and *rabi* cultivation.

iii. Roguing and burning of infected plants, crop and crop residues.

iv. Two to three-year's crop rotation in rust hot spot areas.

v. Cultivation of rust tolerant varieties.

vi. Two to three sprays of hexaconazole, Kresoxim methyl or Oxycarboxin @ 0.1% are found effective.

Collar rot: It is a soil borne, caused by *Sclerotium rolfsii*. Hot and humid conditions favour the disease.

Control measures:

i) Seed treatment with vitavax @3g/kg or with Trichoderma @ 5 g/kg seed.

ii) Field sanitation, rouging and burning of infected plants check spread of disease.

iii) Deep summer ploughing to a depth of 15-20 cm which helps in reducing the pathogen as the sclerotia perpetuate through soil, crop residue and weeds.

iv) Use tolerant variety.

Yellow Mosaic disease: Causal organism: *Mung Bean yellow Mosaic Virus (MYMIV)*

Control measures:

i) Cultivation of resistant varieties.

ii) Seed Treatment with Thiamethaxam 30 FS @ 10 ml/Kg or Imidachloprid 48 FS @1.25 ml/kg seed.

iii) Spray Thiamethoxam 25WG @ 100g/ha at 35 DAS.

iv) Use balanced dose of fertilizer.

v) Rouging and burying of infected plants.

vi) Follow clean cultivation practices.

Insect-pests of soybean

Soybean crop is infested by several insects across the world but in India Stem fly (*Melanagromyza sojae*, Tobacco caterpillar (*Spodoptera litura* Fabricius), Green semiloopers, Girdle beetle (*Obereopsis brevis*), Pod borer (*Helicoverpa armigera*), Whitefly (*Bemisia tabaci*), Leaf miner (*Aproaerema modicella*), Bihar hairy caterpillar (*Spilosoma oblique*), White grub, *Holotrichia consanguinea* are major insect-pests of soybean. They infest the crop in various stages.

Management of soybean insect-pests

1. Use of balanced fertilizer: The recommended dose of nitrogen, phosphorus, potash and sulphur fertilizers is 20:60-80:20:20 respectively at the time of sowing only. Avoid excessive nitrogenous fertilizers because it increases the insect infestation more.

2. Deep summer ploughing: After harvesting of rabi crops deep ploughing up to 8-10 inch should be done so that hibernating insect-pests are exposed to intense sun light and died. Some of them are eaten by insectivores' birds like Indian Mynah, ducks etc.

3. Use insect resistant/tolerant varieties.

4. Use bird perches at 8-10 locations in the field facilitating easy access for birds to feed on insect larvae.

5. Regular monitoring of the field and destruction of egg mass of *Spodoptera litura* and bihar hairy caterpillar in early stage of the crop.

6. Collection and removal stubbles of previous crop.

7. Use of light trap to catch the harmful insect.

8. Use of recommended seed rate @ 60-80 kg/ha.

9. Use of pheromone trap of *Spodoptera litura* (Spodolure/litlure) and *Helicoverpa armigera* (helilure) @ 5-10 pheromone traps/ha in the field for monitoring purpose.

10. Use of nuclear Polyhedrosis virus of 250 LE/ha *Spodoptera litura* (SlNPV) and *Helicoverpa armigera* (HaNPV) @ 25 LE/ha in the field for monitoring purpose.

11. Use of Bio-pesticides like *Bacillus thuringiensis* Bt bacteri*a* @ 1 litre /ha and *Beauveria bassiana* fungus @ 1 kg/ha.

12. Use of trap crops like Daincha for girdle beetle, Suva for defoliators and marigold for soybean pod borer on the field boundaries which attract the insect and spray only it to protect the soybean crop from losses.

Chemical control

Applications of following recommended insecticides need based and judiciously. Use only chemical insecticides, when their populations cross the economic threshold level (ETL). The ETLs of some important insect-pests of soybean has been given in below:

Table. Economic threshold levels (ETL) of some soybean insect-pests.

Sl. No.	Name of Insect-Pest	Economic Threshold levels
1.	Blue beetle (*Cneorane* spp.)	4 beetle/meter of row length at 7-10 days old crop stage
2.	Semiloopers (*Chrysodeixis acuta, Diachrysia orichalsia*, *Gesonia gemma* and *Mocis undata*)	4 larva/meter of row length at flowering stage
3.	Tobacco caterpillar (*Spodoptera litura*)	3 larva/meter of row length at pod formation stage 10 larva/meter of row length at pod developmental stage
4.	Pod borer (*Helicoverpa armigera*)	10 larva/meter of row length at pod developmental stage
5.	Stem fly (*Melanagromyza sojae*)	26% stem tunnelling
6.	Leaf miner (*Aproaerema modicella*)	1 larva/plant at 7-10 days old crop stage

List of recommended insecticides against insect-pests of soybean is given below:

Table. Chemical insecticides recommended against major insects in soybean.

Insect	**Insecticides**	**Dose**
Blue beetle	Quinalphos 25 EC	1500 ml/ha
Stem fly	Thiamethoxam 30 FS	10 ml/kg seed
	Lambda Cyhalothrin+ Thiomethoxam	125 ml/ha
White fly	Thiamethoxam 30 FS	10 ml/kg seed
	Imidacloprid 48 FS	1.25 ml/kg seed
	Betacyfluthrin 8.49% + Imidacloprid 19.81% OD	350 ml/ha
Defoliators (Semiloopers, Tobacco caterpillar)	Chlorantraniliprole 18.5 SC	100 ml/ha
	Indoxacarb 15.8 EC	333 ml/ha
	Profenofos 50 EC	1250 ml/ha
	Quinalphos 25 EC	1500 ml/ha
	Spinetoram 11.7 SC	450 ml/ha
	Betacyfluthrin 8.49% + Imidacloprid 19.81% OD	350 ml/ha
	Flubendiamide 39.35 SC	150 ml/ha
	Flubendiamide 20 WG	250-300 ml/ha
	Thiamethoxam + Lambda Cyhalothrin	125 ml/ha
Girdle beetle	Thiacloprid 21.7 SC	750 ml/ha
	Profenophos 50 EC	1250 ml/ha
	Betacyfluthrin 8.49% +Imidacloprid 19.81% OD	350 ml/ha
	Thiamethoxam + Lambda Cyhalothrin	125 ml/ha
Pod borer (*Helicoverpa armigera*, *Cydia ptychora*)	Profenophos 50 EC	1250 ml/ha
	Chlorantraniliprole 18.5 SC	100 ml/ha
	Indoxacarb 15.8 EC	333 /ha

Harvesting and threshing

Soybean has structural limitation towards mechanization and large-scale handling. The seed coat of soybean is very thin as compared to other leguminous crops. The position of radical axis is also quite raised on the cotyledons.

Mechanical damage to an individual seed can include formation of cracks or breaks in the seed coat, cracks in cotyledon, injury or breakage of hypocotyls-radicle axis and complete breakage of seed to the point, where it would no longer be classified as part of pure seed fraction. The extreme of mechanical harvesting and threshing is splitting of seed thus producing “Dal’ (single cotyledons). The amount of mechanical damage to the seed is inversely related to the seed moisture level. Physical damage increases as the seed moisture decreases below 12%. Large seeds tend to be more susceptible to mechanical damage than small seeds. Seeds that have been exposed to field weathering or that have been dried at high temperatures are more susceptible to mechanical damage.

Optimum time of harvesting is very important for soybean as it causes yield loss due to shattering and seed viability loss due to field weathering. The quality of soybean produced is adversely affected due to rains at maturity stage. Therefore, farmers are advised to harvest their crop at optimum time. When 90% of the pods changes its colour to yellow, it is the right indication to go for harvesting. Harvesting at this stage do not have any adverse effect on germination. Currently, the moisture percentage of soybean seed is around 14-17%. The crop should be harvested when seed moisture is 15-17% with combined harvester specialized for soybean with reduced drum speed (i.e. 400-450 rpm). Most of the combine harvesters are fabricated based on wheat but that cause seed damage in soybean. Timely harvesting in soybean is very critical to save seed from field weathering and losses by pod shattering. The harvested crop should be Dr.ied on the threshing floor for bringing down the seed moisture to around 12% before storage. To maintain viability of seed and to avoid loss/mechanical damage, threshing should be done at 350-400 rpm. If threshing is to be performed later, the harvested soybean should be collected at safe place to avoid damage from rain/shattering. The threshed soybean should again be allowed to sun drying for 3-4 days to bring down the moisture up to 10% which is essential to avoid fungal infection during storage. The seed should be finally Dr.ied in thin layer on cemented floor or tarpaulin. Seeds should be stored preferably in perforated jute bags (not in polylined jute bags) for proper aeration of seeds and natural drying (Kuchlan, 2021).

Drying and storage

To maintain longer shelf-life and avoid fungal damage to soybean seeds during storage, drying to 10% seed moisture content is essential. drying on floor is most common but seed should be gathered every evening and respread during next morning for drying. Hot air speed driers are used on large farms, but care is needed to prevent higher than 40°C, if the seed stock is meant for seed purpose. The storage place should be cool with aeration and insect free. The soybean bags should be kept upright as far as possible. If stacking is to be done, it should be only up to 4-5 bags of not more than 5 feet height (using platform) to maintain the viability/germination of soybean seed. While moving the seed bags to storage house, it should be carefully placed at the appropriate place/platform. The seed bags should not be in direct contact with floor/wall (Kuchlan, 2017). The moisture seepage in the walls/floor may be a source of infection of diseases, hence can be avoided for storage. The tendency of seed to maintain equilibrium moisture in relation to relative humidity (RH) of storage is an unavoidable physiological phenomenon. Therefore, high RH of store increases the seed moisture and cause rapid loss of seed quality. In tropical and subtropical regions, the development of ‘state of the art’ facility where storage temperature and RH can be regulated is quite expensive. Lack of such infrastructures forces to store seeds under ambient condition. The performance of seed in storage varies with areas of storage. The seeds stored in the condition above the safe level of RH (approximately 50-60% & temperature above 25^0 C are deteriorated rapidly. Steel bins, tin cans, jars, polythene bags and gunny bags are most common methods of storage. Moisture proof containers are ideal.

Yield potential

With good crop management, seed yield of about 1,600-2,000 kg/ha under rainfed conditions and 2,000-2,500 kg/ha under irrigated conditions can be expected. Under high input management, yield levels of 3,000-4000 kg/ha can also be realized.

Major issues /challenges in Soybean Crop

1. Primarily rain fed crop and faces unforeseeable challenges of drought, waterlogging, high temperature creates very high risk.
2. High seed volume crop and prone to rapid loss in seed viability during farm operations, storage and transportation.
3. Non-availability of high-quality seed of latest soybean varieties resulting in poor seed replacement rate and low productivity.
4. Non-availability of assured market for soybean in non-traditional areas with high yield potential.
5. Continuous cultivation of the crop in traditional areas has resulted in built up of pathogens and many new diseases are appearing.

Future thrust

- To increase the average soybean yield 1500 kg/ha by 2030 and 2500 kg/ha by 2047.
- Focus on development of latest technology for biotic and abiotic stress management, value addition through industry support, vegetable soybean uses, genome editing, marker assisted selection, genetic resource management and precision farming.

- Enhancement of genetic resources and evaluation for desirable traits to combat the emerging problems. Crop improvement using functional genomics, MAS, transgenic and allele mining approaches.
- Development of specialty soybeans for increased food uses and industrial exploitation.
- To facilitate knowledge imbibition amidst clientele through aggressive and efficient extension tools.
- To promote and develop technology for soybean based secondary agriculture.
- To develop sustainable organic farming in specific areas/regions to cater to the needs of premium local and foreign markets.
- Promotion of natural/organic farming for sustainability of soybean-based cropping systems.
- Promotion of low-cost-resource conservation technologies for minimizing cost of cultivation.

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Chapter 16

Productivity improvement of groundnut through research and development

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Abstract

Groundnut (*Arachis hypogaea* L.) also known as peanut is a legume crop, grown for its edible seeds. The genus *Arachis* consists of 80 described species (Krapovickas and Gregory 1994, 2007; Vallas and Simpson 2005) and is divided into nine taxonomic sections: *Trierectoides, Erectoides, Procumbentes, Rhizomato' sae, Heteranthae, Caulorrhizae, Extranervosae, Triseminatae and Arachis.* It is an important global food having superiority, thus underpins agriculture-dependent livelihood strategies meeting food, nutrition and income security.

It is cultivated in tropical and subtropical regions and is a significant source of vegetable oil and protein. Groundnut is cultivated worldwide on over 100 countries with an estimated area of 26 million hectares and a total production of 44 million tonnes. The average yield of groundnut in the world is approximately 1,655 kg/ha (FAOSTAT, 2017). Worldwide its production is principally dedicated to oil and food products. Its multifarious uses include oil production, direct human consumption and also as animal consumption in the form of hay, silage and cake. Being a grain legume, it has an important nutrition value for human beings and its malnutrition value has been exploited for combating malnutrition in children. Several studies have reported a positive impact of peanut on human health and its nutritional value has been exploited for the claboration of highly nutritious food products used in the treatment of severe child malnutrition (Briend 2001).

It can be cultivated with low inputs and consumption should be encouraged among nutritionally vulnerable groups such infants, young children and women of reproductive age as it is a nutrient dense food. In addition, enhancement of overall peanut industry is required with introducing market demanding varieties, efficient seed systems and improving the value chain. Though groundnut is utilized as edible oil source in other countries, Sri Lankan consumption is mainly as roasted snacks or confectionaries. Here, considering the regional aspects of groundnut I would like to summarize present constraints and research focus for improve the groundnut cultivation sector in the SAARC region.

Present Technological package for groundnut cultivation in Sri Lanka.

Currently around 20,000 ha annually being cultivated, mainly under rainfed agricultural systems in Sri Lanka. Several varieties recommended by Department of Agriculture in Sri Lanka as well as traditional cultivars are being cultivated (Table 1.).

Table 1. Recommended varieties of groundnut in Sri Lanka.

Characters	Tissa	ANKG1	ANKG2 (Lanka Jumbo)	ANKGN3	ANKGN4
Age (Months)	3	3	3 1/2	3 1/2	3
Seed color & size	Tan colored medium seed size	Red colored medium seed size	Tan colored large seed size	Tan colored large seed size	Tan colored small seed size
Average pod yield (Kg/ha)	2000-2500	2300-3000	2500-3500	2500-3500	2000-2500

Mainly short duration (3 months) aged varieties are being cultivated. Recently, large seeded jumbo types are also gainly popularity, especially with the intervention of private sector industries. There is a general recommendation for groundnut cultivation in Sri Lanka targeting 2 season cultivation called Yala and Maha based on the rainfall pattern (Table 2.) It is understood that productivity can be greatly enhanced solely by following the recommendations, especially the fertilizer management and supplementary irrigations. However, these marginal farming systems are gradually changing with the efforts of extension of government agencies.

Table 2. Recommended production package for groundnut.

Cultural practice	Recommendation	Planting time	
		Yala Season	Maha Season
Seed rate (Kg/ha) For small seeded types Pods-100 Seeds-70 For Large seed size Pods-130 Seeds-100 Fertilizer Application (Kg/ha) Irrigation	Spacing 45 cm x 15 cm 45 x 15 cm Urea -35 TSP- 100 MOP-75 Majority is dependent on rains. Supplementary irrigations are on the rise.	April	October

Key issues in groundnut sector

Based on the issues prevailing in the sector we can categorize those in to several sub sectors. Based on these identified issues, we may need different approaches to address those issues. However, identification of the issues and understand the need of a wholistic approach is the appropriate way to stablish a sustainable system for groundnut industry. It can be varied according to the climatic, socio-economic and other relevant factors in the country itself. A list of issues identified in the groundnut sector is summarized below.

Issues related to agricultural inputs

- Insufficient availability of quality seed at proper time is a major concern in groundnut cultivation. It is due to the nature of the crop (low multiplication ratio, bulkiness, rapid loss of viability, high seed rate).
- Heavy dependency on rainfed farming.
- High labor intensity for the cultural practices and post-harvest processing. This has largely increased the cost of production.
- High input costs (fertilizer and fuel) reduced the accessibility of input to the poor farmers. Majority of groundnut farmers are still at subsistence level. As input prices increases, there ability for intensive cultivation decreases.
- Non availability of groundnut varieties which demanded by industry. Some of the quality attributes (oleic acid content in the kernels etc.) are necessary for specific product developments.

Issues related to cultivation

- Poor adaption to already available crop management practices.
- Poor adoption of soil and water conservation techniques.
- Limited availability of appropriate machinery to main labor-intensive operations.
- Intermittent drought at critical growth stages of the crop.
- Limited availability of tolerable varieties to biotic and abiotic stresses.
- Limited availability of technologies, which can increase the productivity under rainfed farming systems.

Issues related to harvesting and processing

- Increased cost of production due to high labor usage and cost.
- Limited efforts to introduce agricultural machinery for medium scale cultivation.

Issues related to post - harvest losses and value addition

- Non availability of proper technologies to minimize aflatoxin infection at post-harvest.
- Limited availability of storage systems with proper environmental control.
- Non availability of medium scale low-cost seed storage technologies at farm level.
- Non adoption of available postharvest practices to avoid quality losses.

Issues related to marketing

- Fluctuation of price, no control over price fluctuation.
- Scattered marketing system.
- Monopoly in the market, which suppress the small-scale industries.
- Low effort for buffer stock management.
- Lack of farmer empowerment to negotiate in the market.
- Lack of data base for seed materials, production and marketing.

Although all these issues may not relate to all the countries, some of them would be common. In fact, for issues related to marketing and input management might be beyond researchers' scope, they should be addressed at policy or strategic level. In this report, I would like to share some of the ideas or research areas which we can work on to improve the groundnut cultivation system in the region. These research areas can be categorized in to two main subjects; crop improvement and cultural management improvement. In crop improvement development of improved varieties addressing the related issues are needed. On the other hand, development of viable technological innovations to improve the efficiency of the cultural management of groundnut is required in various disciplines such as agronomy, soil and water management and post -harvest technologies.

Key research areas in crop improvement of groundnut

- Yield improvement is one of the main objectives in any crop improvement program. Groundnut yield of the SAARC regional countries is comparatively below than some of the major growing countries like China and U.S.A. Therefore, yield targets of more than 4MT/ha should be set for the newly improving varieties of groundnut.
- Resistance/tolerance to abiotic stresses, especially drought is a key trait to be target in groundnut crop improvement programs since intermittent drought can affect a significant yield loss in groundnut cultivation which are done under rain-fed. drought resistant germplasm have been already identified by

researchers in the region (ICRISAT). Exchange of these vital genetic resources are very important to make the progress smooth.

- Improvement of quality parameters such as oil content, oleic acid content and protein content would be important when considering the product development and nutritional aspects. Recently many genes/QTLs were reported in the quality traits. Therefore, marker assisted selection can be proceed if we have the donor parents for these specific traits.
- Resistance to diseases is important considering the continuous cultivation of groundnut in the region. Many resistant genotypes have been reported for major diseases (collar rot, leaf spots) where sharing of such materials can speed up the process.
- Resistance development for Aspergillus is another objective to consider in variety development as it is the most effective method of management of aflatoxin.
- Overall, there should be some general considerations in selecting genotypes having less seed dormancy, pre-harvest sprouting, short maturity duration depending on the season and peg strength etc.

Improvement of cultural management practices

- There are some issues with the maturity synchroneity of groundnut. By agronomic means or growth regulators it can be managed up to some extent. Therefore, practical solutions need to be identified.
- Soil nutrient management is very important in improving the groundnut productivity. New nutrient management packages based on the regional needs should be examined.
- Post-harvest technologies of groundnut coupled with machinery solutions need to identify to improve the quality of the groundnut products. This includes efficient storage techniques and post-harvest handling of groundnut seeds.
- Efficient water management and moisture conservation methods can improve the productivity of the existing cultivation systems. Hence, evaluation and identify such systems would be beneficial.
- Weed management and sustainable pest/disease management practices need to be improved as existing methods are not efficient or environmentally friendly.
- Establishment of efficient seed systems is a very important approach for groundnut productivity improvement. Even in the SAARC region, there are

such sustainable systems developed based on community approaches. Hence, lessons from such initiatives need to be studied and application can be done according to our requirement.

These are some of the key points to be considered in improving groundnut sector in SAARC regions. If we can collaborate and exchange the knowledge and ideas in different countries, the outcome would be much better.

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Chapter 17

Comparison of Groundnut harvesting technologies in Pakistan

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Abstract

Harvesting of groundnut crop using conventional digger blade is labour-intensive and time-consuming practice and involves yield losses up to 28%. The objective of this study was to compare the performance of a newly imported KMC digger-inverter with the conventional digger blade for groundnut harvesting, which is a crop of the Pothohar region of Pakistan. The machine was imported by Agricultural Engineering Institute (AEI) of Pakistan Agricultural Research Council (PARC) and tested at National Agricultural Research Centre (NARC), Islamabad as well as at farmers' fields. Data of both machines were collected for total digging losses, viz exposed pod losses, unexposed pod losses, damaged pod losses and undug pod losses from different locations in the Pothohar region of Punjab, Pakistan. Results revealed that the average pod losses in all operations using a conventional digger blade were 28.26%, whereas by using KMC digger-inverter they were reduced to 4.76%. This means that KMC digger-inverter yielded 17% less pod losses than the conventional digger blade. Additionally, the KMC digger-inverter reduced labour cost from Rs. 26,756 (using conventional digger blade) to Rs. 10,204, which is about 38% less than the conventional digger blade. Therefore, by using improved KMC groundnut digging technology, the farmer can increase his overall profit. By adoption of new technology for groundnut harvester will bring a positive impact in the income of farmer and the country can produce export surplus.

Introduction

Groundnut (*Arachis hypogaea* L.), also called as peanut, is cultivated worldwide on over 100 countries with an estimated area of 26 million hectares and a total production of 44 million tonnes. The average yield of groundnut in the world is approximately 1,655 kg/ha (FAOSTAT, 2017). In Pakistan, groundnut crop is a major Kharif crop of rain-fed (Barani or Pothohar) areas of the Punjab province of Pakistan. It is also cultivated in some irrigated areas of South Punjab, Khyber Pakhtunkhwa and Sindh provinces. About 90% of the total groundnut crop is grown in the rain-fed areas of the North Punjab (Pothohar). A well-drained, coarse-textured and sandy loam soil is suitable for groundnut production. Groundnut is a cash crop and is a major source of income of Pothohar region of the Punjab. The groundnut is mainly grown for table purposes, but it can also be grown as an oilseed crop. The groundnut kernel is rich in both oil (43-55%) and protein (25-28%) (Saeed et al., 2009). In Pakistan, groundnut crop was grown on 129.2 thousand hectares with a total production of 114.4 thousand tonnes with an average yield of 0.885 tonne per hectare (GOP, 2022-23).

The groundnut crop is mostly cultivated on fallow lands from early March to the end of April to conserve soil moisture from winter rains. It can also be grown in May and June after wheat harvest if adequate moisture is available. The crop maturity period is 130-160 days depending on variety and weather conditions. The current practice that is being used for groundnut sowing is the broadcast method, *kera* and *pora* methods and the progressive farmers have modified drills of wheat. The recommended row-to-row distance is 30-45 cm and plant-to-plant is 10-15 cm with a seed depth of 4-6 cm (Agribusiness Pakistan, 2017).

In Pakistan, harvesting of groundnut is finished with a conventional digging blade in two steps. The first step is to slice the soil and soften the roots using a blade, the second step is pulling the crop manually and inverting it to allow drying in the field. After drying, the crop is collected from the field and threshed with a stationary thresher. About 95% of farmers used digging blades to harvest the groundnut when 75% of pods are matured. This groundnut digging blade was designed and developed by the Agricultural Engineering Institute (AEI) formerly called as Farm Machinery Institute (FMI) of Pakistan Agricultural Research Council in 1983 and introduced first time in Pakistan (FMI, 1983). The problem with this harvester was that it was just a digger and did not invert the dug crop. After digging the crop with a blade, many persons are required for picking, shaking and inverting the crop and leaving it in the field for drying. Almost 4-5 persons are involved in inverting the crop in 2-3 hours per acre. In this whole process, a considerable amount of groundnut pods is lost due to insufficient soil moisture or post-maturity condition of the crop (Padmanathan et al., 2007).

Picking, shaking and inverting the crop is a very labour-intensive and time-consuming operation, also a high cost is paid due to non-availability or shortage of farm labour. Furthermore, financial losses occur due to ineffective digging because a significant number of pods remain in the soil digging with blades. Secondly, the shattering losses occur due to manual picking, shaking and inverting the crop. About 30 to 40% of pod losses occur due to conventional blade and manual inverting process. Some local agricultural machinery manufacturers modified the potato digger for groundnut harvesting, but the problem of high crop losses was not resolved.

Due to unavailability of a proper groundnut harvesting technology, this digger blade is considered very helpful and has been used by groundnut farmers.

Therefore, an efficient groundnut digger-inverter is the demand of groundnut farmers to overcome the labour shortage challenge and to reduce crop losses. The mechanical harvesting of groundnut has the advantage of reducing the cost and labour requirements (Ademiluyi et al., 2011).

Different field speeds and working depth can control losses significantly. A study at the Edisto Research and Education Centre showed a recovery savings of 312.5 kg/ha when using the correct digger setting for lighter soils (Warner et al., 2015). Agricultural Mechanization Research Institute (AMRI), Multan recommended the working speed of machine from 4.0 to 4.8 km/h (AMRI, 2005). Bader (2012) advises digging speeds of 5.6 to 8.0 km/h and Vennela et al. (2018) noted that ground speeds over 6.4 km/h can cause significant pod losses. The Kelley Manufacturing Co. (KMC), Georgia, the United States of America suggested that digging too quickly can cause bunching and digging too slowly can pull vines apart, leading to pod losses (KMC, 2023). A study by Asghar et al. (2014) found that each digging machine has an optimal speed to minimize digging losses. Too shallow digging results in below-ground losses as pods below the tap root cut level are missed, while too deep digging increases detachment of pods due to reduced soil loosening, causing greater soil resistance during lifting. Ademiluyi et al. (2011) tested a tractor-drawn groundnut digger-shaker under three soil moisture levels. They found that soil moisture significantly affects the digging efficiency of the implement, with an optimal range of 12 to 15%.

Keeping in view the groundnut crop harvesting issues in the country, Agricultural Engineering Institute of Pakistan Agricultural Research Council addressed this issue and introduced a tractor-mounted groundnut digger-inverter from KMC, the USA to reduce the losses and to solve the problem of labour shortage. This machine performed four functions simultaneously, i.e., digging, conveying, mud removing and inverting the crop in rows. The objective of this study was to evaluate the performance of a 2-row groundnut digger-inverter by varying depth and speed of the machine for its commercialization. Furthermore, comparing the performance of this machine with the conventional digger blade is also the aim of this study.

Materials and Methods

Description of test fields

The study was carried out at the groundnut research field of National Agricultural Research Centre (NARC), Islamabad and two sites in Chakwal district of the Punjab during the year 2023. The size of each field was about one hectare and the soil type of all sites was sandy and sandy loam. The Pothohar variety of NARC was grown for the test with a walking-type precision planter with a row spacing of 45 cm and plant spacing of 15 cm. The maturity period of the crop was 160 days.

Harvesting losses

After completion of digging and harvesting process, three locations were randomly selected from each plot of sample area of 1×1 m^2 for measuring the harvesting losses. From sample areas, the harvested plants along with pods were collected and the damaged pods were separated. The exposed pods, buried pods and undug pods were also collected to determine the harvesting losses. The following formulae were used to determine groundnut harvesting losses (IS: 11235-1985):

A = B + C (Eq. 1)

Percent of damaged pods = $CA \times 100$ (Eq. 2)

Percent of exposed pods = $DA \times 100$ (Eq. 3)

Percent of unexposed pods = $EA \times 100$ (Eq. 4)

Percent of undug pods = $FA \times 100$ (Eq. 4)

Digging Efficiency = 100 - Total % of pod loss (Eq. 5)

Where,

A = Total quantity of pods collected from plants in a sample area.

B = Quantity of clean pods collected from the plants dug, exposed and buried pods.

C = Quantity of damaged pods collected from the plants.

D = Quantity of detached pods lying exposed on the surface

E = Quantity of left-out pods buried in the soil.

F = Quantity of pods remained un-detached from the undug plants.

Total Percentage of Pod Loss = Percentage of Exposed Pod Loss + Percentage of Buried Pod Loss + Percentage of Undug Pod Loss

Description of conventional groundnut digger blade (M_1)

Conventional groundnut digger (M_1) (Figure 1) consists of a main frame with 3-point linkages. Its frame is made from a 75×75×6 mm MS angle with length and width 1524, 560 mm, respectively. For the attachment of the digging blade, a 16 mm V-type MS Plate having a width from the sides is 114 mm and from the centre is 178 mm is welded from the sides with a two-side support made with the 16 mm MS flat having a length 570 mm. Side supports were drilled 15 mm diameter holes at 25 mm spacing for height adjustment of the blade attached to the mainframe through nut bolts. The digging blade is mounted on the bottom of the MS plate with the help of 10 mm nuts and bolts having a cutting width of 1524 mm and made from a 90×12.5 mm spring steel flat bar.

Fig 1. Conventional digger blade.

KMC groundnut digger-inverter (M_2)

The new 2-row groundnut digger-inverter (M_2) procured from the USA (Figure 2) consists of a mainframe with a cat II 3-point hitch. Colter discs are attached to the mainframe to cut the biomass/vines and soil to define the swath with digging blades. V-type two digging blades attached to the mainframe to dig the crop. A conveyor with variable angle is attached to lift the crop from the ground and convey it to the rear hinge fender to form the width of the windrow created during inverting. The inverted cylinders on the rear of the machine invert the crop and inverter rods drop the inverted crop smoothly on the ground making windrow. The conveyor and inverted cylinders are operated via a hydraulic motor and pump through the tractor's hydraulic system. Wheels on the rear side of the machine for the height adjustment according to the crop height. The overall length, width and height of the machine are 3905, 2197 and 2184 mm, respectively.

Fig 2. KMC 2-row groundnut digger-inverter

Data collection

All machine related performance parameters were measured during the testing process. For comparison of both machines, three levels of forward speed were used, i.e., 2, 3 and 4 km/h. The digging depth of both was constant at about 10 cm. Each field was divided into three parts for repeating three tests of machines. Each field was divided into two experimental plots one for a conventional digger blade and the other for the KMC digger-inverter. For operation of KMC digger-inverter, an MF-85 hp tractor was used, whereas for the conventional digger blade an MF-50-hp tractor was used. Forward speed was determined by taking the time at a specific distance. The conveyor angle was fixed at 43 degrees, where it matched with the forward speed. The crop harvesting using conventional and KMC digger-inverter are shown in Figures 3 and 4.

Fig 3. Harvesting of groundnut crop using conventional digger blade.

Fig 4. Harvesting of groundnut crop using KMC digger-inverter.

Statistical analysis

The data collected during the experiment were statistically analyzed by using “Statistix 8.1” software. For post-ANOVA mean separation, the LSD test was used 5% level of probability.

Results and Discussion

Overall machine performance

The volumetric moisture content at the time harvest was 18.4%. The performance of the conventional digger (M_1) and digger-inverter (M_2) was evaluated at three levels of tractor forward speeds S_1, S_2 and S_3 (2, 3 and 4 km/h). The statistical analysis of different variables was conducted. The mean values of different parameters. Means results of machine parameters are summarized in Table 1.

Table 1. Description of field trails and means results of machines.

Parameters	Results of field trials			
	Test 1	Test 2	Test 3	Average
Speed of operation (km/h)	2	3	4	3
Working width (cm)	150	150	150	150
Power requirement (hp)	85	85	85	85
Theoretical field capacity (ha/h)	0.65	0.65	0.65	0.65
Effective field capacity (ha/h)	0.55	0.58	0.56	0.56
Field efficiency (%)	83.94	88.99	85.93	86.33
Fuel consumption (l/h)	6	5.9	6.1	6
Wheel slip (%)	8	10	9.3	9.1

Effect of forward speed on pod damage percentage

The mean of pod damage percentage (Table 2) for both machines (M_1 and M_2) was recorded. The statistical analysis showed a significant difference between the performances of both machines at a 5% probability level. The conventional machine performed better with less pod damage percentage (0.53%) as compared to KMC digger-inverter (0.81%). Both machines exhibited the similar results indicating a decrease in pod damage with increase of forward speed of machines. Results of this study correlate with the study of Saakuma et al. (2016), who concluded that the weight of damaged pods decreased with the increase of the tractor's speed at a constant working depth of 10 cm.

Table 2. Effect of forward speed on both machines on pod damaged percentage.

Speed	M_1	M_2
S_1	0.74 A	1.14 A
S_2	0.48 B	0.90 B
S_3	0.37 B	0.40 C
Mean	0.53 B	0.81 A

Mean with similar letters are statistically non-significant at a 5% level of probability.

Effect of forward speed on exposed pods percentage

The effect of forward speed on exposed pod losses of both machines is summarized in Table 3. The statistical analysis showed that there was a significant difference between the performances of both machines at a 5% level of probability. The KMC machine performed better with less exposed mean pod percentage (0.48%) as compared to the conventional one (6.27%). Both machines shown similar trends in exposed pod losses with increase of forward speed of tractor. This shows that increasing the forward speed of the tractor decreases the exposed pod percentage.

Table 3. Effect of speed on both machines on the base of exposed pod percentage.

Speed	M_1	M_2
S_1	6.68 A	0.41 A
S_2	6.31 A	0.49 A
S_3	5.80 A	0.55 A
Mean	6.27 A	0.48 B

Mean with similar letters are statistically non-significant at a 5% level of probability.

Results of this study are consistent with those of Azmoodeh et al. (2014), who fabricated a groundnut digger and evaluated it at different speeds of operation. They found the lowest exposed pod losses at a high forward speed of 1.8 km/h.

Effect of forward speed on buried pods percentage

Table 4 shows the mean buried pod percentage for both machines (M_1 and M_2). The statistical analysis showed that there was a significant difference between the performances of both machines at a 5% level of probability. The KMC machine performed better with less buried pod percentage (2.68%) as compared to the conventional one (16.69%).

Table 4. Effect of speed on both machines on the base of buried pod percentage.

Speed	M_1	M_2
S_1	17.40 A	3.09 A
S_2	16.59 A	2.12 B
S_3	16.09 A	2.84 A
Mean	16.69 A	2.68 B

Mean with similar letters are statistically non-significant at a 5% level of probability. The mean value of buried pod percentage shows that there was a significant difference at forward speeds S_1 as compared to S_2 and S_3 while the speeds S_2 and S_3 are not significantly different from each other. This shows that the buried pod percentage depends on decreasing or increasing tractor forward speed. Shen et al. (2023) also reported similar results, who concluded that the reduction in the tractor's speed resulted in the increase of buried pods.

Effect of forward speed on undug pods percentage

The mean groundnut undug pod percentage (Table 5) for both machines (M_1 and M_2) was recorded. The statistical analysis machines showed that there was a significant difference between the performances of both machines at a 5% level of probability. The KMC machine performed better with less undug pod percentage (0.79%) as compared to the conventional machine (4.30%). Both machines showed mixed results of undug pod losses with increase of tractor forward speed. This shows that the undug pod percentage increased by increasing or decreasing the speed than the speed S_2 . Results of this study are in accordance with Azmoodeh et al. (2014), who indicated that the undug pod percentage was lower at the speed of 1.8 km/h.

Table 5. Effect of speed on both machines on the base of undug pod percentage.

Speed	M_1	M_2
S_1	4.07 B	0.93 A
S_2	3.62 B	1.05 A
S_3	5.23 A	0.40 B
Mean	4.30 B	0.79 A

Mean with similar letters are statistically non-significant at a 5% level of probability.

Effect of forward speed on total percentage of undamaged pods

The mean total percentage of undamaged pods (Table 6) for both machines (M_1 and M_2) was recorded. The statistical analysis showed that there was a significant difference between the performances of both machines at a 5% level of probability. The KMC machine performed better with a higher amount of total percentage of the undamaged pod (95.25%) as compared to the conventional machine (71.82%). For the conventional groundnut digger (M_1), the mean value of the total percentage of undamaged pods shows that there were no significant differences at three forward speeds while there was a significant difference between KMC machine (M_1) at three different speeds. The results are in favour with Saakuma et al. (2016), who reported that the weight of harvested undamaged groundnuts decreased as speed increased and the harvesting efficiency decreased with higher speeds, mean with similar letters are statistically non-significant at a 5% level of probability.

Table 6. Effect of speed on the total percentage of undamaged pods.

Speed	M_1	M_2
S_1	71.23 A	94.36 C
S_2	71.78 A	96.09 A
S_3	72.44 A	95.29 B
Mean	71.82 B	95.25 A

Effect of forward speed on total percentage of pod losses

Table 7 shows the total percentage of pod losses for both machines (M_1 and M_2). The statistical analysis showed that there was a significant difference between the performances of both machines at a 5% level of probability. The KMC machine performed better with less total percentage of pod losses (4.76%) as compared to the conventional machine (28.26%). The minimum percentage of pod losses was noted at speed S_3 (3.98%) for KMC machine. This shows that increasing the tractor's forward speed decreases the total percentage of pod losses. The results are correlating with the study of Mareppa et al., 2014), who carried out an experiment at 10%, 12.5% and 15% moisture content. The results revealed that the pod loss decreased as forward speeds increased.

Table 7. Effect of speed on both machines on the basis of the total percentage of pod losses.

Speed	M_1	M_2
S_1	28.75 A	5.64 A
S_2	28.63 A	4.67 B
S_3	27.41 A	3.98 B
Mean	28.26 A	4.76 B

Mean with similar letters are statistically non-significant at a 5% level of probability.

Cost analysis

After digging the groundnut with KMC digger-inverter no labour is required for picking and inverting the crop. Therefore, operational cost for KMC machine is Rs. 2,050/- per acre. Moreover, it also saves at least 30% pod losses as shown in previous Tables. It is also clear that on an average 5.54 maunds pods can be recovered by engaging labour force if it is dug by a conventional digger blade. If these losses are recovered by involving labour force, the 50% share goes to labour and 50% share goes to the farmer. The worth of 50% losses is Rs. 22,176, which can be minimized using KMC digger-inverter. The net saving achieved by the KMC digger-inverter was calculated as Rs 16,552 per acre (Table 8).

Table 8. Operational cost for conventional digger and KMC digger inverter.

Parameters	Existing digger (Rs./acre)	KMC machine (Rs. /acre)
Fuel cost	Rs. 1,080 (4 liter)	Rs. 1,620 (6 liters)
Labour cost	Rs. 1,000 (Operator) Rs. 2,500 (Picking inverting)	Rs. 1,000 (Operator)
Pod recovering labour cost	Rs. 22,176 (50% of 5.54 maunds is paid as labour cost)	Rs. 7,584 (0.95 maund losses)
Total cost	Rs. 26,756	Rs. 10,204
Total saving using KMC digger-inverter machine is Rs.16,552 per acre.		

Conclusion

Reducing crop losses is desired by using efficient and precision farm machinery. Results of this study showed that the forward speed is an important factor for groundnut digging/harvesting operation, which has a significant effect on total pod losses. It was revealed that the conventional digger and newly imported KMC digger-inverted have a significant difference in the harvesting losses. Conventional groundnut digger produced higher losses than the KMC digger-inverter in all variables. The average pod losses in all operations using a conventional digger blade were 28.26%, whereas by using KMC digger-inverter they were reduced to 4.76%. This means that KMC digger-inverter yielded 17% less pod losses than the conventional digger blade. Additionally, the KMC digger-inverter reduced labour cost from Rs. 26,756 (using conventional digger blade) to Rs. 10,204, which is about 38% less than the conventional digger blade. Therefore, by using improved groundnut digging technology, the farmer can increase his overall profit. By adoption of new technology for groundnut harvester will bring a positive impact in the income of farmer and the country can produce export surplus.

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Chapter 18

Productivity Enhancement in Coconut

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Abstract

Coconut is an important oilseed crop of the tropics and contributes to the national economies of the SAARC countries that cultivate them. India is the third-largest producer of coconuts in the world followed by Sri Lanka. Area under coconut continues to assume growth in countries like India and Sri Lanka. Coconut growing SAARC nations like India, Sri Lanka, Bangladesh and Maldives should concentrate on productivity enhancement through modern technologies to meet the increasing industrial demand. The major coconut research institutes in India and Sri Lanka are more than a century old and have contributed in the development of varieties, agro-techniques, pest and disease management techniques and value addition. India and Sri Lanka export large quantity of coconut products, but they also import inexpensive coconut raw materials for industrial use. The trade imbalance can be rectified by expanding the area under coconut cultivation and enhancing the output of coconuts in coconut-producing nations. In addition, critical evaluation of the coconut value chain in each coconut-producing nation is the need of the hour which will ensure that farmers receive an equitable share of the profits generated across the whole chain. It is essential to formulate national and international policies for the sustainability of the coconut sector.

Introduction

Coconuts are a substantial contributor to the national economies of the SAARC countries that cultivate them, as they serve as a source of income and employment in rural areas of those countries. This crucial sector not only sustains the livelihoods of millions of these nations, but also makes a substantial contribution to global trade and commerce. The integration of global coconut economies occurred with the proliferating trade liberalization including the ASEAN Treaty, resulting in heightened rivalry among producing nations. Coconut growers presently have grave susceptibility to economic risks and uncertainties owing to substantial price fluctuation. The tropical belt of Asia, East Africa and America is home to more than 93 countries that grow coconuts; these countries are also potential producers, with 11.58 million ha yielding 96.16 billion nuts at a productivity of 8307 nuts per ha during 2020-21. The top ten producers are Indonesia, the Philippines, India, Brazil, Sri Lanka, Thailand, Vietnam, Malaysia, Papua New Guinea and Tanzania. India is the third-largest producer of coconuts in the world, making up more than 22 percent of the world's total nut output. Indonesia, the Philippines and India continue to be the world's biggest producers of coconuts, which accounted for 75 percent of overall production in the world and contribute around 80 percent of the total land for coconut farming. It should be noted that in India the area, production and productivity of coconut showed an increasing trend during 1980-2015 (Preethi et al., 2018). However, Sri Lanka showed a slightly declining yield trend during the 15-year period from 2006-2021 (Namradha and Karunakaran, 2022). Coconut has been used by human and their immediate ancestor species for at least half a million years as tender nut, dry fruit, source of food, drink, oil and wood as well as for shelter and aesthetic purposes.

In the case of coconut, beyond the focus on productivity alone, managing excess output on a national and worldwide scale has been crucial in recent years. Additionally, there is a tendency towards the processing of coconuts into a wider range of value-added goods. For instance, because of their eco-friendliness, coconut value-added goods such coir, coir pith, coir pith briquettes, grow bags, husk chips, geotextiles, shell charcoal, activated carbon, etc. are increasing significance and are currently in high demand. Products like Neera (inflorescence sap) and coconut water are becoming well-known health drinks worldwide and the coconut water market is expanding to become a multi-billion-dollar industry. The market for coconut products as functional foods, functional drinks, nutraceuticals, pharmaceuticals and cosmeceuticals, among other uses, is expanding quickly. The present coconut production, processing and trade system has been impacted by this new trend. Coconut producers must analyse the performance, trade trends and worldwide competitiveness of coconuts and coconut products to capitalise on these new market prospects. Every SAARC nation that cultivates coconuts must do research on the performance, trade trends and global competitiveness of coconuts and coconut products if it hopes to take advantage of these new prospects in the global market.

Despite year-to-year changes in the acreage and production of coconuts, there has been a remarkable increase in coconut plantations in India and Sri Lanka over the years. The coconut industry is extremely competitive since countries like Indonesia and the Philippines actively market a wide range of products made from coconuts, whereas Sri Lanka and India are still lagging (Table 1) in the export of value-added coconut products.

Table 1. Global scenario of coconut.

Country	Area ('000 ha)	Production (million nuts)	Productivity (nuts/ha)	Exports value (million US $)
India	2154	19310	8965	434
Indonesia	3342	15048	4503	2109
Malaysia	85	604	7106	297
Philippines	3604	14931	4143	2563
Sri Lanka	462	3391	7340	817
Thailand	138	676	4899	383
World	12229	67019	5480	--

Source: ICC Coconut Statistical Yearbook 2022

Area under cultivation coconut continues to assume growth in some countries like India, Philippines, Sri Lanka and Indonesia (Narmadha and Karunakaran, 2022). Coconut growing SAARC nations like India, Sri Lanka, Bangladesh and Maldives should concentrate on yield development through good management practices with availability of quality planting material to meet the increasing demand and productivity. The improved coconut production technologies are given below.

Coconut production technologies

Varietal improvement in coconut

Enhancing productivity through cultivation of improved varieties including hybrids is one of the major strategies suggested to make coconut farming more remunerative. The extensive research conducted on coconut improvement at ICAR-Central Plantation Crops Research Institute (CPCRI) and State Agricultural/Horticultural Universities has resulted in the release of 49 improved varieties having high yield potential and other desirable traits such as resistance to biotic and abiotic stresses and suitability for tender nut purpose. Thirty-one improved varieties of coconut suitable for different agro-climatic zones have been developed through selection and released till date, which includes 18 tall and 12 dwarf varieties (Table 2). Besides these, 20 hybrid varieties including 8 Dwarf x Tall and 11 Tall x Dwarf hybrid and one tall x tall hybrid have also been released for cultivation in different agro-climatic regions (Table 3). The released hybrid varieties of coconut have a yield potential of 2.79 to 6.28 tonnes of copra per ha per year in comparison to 2 tonnes of copra yield produced by the tall cultivars which are predominantly cultivated by coconut farmers.

Table 2. Improved coconut varieties released in India.

S. N.	Variety	Important traits	Nut yield (nuts/ha/ year)	Copra yield (t/ha/year)	Recommended regions
	TALL				
1	Chandrakalpa	Drought tolerant, high copra, oil content, suitable for neera tapping	17700	3.12	Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharastra
2	Kera Chandra	High yield, dual purpose, suitable for soap industry	19470	3.86	Kerala, Karnataka, Konkan, Andhra Pradesh, West Bengal
3	Kalpa Prathibha	High yield, dual purpose for copra and tender nut	17052	4.07	Kerala, Maharastra, interior Tamil Nadu, coastal zone of AP
4	Kalpa Mitra	High nut, oil yield, drought tolerant	13973	3.37	Kerala, West Bengal
5	Kalpa Dhenu	High nut, oil yield, drought tolerant	22794	3.66	Kerala, Tamil Nadu, Andaman & Nicobar Islands
6	Kalpa Haritha	Dual purpose, less eriophyid damage	20886	3.70	Kerala, Karnataka
7	Kalpa Tharu	Drought tolerant, ball copra, high yield, coir fibre	20709	3.64	Kerala, Karnataka, Tamil Nadu
8	Kalpa Shatabti	High nut and copra yield	28650	5.01	Kerala, Karnataka, Tamil Nadu
9	Kalpa Ratna	High yield, suitable for tender nut, copra and neera production	23540	4.3	Kerala, Tamil Nadu
10	ALR (CN) 1	High yield	22015	2.88	Tamil Nādu
11	Kera Keralam	High yield, drought tolerant, suitable for neera tapping	26019	3.53	Tamil Nadu, West Bengal, Kerala
12	ALR (CN) 2	High yield	21240	2.89	Tamil Nadu
13	VPM 3	High yield, drought tolerant	14868	3.41	Tamil Nadu
14	Kera Sagara	High yield	17523	3.64	Kerala
15	Pratap	High yield	25230	3.5	Konkan region
16	Kamrupa	High yield	17600	2.86	Assam
17	Kalyani Coconut 1	High yield	14066	2.17	West Bengal
18	Kera Bastar	High yield	19400	3.1	Coastal Zone of AP, Tamil Nādu, Konkan region, Bastar region

S. N.	Variety	Important traits	Nut yield (nuts/ha/ year)	Copra yield (t/ha/year)	Recommended regions
DWARF/SEMI-TALL					
19	Chowghat Orange Dwarf	Tender nut purpose	19824	2.78	All coconut growing regions
20	Kalpa raksha	Semi tall, high nut and oil yield in root (wilt) disease tracts, tender nut purpose	13260 17748*	2.85 3.34*	Kerala, root (wilt) disease tracts
21	Kalpasree	Suitable for root (wilt) disease tracts	15930	1.54	Root (wilt) disease tracts
22	Kalpa Jyothi	Tender nut purpose	20178	2.86	Kerala, Karnataka, Assam
23	Kalpa Surya	Tender nut purpose	21771	4.07	Kerala, Karnataka, Tamil Nadu
24	Kalpa Suvarna	Tender nut purpose	17169		Kerala and Karnataka
25	CARI-C1 (Annapurna)	High copra, tender nut purpose	9133	2.20	Andaman & Nicobar Islands
26	CARI-C2 (Surya)	High copra, tender nut purpose	20231	1.41	Andaman & Nicobar Islands
27	CARI-C3 (Omkar)	Ornamental purpose	24072	1.77	Andaman & Nicobar Islands
28	CARI-C4 (Chandan)	Ornamental purpose	16373	1.67	Andaman & Nicobar Islands
29	Kera Madhura	Semi tall, dual purpose for copra and tender nut	24480	4.08	Kerala
30	Gouthami Ganga	Tender nut purpose	11505	1.80	Andhra Pradesh

Source: Thomas & Shareefa, 2023

Table 3. Coconut hybrids released in India.

S. No.	Hybrid	Parents	Nut yield (nuts/ha/year)	Copra yield t/ha)	Important trait
1	Chandra Sankara	COD x WCT	20532	4.27	High yield
2	Kalpa Samruthi	MYD x WCT	20744	4.35	Dual purpose, drought tolerant
3	Kalpa Sankara	CGD x WCT	14868	3.20	Tolerant to root (wilt) disease
4	Kalpa Sreshta	MYD x TPT	29227	6.28	Dual purpose, high yield
5	Chandra Laksha	LCT x COD	19293	3.76	High yield, dought tolerant
6	Kera Sankara	WCT x COD	19116	3.78	High yield, drought tolerant
7	Laksha Ganga	LCT x GBGD	19116	3.73	High yield
8	Ananda Ganga	ADOT x GBGD	16815	3.63	High yield
9	Kera Ganga	WCT x GBGD	17700	3.56	High yield
10	Kera Sree	WCT x MYD	23364	5.05	High yield
11	Kera Sowbhagya	VCT x SSAT	23010	4.49	High yield
12	VHC-1	ECT x MGD	21240	2.87	High yield
13	VHC-2	ECT x MYD	25134	3.74	High yield
14	VHC-3	ECT x MOD	27612	4.47	High yield
15	VHC-4	LCT x CCNT	28497	4.22	High yield
16	Godavari Gang	ECT x GBGD	18585	2.79	High yield
17	Konkan Bhatye Coconut Hybrid-1	CGD x WCT	20532	3.47	High yield
18	Kalpa Ganga	GBGD x FJT	21417	3.38	High yield, suitable for ball copra
19	Vasista Ganga	GBGD x PHOT	22125	3.88	High yield
20	Kalpa Vajra	WCT x WCT	19250	4.15	Tolerant to root (wilt) disease

Source: Thomas & Shareefa, 2023

Production of quality planting materials

Selection of seed nuts and seedlings are very important in coconut cultivation as the performance of the new progeny can be known only several years after planting. If the seed nuts and seedlings happen to be of poor quality, the new plantation will be low yielding and uneconomic, causing considerable loss of time and money to the grower. The fact that, coconut is a cross- pollinated palm and it does not breed true, makes the selection of seed nuts and then of seedlings in the nursery more important. By means of a series of selections made at different stages, it is possible to eliminate poor quality seed nuts and seedlings.

Selection of seedlings

Only good quality seedlings are to be selected from the nursery for field planting. In tall varieties, vigorous seedlings which are one-year old, more than 100 cm in height with 5-6 leaves and girth of 10 cm at the collar should be selected for planting. In dwarf varieties, the girth and height of good quality seedlings should be more than 8 cm and 80 cm, respectively. Early splitting of leaves is another character preferred for selecting good seedlings. Generally, one-year-old seedlings are preferable for planting.

Tissue culture

At ICAR-CPCRI, coconut tissue culture programs have been continuing for the past several decades. The attempts were made which include experimentation with different explants viz., immature inflorescence, plumular tissues, mature palm shoot meristem, ovary and anthers and different culture media supplemented with varying levels and types of hormones. Some of the successful protocols developed at the Institute include coconut zygotic embryo culture for collection and exchange of germplasm, cryopreservation and retrieval of zygotic embryos and pollen, plantlet regeneration from plumular tissues and coconut pollen cryopreservation.

Even though ICAR-CPCRI has succeeded in obtaining plantlets via direct organogenesis from inflorescence explants, the absence of friable calli formation from explants, the low rate of somatic embryo formation, large number of cultures turning to abnormal shoot development, non-conversion of somatic embryos into plantlets and formation of abnormal somatic embryos remain the major bottlenecks.

Coconut cultivation practices

The coconut palm is grown under varying climatic and soil conditions. It is essentially a tropical plant, growing mostly between 20° N and 20° S latitudes. The ideal mean temperature for coconut growth and yield is 27±5°C and relative humidity more than 60 per cent. Very high humid conditions right through the growth of palms is not considered good. The coconut palm grows well up to an elevation of 600 m above mean sea level. However, near the equator, productive coconut plantations can be established up to an elevation of about 1000 m above mean sea level. The palms tolerate a wide range in intensity and distribution of rainfall. However, a well distributed rainfall of about 2000 mm per year is the best for proper growth and high yield. In areas of inadequate rainfall and uneven distribution, irrigation is needed. The coconut palm requires plenty of sunlight and it does not grow well under shade or in too cloudy regions. About 2000 hrs of sunshine in a year is considered necessary for the healthy growth of the palm. The natural habitat of coconut is the coastal belt of the tropics where sandy and red sandy loam soils are predominant.

Coconut grows well in almost all types of soils including sandy, laterite, swampy, alluvial, black and saline soils, provided they have proper drainage system, permitting unrestricted root development, aeration and absence of rock or a hard substratum within 2 m of the surface. It tolerates salinity and a wide pH ranging from 5.0-8.0.

Field preparation and planting

Preparation of land for planting coconut depends largely on soil type and environmental factors. The depth of pits will depend upon the type of soil. In laterite soil with rocky substratum, deeper and wider pits, 1.5 m length x 1.5 m breadth x 1.2 m depth may be dug and filled up with loose soil, powdered cow dung and ash up to a depth of 60 cm before planting. In case of laterite soil, application of 2 kg of common salt will help in loosening the soil. In loamy soils with low water table, planting in pits of 1 m x 1 m x 1 m filled with topsoil to height of 50 cm is generally recommended. The coconut seedlings are planted in the centre of the pit by making small hole within the pits and the soil around the seedlings must be firmly pressed, but soil should not be allowed to bury the collar region of the seedling or enter the leaf axils. However, when the water table is high, planting at the surface or even on mounds may be necessary.

Spacing

For realizing better yield from coconut, optimum plant density must be maintained in the field. A spacing of 7.5 m x 7.5 m to 8.0 m x 8.0 m in the square system is generally recommended for coconut. This will accommodate 177 and 156 palms per ha, respectively. If the triangular system is adopted, an additional 25 palms can be planted. Hedge system can also be adopted giving a spacing of 6.5 m along the rows and 9.5 m between rows. For facilitating multiple cropping in coconut gardens, it is advisable to go for wider spacing of 10 m x 10 m to provide ample opportunity to accommodate several perennial and annual crops in the interspaces.

Manuring and fertilizer application

Regular manuring right from the first year of planting is essential for good vegetative growth, early flowering and bearing and high yield of coconut palms.

It is always advisable to test soil in the coconut garden (once in three years) based on the results of which, type and dosage of chemical fertilizers can be decided. The first application of chemical fertilizer should be done three months after planting and the quantity of fertilizer to be applied is approximately one tenth of the recommended dose of fertilizer for adult palms. During the second year, one third of the dosage recommended for adult palms may be applied in two split doses in May- June and September-October. This dosage may be doubled during the third year. From the fourth year onwards, fertilizers maybe applied at the rate recommended for adult palms. Application of 500 g N, 320 g P_2O_5 and 1200 g K_2O per palm per year is generally recommended for adult plantations. To supply the above quantity of nutrients for an adult palm, it is necessary to apply about 1 kg urea, 1.5 kg rock phosphate (in acidic soil) or 2 kg super phosphate (in other soils) and 2 kg of muriate of potash (MOP). It can be also applied through 700 g Diammonium phosphate (DAP), 815 g of Urea and 2 kg of MOP. After the receipt of summer showers, in May-June, one- third of the recommended dose of fertilizers may be spread around the palms within the radius of 1.8 m and forked in.

Application of soil amendments

In soils with acidic nature, in addition to the recommended level of fertilizers, 1 kg of dolomite or 1 kg of lime may be applied per palm per year. Dolomite / lime may be broadcasted and incorporated in the basin one month prior to the application of chemical fertilizer. For coconut palms showing yellowing of leaves due to magnesium deficiency, 0.5 kg of magnesium sulphate can be applied in the basin along with other fertilizers during September- October. Deficiency of the micronutrients, especially boron, is also observed in coconut palms in certain localities. About 75 g of borax is to be applied at bi- monthly intervals till the symptom disappears.

Basin management with legume cover crops

An agro-technique has been developed to generate significant quantities of organic manure and nitrogen in coconut gardens, utilizing the leguminous cover crops. It involves cultivation of leguminous plants having symbiotic association with efficient Rhizobium strains in coconut basins and interspaces during the monsoon period and incorporation of biomass generated to the palms at the maximum vegetative growth stage of legumes. Field experiments on basin management with legumes in adult coconut plantations have revealed the effectiveness of this technique to substitute nitrogen fertilizer for coconut up to 30 per cent. The effectiveness of the legume treatment as a component in the management programme for root (wilt) disease of coconut has also been well demonstrated. *Pueraria phaseoloides*, *Mimosa invisa*, *Calopogonium mucunoides*, cowpea (*Vigna unguiculata*), sunhemp (*Crotolaria juncea*), horse gram (*Macrotyloma uniflorum*), daincha (*Sesbania aculata*) and *Sesbania spinosa* are the species of legumes superior in biomass and nitrogen contribution in coconut basins. They contribute about 15- 25 kg of biomass and 100- 200 g of nitrogen in coconut basins during a growth period of 60-120 days in monsoon season.

Irrigation

Irrigation methods commonly adopted in coconut gardens are flooding, basin irrigation, sprinkler or perfo-sprays and drip irrigation. In basin irrigation, water is applied in the basins of 1.8 to 2.0 m radius which is the active root zone of coconut. Sprinkler irrigation or perfo-sprays are most suited for inter or mixed cropping systems where the entire surface requires wetting. The quantity of water applied should be at least 75 percent of open pan evaporation (Eo). drip irrigation is ideally suited for widely spaced crops like coconut as it saves water, energy and labour and the WUE is high. drip irrigation is a micro-irrigation system in which the water is applied to the root zone at the rate at which the palm can take up. It is ideal considering the advantage of water saving. Based on a study conducted at ICAR- CPCRI, it was concluded that yield of coconut with drip irrigation daily @ 66% of the Eo from December to May was adequate (32 litres/palm/day when the evaporation rate is 4 mm per day) and comparable to basin irrigation @ 200 litres per palm once in four days. Thus, there is 34 per cent saving of water in drip irrigation. This is applicable to varieties and hybrids and in different soil types. The number of dripping points should be six for sandy soils and four for other soil types. The rate of water application should be 2-4 litres per hour per emitter.

Drought management

Intercropping and mixed cropping

Coconut based cropping systems by raising compatible subsidiary crops and / or integrating with livestock enables to increase the productivity and net returns from unit area of coconut plantations. Farm resources like land, labour, sunlight, water and nutrients can be effectively utilized in such a system and higher productivity could be achieved because of synergistic interaction among the crop and crop-livestock components. Crop diversity involving several annual, biennial or perennial crops as inter/mixed crops in perennial stands of coconut also promote the productivity and sustainability of the system. Coconut offers scope for intercropping in the initial stage of the growth of palms and mixed cropping in the later part of life of palms. A variety of intercrops like tubers and rhizomatous spices (tapioca, elephant foot yam, sweet potato, greater yam, lesser yam, chinese potato, colocasia, ginger and turmeric), cereals and millets (paddy, sorghum, maize, pearl millet and finger millet), pulses and oilseeds (cowpea, green gram, black gram, red gram, ground nut, soybean, bengal gram and sunflower), vegetable crops (pumpkin, ash gourd, chillies, potato, french bean, snake gourd, amaranthus, brinjal, bottle gourd, ridge gourd, *Coccinia* sp.,Dolichos bean, annual moringa, curry leaf and tomato), fruit crops (banana, pineapple and papaya), flowering crops (Heliconia sp., Anthurium sp. and Jasminum sp.) and fodder grass and legumes can be raised in coconut gardens up to 5 to 7 years. During the second growth phase of palms, i.e., 5-20 years of age, growing of other crops in the interspace may be difficult due to poor sunlight availability. However, crops like colocasia, some varieties of banana like Robusta, Grand Naine, Palayamkodan *etc*., fodder grass, shade loving medicinal plants etc. which can tolerate shade can be cultivated in this phase. After the palms attain a height of 5 to 6 m (above 20 years) *i*.e., in older plantations, the crops mentioned in the initial stage and perennials like cocoa, vanilla, black pepper, cinnamon, clove and nutmeg, sapota and medicinal and aromatic crops.

High Density Multispecies Cropping System

High density multispecies cropping system (HDMSCS) involves growing many crops to meet the diverse needs of the farmer such as food, fuel, timber, fodder and cash. This is ideally suited for smaller units of land and aims at maximum production per unit area of land, time and simultaneously ensuring sustainability. This system includes annuals, biennials and perennials. The crops selected include cash crops, food crops and fodder crops. The biomass other than the economic part is recycled within the system. From the experimental plot on HDMSCS maintained at CPCRI Kasaragod, which involves coconut and other crops like banana, pineapple, pepper, clove and nutmeg, it is observed that an average annual net income of 5 to 6 lakh rupees can be obtained per ha. Besides, 25 tonnes of organic wastes are also made available per ha which can be recycled and applied to the crops as vermicompost. In HDMSCS if organic recycling is effectively carried out, we can reduce the chemical fertilizer input for coconut to two third of the recommended dose.

Major pests of coconut

Rhinoceros Beetle (*Oryctes rhinoceros* Linn.)

This ubiquitous and cosmopolitan pest has currently become the greatest impediment in the early establishment of juvenile palms causing more than 20% damage through collar entry. Adult beetle bore into unopened fronds and spathes. The attacked frond when fully opened shows characteristic V shaped cutting on opened leaves.

Control

Field sanitation to prevent breeding of beetles. Hook out the beetles from the attacked palms by using beetle hook. Apply 250 g neem cake or marotti cake mixed with equal volume of sand in the innermost 2-3 leaf axils. Do twice - before the onset of S-W monsoon and after the S-W monsoon Naphthalene balls 12g (approx. 4 nos.) in innermost 2 leaf axils at 45days interval Incorporate *Clerodendron infortunatum* in the cow dung or manure pits. Release Baculovirus oryctes infected adults @10-15/ha to bring down the pest population. Inoculate the breeding sites with entomopathogenic fungus *Metarrhizium anisopliae* (@ 5 x 1011 spores/m^3) causes mortality to the grubs Leaf axil filling with chlorantraniliprole (0.4WG) / chloridust @ 5g mixed with 250g of sand during April-May and September -October.

Red Palm Weevil (*Rhynchophorus ferrugineus* Olivier)

Red palm weevil is a fatal enemy of coconut palm. Young palms of less than 20 years of age succumb to severe damage when infested by this pest.

Control Measures

Remove and burn all wilting or damaged palms in coconut gardens to prevent further perpetuation of the pest. Avoid the cutting of green leaves. If needed, they should be cut about 120 cm away from the stem to prevent successful inward movement of the grubs through the cut end. Spot application of 0.02% imidacloprid 17.8 SL (@1.12 ml per litre of water) or 0.013% spinosad 2.5 SC (5 ml per litre of water) or 0.04% indoxacarb 14.5 EC. When the pest infestation is through the crown, clean the crown and slowly pour the insecticidal suspension. In case of entry of weevil through the trunk, the hole in trunk may be plugged with cement / tar. A slanting hole is made with the aid of an auger and the insecticide solution is poured with funnel. Fill the crown and the axils of top most three leaves with a mixture of fine sand and neem seed powder or neem seed kernel powder (2:1) once in three months to prevent the attack of rhinoceros beetle damage in which the red palm weevil lays eggs.

Eriophyid mite (*Aceria guerreronis)*

Coconut gardens in India are seriously affected by this non-insect pest. These mites infest by sucking sap from the soft meristematic tissues beneath the tepals on buttons. The mite infests and develops on the meristematic tissues under the perianth. Initial symptoms exhibit as triangular pale white or yellow patches close to the perianth. Continuous feeding results in necrosis of tissues leading to formation of brown colour patches, longitudinal fissures and splits on the outer surface of the husk; oozing of brown gummy exudation; reduced nut size, copra content and malformation of nuts.

Control

Apply 1% Azadirachtin *i.e.* 4 ml in 1 litre of water. Root feeding azadirachtin 10,000 ppm @ 10 ml + 10 ml water. Apply 2% Neem garlic emulsion *i*.e. 20 ml neem oil, 20 g garlic, 5 g bar soap in 1 l water Kalpa Haritha (a tall selection from Kulasekharam green dwarf) recorded lowest mite incidence in the field and could be a preferred choice in endemic zones. Application of talc-based preparation of *Hirsutella thompsonii* @ 20 g / l/ palm containing 1.6 x 10 8 cfu with a frequency of three sprayings per year reduces mite population. Apply manures and fertilizers as per the recommended dose.

Diseases

Bud rot

The disease kills the palm if not controlled at the early stages. Palms of all ages are liable to be affected but normally young palms are more susceptible. The disease is more prevalent during monsoon when the temperature is low and humidity is high.

Control measures

Provide adequate drainage in gardens. Adopt proper spacing and avoid overcrowding in bud rot prone gardens. Remove all the affected tissue of the crown region and drenching the crown with copper oxychloride 0.25%. Apply Bordeaux paste and protect it from rain till normal shoot emerges. Spray 0.25% Copper oxychloride or 1 % Bordeaux mixture on the crown of the neighbouring palms as a prophylactic measure before the onset of monsoon. Small, perforated sachets containing 2 g of mancozeb may be tied to the top of leaf axil. When it rains, a small quantity of the fungicide is released from the sachets to the leaf base, thus protecting the palm. The infected tissues from the crown region should be removed and dressed with Bordeaux paste sprayed with 1% Bordeaux mixture as pre-monsoon spray (May and September). Spray with Copper oxychloride 0.25% after the onset of Monsoon.

Stem bleeding disease (*Thielaviopsis paradoxa)*

Stem Bleeding is characterized by the exudation of a dark reddish-brown liquid from the longitudinal cracks in the bark and wounds on the stem trickling down for several inches to several feet. The lesions spread upwards as the disease progresses. In advanced cases, the inner portions of affected trunks are hollow due to decay of inner tissues. As a result of extensive damage in the stem tissue, the outer whorl of the leaves turns yellow, dry and shed prematurely. The production of bunches is affected adversely. Nut fall is also noticed.

Control measure

Destroy the chiselled materials by burning. Avoid any mechanical injury to trunk. Along with 50 kg FYM, apply 5 kg neem cake containing the antagonistic fungi, Trichoderma @ 200g/palm/year culture to the basin during September. Provide adequate irrigation during summer and drainage during rainy season along with recommended fertilizer. Chisel out completely the affected tissues and paint the wound with Bordeaux paste. Apply coal tar after 1-2 days on the treated portion. Burn off chiselled pieces.

Root (wilt) disease

The important visual diagnostic symptoms of the disease are abnormal bending or ribbing of the leaflets termed as “flaccidity”, a general yellowing and marginal necrosis of the leaflets. The nuts are smaller and the kernel is thin. The oil content of copra is also reduced. Since the disease is not lethal but debilitating and no curative measure is known at present, the approach will be to manage the disease in the already infected gardens. Palms of all age groups are affected. However, palms contracting the disease in the pre-bearing age may not come to flowering and bearing. The disease also causes several internal changes in the palm.

Control measures

Use of tolerant varieties. As root (wilt) disease is not amenable to conventional plant protection measures, cultivation of tolerant varieties is the most ideal method for management. The tolerant varieties Kalparaksha (selection from Malayan Green Dwarf), Kalpasree (selection from Chowghat Green Dwarf) and the hybrid Kalpa Sankara (Chowghat Green Dwarf x West Coast Tall) and Kalpa Vajra (WCT x WCT) released from ICAR- CPCRI are suitable for cultivation in root (wilt) disease endemic tracts.

Management practices

The integrated disease management technology module includes removal of all disease advanced and uneconomic palms with annual yield of less than 10 nuts, replanting with disease tolerant varieties or elite seedlings from high yielding disease-free palms located in hotspot endemic areas, application of organic manure (25 kg FYM or 10 kg vermicompost), biomass recycling by application of leguminous green manure crops and glyricidia leaves, soil test based application of fertilizers (500g N, 300 g P_2O_5,1250 g K_2O and 1kg Mg SO_4/palm/year) in two splits, application of soil amendments, irrigation with 200-250 L of water/palm/week, soil moisture conservation, adequate drainage, inter cropping and mixed farming coupled with recycling of organic matter and adopt recommended management strategies for leaf rot disease, rhinoceros beetle and red palm weevil.

Value addition in coconut

India consumes more than 50% of its coconut production as raw nuts for culinary and religious purposes. 35% of the production is utilized for conversion to copra, 11% for tender nuts, 2% for seed purposes and hardly 2% is utilized for value addition and industrial purposes. There are so many value-added products are available from the coconut. Some of the value-added products which can be produced as a part of enterprise for producing higher income include for example the best benefit from coconut-based enterprises is that the by-products of it are also useful in one or other way so, the entrepreneur can assure zero wastage from his firm. The recycling of the products and by products increases the feasibility of the enterprises and the outcome also grow more than entrepreneur can expect.

The principal value-added edible coconut products are coconut oil, desiccated coconut, virgin coconut oil, coconut chips, tender coconut, coconut inflorescence sap and coconut sugar. Several by-products are generated while processing these value-added products, which have immense health benefits and offer scope for further value addition. These by-products are obtained from mature coconut, tender coconut, coconut inflorescence, etc., which could be of edible and non-edible nature.

By-products derived from mature coconut

In the coconut processing chain, virgin coconut oil (VCO), is one of the major value-added products and several by-products such as husk, shell, testa, nut water, coconut milk residue and VCO cake are obtained. During VCO processing, 500 nuts yield about 200 kg of husk, 67 kg of shell, 50 L of nut water, 3.3 kg of testa, 25 kg of milk residue and 5 kg of VCO cake. The husk has immense utilities in coir industries, in the preparation of potting mixtures. Shell charcoal, activated carbon and shell flour are the commercial products obtained from the shell. Mature coconut water is commercially utilized for the preparation of vinegar, the production of nata de coco and soft drinks or squash. Coconut testa is enriched with phenolic compounds and appreciable antioxidant activity and hence used as an ingredient in high fibre digestive biscuits. Milk residue and VCO cake are the two co-products, presently underutilized or discarded as waste. In addition to VCO, husk, shell, water and testa are the common by-products obtained during the processing of other major value-added products such as desiccated coconut, coconut milk, etc.

Mature coconut water

Mature coconut water has been considered a waste, especially in coconut processing plants. The most economical and practical way to enhance the value of coconut water are preparing vinegar, nata de coco as a natural soft drink or non-carbonated beverage. Other value-added products are Neera-coconut inflorescence sap, a healthy drink and the sap coconut sugar and jaggery are obtained by evaporating the water of unfermented sap at 115°C.

Byproducts from coconut shell and husk charcoal, activated carbon and coconut husk biochar. Enormous potential exists for utilising by-products of coconut into diversified value-added products for income generation and livelihood enhancement. Value addition paves the way for employment generation and doubling the income of farmers for their sustainable livelihood.

Conclusion

Countries such as India and Sri Lanka export coconut goods; however, they also import inexpensive coconut raw materials for industrial use. To rectify the trade imbalance, it is recommended to expand the cultivation area and enhance the output of coconuts in coconut-producing nations. To attain self-sufficiency in the coconut sector, SAARC nations must prioritise enticing and incentivising new farmers to engage in coconut cultivation by facilitating access to excellent planting materials, cutting-edge production methods and capital support services. Considering the significant potential of coconut plantations, particularly their ecosystem services and carbon sequestration capabilities, targeted initiatives should be implemented in SAARC countries to identify appropriate areas for the expansion of coconut cultivation and to develop region-specific sustainable production technologies aimed at enhancing farmers' income.

As part of trade liberalisation, all coconut-growing SAARC countries must radically enhance processing and value addition to ensure the coconut sector's profitability. Coconut production and productivity are declining worldwide, which requires particular attention from each coconut-producing SAARC nation. It is essential to formulate national policies expeditiously to enhance the existing circumstances. Prioritising participatory research that engages farmer groups is essential for optimising technology in the coconut industry for enhanced efficiency. SAARC Countries that cultivate coconuts ought to assess their strengths and leverage that data to formulate a strategic, time-sensitive plan aimed at advancing their coconut sector. It is essential to meticulously evaluate the coconut value chain in each coconut-producing nation and ensure that farmers, who are the primary stakeholders of the chain, receive an equitable share of the profits generated across the whole chain. International coconut trade policy, including tariff measures, should be considered on a single platform to create a sector-wide policy that benefits all coconut-growing nations.

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Chapter 19

Productivity Enhancement of Different Industrial Oilseed Crops in Arid Climate Region of Pakistan

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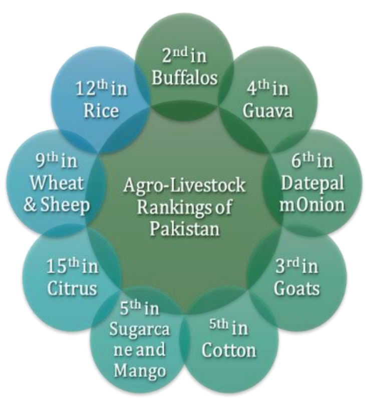
Introduction

Pakistan is a country in South Asia that is dry to semi-arid. There is approximately 250 mm of rainfall on average every year. The monsoon season, which runs from July to September, accounts for about 67% of total rainfall. Out of the 80 million hectares of land in Pakistan, 22 million hectares are used for agriculture, 17 Mha and 5 Mha of the 22 Mha total areas are rain-fed and irrigated, respectively. Croplands are irrigated by surface water from the Indus Basin Irrigation System. Additionally, groundwater is crucial in supplying roughly 50% of the irrigated land's irrigation needs. Roughly 10% of the nation's overall agricultural output comes from rain-fed agriculture.



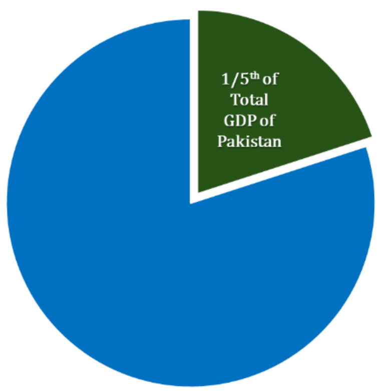


Fig 1. Global Ranking of Potential of Agriculture Sector of Pakistan

Increased productivity in agriculture is essential to the growth of the economy in the future, food security, improved livelihoods and the reduction of poverty. The most urgent issues facing Pakistani agriculture, are related to water, land, the environment, agronomy, institutions and society, all of which have a significant impact on agricultural production. Comprehensive plans and initiatives must be created and put into practice for better management of the water and non-water components of agricultural productivity.

Since the early 1970s, the nation has shifted from being self-sufficient to becoming a significant importer of edible oil. Less than 20% of demand is currently met domestically, with more than two-thirds coming from imports. This is an unjustifiable strain on the nation's foreign exchange reserves. Since 1969-1970, domestic supply has doubled, but the demand for edible oil and vegetable ghee made from oil seeds has grown 16 times.

Industrial Oil seed Crop

Using fossil fuels to meet energy needs leads to several problems for the environment and human health. Increased greenhouse gas (GHG) emissions and climate change are caused by increased exploitation, technological advancement and prospective reserves. An exponential rise for carbon dioxide in the atmosphere causes the global temperature to climb as well. The availability of the source, its impact on the environment and its economic potential all play a role in the choice of alternative energy sources. Because biofuels have the potential to address environmental issues and lower GHG emissions, they are a suitable alternative to petroleum-based fuels and can be used as transportation fuels with minimal technological change.

Industrial oil seed crops such as *Jojoba, Jatropha curcas, Pongamia pinnata and Ricinus communis* play a vital role in sustainable agriculture, biofuel production and multiple industrial uses. Enhancing their productivity is crucial for meeting global demands while promoting environmental sustainability. The goal of this discussion is to explore strategies for productivity enhancement of these crops, through innovative practices to improve yield and quality.

Jojoba (*Simmondsia chinensis*)

Introduction and Background history

Identification, choice and establishment of suitable plants in desert areas have always been a challenging task for plant scientists. Hot desert regions pose special problems to the newly introduced plants mainly because of scarcity of soil moisture (precipitation in such areas seldom exceeds 300 mm per annum). Sandy soils have poor water holding capacity and inadequate plant nutrients. droughts and extremes in temperatures are common features of these areas. The ecological degradation in such regions due to natural and manufactured causes and consequently a gradual decline in productivity are the main threats to bring these areas to the verge of a point where human and animal life can sustain.

Among several arid zone plant species, Jojoba (Simmondsia Chinesis), being an evergreen, perennial, multi-stemmed and multipurpose plant has attracted wide attention due to its economic value, potential by-products and ability to withstand vagaries of desert environment.Jojoba was originated from the Sonoron desert of America and Mexico and it has been reported for the first time as a plant having medicinal value, in a report published back in 1716. Subsequently, in 1929 in Arizona State of USA, oil was extracted from the seed of jojoba and it was found out that the chemical composition of jojoba oil resembles that of whale fish oil. As a strict ban is being observed on the hunting of whale fish at the international level, an increased attention is being paid since the 1970s to the alternate source of oil (i.e Jojoba oil) on a commercial scale. The leading countries for jojoba cultivation are America, Mexico, Israel, Kenya, Brazil, Australia and India. It has been reported that the Jojoba crop has been cultivated on an area of 82,000 acres in the USA and 27,000 acres in rest of the world. While realizing the importance of this desert plant, Arid Zone Research Institute (AZRI) Bahawalpur initiated a research plan on its production technology in 1990 at both Cholistan and Bahawalpur farms of AZRI under the activities of "Oil Crops Cultivation in Cholistan Project" of PARC**.**

Fig 2. Jojoba Experimentation at PARC AZRI Research Farm Bahawalpur

Economic value/ possible utilization:

There are several important uses of jojoba. Some of which have been enlisted here.

Industrial usage

When jojoba oil is mixed with sulphur dioxide, it is used as printing and pasting material. If hydrogen is mixed in jojoba oil, it is used as wax in the cosmetics industry, Jojoba wax is also used in making candles and in paper, match and textile industry. Its oil is also used as fungicide.

Medicinal usage / Cosmetic usage

Jojoba oil is used in many medicines used for skin diseases, eczema and skin cancer. It inhabits the growth of germs of tuberculosis. Jojoba oil is not digested in the human body and it is excreted from the body without being converted into calories, so it is called as zero calories and is often used by heart patients. It is used in making cosmetics such as hair oil, shampoo, facial cream, soap and lipstick etc.

As a Lubricant

By mixing Sulphur in jojoba oil, it is used in heavy machinery. American Engineering Association has claimed that if jojoba oil is used as lubricant in the vehicle, the vehicle will run 80,000 km/without changing the oil,

Physical Characteristics

The scientific name of Jojoba is *Simmondsia Chinesis*, it belongs to the family Euphorbiacae. Its chromosome No. is 2n = 52. Jojoba is considered as a very precious plant which can survive under saline water conditions and resists pest attack. This plant has been reported to survive for about 160 years. Under favorable environmental conditions, Jojoba can reach up to 15 feet and its roots can go down to 70 feet deep in the soil. In this manner, this plant can survive under extremely hot desert conditions for 100-160 years. An interesting fact about the Jojoba plant is that nature has covered its leaves with a waxy coating/sheet which helps to reduce the evapotranspiration from its leaves thus reducing the loss of moisture at a very minimum level. This probably is one of the most important reasons for its survival under desert conditions. Its female plants bear fruits (seed) in February-March; the fruit matures in May-June. There are approximately 1600 seeds in one kilogram. The percentage of oil extracted from one kg of seed has been reported to be 45-55%. The oil extracted from Jojoba is usually called as “Liquid Gold”. This oil is one of the most expensive commodities out of several other agricultural products sold in international markets.

Climatic Conditions

As this plant is being cultivated in the Sonoron and Arizona desert of America, the summer temperature reaches up to 52^{o}C. These climatic conditions are quite like that of Cholistan desert. However, this plant can be cultivated in areas where the annual rainfall is 125-450 mm and the average temperature ranges between 1-50^{o}C. Its seeds germinate between 25-35^{o}C. Pollination takes place between 15-25^{o}C and the suitable temperature for seed ripening is 40-45^{o}C.

Soil requirements

Sandy loam soil with good drainage is suitable for jojoba cultivation. It should not be cultivated on waterlogged soil, as the Jojoba plant has a very deep root system, so underground high-water table can damage the root system.

Production Technology

Direct Sowing

The seeds can be directly sown in the soil, Soil should be well prepared and ditches should be made South-North at 12.5 feet. These should be filled with water; the seed may be buried on the sides of ridges at two feet each so that at a later stage, the exact male, female ratio could be maintained. After germination, irrigation should be applied at an interval of 15 days. This, however, is a laborious method.

Indirect method

Raising Jojoba nursery

The jojoba seedlings can be raised in polythene bags of 9 x 3.5 inches size. The soil media having sand, silt and clay (in 1:1:1 ratio) is filled in polythene bags with a hole at bottom of bag for aeration. The healthy and mature seeds be sown at vertical direction at a depth of 1 cm and after sowing, irrigation should be applied with a sprinkler.

The nursery can be raised in two seasons, when the average temperature ranges between 25 - 35^{o}C.

- 15th August to 15th September
- 15th February to 15th March.

Irrigation needs to be applied to freshly germinated seedlings at a regular interval of 15 days during summer. When the seedling attains the height of 1-2 feet, shifting within the nursery shed is recommended to avoid root penetration in the soil. The six-month-old seedlings are ready to be transplanted in the field.

Transplanting of Nursery

Before transplanting the seedling, the field must be properly prepared. When the jojoba plant attains a size of 1 - 2 feet size, they are ready for transplantation. At the time of transplantation, a proper layout according to the size of plot needs to be prepared. Plant to plant distance of 04 feet and row to row distance of 12 feet is usually recommended. In this manner, 720 plants should be needed for one acre. It is further recommended that while keeping a ratio of 1:4 in mind, 100 male plants and 620 female plants would be required. Irrigation should be applied at once after the transplantation of these plants.

Maintaining the Exact Male and Female Ratio

Male and female plants of Jojoba cannot be found unless they bear flowers. The male plants begin flowering at the age of two years while the female plants start flowering after three years.

After identification of female and male plants, male-female ratio (1:4) should be maintained as soon as possible through.

1. Grafting
2. Stem cutting
3. Aerial layering

Irrigation requirements

It is generally thought that being a desert plant, Jojoba needs less irrigation. In fact, at initial stages of its growth it needs more irrigation. After three years, when its roots penetrate deeper into the soil only then the irrigation requirement lessens.

The following irrigation techniques were applied /tested for Jojoba cultivation.

i). PVC pipe method

ii). Plastic bag

iii). Pitcher plantation

iv). Pits

v). Farrows

vi). Drip irrigation

Fertilizer requirement

It has been proved through experimentation that a suitable dose of urea fertilizer can substantially enhance the growth and increase the seed yield of Jojoba. As these plants are planted in sandy soils which are deficient in NPK. In the beginning, a solution of 1-2% of urea fertilizer should be applied monthly and after three years, one bag of Potash, DAP and urea fertilizer (in a 1:1:1 ratio) on per acre and yearly basis is recommended dose of fertilizer. Jojoba certainly required less quantity of fertilizer when compared to any other crops.

Harvesting of Jojoba

The jojoba plants become productive after three years, but the plants become fully productive after nine years. One mature plant of jojoba produces 6 kilograms of seed. Jojoba plants remain highly productive between the age of 10-136 years. The pods when mature should be picked by hand and dried under sunlight. The seeds should be cleaned and stored in proper storage place.

Constraints in marketing

One of the serious most serious factors in making proper projection of Jojoba cultivation is the lack of marketing system in Pakistan. There is no market at the national level where the farmers can sale his/her produce. For making efficient use of this precious plant at a commercial scale in the country, it is suggested that.

a) Concrete efforts need to be made to establish at least two marketing points in the most suitable desert places in the country

b) Oil extraction from Jojoba seed should be encouraged for its further use (on a small and then on a commercial scale basis) in various industries.

2. Jatropha curcas

Geographical Distribution

Jatropha curcas originated from Central America. From the Caribbean islands it was probably distributed by Portuguese seafarers via the Cape Verde Islands and formerly Portuguese Guinea to other countries in Africa and Asia. Today it is cultivated in almost all tropical and subtropical countries as protection hedge around gardens and fields, since it is not browsed by cattle.

Taxonomical Distribution

It is a small tree or shrub with smooth gray bark, which exudes whitish colored watery latex when cut. Normally it grows between three to five meters in height but can attain a height of up to eight or ten meters under favorable conditions.

Leaves / Flowers / Fruits

It has large green to pale-green leaves, alternate to sub-opposite, three to five lobed with a spiral phyllotaxis. The petiole length ranges between 6-23 mm. The inflorescence is formed in the leaf axil. Flowers are formed terminally, individually, with female flowers usually slightly larger and occur in the hot seasons. In conditions where continuous growth occurs, an unbalance of pistillate or staminate flower production results in a higher number of female flowers. More number of female flowers is grown by the plant if bee keeping is done along with. More female flowers give a greater number of seeds.

Fruits are produced in winter when the shrub is leafless or it may produce several crops during the year if soil moisture is good and temperatures are sufficiently high. Each inflorescence yields a bunch of approximately 10 or more ovoid fruits. A three, bi-valved cocci is formed after the seeds mature and the fleshy exocarp dries seeds:

The seeds become mature when the capsule changes from green to yellow, after two to four months from fertilization. The blackish, thin shelled seeds are oblong and resemble small castor seeds. An innovative research activity on cultivation of Jatrpoha curcas in barren and low productive arid lands of Pakistan was initiated by PARC AZRI, Bahawalpur by Keeping in mind the enormous potential of biofuel plants and up-scaling the on-going research activities on Jatropha curcas, for assessing their growth/yield potential. Intercropping of various biofuel plants were tested to achieve maximum economic return. Seed of different Jatropha Species (Australia, Indian, Malaysian, African. Thai) etc. were collected for own nursery and extraction of oil from those seeds were carried out and finally it was exercised to work out the yield / plant and on per hectare basis. Quantified the oil potential of selected non-edible biofuel plant species propagated at a large scale at AZRI, Bahawalpur which showed 20-25 % oil contents which varied in different species. The package of technology was developed for most promising biofuel plants and its introduction to the farmers with an aim to become self-sufficient in bio-diesel production.

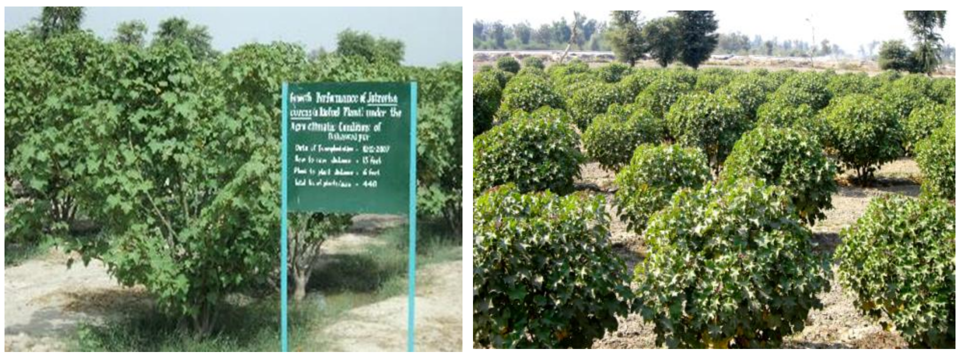


Figure 3. A field view of fully established Jatropha curcas at AZRI, Bahawalpur

Ecology

Jatropha is widely distributed in the wild and cultivated tropical areas of Central America, South America, Africa, India, Southeastern Asia and Australia. Therefore, it typically grows between 15 and 40^0C with rainfall between 250 mm and 3000 mm and is more altered by lower temperatures than by altitude or day length. However, it is an open-field plant species that requires intense sun shine such as found in the savanna or desert periphery. It can also grow on an enormous range of soil provided they are well drained and aerated. In Egyptian growth conditions, the average rate of water consumption by Jatropha was found to be 6 L/week throughout the growing season, which means that Jatropha can survive and produce significant seed yield of acceptable quality with minimum water requirements compared to other crops.

Propagation

Jatropha is propagated through cuttings or seeds. Cuttings are typically prepared with one-year-old terminal branches of 25-30 cm. It is good practice to inoculate cuttings with mycorrhizal fungi when establishing them into nursery. This treatment improves the quality of plant-fungal symbiosis in the field conditions especially in soil with poor fertility. Endo-mycorrhizal fungi were demonstrated to be commonly found in association with Jatropha in natural conditions. Seeds are presoaked for 24 h in water and germinate in 5-10 days at 27-30^0C with humidity saturation. The cuttings and seedlings are grown in nurseries for 44 days.

Planting density

There are two basic models for planting, Indian and Cuban. Under the Indian model, the tree density is high, i.e., 2500 ha^{1}, with a planting distance of 2*2 m^{2}. The total seed production with three harvests per year ranges between 2000 and 4000 kg/ha and is typically around 3200 kg/ha, corresponding to about 1.5 t oil/ha with an annual rainfall of 700-800 mm. For comparison, palm trees produce 3.7 t oil/ha and soybean produces 0.38 t oil/ha. Unfortunately, high planting densities at 2*2 m^{2} make tractor pulverization for weeding or pests and diseases control impossible.

By contrast, under the Cuban model, the density of trees is lower, i.e., 357 ha^{1} with a planting distance of 7* 4 m^{2}. Under this model, the number of fruit grapes per tree is higher and reaches 14 kg seeds/plant or 5000 kg/ha. It seems that a density of 5*2 m^{2} (1000 ha^{1}) would be a good compromise for production and mechanization.

Oil extraction and properties

Fruits are harvested at seed maturity, which occurs 40 days after flowering and then dried to 10% oil remains in the seed cake after extraction. Given the high variability in oil rate extraction found in practical applications, oil production may vary greatly from one place to another, however, in Brazil oil production is usually 1-2 t/ha. The oil extracted from the Jatropha kernel contains approximately 24.6% crude protein, 47.2% crude fat and 5.5% moisture.

The advantages of Jatropha plant

Good agronomic traits

1. Hardy shrub which grows in semi-arid conditions and poor soil

2. Can be intercropped with high value crops such as sugar, coconut palm, various fruits and vegetables, providing protection from grazing livestock and phyto-protection action against pests and pathogens.

3. It is easy to establish and grow relatively quickly.

4. Yields around 4 tons of seed per hectare in unkept hedges are achievable.

5. Has low nutrient requirements.

6. Requires low labour inputs.

Multi-purpose plant

1. Protective hedges around fields.

2. Reclaims marginal soils.

3. Non-edible and therefore does not compete with food supply when used for biodiesel production

4. Is energy crop that produce seeds with high oil yields.

3. Sukh chain *(Pongamia Pinnata)*

Pongamia pinnata Linn. Pierre is a glabrous hierarchy of medium altitude. *P. pinnata*, also known as Derris indica, is a monotypic species that develops prolifically along Myanmar's beaches and canal reservoirs. The hierarchy is well recognized and designed for its many uses and as a possible biodiesel resource. The seeds are said to contain 28% to 34% oil on average, with a high percentage of polyunsaturated fatty acids. 2 P. pinnata is an element of the Fabaceae folks.

Botanical and chemical characteristics

Pongamia pinnata is a medium-sized plant that grows extremely quickly. It typically reaches heights of 30 to 40 feet and extends its canopy to provide moderate shade. *Pongamia pinnata* can grow in a variety of environments and has a wide range of habitat distribution. It can thrive in a variety of soil types, including alkaline, salty, sandy, clay, stony and waterlogged soils. It also has a great tolerance for drought and can withstand temperatures of up to 50^{o}C. The trunk typically has a diameter of more than 1.64 feet and is short, Pongamia has a deep and robust taproot system with numerous secondary lateral roots. The complex, alternate leaves have 5 or 7 leaflets, 2 or 3 pairs of which are oriented in opposite directions and a single terminal leaflet. Leaflets have a pointed tip and measure 5-10 cm length by 4-6 cm wide. The tap root is thick and long and the bark is thin, grey to grayish brown in colour and yellow on the interior. Pea shaped flowers are typically 15-18 mm long and pink, white or light purple in hue. The elliptical pods, which are 3-6 cm long and 2-3 cm wide, contain a single seed inside of a thick-walled shell. The seeds are retrieved by thrashing after the pods have been sun-dried. The seeds are 1.0-1.5 cm long and are a light brown colour. One tree may produce between 9 and 90 kg of seed pods and these seed pods can produce up to 40% oil per seed, 50% of which is C18:1, which is thought to be appropriate for making biodiesel. One tree provides 8-24 kg of kernels, which contain 30-40% oil. Normally, seeds last for around six months. 19.0% of the air-dried kernels are moist, 27.5% are oily and 17.4% are solid.6.6% starch, 7.3% crude fibre, 2.3% ash and 2.3% protein.

Fig 4. Pongamia pinnata plants

Cultivation of Pongamia pinnata

Pongamia pinnata is indeed a nitrogen-fixing tree, which means it can convert atmospheric nitrogen into a form that can be used by plants. It is commonly propagated through seeds and seed storage is a popular and cost-effective technique for preserving the genetic variety of the species. When planting Pongamia trees, it is recommended to dig pits with dimensions of approximately $60 \times 60 \times 60$ cm³. This size provides sufficient space for the roots to establish and grow. The spacing between rows should be around 5 meters and the recommended distance between individual plants within a row is 4 meters. These spacing guidelines help ensure adequate light penetration and airflow for the optimal growth and development of the trees. To support the better growth and development of Pongamia trees, it is generally recommended to provide three irrigations per year. Adequate water supply is crucial, especially during the initial stages of establishment and during dry periods. However, specific irrigation requirements may vary depending on factors such as soil type, climate and rainfall patterns in the region where the trees are grown. Monitoring soil moisture levels and adjusting irrigation practices accordingly is important for optimal plant health. Overall, following these guidelines for seed storage, planting spacing and irrigation can contribute to the successful cultivation of *Pongamia pinnata* trees and their growth and development.

Propagation

Pongamia are often reproduced from seeds, which is labour intensive and unsuitable for maintaining genetically superior lines. Pongamia is an obligatory out crosser, with bees serving as the main pollinators. Therefore, a pollen donor could be any tree that is close enough for a bee to transport and spread pollen from (approximately 3 km radius). After choosing the genetic material that would produce the greatest results, trees must be clonally propagated by stem cuttings, grafting or tissue culture.

Applications for *Pongamia pinnata*

Pongamia pinnata is a plant whose flower, seed, leaf, root and other parts have all been used to make traditional remedies, animal feed, green manure, wood, fish poison and other things.

Fertilizer management

Early growth and establishment success are presumably improved by fertilizer application to seedlings. To sustain soil fertility over the long term, the addition of macronutrients like phosphorus and potassium as well as micronutrients may be necessary.

Pongamia oil

There are different methods used to extract Pongamia oil from the seeds, including cold pressing, solvent extraction and expeller pressing. Each method has its own advantages and may result in slight variations in the physical properties of the oil obtained. In Table 6, the crude Pongamia oil's physical properties are displayed. The color of the oil typically ranges from orange yellow to brown, which is a characteristic attribute of Pongamia oil. It is important to note that Pongamia oil should not be consumed orally as it is known to be poisonous and can cause nausea and vomiting if ingested. Despite its toxic nature, Pongamia oil has been traditionally used in various treatments. It is rich in fatty acids. Triglycerides are one of the major components of Pongamia oil. However, the presence of bitter flavonoid components, such as pongamol, karanjin, karanjachromene and tannins, gives the oil an unpleasant taste and odor. These bitter components contribute to the characteristic properties of Pongamia oil but may limit its direct consumption or use in certain applications. However, they also contribute to the oil's bioactive properties, such as insecticidal and antimicrobial effects, which are valuable in agricultural and medicinal applications.

Cator bean *(Ricinus Cummunis)*

Castor bean, (*Ricinus communis)*, is a perennial or annual crop which is grown throughout tropical and sub-tropical regions of the world. Castor is extraordinarily rich in unique hydroxyl fatty acid; rich in oleic acid and is reported by many researchers, almost 87 to 90 percent over 89 percent. Characteristics of caster from China, India, Brazil and Africa have been studied. Different genotypes of castor began when evaluated in varying stressed and unstressed environments, it was observed that qualitative and quantitative parameters were greatly affected by environmental conditions. Physiologically, the castor bean is highly responsive to environmental conditions which shows its ability to survive under changing environmental conditions and its chances of improvement in quantitative and qualitative traits under the predicted new environmental conditions.

Fig 5. Castor bean plant sown in PARC- AZRI Bahawalpur.

Agronomy

Castor bean cultivation is generally done by small farmers all over the world, mainly in India, Mozambique, China and Brazil. The production in these countries is concentrated in arid and semiarid regions, where the rainfall is generally low, although the limited availability of water is the major factor affecting yield. The culture system generally involves intercropping with food crops (such as maize and beans) with low adoption of technologies. The entire system of production, from planting to processing, is manual with little or no soil tillage and fertilization. Mostly local varieties are cultivated and they are characterized by a long vegetative cycle and uneven seed maturation. To increase castor yields, the mechanization of the production process is pivotal and breeding programs to develop suitable plant architecture are currently the only way to make the mechanization of the crop cycle possible. The annual varieties of castor require about four to nine months to reach maturity while the perennials may continue yielding for 10-15 years. Capsules of non-shattering varieties (improved varieties) can be harvested when they are fully dry, while shattering types are harvested when they turn in color from green to yellow.

The central spike on the main rachis matures before the side-branches' spikes, making necessary two to three pickings to complete the harvest. It is worth noting that harvesting of immature capsules should be avoided because of the negative impacts on oil content. Furthermore, it has been reported that before threshing, the capsule should be sun dried for four to five days. Castor yield may vary from 1 to 3 tons of seed/ha depending on climatic conditions, crop management and variety. The percentage of oil obtained can reach up to 50% by weight. Castor seeds are characterized by slow, irregular and cold-sensitive germination. Furthermore, 14-15 °C is the minimum tolerated temperature for germination, the optimum is 31 °C and the maximum 36 °C. Germination and seedling emergence are often delayed by low soil temperature, resulting in irregular crop development. By implementing appropriate agronomic practices, such as selecting suitable cultivars, utilizing high-quality seeds, strategic planting dates, irrigation, soil fertilization, effective weed and pest management, disease control, mechanical harvesting and postharvest management, seed yield in most regions of castor production can be significantly increased. A castor field yielding 2000 kg/ha of seed will remove 80 kg/ha of N, 18 kg/ha of P_2O_5, 32 kg/ha of K_2O, 13 kg/ha of CaO and 10 kg/ha of MgO from the soil. In the early phases of development, the growth of the castor's leaf area is slow. For this reason, weeds can quickly cover all the available soil surface. Trifluralin, Pendimethalin and Clomazone are some of the pre-emergence herbicides that can be used in castor cultivation. These herbicides are useful to control monocotyledonous weeds, but less effective against broad-leaved plants. For combatting the growth of broad-leaved weed plants, the only post-emergence herbicide that has been proven to be effective in castor cultivation is Chlorimuron-ethyl. An effective weed management program that does not lead to phytotoxicity on the castor crop is a treatment with a pre-emergence followed by a post-emergence herbicide applied at 20 DAE (days after emergence). Castors are affected by several diseases, but only a few of them are responsible for economic losses.

Crop Nutrition and Fertilization

Soil analysis should always be done to inform nutrition management and fertilization. The most crucial factor in fertility management of castor beans is the supply of nitrogen in the soil. Insufficient nitrogen results in reduced castor bean yields, while excessive nitrogen produces heavy vegetative growth with little or no increase in seed yield. The amount of nitrogen required by castor beans depends on the soil organic matter content. If the soil is deficient in nitrogen, 90 to 135 kg/ha of nitrogen usually are needed for maximum yields. A split application of nitrogen is often used, with the second half applied approximately 1 month after planting. A minimum of 37 to 56 kg/ha of phosphorus is needed for production of castor and 15 to 19 kg/ha of potassium. If phosphorus is needed, application should be made before planting time. Potassium may be applied at planting time. Castor beans do not generally respond to phosphorus and excess soil phosphorus levels can decrease yields. A general fertilization technique is the addition of manure to plant holes before seeds are sown. This assists new root formation, promotes better anchorage and retains moisture, which is especially beneficial to the plant during the dry season. Waste castor bean husks and cake may also be reused as an organic fertilizer. Biochar from castor meal may also be incorporated as a soil amendment for improved soil quality and slow-release fertilizer.

Harvesting

To prevent premature seed dispersal, local varieties should be harvested when the coat covering the capsules is removable and the colour of capsules changes from green to yellowish-brown and a few capsules start drying. Generally, 15-30% of the bunches (panicles) should be dried. Castor produces 4-5 sequential order bunches which may be conveniently harvested in 3-4 pickings, starting from 90-120 days, at intervals of 25-30 days. Premature harvesting leads to reduced seed weight, oil content and germination. Bunches may be harvested by hand, pruning scissors or pole pruners for taller branches. Harvested bunches may be placed in bags or boxes and transported to the drying area. After harvest, stalks should be broken up mechanically and worked into the soil to furnish organic matter. Castor bean hulls may also be used as organic matter. Seeds remaining in the field may result in a volunteer problem in the next year's crop. Ploughing in the young plants after the seeds germinate and crop rotation with a row of grain crops will assist in control.

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Proceedings

Regional consultation meeting on "Productivity Enhancement of Oilseed Crops in SAARC Member States"

18-20 November 2024

A three days (18-20 November, 2024) regional consultation meeting was conducted by the SAARC Agriculture Centre (SAC) in virtual mode on *"Productivity Enhancement of Oilseed Crops in SAARC Member States"***.** It was approved by the 15th meeting of SAC Governing Board and the 59th meeting of Programming Committee, of SAARC Agriculture Centre (SAC) Dhaka Bangladesh.

Background:

Current population of SAARC countries is more than 1.90 billion over the landmass of 6.4 million square kilometres which is about 3.5% of Earth's land areas. Arithmetically, it implies approximately 25% of global population and it is the most densely populated region of the world (Xue et al., 2021). One-third of the world's poor (earning less than 1.9 $/day) live in this region and it was estimated that 41% (532 million) of the total 1.3 billion multi dimensionally poor people in the world were from this region (UNDP & OPHI, 2021).

Due to the rapid population increase the demand of all crops including oilseed crops is increasing with the passage of time in this region. Oilseed crops occupy a major area under cultivation next to cereals in SAARC Member States but still the yields of these crops are low and fluctuating yields of these crops are primarily due to a number of factors which include planting of these crops on marginal lands, lack of irrigation, use of low inputs, use of low quality seed, less use of seed of improved varieties, pests attack and similarly improper crop management are the main reasons of less yields of oilseed crops. Horizontal expansion of area under oilseeds crops is limited due to the decrease of per capita land availability due to rapid population increase and similarly also due to the different competing crops. However, many new cropping systems have been identified, where oilseed crops can be adjusted in the SAARC Members States.

Oilseeds crops are very important for all SAARC Member States and according to demand projections of South Asia under low-income scenarios, overall demand in this region for edible oil would grow at more than 1.6% per annum (SAC, 2009). With population increase along with increased per capita consumption of edible oils in all SAARC Member States, there is a dire need of higher per acre production of all oilseed crops. Presently all SAARC Member States are spending vast amounts of their foreign currency for the import of edible oil. Due to higher costs of imported edible oils, many poor people have resort to cheaper unhealthy alternative edible oils.

Yields of Oilseed crops of SAARC Member States are still low and there are big yield gaps between the average yields of oilseed crops on the farmer's fields as compared to the potential yields of different available latest varieties of various oilseed crops. Various factors responsible for less production of oilseed crops include use of old varieties, improper crop management, climate change, availability of land for the planting of oilseed crops, unavailability of suitable machinery, market prices and similarly policies of the governments. In this region use of seed of latest varieties of oilseed crops is very low as compared to the other major food crops. Similarly, there are several biotic, a biotic, technological and socio -economic and institutional factors which inhibit exploitation of yield potential of oil seed crops.

There is a need to enhance the per hectare production of all oilseed crops through development of high yielding, disease resistant and climate resilient varieties and by using the latest crop management technologies. Similarly, there is also a need of making the processing industry more efficient, along with the distribution and logistics improvements.

There is a dire need to take long-term measures to improve the productivity of oilseed crops, which can be supportive to all SAARC Member States in bringing back to the minimum importing of edible oils status. There is also a need of strengthening a stable domestic and trade policy with a long-term vision by including all stakeholders on edible oil products to strengthen industry and farmers to stabilize the prices in these countries. Likewise, SAARC Member States can help each other by exchange of knowledge for better production of different oilseed crops.

There are huge losses of oilseed crops at the harvesting stage due to unavailability of sophisticated machines which are specially designed for harvesting and processing of oilseed crops. Similarly, unavailability of oil extracting machines which should enable local farmers to extract oils themselves for domestic consumption and for commercial scale which can be supportive in improving the economic condition of the farming community. Given the competing demands on agricultural land from various crops, the production of oilseed crops can be increased, only if productivity is improved significantly and farmers get attractive prices. The main purpose of this regional consultation meeting was to bring together Focal persons / oilseed crops scientists of SAARC Member States to find out the ways for the production enhancement of these crops in this region.

Objectives

- To know about the production status of different oilseed crops and main causes of less oil seed crops productivity of SAARC Member States.

- To share ongoing different innovative practices and policies regarding oilseed crops productivity enhancement.
- To find out the status of different post-harvest technologies being used in the different SAARC Member States.
- To sensitize SAARC Member States to scale up the novel innovations in this sector.

Expected output

- Find out the status of production of different oilseed crops in SAARC Member States.
- Find out the hurdles, which are hindering in getting the maximum productivity of different oilseed crops in SAARC Member States.
- Finding out the ways for the maximum production of different oilseed crops.
- Find out the different post-harvest technologies which are being used by the different SAARC Member States.

Methodology

Three days (18-20 November, 2024) regional consultation meeting was conducted in virtual mode in which nominated Focal points of SAARC Member States, oilseed crops scientists of different organizations and similarly professors of different universities of SAARC Member States participated and presented their papers on different oilseed crops, their machinery and quality etc. Their were detailed discussions on the different aspects of oilseed crops productivity enhancement. and it was tried to find out the ways for the maximum production of different oilseed crops in this region.

Inaugural Ceremony

Focal points of different SAARC Members States including Bangladesh, Bhutan, India, Nepal, Maldives, Pakistan and Sri Lanka and scientists of different research organizations and as well as universities of different SAARC Member States participated in these 3 days regional consultation meeting on *"productivity enhancement of oilseed crops in SAARC Member States".*

Dr. Md. Mahmudur Rahman, Additional Secretary (PPC)Ministry of Agriculture Bangladesh & G.B Member SAARC Agriculture Centre was the Chief guest. Dr. Nazmun Nahar Karim, Executive Chairman Bangladesh Agricultural Research Council (BARC), was the Special guest, while Mr Jamalud Din Ahmad, Director (ARD & SDF), SAARC Secretariat Nepal was the Guest of Honor of inauguration of this regional consultation meeting. Dr. Md. Harunur Rashid, Director SAARC Agriculture Centre (SAC) welcomed the participants, while Dr. Sikander Khan Tanveer, Senior Program Specialist (Crops), SAARC Agriculture Centre gave a detailed presentation about the purpose of arranging this meeting.

Guest of Honor, Mr Jamalud Din Ahmad, Director (ARD & SDF), SAARC Secretariat Nepal appreciated SAC, for organizing this meeting. He said that as demand for edible oils is increasing, so there is need of use of latest varieties, along with best crop management and pests' management practices. Similarly, implementation of appropriate policies can be helpful in increasing the productivity of oilseed crops in this region.

Special guest, Dr. Nazmun Nahar Karim, Executive Chairman Bangladesh Agricultural Research Council (BARC), appreciated SAARC Agriculture Centre (SAC), for arranging this very important regional consultation meeting. It will contribute in increasing the productivity of all oilseed crops. Edible oils play an important role in human health by supplying calories and are an important source of calories. Due to increasing population, demand for oilseed crops is increasing with the passage of time. She said that SAARC region is facing malnutrition issue and similarly this region is facing many issues, like decreasing per person land availability, deteriorating soil health and climate change. Use of latest, high yielding, climate resilient varieties can help in increasing the productivity of oilseed crops in this region.

Dr. Muhammad Anjum Ali Anjum, Former Member Plant Sciences Division, Pakistan Agricultural Research Council (PARC) & Former Director General Agriculture Extension & Adaptive Research Punjab, Pakistan was the Key Note Speaker and he gave a detailed presentation on oilseed crops. Similarly, he gave suggestions for the productivity enhancement of all oilseed crops in the SAARC Member States, like use of latest varieties of all oilseed crops along with recommended management practices. Promotion of latest varieties and technologies of all oilseed crops through field extension services, planting of demonstration plots, competition among the farmers for getting the maximum yields of different crops, media campaigns, training of the farmers and training of the trainers and Extension departments staff. Use of latest machinery and similarly appropriate pricing of all oilseed crops. Exchange of oilseed crops germplasm and knowledge among SAARC Member States can be helpful in increasing the productivity of all oilseed crops.

Dr. Md. Mahmudur Rahman, Additional Secretary (PPC) Ministry of Agriculture Bangladesh & G.B Member SAARC Agriculture Centre was the Chief guest and he appreciated SAC, for organizing this meeting. He said that Focal points of SAARC Member States and experts of different oilseed crops will share their knowledge and latest updates on oilseed crops. He said that food security is very important and its importance is increasing with the passage of time due to the increasing population, shrinking land holdings and urbanization. Climate change is a big threat for the agriculture sector. There is an urgent need of making agriculture more profitable by by using the latest technologies. SAC, can play an important role in increasing the production of agriculture and food security of the region. Oilseed crops production enhancement is very vital for all the SAARC

Member States. There is need of making the SAARC countries self-sufficient in oilseed crops production.

Focal points of the SAARC Member States gave their detailed presentations on the status of production of different oilseed crops in their respective states. In addition to the Focal points presentations, there were also fifteen presentations by the eminent scientists of the SAARC Member States on the different oilseed crops, including Canola, Rapeseed, Mustard, Sunflower, Soybean, Sesame, Oil Palm, Olive, Castor bean, Groundnut, Coconut and Industrial Oilseed crops (Jojoba, Jatropha Curcas, Pongamia Pinnata *L*. & Ricinus Cummunis). There were also presentations on role of private seed sector in seed availability of oilseed crops and similarly on the use and availability of different types of machinery for the oilseed crops from sowing to extracting.

At the end all the aspects related to oilseed crops productivity enhancement were discussed in detail including, research and development, policies of the government, seed availability, machinery and marketing etc. It was concluded that there is a lot of potential for increasing the productivity of all oilseed crops in this region. There is need of minimization of yield gaps, which is possible by using the seed of latest varieties of all oilseed crops, adaptation of latest crop management practices, better processing and marketing etc. Exchange of seed of different oilseed crops varieties with in the SAARC Members States can also play a pivotal role in the productivity enhancement of all oilseed crops in this region.

Technical Sessions

There were four technical sessions. These sessions were chaired by the eminent scientists. First two sessions were mostly covered the country papers by the Focal points of the SAARC Member States, while in the remaining two sessions, there were presentations on the different oilseed crops and oilseed crops related machinery etc by the invited guest speakers. At the end of each session, there were questions and answers and as well as discussion on the different aspects of the presented oilseed crops papers.

List of invited Guests

Sl. No	Name	Designation	Organization
1.	Dr. Md. Mahmudur Rahman (Chief Guest)	Additional Secretary (PPC) & SAC, G.B, Member	Ministry of Agriculture Bangladesh Secretariat
2.	Dr. Nazmun Nahar Karim (Special Guest)	Executive Chairman	Bangladesh Agricultural Research Council (BARC), Dhaka Bangladesh.
3.	Mr. Jamal Uddin Ahmed (Guest of Honor)	Director (ARD&SDF)	SAARC Secretariat, Nepal.

Technical sessions & along with the detail of Session Chairs

Sl.No	Name	Designation	Organization
1.	Dr. Md. Harun ur Rashid	Director	SAARC Agriculture Centre
2.	Dr. Md. Harun ur Rashid	Director	SAARC Agriculture Centre
3.	Mr. Md. Aziz Zilani Choudhry	Former Member Director Crops	Bangladesh Agricultural Research Council (BARC) Dhaka Bangladesh
4.	Dr. D.K. Yadava	Assistant Director General (Seeds) ICAR & G.B Member, SAC	Indian Council of Agricultural Research (ICAR) New Delhi, India

Detail information of Key Note Speaker and other Guest speakers of the Regional Consultation meeting on Productivity Enhancement of Oilseed crops in SAARC Members States

Sl. No	Name	Designation	Title
1.	Dr. Mohammad Anjum Ali (Key Note Speaker)	Former - Member Plant Sciences Division Pakistan Agricultural Research Council (PARC) & Former Director General Extension & Adaptive Research Punjab - Pakistan.	Increasing the productivity of Oilseed crops - breaking the barriers.
2.	Dr. Khalida Islam	Professor and Former Director, Institute of Nutrition and Food Sciences University of Dhaka, Bangladesh	Nutritional Importance of cooking oil for Human health.
3.	Dr. Hafiz Muhammad Saad Bin Mustafa	Scientific Officer Oilseed Directorate Ayub Agriculture Research Institute (AARI) Faisalabad-Pakistan	Canola crop productivity enhancement.

Sl. No	Name	Designation	Title
4.	Dr. Subhash Subedi Senior Scientist Nepal	Dr. Subhash Subedi Senior Scientist Nepal	Rapeseed crop productivity enhancement
5.	Dr. Ihsan Ullah Khan	Principal Scientific Officer / Program Leader Oilseed Crops, PARC-NARC Islamabad	Sunflower crop productivity enhancement.
6.	Dr. M. Shalimuddin	Proncipal Scientific Officer (PSO), Oilseeds Research Centre BARI Gazipur Bangladesh	Mustard crop productivity enhancement
7.	Dr. Mahmood ul Hassan	Princiapl Scientist, NIAB Faislabad Pakistan	Sesame production status and future opportunities in Pakistan.
8.	Dr. K.H.Singh	Director, Indian Institute of Soybean Research Indor, India.	Soybean productivity enhancement.
9.	Dr. Muhammad Ramzan Anser	Project Director, Centre of Excellence for Olive Research and Training (CEFORT), BARI Chakwal Pakistan	Olive production in Pakistan-A breakthrough.
10.	Dr. K. Manorama	Principal Scientist, Institute of Oil Palm Research Peddivegi, AP, India.	Oil Palm Productivity enhancement.
11.	Dr. Y.P.J. Amarasinghe	ADA (Research), Grain Legumes and Oil Crops Research and Development Institute, Angunakolapelessa Sri Lanka	Groundnut productivity enhancement
12.	Dr. Hafiaz Sultan Mehmood	Director, Agriculture Engineering Institute NARC Islamabd	Groundnut digger & inverter.
13.	Dr. Regi Jacob Thomas	Principal Scientist / Director, ICAR-CPCRI,Regional Statation,	Coconut Productivity Enhancement

Sl. No	Name	Designation	Title
		Kayamkulam Krishnapuram Alappuzha, Kerala India	
14.	Dr. Malik Muhammad Yousaf	Senior Director PARC-Arid Zone Research Institute (AZRI) Bahawalpur Pakistan	Productivity enhancement of different industrial Oilseed crops (Jojoba, Jatropha Curcas, Pongamia Pinnata *L.* & Ricinus Cummunis).
15.	Dr. M. Tauseef Asghar	Assistan Professor, Department of Food Engineering, University of Agriculture Faisalabad	Oilseed crops planting, harvesting, threshing and extraction machinery.
16.	Dr. R.S.Mahla	President,(Research Field Crops), Seed Works International Hyderabad India.	Role of Private seed sector in seed availability of Oilseed crops.

Main Findings:

SAC organized a three days regional consultation meeting on "Productivity enhancement of oilseed crops in SAARC Member States". Due to the increasing edible oil requirement, in addition to own production of edible oils, all SAARC Member States have to import the edible oil and for this purpose, the countries are spending a lot of their foreign currency. Fluctuations in productions of oilseed crops is a common issue in almost all SAARC Member States. Thus, there is an urgent need to emphasis on research and development work on productivity enhancement of oilseed crops in SAARC Member States. In these countries there are big yield gaps between the potential yields of different available varieties of oilseed crops as well as between the average yields of these oilseed crops on the farmers' fields, which needs to be minimized. There is less adoption of modern varieties of oilseed varieties in the region.

It is observed that productions / yields of oilseed crops are increasing in these countries with the passage of time but, due to population increase, requirement of edible oil is also increasing. Recommended edible oil consumption by the Medical Association is about 12 kg/per person/year or 30 gm/person/per day. Over cooked/burned oil is not good for human health. Similarly, Trans Fatty Acids especially, the artificial ones are not good for human health. So public education is needed on dietary guideline. There will be less expenditure on human health treatment at a large scale, which is the result of over use of edible oil. Value addition of oilseed products is also needed on large scale. It is imperative that SAARC Member States developed biofortified crop varieties such as India and Bangladesh have developed biofortified varieties of different oilseed crops. For the proper use of edible oil, women need to be informed by using all types of media sources.

There is need, in SAARC Member States, to develop appropriate policies for the productivity enhancement of oilseed crops. Farmers should be aware of use of seed of latest high yielding, disease resistant and climate resilient varieties of oilseed crops, along with the use of latest production technologies for getting the maximum yields. Governments should take steps to introduce the latest modern varieties at a large scale and for this purpose, availability of quality seed of high yielding varieties needs to be made available. Availability of quality seed of modern varieties is very important to replace the old varieties and similarly seed replacement rate of all oilseed crops need to be enhanced. Seed standards need to be harmonized and similarly to encourage the farmers, governments should give special packages to the farmers who are involved in the production of oilseed crops.

Precision farming for oilseed crops needs to be given more importance. Planting of oilseed crops by using the proper recommended machinery for the different oilseed crops, mechanized irrigation, mechanical harvesting and processing can be helpful in increasing the significant production of oilseed crops. Similarly, use of drones for plant protection and for spray of nutrients can also be supportive in increasing the productivity of oilseed crops. Use of latest crop management practices, like planting of oilseed crops on beds, keeping the crops weed, insects and pests free can be supportive in getting the better production of oilseed crops. Intercropping of oilseeds and inclusion of oilseeds in existing new cropping systems may get priority.

Post-harvest loss in oilseeds is a great concern. Therefore, to minimize these losses, proper mechanization is needed to be promoted at large scale in SAARC Member States. Availability of latest oilseed crops planting, harvesting and processing machinery needs to be made available at local levels.

Marketing of oilseed crops is a usual issue in the promotion of oilseed crops. Proper marketing can be supportive in the promotion of these crops. Minimum support prices of oilseed crops need to be fixed to encourage the farmers and financial incentives need to be given to the farmers.

Strengthening of Public-private partnerships (PPPs) mode is also needed to enhance oilseed crops productivity through collaboration between government and private sector to achieve higher yields, stable prices, processing and supply chains.

List of potential varieties of all oilseed crops, developed by the SAARC Member States needs to be documented. Oilseed crops varieties can be exchanged on request. Climate change is negatively affecting agriculture sector, including oilseed crops in this region. There is a need of development of oilseed crops varieties for adopting, in the changing environment. There is need of development and maintenance of gene bank of all oilseed crops, which would be helpful in the characterization of germplasm. There is also need of exchange of germplasm of oilseed crops among the SAARC Member States. For enhancing these initiatives, a regional centre for oilseed crops may be established.

Training of researchers and exchange visits of scientists of oilseed crops in the region can be helpful in their further learning from the experiences of each other. There is also need of enhancement of technical capacity of the staffs of agriculture Extension departments of SAARC Member States for the promotion of oilseed crops. Using multiple media can be helpful for faster adoption of technologies. More investment is necessary for the productivity enhancement of oilseed crops for the SAARC Member States.

Recommendations

Specific recommendations noted in the regional consultation meeting on "Productivity Enhancement of Oilseed Crops in SAARC Member States" are summarized below:

1. Research and Development

- Use of both conventional and latest crops breeding technologies for the development of high yielding, disease resistant and climate resilient varieties of all oilseed crops.
- Development of hybrids of all oilseed crops.
- Research for development of biofortified varieties of different oilseed crops.
- Standardization of packages of agronomic management of all oilseed crops.
- Use of precision agriculture technologies for oil seed crops.
- Surveillance of diseases and pests of major oilseed crops.
- Research and development for value addition of oilseed crops.
- Testing and promotion of different oilseed crops in the existing cropping systems.
- Identification of efficient cropping systems and crop rotations in the inclusion of oilseed crops.
- Research and development to minimize yields gaps.

2. Seed

- Strengthening of seed system of all oilseed crops.
- Seed standardization.
- Strengthening of early generation seed distribution for quick multiplication.

- Community based seed programs.
- Promotion of Public Private partnerships for seed supply.
- Seed value chain development.
- Enhance seed replacement rate.

3. Machinery:

- Development of machinery for oilseed crops for their sowing, harvesting/threshing and extracting.
- Availability of machinery for oilseeds i.e., for sowing, harvesting / threshing to the farming community.
- Precision irrigation, pest management and post-harvest processing.

4. Technology validation and upscaling:

- Popularization of promising varieties of different oilseed crops at farmers levels.
- Training of Agriculture Extension agents for large scale dissemination.
- Exposure visits.
- Campaigns through media i.e., Television, Radio, YouTube, Facebook and WhatsApp etc.
- Awareness regarding proper milling of different oilseed crops at the local levels.

5. Marketing:

- Proper market price of oilseed crops at the time of harvesting.
- Proper pricing of edible oils.
- Quality assurance of edible oils in the markets.
- Promotion of involvement of SMEs in the locally produced oil.
- Promotion of PPP in oilseed sector.
- Value chain improvement.

6. Capacity building:

- Training of scientists and staffs of extension personnel.
- Capacity development of farmers.

7. Policy

- Germplasm exchange within the SAARC Member States.

- Need of campaigns for promotion of oilseed crops through multiple medias.
- Price stabilization.
- Fixation of minimum support prices by the Governments.

8. Regional Cooperation:

- Regional ease in exchange of seed of different oilseed crops among the SAARC Member States.
- Mutual scientific visits for exchange of knowledge, experiences and success story.
- Regional trainings and workshops on oilseed crops.
- Exchange of information, knowledge and materials.

Regional Consultation Meeting on

"Productivity Enhancement of Oil seed Crops in the SAARC Member States"

Date: 18-20 November, 2024
Organized by SAARC Agriculture Centre (SAC)
Venue: virtual

Program Schedule

Meeting Time: November 18-20, 2024 (10:30 am to 2:00 pm, every day, BD Time)

Zoom Meeting link: https:// us02web.zoom.us/j/86761045963

Meeting ID: 867 6104 5963

Day 1 (18 Nov. 2024)- Inaugural Session; M.C: Dr. AHM Taslima Akhter, STO, SAC

Time	**Program**	**Responsibility**
Inaugural Session		
10:30-10:40	Welcome address	Dr. Md. Harunur Rashid Director, SAC
10:40-10:50	Introduction of the participants	
10:50-11:00	Consultation meeting objectives and overview of the program	Dr. Sikander Khan Tanveer Senior Program Specialist (Crops), SAC
11:00-11:20	Increasing the productivity of Oilseed crops - breaking the barriers	Dr. Mohammad Anjum Ali Ex- Member Plant Sciences Division Pakistan Agricultural Research Council (PARC), Director General Extension (Retired) Punjab - Pakistan.
11:20-11:40	Remarks by Guest of Honor	Mr. Jamal Uddin Ahmed Director (ARD&SDF), SAARC Secretariat, Nepal
11:40-11:50	Remarks by the Special Guest	Dr. Nazmun Nahar Karim, Executive Chairman, BARC
11:50-12:00	Remarks by the Chief Guest	Dr. Md. Mahmudur Rahman Additional Secretary (PPC) Ministry of Agriculture Bangladesh & SAC, G.B, Member
12:00-12:10	**Break**	

Technical Session: 01, Session Chair (Dr. Md. Harunur Rashid, Director, SAC) Rapporteurs: SPS (PSPD) and SPO (NRM)		
Country Paper Presentations		
12:10-12:30	Country paper presentation of Bangladesh.	Dr. M. Shalim Uddin PSO Oilseeds Research Centre BARI Gazipur, Bangladesh
12:30-12:50	Country paper presentation of Bhutan	Ms Deki Lhamo Deputy Chief Agriculture Officer Department of Agriculture & Livestock Bhutan
12:50-1:10	Country paper presentation of India	Dr. V. Denish Kumar Principal Scientist & Head (Crop Improvement), ICAR-IIOR, HYderabad
1:10-1:30	Country paper presentation of Maldives.	Mr. Lahfaan Moosa Assistant Agriculture Officer Ministry of Agriculture and Animal Welfare Maldives
1:30-1:50	Nutritional Importance of cooking oil for Human health.	Dr. Khalida Islam Professor and Former Director Institute of Nutrition and Food Sciences University of Dhaka, Bangladesh
1:50-2:00	Reflection over paper presentations/Discussions/ Questions & Answers	
Closing of the Day 01		
Day-2 (Nov.19, 2024) Technical Session-02 (Session Chair: Dr. Md. Harunur Rashid, Director, SAC) Rapporteurs: SPS (NRM) and SPS (Livestock)		
Country paper Presentation		
10:30-10:50	Country paper presentation of Nepal.	Dr. Subash Subedi Senior Scientist Oil Research Program Nawalpur, Salahi Nepal
10:50-11:10	Country paper presentation of Pakistan.	Dr. Muhammad Asim National Coordinator (Oilseed) Pakistan Agricultural Research Council (PARC), Pakistan

11:10-11:30	Country paper presentation of Sri Lanka.	Dr. Y.P.J. Amarasinghe ADA (Research) Grain Legumes and Oil Crops Research and Development Institute, Angunakolapelessa Sri Lanka
11:30- 11:40	Break	
Technical session-03 (Chair: Mr. Md. Aziz Zilani Choudhry, Former Member Director Crops, BARC) Rapporteurs: STO and SPO (NRM)		
11:40-12:00	Canola crop productivity enhancement.	Dr. Hafiz Muhammad Saad Bin Mustafa Scientific Officer Oilseed Directorate Ayub Agriculture Research Institute (AARI) Faisalabad-Pakistan
12:00-12:20	Rapeseed crop productivity enhancement	Dr. Subhash Subedi Senior Scientist Nepal
12:20-12:30	Sunflower crop productivity enhancement.	Dr. Ihsan Ullah Khan Principal Scientific Officer / Program Leader Oilseed Crops PARC-NARC Islamabad
12:30-12:50	Mustard crop productivity enhancement	Dr. M. Shalimuddin PSO Oilseeds Research Centre BARI, Gazipur Bangladesh
12:50-01:20	Sesame production status and future opportunities in Pakistan.	Dr. Mahmood ul Hassan Princiapl Scientist NIAB Faislabad Pakistan
1:20-01:40	Soybean productivity enhancement.	Dr. K.H.Singh Director Indian Institute of Soybean Research Indor
01:40-01:50	Reflection over paper presentations / Discussions / Questions & Answers	

Closing of the day 02.		
Day-3 (November 20, 2024)		
Technical Session -04: (Session Chair: Dr. D.K. Yadava, Assistant Director General (Seeds) ICAR / G.B Member SAC), Rapporteurs: STO and SPS (Livestock)		
10:30-10:50	Olive production in Pakistan-A breakthrough.	Dr. Muhammad Ramzan Anser, Project Director Centre of Excellence for Olive Research and Training (CEFORT) BARI Chakwal Pakistan
10:50-11:10	Oil Palm Productivity enhancement.	Dr. K. Manorama Principal Scientist Institute of Oil Palm Research Peddivegi, AP, India.
11:10-11:30	Groundnut productivity enhancement	Dr. Y.P.J. Amarasinghe ADA (Research) Grain Legumes and Oil Crops Research and Development Institute, Angunakolapelessa Sri Lanka
11:30-11:50	Groundnut digger & inverter.	Dr. Hafiaz Sultan Mehmood Director FMI NARC Islamabd
11:50-12:00	Break	
12:00-12:20	Coconut Productivity Enhancement	Dr. Regi Jacob Thomas Principal Scientist / Director ICAR-CPCRI Regional Statation, Kayamkulam Krishnapuram Alappuzha, Kerala India
12:20-12:40	Productivity enhancement of different industrial Oilseed crops (Jojoba, Jatropha Curcas, Pongamia Pinnata *L.* & Ricinus Cummunis).	Dr. Malik Muhammad Yousaf Senior Director PARC- Arid Zone Research Institute (AZRI) Bahawalpur Pakistan
12:40-1:00	Oilseed crops planting, harvesting, threshing and extraction machinery.	Dr. M. Tauseef Asghar Assistan Professor Department of Food Engineering University of Agriculture Faisalabad

1:00-1:20	Role of Private seed sector in seed availability of Oilseed crops.	Dr. R.S.Mahla President (Research Field Crops) Seed Works International Hyderabad India
1:20- 1:30	Tea Break	
1:20- 1:40	Strategy Action plan Recommendation	Dr. Sikander Khan Tanveer, SPS (Crops), SAC
1:40 - 1:50	Recommendations / Conclusion	
01:50 - 2:00	Remarks from the participants Closing remarks	Dr. Md. Harunur Rashid Director SAARC Agriculture Centre Dhaka

Regional Consultation Meeting on

"Productivity Enhancement of Oil seed Crops in the SAARC Member States"

18-20 November, 2024
Organized by SAARC Agriculture Centre (SAC)
Venue: virtual

List of Participants

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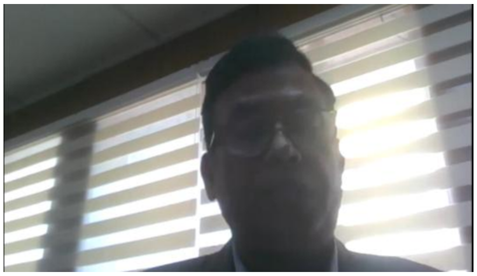
Photo Gallery

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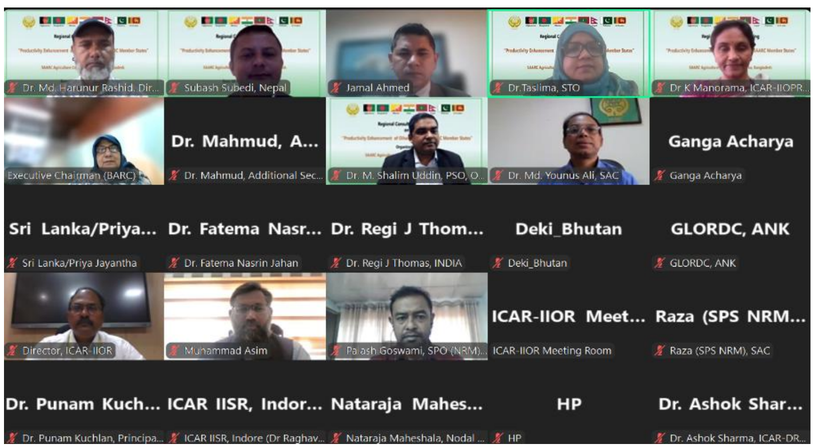
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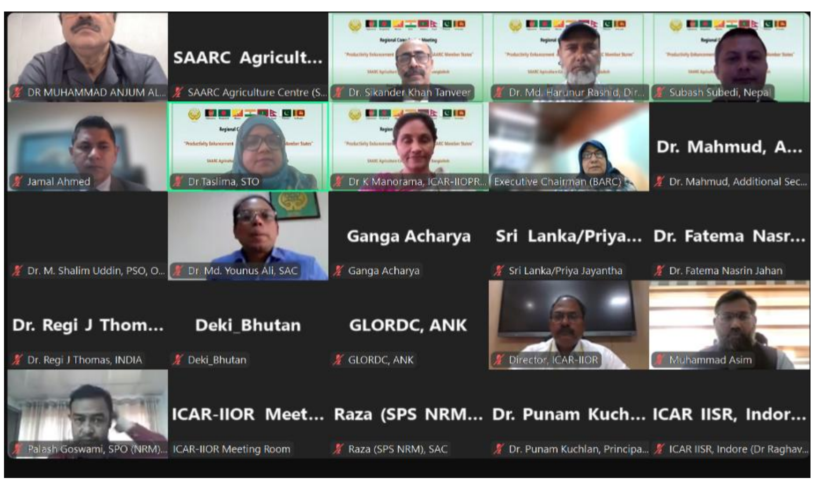
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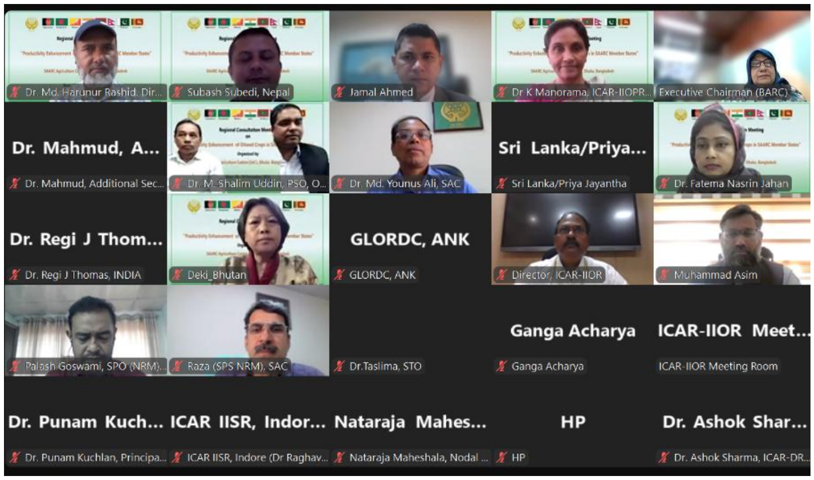
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