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COMPETITIVE AGRICULTURAL RESEARCH GRANT: AN EXPERIENCE OF CONTRACT RESEARCH PROGRAMME IN BANGLADESH

WAIS KABIR¹

ABSTRACT

Competitive grant programme (CGP) for agricultural research is getting popular among donor agencies and research managers in recent days. The main focus is to supplement agricultural research support for solving problem of immediate nature with inter-institutional participation. The Competitive grant program (CGP) has been practiced in different countries in different ways. The experience of such practices in different countries have been discussed in the paper and the experience of contract research program of Bangladesh Agricultural Research Council. The contract research scheme has been implemented through USAID and IDA (The World Bank) supported projects. Effort has been made to make the contract research program more competitive with the participation of public, private and NGOs. The paper discussed the important cycle of operation and recommendations made for efficient management of the scheme.

INTRODUCTION

Agricultural research played a very important role in developing countries for increased food production. This was possible due to significant investment in agricultural research during 1961-1985 in developing countries, which grew at the rate of 6% annually. The investment was in the form of project support in the public sector, which included facilities and human resources development in research and extension. The investments helped develop high yielding varieties, crop-disease-fertility management and skill. Cereal production, mainly boro, aman, and wheat, increased from 10.26 million metric tons in 1972-73 to more than 28 million metric tons in Bangladesh. The production of potato and vegetables showed significant growth in yield. The public sector institutes played the significant role in production gain through research and extension. Although the agricultural research has high pay off, but the public investment is declining due to decrease in donor support. Private investment in agricultural research is growing in the developed countries at the rate of 5% annually and stood at more than 50% of total investments in agricultural research compared to 10-15% in the developing countries. The share of the agricultural R & D to the agricultural GDP is 0.5-0.6% in developing countries, (Asia 0.62, Latin America 0.98 and Sub-Sahara

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Africa 0.85 and 2-3 % in developed countries). For Bangladesh, total Agricultural R & D has been estimated to be 0.2 percent of Agril. GDP in recent years. The ratio of expenditure on R&D to the GDP has been estimated to be 0.005% only during 2001-02 (GOB, 2004). Research led by the international research centers, expanded during pre-and post green revolution, has sharply decline recently as international donors no longer support agricultural R & D. An estimate indicates the declining of USAID support to LDC agricultural R & D by 75% from mid 1980s to 1996. The slowdown of science in the south limits the potential of poor countries to develop locally relevant technologies and tap into northern knowledge stock (Pardey and Beintema. 2000). In developed countries, about 43% of the public research are done by universities compared to 10-25 percent in the developing countries. The private companies and National Research Institutes including universities are carrying out agricultural research all over. The characteristics of the two types of research are:

Private Companies	National Research Institutes
Usually applied	Usually basic, fundamental or speculative
Relatively short time horizon/discrete	No specific time horizons or limits/discontinuous
Commercially beneficial	Generation & widespread disseminations of new knowledge

The focus of the private research has been on agricultural machinery, post harvest food processing, plant breeding and veterinary pharmaceuticals. Agricultural chemicals have recently grown in the private sector due to ensured and short-term profit market.

Table 1. Estimated global public and private agricultural R & D investments (Pardey and Beintema. 2000)

	Share (%)		
	Public	Private	Total
Developing countries	94.5	5.5	100
Developed countries	48.5	51.5	100
Total	65.3	34.7	100

Agricultural research funds are provided by the governmental in most of the countries. The allocation is made either as a block grant or line item of the budgetary system. Competitive research grant is another important method of research funding globally. Research fund is provided to the researchers on the merit of competitive research proposals. Competitive research grant is creeping in NARS under a situation where public and donor funding in agricultural research is declining, but private investment is increasing. The CG funds cannot

solve all problems of research financing and should be linked to funding sources of NARS. The basic features of the competitive research fund management are the following:

- Priority setting
- Advertising
- Pre-review processing
- Review
- Contracting
- Funding
- Monitoring, feed back and evaluation
- Dissemination of the research result

The CG funding mechanism is known as contract research in Bangladesh Agricultural Technology Development Project in Columbia (PRONATTA), PRODETAB in Brazil (represents 2% of Embrapa's total research funding), competitive fund for agricultural research in Ecuador, Competitive Agricultural Research Grant Scheme (CARGS) in Ghana. Most of these have been initiated recently and supported by the donors (World Bank projects). In USA, competitive research grant under the national research initiative account for about 12 % of the total research portfolio. In Africa and Asia, 95% of the World Bank support is spent on institutional loans and grants while in Latin America competitive fund accounts for 48%. Pakistan Agricultural Research Council (PARC) operates competitive grants programme under the Agricultural Linkage Programme (ALP). ALP is operated through a corpus fund created and supported by the government intended to establish institutional linkage, to generate agricultural technology and to support farm problem. ICAR (world's largest research system, having 7,000 researchers and 31,000 total agricultural scientists) of India provides competitive research grant through Agricultural Produce Cess (AP Cess) fund, which has been small fraction (percent) of the agricultural product export. Indian government recently is considering to make the fund available from other sources.

The PRODETAB in Brazil is a successful approach of competitive research programme. The programme is managed by an Executive Committee (ExCo) of nine members, the majority being external to Embrapa (Brazilian Agricultural Research Corporation, the 3rd largest in the globe, having 5,500 full time researchers. It coordinates the National Agricultural Research System, which includes most public and private entities involved in agricultural research in the country). The president of ExCo is nominated by the president of Embrapa. ExCo is supported by a Secretariat which is part of Embrapa's Secretariat. PRODETAB Secretariat makes full use of Embrapa's own technical and administrative units (technical committee, legal office, finance department, audit office etc.) for project management and support. Nonetheless, small and manageable conflicts due to competing activities are observed daily (Reifschneider, 2000).

The major issues responsible for the success of the competitive research funding are

- Sustainability must be ensured during the onset of CGP
- Transparency at all stages
- Adequate management capability including monitoring and evaluation

Size of the Agricultural Research System

Bangladesh has got fairly large agricultural research infrastructure where several agricultural research institutes and universities are involved with agricultural research. Bangladesh Agricultural Research Council (BARC) is the national agency to coordinate agricultural research in the country. Ten agricultural research institutes, formally constitute the National Agricultural Research System (NARS), are under four ministries. The institutes conduct research on all commodities of agriculture including natural resources. BARC, the Apex Body of the NARS, Plans, prioritizes, monitors, evaluates and coordinates various programs and activities. Agricultural universities, public universities, scientific and industrial research organizations and NGOs are associated with NARS activities. The BARC is governed by a Governing Body (GB) consisting of different stakeholders including three cabinet ministers and secretaries. Executive Council is composed of the Chief Executive of BARC (Executive Chairman) as Chairman, Head of the Divisions of BARC (Member-Director) and Head of the NARS institutes. It implements the decisions of the GB and has the responsibility of reviewing the research program of the NARS.

NARS has position of 1600 scientists of which around 1300 are currently in position. Each institute has research stations/substations spread all over the country representing 30 agro-ecological zones. NARS has approximately 5000 hectares of experimental areas. Among the total number of researchers, more than 330 are Ph.D.s in major fields of agriculture (agronomy, breeding, entomology, horticulture, soil, water management, livestock, fisheries, forestry etc.) (Table1). Bangladesh Agricultural Research Institute (BARI) alone has 128 Ph.D. in the field of crop science. Agricultural researchers are primarily concentrated in commodity-based public institutes. The research in the private sector is meager, so far which provides less for enough competitiveness required for CGP environment. The three major public agricultural universities have also more than 600 teachers, many of them are involved in research. Researchers in the field of livestock including poultry are working only in BLRI.

However, there are 26 other agencies/institutes under the university system (as faculty, institute/departments etc.) and public institutes (e.g. Bangladesh Council of Scientific and Industrial Research etc.) who are working in diversified fields of agricultural research. The number of scientists of these non-NARS institutes is around 1200 of which 500 are Ph.D. degree holders.

Table 2. Scientific Strength of NARS

NARS Institutes	Number of Scientists			
	Ph.D	M.Sc.	B.Sc.	Total
1. Bangladesh Agricultural Research Council (BARC)	18	3	0	21
2. Bangladesh Rice Research Institute (BRRI)	59	105	4	168
3. Bangladesh Agricultural Research Institute (BARI)	128	356	42	526
4. Bangladesh Sugarcane Research Institute (BSRI)	17	27	07	51
5. Bangladesh Jute Research Institute (BJRI)	14	74	49	137
6. Bangladesh Institute of Nuclear Agriculture (BINA)	27	48	3	76
7. Soil Resources Development Institute (SRDI)	6	108	4	118
8. Bangladesh Fisheries Research Institute (BFRI)	30	16	0	46
9. Bangladesh Livestock Research Institute (BLRI)	17	23	2	42
10. Bangladesh Forest Research Institute (BFRI)	15	49	14	78
11. Bangladesh Tea Research Institute (BTRI)	3	19	0	22
Total	334	828	125	1285

The number of scientists working on high value agricultural crops like pulses, oilseed, spices, horticulture (floriculture, vegetables and fruit) are very small. The number of researchers in fruits has been estimated to be around seven, 12 in vegetables, 1-2 in floriculture, 2-3 in spices, none in precision agriculture, quite few (1-2) in genetic engineering, food processing and six in hybrid rice in the NARS institutes. This number depicts a gloomy picture of the total research capacity in important areas.

The NGOs and the private sectors have little or no agricultural research infrastructure. Bangladesh Rural Advancement Committee, widely known as BRAC, is developing capacity in crop research. A few private organizations are engaged in vegetable seed and socio economic policy research.

Competitive Research Funding

Ministry of Science, Information and Communication Technology provides two million dollar research grant every year among different individuals/agencies. The Research & Extension in Farm Power Issues (REFPI), supported by DFID and implemented by Department of Farm Power and Machinery of Bangladesh Agricultural University, focused important but small part of total agricultural research. REFPI worked on R&D and extension of farm machinery and agricultural processes through competitive grant award to BAU,

NARS institutes and NGOs, which was completed during 2003. Poverty Elimination through Rice Research Assistance (PETRRA), a DFID supported project is operated by competitive grant of award. The project was managed by IRRI in close partnership with Bangladesh Rice Research Institute. The project based research efforts cannot maintain continuity and sustainability of research. Public universities receive very insignificant amount of research grant from the University Grants Commission, which is used mainly for master thesis.

Financing of Agricultural Research

Government of Bangladesh with the support of the World Bank (IDA) and USAID has been the major source of funding in agricultural research system in the country. Collaborative research with international agricultural research centers such as IRRI, CYMMIT, World Fish Center, and ICRISAT is also carried out in some institutes. Donor project with domestic counter-part funding constitutes the NARS budget. Although very recently government has increased support in research operational budget, but it (input, labor, travel) has been very low compared to total budget allocation for the NARS institutes. Major expenditure occurs on account of salaries and other overhead line items.

Contract Research Programme (CRP)

The contract research program of the Bangladesh Agricultural Research Council (BARC) awards grants on competitive basis to conduct high priority research by the scientists of the NARS and other organisations to support national development goals. This is also intended to maximise research capability where the expertise is underutilized with inadequate operational support. The CRP provides complementary funds to the Agricultural Research Institutes/agencies on a competitive basis and focuses on areas for increasing agricultural productivity. The CRP is relatively short term and designed to address specific problems of agricultural production. The research is carried out either singly or in collaboration with scientists of the same or other institute or in farmers' field. The program has enabled BARC to adequately support research on problem areas of high priority and high probability of success within a reasonable time frame.

Contract research has been institutionalized as one of the components of investment for research supported by the Agricultural Research Project I and II (IDA and USAID) since 1976. Initially, NARS institutes, some public research agencies and universities participated in the CRP. An amount of 1.35 million dollar (less than 50 % of the provision) had been spent for contract research during 1981-87. The management of the contract research involved approval by technical advisory committee (TAC), Executive committee (EC) and Finance Committee (FC). A total of 145 contract research projects costing 72 million dollars, provided in ARP-II (1455 BD), were implemented during July 1985 to June 1992. Actual utilization of fund was 50 to 60 percent of the budget provision. Absence of adequate

and wide-range research capability in the NARS system might be responsible for low utilisation of funds. Inadequate monitoring of the utilisation of research grant also hampered the contract research performance.

Step Forward

The WB funded Agricultural Research Management Project (IDA credit), allocated US\$ 7.7 million (13 % of the total project cost of US\$ 59.0 million) for contract research 1997-2001. The project was designed for wider participation of various agencies including private sector and the NGO.

The evaluation process for the competitive contract research project was redesigned to include vetting by regional Agricultural Technical Committee (ATC) /National Agricultural Technology Coordination Committee (NATCC). ATC provides a forum for linkage between extension and research staff at the regional level while NATCC is the highest forum at the national level.

Contract research program has the following cycle of operation:

- Fixation of the research priority
- Announcement inviting for contract research proposal
- Vetting from Regional/National Committee
- Submission of proposals
- Review process for approval
 - Technical Division Level (processing)
 - Technical Advisory Committee (TAC)
 - Executive Council & endorsement in the Governing Body
- Contract signing
- Release of fund on installments
- Monitoring: desk monitoring and field monitoring
- Submission of quarterly technical and financial reports
- Submission of annual reports
- Presentation of the progress in the annual review workshop and evaluation
- Submission of final reports (completion report)
- Evaluation of the process.
- Technology transfer

Priority of the research areas was fixed by BARC based on national priority through consultation and number of exercises. The document "Strategic Plan for the National Agricultural Research System to the Year 2010 and Beyond" has been prepared by the experts of various disciplines under the leadership of BARC. The source of input was the

relevant literatures and outcome of national seminars and workshops. Individual divisions or units under BARC prepared short and medium term priority research. The technology /information generated through contract research are documented for wider dissemination.

Participation and Ceiling for Each Contract Grant

All institutes involved in agricultural research are eligible for grants. Usually any amount is acceptable but US\$ 50,000.00 (maximum) per contract has been found to be easy for management. Provision for operational support and research personnel of essential nature (only if justified) is under the contract grant. Small equipment of maximum 20% of the total cost has been made admissible under the contract. Research proposals of maximum three years duration are allowed for funding.

Approval Process

The research proposal for contract grant is evaluated on the basis of a set of priority criteria and a scoring system. The scoring depends on the following criteria of the proposals:

- Capability of the proponent within the resources available
- Field relevance/solving current issues/problems (the proposals are vetted in the ATC/NATC depending the nature of the problem, regional or national)
- Immediate applicability
- Representative of a major area
- Soundness of methodology and high probability of success
- Reasonable budget
- Inter-institutional
- Inter disciplinary

The proponent institute/agency evaluates the proposals prior to submission to the BARC. After reaching the proposals at BARC, these are distributed among the related technical divisions for processing. The technical divisions then place the proposals in the Technical Advisory Committee (TAC) for evaluation and recommendation. The members of the TAC are drawn from a pool of professional experts maintained at BARC (mainly, eminent scientists, outside of BARC) and senior level managers of BARC including program leader of the socio-economics division. The proposal is sent to the members of the TAC ahead of the meeting. Anonymity of the external TAC members (experts) is maintained. Recommended proposals are placed in the Executive Council for final approval following endorsement of the GB. The approval process has been made transparent throughout. The proponents whose projects fail to qualify are informed of the outcome of the evaluation process.

Fund is released by installments. Initially 25 percent of the total cost is made available shortly after the contract signing and another 65 percent during the project period based on progress towards objectives. The rest ten percent of the total cost remains with the Council until the satisfactory final report is submitted and accepted by the BARC. The Principal Investigator and co-investigator receives remuneration equivalent to one month basic salary at the end of the contract period. Project monitoring is based on regular quarterly progress reports sent by the recipient and field visit by the concerned division of BARC. In addition, monitoring is also done centrally through constitution of multidisciplinary team. The contract research manual developed by the BARC is followed. Total disbursement under contract research has been only 280 million taka, which is 65% of the total fund committed (460 million taka) for the project.

Participation for Contract Research Grant

A large number of agencies, government, NGO and private sector agencies applied for the grant by submitting full proposals. Newspaper announcements nationally created enough awareness among the potential participants. As many as 650 proposals were received. Of these, 231 research proposals (33 %) qualified and accepted for implementation. NGOs and private sector organizations took part in the bidding for competitive grants under contract research for the first time. NARS agencies got the major share of contract followed by universities as in (Table 3). NGOs got 7 percent of the total number of contract and the private agencies the least. The distribution of grant varied discipline-wise. The share of crop research was the highest (34%) followed by soils (13.6%), economics and social science (9.5%), livestock (8.4%) and so.

Table 3. Agency Wise Distribution of Contract Research Grant under Agricultural Research Management Project (ARMP)

Institutes involved	Total no. of contracts	Percent
NARS	127	55
Universities	73	31
Other public agencies	10	4.3
NGOs	16	07
Private agency	5	2
Total	231	100

Lessons Learnt

Agricultural research funding through contract grant, administered by BARC, is one of the important components of donor supported investment projects. But this has made research-funding system unsustainable due to intermittent nature of project support. The life

of contract research programme ends with termination of project grant. This affects the continuity of research programme.

The lack of appreciation by the proponent agency for the research being undertaken and of belongingness of the implementing research agency impedes smooth implementation of the program. Lengthy processing time discourages the potential researchers to participate in the competitive process. Requirement of half yearly financial and technical reports for subsequent fund release disrupts continuous funding.

Besides, contract grant provides less attractive financial remuneration to the researchers than the donor supported piecemeal research work.

Inadequate research capability of the NGOs and private sector restricts their participation. Some NGOs even though writes good proposals with the external support but have deficiencies in proper implementation of the projects and documentation of results. Contract grant does not provide equipment support and many agencies having expertise fail to participate due to lack of equipment support.

Due to its attachment with the core project, the contract research program are time bound and a large number of projects are managed within a stipulated project time frame with limited number of professional staff at the council level.

The market size for the contract research seems to be smaller than the size of the fund allocated under the project. Though the peer review of the research proposals is done by the Technical Advisory Committee (TAC) including external expertise, but financial for incentive the external reviewer is absent. This has affected the quality of review process. The dearth of independent reviewers in the of biotechnology, animal breeding, food processing, precision agriculture, livestock and fisheries disease management etc, has made adequate review of the research proposals difficult. The monitoring and evaluation (M&E) of the research programmes was carried out as per financial rules of the government. This discouraged the Council's scientific professional to take part in the exercise due to unattractive remuneration package. The contract grant projects under PETRRA was very remunerative for the M & E, activities.

The vetting requirement by the extension department for research relevance has been introduced during the implementation of the project. The institutional arrangement for the vetting process has been inadequately organized at the regional level for addressing the regionally focused research proposals. As a result the idea of the vetting, though appreciable, could not help smooth implementation the contract research. Newspaper advertisement for the contract has created significant awareness among the researchers but a large number of irrelevant proposals were also received.

A large pool of knowledge and techniques has been developed through the contract research scheme. Inadequate institutional linkage to disseminate the knowledge and follow up of the efforts has been found to be a major weakness in the contract research process.

CONCLUSION AND RECOMMENDATIONS

Contract research grant has been in operation with donor's assistance, but not on continuous basis. The existing time fixed funding for contract research should be made sustainable by devising alternate mechanism. Some endowment fund (or corpus fund) without project attachment could be provisioned to finance research project on a competitive and sustainable basis. This would make the fund management easier and enhance research output

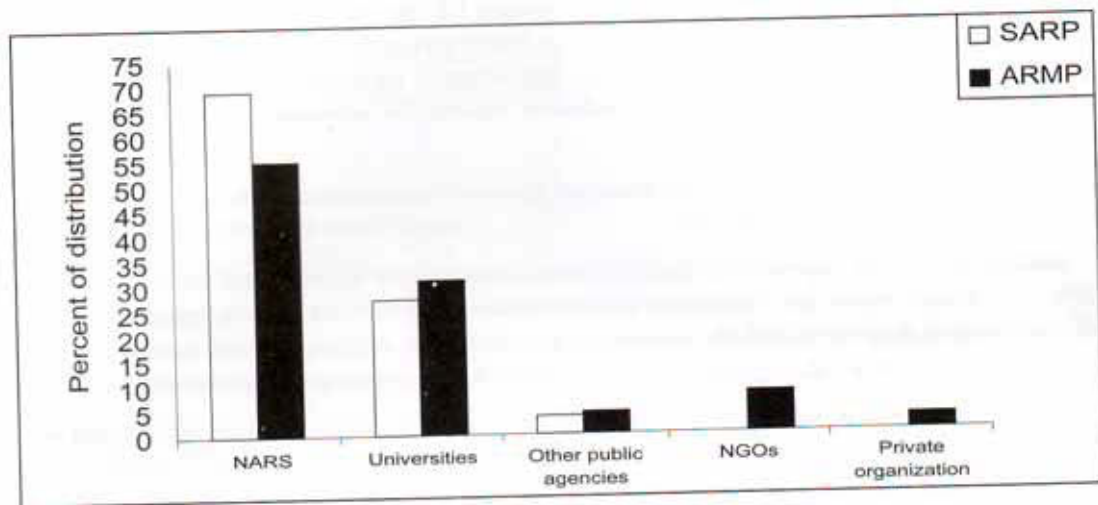


Fig 1. Distribution of successful contract research among different group

Table 4. Comparison of Contract Research Program under Second Agricultural Research Project, SARP (IDA 1455-BD) and ARMP (IDA-28150 BD)

Works	SARP	ARMP
Duration	April 1985- June1992	July 1996-December 2001
Total number of proposal received	Not recorded	642
Announcement for participation	Official announcement	Newspaper advertisement
Total Number of contracts awarded	145	231
Total awarded Project cost (lakh Taka)	4186	50 million dollar
Allocation (Budget) for contract research(Lakh Taka)	3254	4400 (7.7 million US\$)
Fund utilized (Lakh Tk.)	1627(50%)	Tk. 2800 (80%)
Professional monitoring staff at BARC	50	23

SARP = Second Agricultural Research Project; ARMP = Agricultural Research Management Project.

Incentives may be considered for the researchers and the research managers to create more competitiveness. Adequate institutional arrangement is required to continue contract research project. A training course for the NGOs and private sector may be arranged to upgrade the skill of writing good proposals. A concept note may be invited first. Based on the successful concept note, the proponent may be requested to submit the complete proposal.

The priority setting of the research agenda for both strategic and short-term research should be institutionalized through rigorous consultation and economic analysis. The exercise should be updated periodically focusing national priority. The capability of both public and private agencies should be strengthened further in terms of facilities and expertise in order to be able to compete for the contract grant.

Transparency is an important component for the success of the competitive research programme. For this matter, web based management of the programme may be introduced where the researchers may participate directly through web. The management may keep the updated web page posting the research proposals submitted by the individual agencies for greater transparency.

Technical assistance from the international centers located in Bangladesh may be explored for the review process in the areas where there is dearth of expertise. Financial reporting may be kept at minimum by using simplified format accompanied by technology friendly financial rules.

The size of the research fund should reflect the market size of competition for the research. A number of factors should be considered in selecting the size of the fund. These are: available reviewers across the country in different disciplines and technical, administrative, and financial capacity of the sponsoring agency.

A strong M&E group is to be constituted to evaluate performance of the research. Team of experts may be constituted for field monitoring of the contract research. For that matter, remunerative package should be developed for the professional to take part in the exercise.

The scientific pool of experts in the critical areas of agricultural research must be increased through human resources development program and efficient management of the NARS.

Competitive research program should be one of option for research funding. It should not be taken for solving all research issues. It should supplement long-term public funding for strategic research. A separate financial and management rules are required for implementation of the contract research programs.

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GENOTYPE X ENVIRONMENT RESPONSE AND STABILITY ASSESSMENT IN TOMATO (*Lycopersicon esculentum* Mill.)

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ABSTRACT

Genotype and environment response study was carried out with nine genotypes and a check variety under five environments. Mean squares due to environments, genotypes and G x E interactions were highly significant for 4 characters under study. The analysis after Eberhart and Russell indicated that most of the genotypes was affected by environmental changes, and performance of these genotypes could hardly be predicted. Varieties like World Champion and *Gen-3* were the most stable genotypes for early flowering and *Gen-1* was found stable for 50% flowering in this model. *Gen-1*, *Gen-5* and *Gen-7* were found stable for number of fruits/plant and *Gen-18* was responsive and suited for favourable cultural environments. For Individual fruit weight *Gen-1*, *Gen-6* and *Gen-15* were found stable and well adapted. *Gen-1*, *Gen-5* and *Gen-7* were found stable for yield/plant, while World Champion, *Gen-6*, *Gen-15* and *Gen-18* were sensitive to changes in environments and adapted to favourable environments only. However, *Gen-1*, *Gen-5* and *Gen-7* recorded high mean number of fruits/plant and yield, average responsiveness to environment and stability in both approaches. These genotypes could be recommended for large-scale cultivation. To obtain high yielding and stable segregants, these genotypes may be used in breeding programme. It is also observed that the simple genotype grouping technique is efficient tool in identifying stable genotypes.

Key words: Genotype-environment response, grouping technique and tomato (*Lycopersicon esculentum* Mill)

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important and nutritious vegetable in the world because of its domestic consumption as well as industrial use. Yield and yield contributing traits of a crop are highly influenced by environment. Stable genotypes of tomato are necessary to increase the productivity. A study of genotype-environment interaction is of much valuable in the selection of better genotypes (Islam and Newaz 2001). The magnitude of components of genetic variation and genotype-environment interaction can help to select the better genotypes (Haque et al., 2003). The mean

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performance appeared to be associated with linear component of genotype-environment interaction (Jatasra and Paroda, 1981). The variety with higher mean yield, regression coefficient b_i near to unity and deviation from regression s^2_{di} value close to zero would be suitable wide range of environments (Shahid and Kabir, 1997). Stability in performance is one of the most desirable properties of a genotype to be released as a variety for wide cultivation. In dealing with instability and uncertainty of yield and in developing improved varieties for wide adaptation, Genotype-Environment (GxE) interaction is of major concern for crop improvement (Eberhart and Russell, 1966). The present experiment was undertaken with a view to study GxE response and to identify both high yielding and stable genotypes over environmental changes.

MATERIALS AND METHODS

The research work was conducted at the Experimental Farm of the Department of Genetics and Plant Breeding, Bangladesh Agricultural University, Mymensingh during off season (August - December 1999) and on season (November - April 2000). Ten genotypes of tomato were grown in a Randomized Complete Block (RCB) design with three replicates under five cultural environments. For the study (GxE interaction study) three spacing densities, two fertilizer package and two transplanting dates with seedlings of same seeding date but differential age at transplanting were manipulated to create five experimental (cultural) environments. Data were recorded on an individual plant basis from five randomly selected plants per genotype in a replicate. The data were analyzed using Eberhart and Russell (1966) and genotype grouping technique (Francis and Kannenberg, 1978) was utilized to group the genotypes into different similar groups. According to this technique, a scatter graph was plotted in which the abscissa was marked with grading of a character and the ordinate with coefficient of variation (CV). Observed mean values of respective genotypes were then plotted against their CV% for a character. The vertical line on this graph represented overall mean of all the genotypes and the horizontal line represented CV percentage. These two lines grouped the genotypes into 4 categories:

Group- I : High mean value versus low variation.

Group- II : High mean value versus high variation.

Group- III : Low mean value versus low variation.

Group- IV : Low mean value versus high variation.

RESULTS AND DISCUSSION

Genotype and environment response

The combined Analysis of Variance (ANOVA) after Eberhart and Russell's model (Table 1) shows that mean squares (MS) due to genotypes were significant for all the characters. ANOVA also shows highly significant G x E interactions (Linear) for number of fruits/plant and yield/plant. Non-linear components (pooled deviations) were highly significant for these

characters, which imply that part of the variability was unpredictable in nature. On the other hand, the non-linear components were nonsignificant for days to 50% flowering and individual fruit weight. These denote that deviation of all the genotypes, from their expected performances was similar in magnitude, and unpredictable causes of variation were not responsible for observed G x E interaction. Relatively unpredicted component of G x E interaction is of greater importance than the relatively predictable components

Table 1. Combined analysis of variance (MS) for four characters of tomato after Eberhart and Russell's model of stability analysis

Item	df	Mean Square			
		Days to 50% flowering (d)	No. of Fruits/Plant (No)	Ind. Fruit Weight(g)	Yield /plant (kg)
Genotype	9	56.52+ ** *	887.06+ ** *	434.04+ ** *	2.611+ ** *
Env.+(Gen. x Env)	40	74.41+++	89.29	88.30 +++	0.408 +++
Env.(Linear)	1	2709.21+++	2026.46+++	2838.53+++	11.23+++
Gen.x Env.(Linear)	9	11.49**	88.53	45.08++	0.3023+++
Pooled deviation	30	5.46	24.95**	9.595	0.079**
Gen-1	3	1.503	3.928	9.883	0.022
Gen-3	3	10.71*	61.56***	3.843	0.193***
Gen-4	3	2.6267	153.79***	9.189	0.404***
Gen-5	3	2.9372	12.45*	10.89	0.057
Gen-6	3	1.2932	3.5431	21.04	0.015
Gen-7	3	1.8971	1.0865	5.283	0.007
Gen-15	3	0.3183	6.2725	6.561	0.014
Gen-18	3	0.0501	4.1414	2.867	0.039
Gen-20	3	25.92***	2.5529	22.61	0.035
World Champion (Ck)	3	7.309	0.143	3.787	0.001
Pooled Error	100	3.675	4.150	15.59	0.0338

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ (= Tested against pooled error).

++ $P < 0.01$, +++ $P < 0.001$, ns = nonsignificant (= Tested against pooled deviation).

The results concerning stability and response of the genotypes to different environments are discussed character wise as follows:

Days to 50% flowering

Mean days to 50% flowering for each cultural environment together with values of response and stability parameters and phenotypic indices are presented in Table 2. Upon examination of environmental indices it appears that Env-5 was the most unfavourable environment because it prolonged 50% flowering for most of the genotypes. Most favourable environment for 50% flowering was observed in Env-1. Phenotypic index values suggest that *Gen-1*, World Champion, *Gen-4*, *Gen-5*, *Gen-15* and *Gen-18* were desirable. The values for regression coefficient (b_i) for genotypes *Gen-15* and *Gen-18* were found significantly different from unity, which implies that they were below average in stability. Moreover, they had nonsignificant S_{di}^2 values indicating that they were more responsive and very high sensitive to changes in the cultural environments and were suitable only for favourable environments. On the other hand the regression coefficient (b_i) for rest of the genotypes were non-significantly different from unity, these (except *Gen-20*) also showed nonsignificant deviation from regression, which suggests that these were average in stability and hence these might be well adapted. *Gen-20* had significant S_{di}^2 value, so its performance under different environments was unpredictable. *Gen-1* with lower regression coefficient (b_i), closer to unity, S_{di}^2 value not significantly different from zero and with negative phenotypic index appeared to be the most desirable and stable genotype for days to 50% flowering.

Number of fruits/plant

The average number of fruits/plant for different cultural environments with stability parameters is given in Table 2. *Gen-5* had the highest and *Gen-15* the lowest phenotypic indices ($\pi_i = 25.42$ and -16.58 respectively), reflecting their highest and lowest fruit production abilities respectively. *Gen-1*, *Gen-4*, *Gen-7* and *Gen-18* had positive phenotypic indices, so they were desirable too. The regression coefficients (b_i) of genotypes World Champion, *Gen-6* and *Gen-18* were significantly different from unity, which indicate that these were below average in stability and highly responsive to changes in environments, these might be suitable only for favourable environments. The regression coefficients of other genotypes were not significantly different from unity suggesting these were average in stability and hence well adapted to both favourable and unfavourable environments. *Gen-3*, *Gen-4* and *Gen-5* had significant S_{di}^2 values indicate that their performances were unpredictable in nature. Except those three genotypes all other genotypes showed nonsignificant S_{di}^2 values, which suggest that they were relatively stable under environmental fluctuations. *Gen-1* and *Gen-7* with low b_i values (around unity), nonsignificant S_{di}^2 values and positive phenotypic index were less responsive to the environmental changes and therefore more desirable.

Individual fruit weight

Table 2 shows that, environmental mean ranged from 50.72 to 70.79 gms. Env.3 was the most favourable environment (70.79g) followed by Env.4 (70.47g) and Env.5 was the least (50.724g). Gen-20 had high phenotypic index ($pi = 23.708$). So, Gen-20 is the most desirable genotype. The pi values of Gen-4, Gen-6 and Gen-15 were also positive and all other genotypes had negative pi values for individual fruit weight. With the exception of Gen-1 and Gen-5 the regression coefficients (b_i) for all the genotypes do not differ significantly from unity (i.e. $b_i = 1$), suggesting they were average in stability. Gen-1 and Gen-5 had significant b_i values and thus below average in stability. All the genotypes had nonsignificant S_{di}^2 values indicating the performance of the genotypes were predictable. Considering the three stability parameters, Gen-1, Gen-6, Gen-15 and Gen-20 were the most stable genotypes, hence they were desirable for individual fruit weight under all environmental conditions. Though World Champion, Gen-3, Gen-4, Gen-7 and Gen-18 were stable they were undesirable because they had negative pi values.

Yield/plant

Cultural environment has a considerable influence on the yield of a given genotype. The evaluation of genotypes for their responsiveness under different cultural environments has been emphasized in relation to individual traits and yield. Stability and response parameter as estimated in three models in the present study along with mean values of yield/plant are presented in Table 3. The environment means ranged from 1.115 to 2.303 kg/plant, while the genotype means ranged from 3.008 to 3.295 kg/plant over the five cultural environments. Gen-5 had the highest phenotypic index ($pi = 1.302$) and Gen-15 the lowest ($pi = -0.985$), giving the highest and the lowest yield respectively on average of all environments. According to this model, World Champion, Gen-6, Gen-15 and Gen-18 were found below average in stability, as their regression coefficients were significantly different from unity. Rest of the genotypes viz. Gen-1, Gen-3, Gen-4, Gen-5, Gen-7 and Gen-20 had nonsignificant b_i values, hence they were average in stability and might be well adapted in wide range of environments. Deviation from regression (S_{di}^2) of the genotypes Gen-3 and Gen-4 were significantly different from zero, as such the linear prediction of these genotypes in different environmental conditions would not be possible. All other genotypes had nonsignificant deviations from regression; these genotypes were thus average in stability and might be well adapted. With positive phenotypic index, nonsignificant b_i and S_{di}^2 values (i.e. $b_i=1$ and $S_{di}^2=0$) Gen-1, Gen-5, and Gen-7 were the most stable and desirable genotypes and performed better than the standard check.

Stability assessment using genotype-grouping technique

The results of stability assessment of genotypes for different characters following grouping techniques are depicted as follows:

Days to 50% flowering

The average number of days required for 50% flowering from seeding date along with the values of stability and response parameters, coefficients of variation (CV%) and the phenotypic indices are showing Table 2. The most stable genotypes for early flowering were those, which are placed in Group-III since they registered fewer days with consistent performance over environments. Gen-1, Gen-2, and Gen-4 are placed in group-III. Based on this technique they might be considered as stable and desirable genotypes for days to 50% flowering.

Number of fruits /plant

The average number of fruits/plant of all the genotypes along with the values of stability and response parameters, coefficients of variation (CV %) and the phenotypic indices are shown in Table 2. Among the genotypes, the most stable genotypes for number of fruit/plant were those, which are placed in Group-I as they recorded high number of fruits/plant with consistent performance over environments. According to "genotype grouping technique" Gen-1, Gen-5 and Gen-7 were considered as stable and desirable genotypes for number of fruits/plant as they are placed in group-I

Individual fruit weight

Table 2 showed the mean individual fruit weight of all the genotypes along with the values of stability and response parameters, coefficients of variation (CV%) and the phenotypic indices. Among the genotypes, the most stable genotypes for individual fruit weight are those, which are placed in Group-I since they exhibited large fruit size (individual fruit weight) with consistent performance over environments. It appears that Gen-6 and Gen-15 were the most stable and desirable genotypes for individual fruit weight as they are placed in Group-I.

Yield/plant

The mean yield/plant of all the genotypes along with the values of stability and response parameters, coefficients of variation (CV%) and the phenotypic indices are shown in Table 2. Among the genotypes, the most stable genotypes for yield are those which are placed in Group-I since they registered high yield with consistent performance over environments as typified by relatively low CV%. Based on this technique Gen-1, Gen-4, Gen-5 and Gen7 could be adjudged as the most stable and desirable genotypes for yield/plant.

Table 2: Stability parameters i.e. mean, phenotypic index (pi), regression co-efficient (bi) and deviation from regression (S_{2di}) for all characters of ten tomato genotypes evaluated under different environments

Geno type	Days to 50% flowering					No. of fruits /plant					Individual fruit wt					Yield/Plant					
	\bar{x}	CV (%)	P _i	b _i	S ² _{di}	\bar{x}	CV (%)	P _i	b _i	S ² _{di}	\bar{x}	CV (%)	P _i	b _i	S ² _{di}	\bar{x}	CV (%)	P _i	b _i	S ² _{di}	
	Gen-1	77.40	8.895	-3.46	0.86	0.12	42.20	16.59	9.820	1.010	2.450	66.99	19.93	4.106	1.626*	4.527	2.847	26.13	0.854	1.439	0.0089
Gen-3	81.13	12.32	0.27	1.25	9.33	30.00	29.25	-2.380	0.910	60.08***	57.09	13.93	-5.797	0.9531	-1.507	1.748	37.54	-0.245	1.106	0.2802**	
Gen-4	77.17	9.946	-3.69	0.98	1.24	40.13	29.15	7.750	0.910	152.31***	59.10	12.98	-3.784	0.8104	3.839	2.334	25.94	0.341	0.550	0.3912***	
Gen-5	80.53	10.49	-0.33	1.09	1.55	57.80	19.84	25.42	1.630	10.97*	56.54	8.98	-6.34	0.3454*	5.538	3.295	24.32	1.302	1.486	0.0439	
Gen-6	82.27	7.830	1.41	0.82	-0.09	16.00	17.36	-16.38	0.2653**	2.060	66.68	13.24	3.79	0.9332	15.69	1.070	22.19	-0.920	0.3954*	0.0022	
Gen-7	82.47	11.06	1.61	1.18	0.51	37.00	20.35	4.620	1.060	-0.390	54.99	14.16	-7.892	0.8372	-0.067	2.040	24.55	0.050	0.910	-0.0055	
Gen-15	78.67	12.43	-2.193	1.260**	-1.066	15.80	25.79	-16.58	0.490	4.790	63.28	10.14	0.40	0.6988	1.211	1.010	29.58	-0.990	0.5395*	-0.0015	
Gen-18	79.00	10.91	-1.860	1.114**	-1.334	38.33	44.07	5.950	2.5406**	2.660	57.41	17.77	-5.473	1.275	-2.483	2.240	45.3	0.250	2.0331*	0.0262	
Gen-20	89.07	8.124	8.2	0.7214	24.53***	19.93	24.17	-12.45	0.666	1.073	86.59	16.35	23.71	1.605	17.26	1.730	27.49	-0.260	0.880	-0.091	
World	80.20	8.056	-0.66	0.73	5.93	26.60	13.61	-5.78	0.5188***	-1.340	60.16	13.04	-2.718	0.9158	-1.563	1.614	21.73	-0.379	0.6679***	-0.0118	
Champi on (Ck)																					

*P<0.05, **P<0.01, ***P<0.001

CONCLUSION

The present study revealed that the genotypes viz. Gen-1, Gen-5 and Gen-7 showed superiority over other genotypes i.e. these 3 were the most stable and desirable genotypes and performed better than the standard check. High mean performance, responsiveness to environment and stability of yield and its component traits under study were recorded in these 3 genotypes in both the method. Thus, these genotypes could be recommended for commercial exploitation through widely cultivation. To obtain high yielding and stable segregants, these genotypes may be used in designing future breeding programme. It is also observed that the simple genotype grouping technique is efficient tool in identifying stable genotypes.

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GROWTH PERFORMANCE AND THEIR DECOMPOSITION TOWARDS TEA PRODUCTION IN BANGLADESH

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ABSTRACT

The present study examines the growth rates of acreage, production and yield of Bangladesh tea from 1947-1970 to 1972-2001 split into pre and post liberation periods. Production, acreage and yield grew significantly @ 1.95, 1.12 and 0.83 percent respectively per annum over the study period.

The growth rates of production and yield were significantly higher during post-liberation than that of pre-liberation period. Area expansion and yield were the main vehicles for increased tea output. So, emphasis should be given to the increase in yield and intensifying cropping through technological advancement, varietal research and strengthening advisory services

Key Words: Growth rate, Sustainability, decomposition, yield augmentation.

INTRODUCTION

The increase in yield of a crop is considered as an indicator of progress and achievement. Increase in output may be achieved through increased area allocation from alternative uses and /or through yield increases. Bangladesh Tea Industry has attained its extensive margin of cultivation of land and there is practically not enough additional land to be brought under new cultivation. Possibilities of cultivation of tea at Panchagarh (greater Dinajpur) are under trial of tea cultivation although the establishment of tea cultivation has already been started. Therefore, achievement of total output growth has to be attempted normally through yield augmenting efforts and crop intensification. This is more imperative in a land scarce situation like Bangladesh where its average yield lags behind its neighboring countries with comparable environmental and physical resources. The average yield of Bangladesh tea is low (1176 kg/ha) compared to Kenya (2235 kg/ha), India (1678 kg/ha) and Srilanka (1566 kg/ha (ITC, 2002)). On the other hand, per capita consumption of tea is increasing at an increasing rate of 3.5 % per annum whereas production is increasing @ 1 % per annum (BTB, 2002). This is obvious that production of tea in the country will have to increase every year to keep pace with the increased per capita consumption at

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clonal yield levels have been much higher than the seedling types. Of the total tea area, only 21% was clonal variety in 2001 (Alam, 2002). Scope for increasing tea is enormous because the bulk of the tea area is yet now under traditional variety. Bangladesh entered into an important phase of development in tea industry and it has passed more than three decades. Time has come to evaluate the progress made in tea industry. The growth rates of area, production and yield of tea in Bangladesh will help facilitate compilation, interpretation and forecasting on the future development of tea.

It provides a guideline for future action in the perspective of the past. In pre-liberation period, a 3% mandatory extension programme was launched starting from 1960, and more than 11,000 hectares of additional land were brought under tea plantation upto 1970 (BCS, 1961). Since no high yielding and improved quality clone was not available during that period, it was not possible to introduce clones in the said extended area. On the contrary, 2% extension programme was implemented in the post-liberation period over 12 years starting from 1980 with the financial assistance from British ODA, EEC and GOB (BCS, 1980). Bangladesh Tea Research Institute so far has identified 15 high yielding and improved quality clones during post-liberation period. These clones were introduced in half of the extended 4377 hectares of land brought under 2% extension programme and about 2200 hectares of clonal area have started giving full benefits following the year 2000. Tea is perennial crop and a highly labour intensive crop. Its plantation is very expensive and it takes more than two lacs taka to bring one hectare of land (Gazi, 1996) into cultivation. Thus finance is the most limiting factor to bring new area under tea. Moreover, availability of suitable land for tea plantation is another constraint. Only 11,581 hectares of grant area is suitable for extension of tea plantation in the existing tea industry (PDU, 2002). Keeping this view in mind the proposed study would enable us to raise questions relating to the underlying factors responsible for such performances and is expected to serve as a basis for future policy decision. The present study aims at analyzing the production growth rates of tea and identifying factors contributing to the growth. In the context of Bangladesh, the information to be generated from this study bears a great importance. The specific objectives of this study were :

- i. To estimate the growth rates of acreage, production and yield of Bangladesh tea.
- ii. To identify and measure the effects of the factors influencing the yield of growth of tea
- iii. To analyse the contribution of area and yield with increases in output of tea.

MATERIALS AND METHODS

To carryout the objective of production, growth, and yield of Bangladesh tea, secondary data were used. The data on area, production and yield of Bangladesh tea were collected from the various issues of Annual Report of Bangladeshyio Cha Sangsad (BCS) and International Tea Committee (ITC) etc. Data covered two distinct periods related to pre-liberation period (1947-1970) and post-liberation period (1972-2000) of Bangladesh.

Growth Model :

The exponential growth model was run to estimate the growth rate of production, acreage and yield of Bangladesh tea. Following Gujarati (1988), the following growth model was applied.

$$\text{Exponential: } Y = ae^{bt} \dots\dots\dots(1)$$
$$\text{or } \ln y = \ln a + bt$$

Where, Y is the amount of production, acreage, yield, t is the time, b is the growth parameter to be estimated and ln stands for natural logarithm.

Testing the stability of growth parameter :

The stability of growth parameters between pre and post liberation was tested using the following

F-statistics

$$F = \frac{[e_{p2} - (e_1^2 + e_2^2)]/k}{(e_1^2 + e_2^2) / (n_1 + n_2 - 2k)} \text{ with } k (n_1 + n_2 - 2k) \text{ df}$$

Where

e_p^2 = Residual sum of squares for pooled sample

e_1^2 = Residual sum of squares for period 1

e_2^2 = Residual sum of squares for period 2

n_1 = Sample size of period 1

n_2 = Sample size of period 2

k = Number of parameter

df = Degrees of freedom

Decomposition analysis :

Decomposition of the growth of agricultural crops has been investigated by Alam (1992), Kamruzzaman et al. (1996) using Minhas and Vaidyanathan (1965) formulae. To decompose the components of change in output increases and their contribution, Minhas and Vaidyanathan algebraic formula used by the above authors is as follows.

Change in total output t $P_t - P_0$

Contribution of area change t $Y_0 [A_t (1 + C_0 - C_t) - A_0] +$
(absolute change in area)

Contribution of yield change t $[A_t \{1 + (C_0 - C_t) (Y_t - Y_0)\}] +$

Contribution of cropping pattern t $[A_t Y_0 \{(C_t - C_0)\}] +$

Change in interaction of cropping pattern & yield t $[A_t - (Y_t - Y_0) (C_t - C_0)]$

Where

P_0 = Production of tea from 1947-1970

P_t = Production of tea from 1972-2000

A_0 = Area under tea from 1947-1970

At = Area under tea from 1972-2000
 C0 = The proportion of area under the crop to gross cropped area under all crops in 1947-1970
 Ct = The proportion of area under the crop to gross cropped area under all crops in 1972-2000
 Y0 = The yield of tea from 1947- 1970
 Yt = The yield of tea from 1972- 2000

Wenragren et al. (1984) have studied the growth of agricultural crops including tea by using Minhas and Vaidyanathan (1965) formula. Minhas and Vaidyanathan formula appears to be quite all right for seasonal crops where cropping pattern may change year to year. But unlike other seasonal crops, tea being a perennial crop does not have any cropping pattern. Therefore, Minhas and Vaidyanathan (1965) exact formula applied by Wenragren (1984) does not seem to be relevant. In the present study, Minhas and Vaidyanathan (1965) formula has been used with minor change dropping the cropping pattern and its interaction with cropping pattern and yield. The restricted formula applied in the present study is thus:

Change in total output t Pt - P0
 Contribution of area change (absolute change in area) t Y0 [A t - A 0] +
 Contribution of yield change t [A t (Yt - Y0)] +

Where
 P0 = Production of tea from 1947-1970
 Pt = Production of tea from 1972-2000
 A0 = Area under tea from 1947-1970
 At = Area under tea from 1972-2000
 Y0 = yield of tea from 1947- 1970
 Yt = yield of tea from 1972- 2000

Factors influencing the yield of tea

To estimate the factors influencing the yield of tea were specified in a log-linear fashion. The equation was specified as follows :

$$Y = Ax_1^{b1} x_2^{b2} \dots\dots\dots x_n^{bn}$$

Where Y was dependent variable and x1 through xn were the explanatory variables; A was the constant and b1 through bn were the production coefficient for x1 through xn. The logarithmic form of the equation is t

$$\text{Log } Y = \text{Log } A + b_1 \text{Log } x_1 + \dots\dots\dots b_5 \text{Log } x_5 + e$$

Where
 Y = Yield of tea (Kg/ha)

x1 = Price of tea (tk/kg)
X2 = Rainfall (mm)
X3 = Rany days
X4 = Temperature (0C)
X5 = Time trend and
b1... b5 are the parameters to be estimated .
e = error term

RESULTS AND DISCUSSION

Production of tea has evidenced a significant upward movement from 18.88 million kg. in 1947 to 56.00 million kg. in 2001, i.e., 196 percent increase having an average rate of 1.95 percent growth per annum (Table 1). The area under tea during this period increased from 30,353 hectares in 1947 to 50,150 hectares in 2001 i, e, the rate of growth per annum was 1.12%. Contrary to the growth rates of production and area over the same period, the yield had shown a marginal increase to the tune of 0.83 percent per annum (Table 2). During post-liberation period the yield had evidenced a significant upward move from 762 kg/ha in 1974 to 1176 kg/ha in 2001 i.e., 54% increase whereas during pre-liberation period that had increased from 622 kg/ha in 1947 to 735 kg/ha in 1970 i.e., only 18% increase. The annual tea production during pre-liberation period increased from 18.88 million kg. to 31.38 million kg in 1970 i.e., 66% increase. Similarly during post liberation period annual tea production increased from 32.16 million kg. in 1974 to 56 million kg. in 2001 i.e., 71% increase. The area under tea plantation was increased by about 40% during the pre-liberation period as against 18% during post- liberation period.

Annual growth trend of area; production and yield was found to be significant in post-liberation period. The yield trend was insignificant (0.20%) in pre-liberation period while production (1.66%) and area (1.46%) were significant (Table 3). The reason for low yield in pre-liberation period resulted from annual production growth rate (1.66 %), which was marginally higher than the growth rate of area (1.46%). The annual growth rates of production during post and pre liberation period were found to be 2.17 and 1.66 percent respectively. It was observed that inspite of lower significant growth rate of area (0.70%) in post liberation period the production (2.17%) as well as yield (1.47 %) growth rates were higher compared to pre-liberation period. This is evidently a good signal for future prospects and sustainability of Bangladesh Tea Industry. In the context of land scarce country like Bangladesh, particularly for lands suitable for tea cultivation, such a result is really expected which has taken place mainly due to the intensification of production process including the introduction of clonal varieties. In this connection it is to be noted that during post liberation period, many developments of far-reaching consequences occurred. There has been a technical revolution in the tea plantation and rationalization in the production process in different ways. Among these instruments of changes, the development and introduction of

high yielding and better quality of vegetative clones, the intensive and appropriate use of fertilizers and manures, scientific intercultural operations, integrated pest management approach, scientific knowledge of tea planters through annual training courses of BTRI modules and high efficiency of management are noteworthy.

Table 1. Area, production and yield of Bangladesh tea

Year	Area (ha)	Production (mkg)	Yield (kg/ha)
Pre-liberationperiod(1947)	30353	18.88	622
1948	30377 1	9.86	654
1949	30500	21.01	689
1950	31877	21.69	680
1951	29507	23.91	810
1952	29651	23.71	800
1953	29695	24.83	836
1954	30094	24.78	823
1955	30262	23.82	787
1956	30374	24.78	816
1957	30732	21.09	686
1958	31029	25.55	823
1959	31287	25.65	820
1960	31406	18.97	604
1961	31689	26.78	845
1962	32323	23.42	725
1963	33494	24.96	745
1964	35005	29.67	848
1965	36486	27.07	742
1966	37778	28.53	755
1967	39292	29.7	756
1968	40604	28.39	699
1969	41935	30.16	719
1970	42688	31.38	735
1971	43398	12.45	287
Post-liberation period (1972)	40448	23.84	589
1973	41406	27.55	665
1974	42195	32.16	762
1975	42399	29.09	686
1976	42076	33.5	796
1977	41734	38.14	914
1978	42627	37.92	890
1979	42456	36.13	851

1980	43255	40.04	926
1981	43839	41.29	942
1982	43780	40.94	935
1983	44277	43.43	981
1984	44438	38.21	860
1985	46115	43.4	941
1986	46372	37.59	811
1987	45437	40.31	887
1988	44935	43.58	970
1989	46308	39.08	844
1990	46688	45.89	983
1991	47306	45.23	956
1992	47561	49.13	1033
1993	47789	50.62	1059
1994	47492	51.64	1087
1995	47749	47.2	989
1996	48097	53.52	1113
1997	49388	53.49	1083
1998	49389	55.92	1132
1999	49210	47.25	960
2000	49910	51.25	1027
2001	50150	56.00	1176

Source : BTB 2002.

Table 2. Growth rates (exponential) of acreage, production, and yield of Bangladesh tea from 1947-2000

Dependent variable	Intercept	Growth rate(%)	R2
Area	10.27	1.12 * (24.85)	0.92
Production	2.96	1.95 * (24.77)	0.91
Yield	6.50	0.83 * (8.97)	0.61

Figures in Parentheses indicate t- values.

* represents significant at 1% level of probability

Table 3. Growth rates (exponential) of acreage, production and yield of Bangladesh tea from 1947-1970 (Pre-liberation period)

Dependent variable	Intercept	Growth rate (%)	R2
Area	10.22	1.46 * (8.18)	0.75
Production	3.00	1.66* (6.27)	0.64
Yield	6.59	0.20 (.680)	0.02

Figures in Parentheses indicate t- values.

* represents significant at 1% level of probability

Table 4. Growth rates (exponential) of acreage, production and yield of Bangladesh tea from 1972-2000 (Post-liberation period)

Dependent variable	Intercept	Growth rate(%)	R2
Area	10.45	0.70 * (29.95)	0.97
Production	2.87	2.17 * (11.50)	0.82
Yield	6.23	1.47 * (7.83)	0.69

Figures in Parentheses indicate t- values.

** represents significant at 1% level of probability*

The stability of growth parameters between pre and post- liberation period was tested by using the Chow Test. The growth rates of yield during pre and post-liberation period were 0.20% and 1.47% respectively, the difference of which was found to be statistically significant at 1% level of probability (Table 5). Similarly the growth rates of area during pre and post - liberation periods differed significantly at 1% level. The growth rates of production in pre and post- liberation periods were 1.66% and 2.17% respectively, but their difference was found to be insignificant. It is clear from the table that the null hypotheses that existence of no difference in growth rates exist in area and production between the pre and post -liberation period is rejected and it was concluded that the differences in growth rates between two periods in terms of area and yield were significant at 1 percent levels of significance. The fact remains that the yield growth rate in post- liberation period was much higher than that of pre-liberation period. The reverse had happened in case of area growth, which was higher during pre-liberation period. Therefore, planters had rightly taken advantages of the technologies during the post liberation period.

Table 5. Significance of the difference of per annum growth rate in pre and post-liberation period

Dependent variable	Growth Rate (%)			Differences in Growth Rate	
	Pre Liberation	Post liberation	Aggregate	Calculated Fc	Tabulated F2.50
Area	1.46*	0.70*	1.12* 1	6.57*	5.08
Production	1.66*	2.17*	1.95*	1.32	5.08
Yield	0.20	1.47*	0.83*	8.03*	5.08

** represents significant at 1% level of probability.*

Auction price had a significant role on the yield of tea (Table 6). Temperature and rainydays of the growing season showed a negative impact on the yield of tea. It indicates that excess temperature (drought) and more number of rainydays reduce the yield of tea. Variations of rainfall in the growing season played a positive role on the yield of tea but it

was not statistically significant. Time trend also showed a positive impact on the yield of tea. The policy implication of these results is that for yield augmentation of tea, emphasis has to be given to technological advancement, varietal research and strengthening of advisory services rather than influencing product prices.

Table 6. Factors influencing the yield growth of tea during 1947-2000

Dependent variable (Yield kg/ha)	Intercept	Auction price (tk/kg)	Rainfall (mm)	Rainydays (No.)	Temperature (C0)	Time Trend	R2
Tea	7.09*	0.116*	.0099	- 0.. 214	-. 0.129	0.00092	0.67
	(4.92)	(3.08)	(.782)	(1.75)	(0.475)	(0.3165)	

Figures in parenthesis indicate respective t -ratios.

**indicates significant at 1% level of probability.*

Table 7 revealed the relative importance of changes in area and yield (the data averages between two periods for estimation). On an average, tea output had increased by 70.37 % between pre and post - liberation periods (Table 6.11); 54.35 % of the output increase was due to area expansion and 45.65 % due to increase in yield. In Bangladesh, there is no enough additional land for expansion of tea area. So, more emphasis should be given to increase the contribution from yield. Contribution to yield can be increased through varietal improvement, intensive cultivation of tea, maintaining soil fertility and strengthening advisory services to the tea estates rather than influencing product prices.

Table 7. Sources of change in tea output growth between pre and post liberation period (1947-1970 and 1972- 2001).

Parameter	Changes in output between periods (%) (%)	Contribution of area	Contribution of Yield (%)	Total
Tea	70.37	54.35	45.65	100

CONCLUSION

Area, production and yield of tea displayed significant growth over last 53 years. The rate of increase in production and yield however, during post liberation period, is significantly higher than that of pre liberation period. Area grew at a faster rate during the pre-liberation period. These implied two things: first, when technology was traditional major output expansion came from area increase; second, when technology started improving major output expansion was the result of yield enhancement, particularly during the post-

liberation period. Since expansion of output due to area increase would soon reach its limit, dependence on this strategy is not feasible in the long run. The long run strategy for expansion of tea output has to be yield augmented. Therefore, Bangladesh can keep on expanding potential land for tea cultivation to increase output as long as the area permits, but ultimately the country has to rely on yield augmentation strategy. To tap these opportunities Bangladesh tea estates management should: i. explore suitable additional land and bring them under tea cultivation.. ii.intensify plant improvement research at BTRI, i, e., to introduce high yielding and better quality vegetative clones and seeds among the tea estates so that per unit productivity is increased

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HETEROISIS IN RELATION TO COMBINING ABILITY IN RICE (*Oryza sativa* L.) INVOLVING CYTOPLASMIC-GENETIC MALE STERILITY SYSTEM

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ABSTRACT

Heterosis in relation to combining ability from line x tester crosses in rice was estimated to quantify their interrelations from a 5 line \times 8 tester crosses. Non-additive gene action was preponderant for all the traits studied. The estimates of gca effects revealed that none of the parent was general combiner for all the traits in desired direction, although Gan46A, You1A, IR46R, BR827R and BR168R were good general combiner for earliness, shorter plant type and higher grain yield. The hybrids involving Gan46A You1A as female parent and IR34686R or IR10198R or BR827R or BR168R as male parent produced higher degree of relative heterosis as well as heterobeltiosis for grain yield indicating the potential of these parental lines developing heterotic rice hybrid. On categorization of the heterotic crosses based on the parental gca effect maximum heterotic crosses (40% over mid parent and 37.2% over better parent) were found to evolve from H \times L combinations and majority of them (80% and 74.5% crosses for relative heterosis and heterobeltiosis, respectively) involved at least one parent with high gca effect in desired direction. In addition, strong correlation between sca effect and heterosis over mid and better parent revealed the importance of sca effect for realizing high heterosis of a cross combination

Keywords: Heterosis, heterobeltiosis, combining ability, Cytoplasmic male sterility, rice

INTRODUCTION

Heterosis in grain yield is the result of many morpho-physiological processes. Identification of the processes responsible and their genetic control may not only help plant breeders to develop high yielding cultivars but also help agronomists to establish suitable cultural practices. To attain such complex processes comprehensive research should be carried out relating to genetic improvement of morphophysiological traits of rice plants. Combining ability is one of the powerful tools in identifying the bestcombiners that may be used in crosses either to exploit heterosis or to accumulate productive genes. It also helps to understand the genetic architecture of various characters that enable the breeder to design effective breeding plan for future improvement of the existing materials. Thus, a study was undertaken to estimate heterosis in relation to combining ability in rice.

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MATERIALS AND METHODS

Forty crosses were made using 5 cytoplasmic-genetic male sterile (CMS) lines and 8 restorer lines following Line X Tester model in 2002. The F1 hybrids along with their parents were grown in the experimental field of Bangladesh Rice Research Institute (BRRI) in the Boro season, 2003. Singleseedling per hill of thirty day old was transplanted with a spacing of 20x15cm in RCB design with three replications. The unit plot size was 1.8m x 5 rows. The crop management was done at par BRRI recommendation for hybrid rice (BRRI, 2004). Data on plant height, days to 50% flowering, panicle length, panicles/plant, filled grains/panicle, spikelet sterility, 1000-grain weight and grain yield/plant were recorded from ten randomly selected plants from each entry. Analysis of variance (ANOVA) for combining ability and *gea* and *sca* effects were estimated according to Kempthorne (1957). The overall mean value for each parent and hybrid in all the three replications for each character was taken for the estimation of heterosis.

RESULTS AND DISCUSSION

The ANOVA showed that the genotypes differed significantly for all the characters (Table 1). On partitioning the genotypic variance, the variances due to parents and crosses (hybrids) were also highly significant for all the characters studied. Variances due to interaction effect of parents and crosses were significant for all traits indicating the presence of considerable average heterosis in the cross combinations. The variance components of combining ability showed that none of the trait had significant *gca* component (s^2_{gca}) but most of the traits except panicle length and 1000-grain weight were significant for *sca* components (Table 1). It indicated the importance of dominance gene expression for these traits. The relative proportions of the components (s^2_{gca}/s^2_{sca}) for these characters also indicated preponderance of non-additive gene actions. Bobby and Nadarajan (1993), Ramalingam *et al.* (1993) and reported predominance of non-additive gene actions in plant height, tiller/plant, days to flowering, panicle length, filled grains/panicle, 1000-grain weight and grain yield. Lang and Buu (1993) had similar findings for grain yield. The results of Sarker (2001) and Bashar (2002) were also in agreement with the present findings. The dominant gene action underlined the importance of these parental lines in the expression of heterosis in F1 hybrids.

Table 1. Analysis of variances for different characters in rice

Source of variation	df	Plant height	Days to 50% flowering	Panicles /plant	Panicle length	Filled grains/panicle	Spikelet sterility weight	1000 grain	Grain yield/plant
Replication	2	102.32**	17.55**	0.07 4.	17**	112.5	214.19**	0.39	31.17
Genotype	52	188.80**	189.16**	5.35**	9.37**	2467.8**	321.12**	15.95**	171.2**
Parent	12	489.59**	508.06**	2.42**	22.18**	2438.9**	93.47**	22.23**	59.43**
Crosses	39	98.58**	68.25**	6.04**	5.56**	2435.6**	392.96**	14.14**	188**
Parent vs. crosses	1	98.17**	1078.04**	13.62**	3.87*	4069.1**	251.14**	10.81**	855.8**
Error	104	11.94	3.03	0.97	0.86	120.8	25.33	1.04	10.79
Variance components									
s ² gca		1.096	0.887	0.012	0.820	1.77	3.68	0.201	0.942
s ² sca		8.174	4.968	1.456	0.939	738.2	53.04	0.576	41.27
s ² gca/s ² sca		0.134	0.179	0.008	0.873	0.002	0.069	0.349	0.023

* $p < 0.05$, ** $p < 0.01$

Combining ability

The general combining ability effects of the parental genotypes varied randomly among the lines and testers (Table 2). The estimates of gca effects showed that none of the parent was general combiner for all the traits in desired direction. However, Gan46A, You1A, IR46R, BR827R and BR168R had significantly negative gca effects for days to 50% flowering and plant height, and significant positive gca for grain yield. This indicated that these were good general combiner for earliness, shorter plant type and higher grain yield. IR58025A was good general combiner for panicle/pant, panicle length and filled grain/panicle and You1A, IR46R, IR34686R and BR168 were good combiners for less sterility. For heavier 1000-grain weight, the best general combiners were Gan46A, you1A, D ShanA, IR29723R, IR34686R, IR10198R, IR34686R and BR827R. IR46R, IR34686R, Gui99R and BR168R were the best combiners for filled grains/panicle IR10198R, Gui99R and BR827 were the best for panicles/plant.

Table 2. Estimates of general combining ability (gca) effects of parents for different growth traits in rice

Parents	Plant height (cm)	Days to 50% flowering	Panicles/plant	Panicle length (cm)	Filled grains/panicle	Spikelet sterility (%)	1000 grain weight (g)	Grain yield/plant
A lines (line)								
Gan46A	-1.29	-3.40**	-0.32	-0.61**	-6.47**	3.12**	0.53*	3.51**
You1A	0.86	-0.36	-0.15	-0.22	3.63	-5.00**	1.18**	2.99**
BRR11A	-6.38**	-0.98**	0.23	-0.49**	-9.67**	-1.10	-1.30**	-1.43*
D ShanA	0.02	-0.15	-0.50*	-0.42*	-3.59	-1.14	1.11**	-0.47
IR58025A	6.79**	4.89**	0.75**	1.75**	16.10**	4.13**	-1.52**	-4.59**
SE (gi)	0.705	0.356	0.201	0.189	2.244	1.027	0.21	0.671
SE (gi-gj)	0.998	0.500	0.285	0.267	3.173	1.453	0.295	0.948
R lines (tester)								
IR29723R	-0.40	3.24**	0.13	-0.17	-23.62**	17.35**	0.70**	-6.64**
IR46R	2.53**	1.24**	-0.22	0.54*	14.36**	-5.00**	-1.27**	2.10*
IR34686R	2.61**	4.38**	-0.18	0.48*	5.88*	-8.98**	2.66**	1.47
IR10198R	-2.84**	-2.42**	1.01**	0.11	-13.24**	1.11	0.73**	0.77
Gui99R	0.84	1.78**	0.75**	-0.15	8.32**	-4.47	-0.37	0.90
BR827R	2.83**	-0.89*	0.52*	-0.59*	-0.45	-1.73	0.82**	5.55**
BR736R	-2.63**	-6.63**	-0.7**	-0.57*	-6.09*	9.76**	-3.16**	-8.18**
BR168R	-2.94**	-0.69	-1.31**	0.34	14.83**	-8.03**	-0.10	4.03**
SE (gi)	0.892	0.450	0.255	0.239	2.838	1.300	0.264	0.848
SE (gi-gj)	1.262	0.640	0.36	0.338	4.014	1.838	0.835	2.682

* $p < 0.05$, ** $p < 0.01$

Generally best specific combiner crosses includes good x good and/or good x poor general combiner parents. Among the 40 hybrids, Gan46AxGui99R possessed the good specific combination for earliness, longer panicle, panicles/plant, filled grains/panicle and grain yield (Table 3) as it showed significant sca effect in desired direction of the traits. A similar finding was observed for panicles/plant, filled grains/panicle, less sterility and grain yield in You1AxIR29723R, whereas IR58025AxIR34686R had significant sca effect for earliness. IR58025AxIR46R appeared as good specific combination for shorter plant height and longer panicle, while IR58025AxBR736R was observed as good for lateness, taller plant, greater number of filled grains/panicle, less sterility and higher grain yield. For higher number of filled grain/panicle, less sterility and higher grain yield, You1AxBR736R, D ShanAxIR34686R and IR58025AxIR29723R were found to be good specific combinations, while D ShaAxIR10198R was good specific combiner cross for earliness and higher grain yield as reflected by its significant sca effects.

Table 3. Estimates of specific combining ability (sca) effects of hybrids for different growth traits in rice

Hybrid	Plant height (cm)	Days to 50% flowering	Panicles/plant	Panicle length (cm)	Filled grains/panicle	Spikelet sterility (%)	1000 grain weight (g)	Grain yield/plant (g)
Gan46A x IR29723R	5.38**	2.47*	0.06	0.33	-21.39**	12.85**	-0.51	-8.47**
Gan46A x IR46R	0.92	-0.87	0.94	0.38	11.96	-6.02*	0.52	6.96**
Gan46A x IR34686R	-0.96	1.33	-0.23	-0.56	-4.09	-3.41	0.23	3.79*
Gan46A x IR10198R	-0.91	0.47	-1.22*	0.46	7.03	-4.68	-0.25	-1.35
Gan46A x Gui99R	1.35	-2.07*	1.34*	1.25*	39.07**	-3.79	-0.53	5.44**
Gan46A x BR827R	-1.32	-0.40	-0.53	-0.16	1.77	-1.29	1.40*	-1.67
- Gan46A x BR736R	-0.72	0.00	-0.58	-1.46**	-48.65**	6.57*	-1.14	-12.81**
Gan46A x BR168R	-3.75	-0.93	0.23	-0.23	14.29*	-0.24	0.28	8.10**
- You1A x IR29723R	2.63	-0.24	1.29*	0.31	32.65**	-16.68**	0.31	8.16**
You1A x IR46R	0.17	-0.91	-0.16	-0.77	-0.80	3.46	-0.89	3.70
- You1A x IR34686R	3.27	3.96**	0.05	2.77**	-25.35**	10.69**	1.20*	-7.85**
You1A x IR10198R	-2.66	-2.91**	-0.52	-0.78	-13.13*	5.10	0.14	-2.08
You1A x Gui99R	1.36	0.22	-0.93	0.31	-11.69	4.16	-0.76	-1.80
You1A x BR827R	-0.60	-0.11	0.64	-0.85	-2.39	1.37	0.55	-7.70**
You1A x BR736R	-2.14	1.29	-0.35	-0.94	17.72**	-6.27*	0.71	7.83**
You1A x BR168R	-2.03	-1.31	0.00	-0.03	3.00	-1.82	-1.25*	-0.27
BRR11AxIR29723R	-3.33	-2.62**	-0.90	-0.26	-12.79*	8.99**	0.04	-2.84
BRR11A x IR46R	2.47	0.05	0.25	1.06*	-8.97	3.65	0.02	1.91
BRR11A x IR34686R	1.53	0.92	-2.06**	-0.10	6.45	-2.22	-0.54	0.55
BRR11A x IR10198R	-0.56	3.05**	1.15*	-0.89	3.76	4.51	1.94**	0.03
BRR11A x Gui99R	-0.70	-1.82	-0.22	0.41	22.87**	-4.19	0.07	1.06
BRR11A x BR827R	1.77	1.85	-0.42	-1.07*	20.17**	-5.68	-0.54	6.36**
- BRR11A x BR736R	-3.57	-2.42*	0.93	0.90	-40.59**	-0.87	-0.64	-7.42**
BRR11A x BR168R	2.40	0.98	1.27*	-0.06	9.09	-4.19	-0.34	0.35
D ShanAxIR29723R	-1.86	-0.12	0.10	-0.26	-20.2**	11.51**	0.68	-4.17*
D ShanA x IR46R	1.87	0.22	0.65	0.25	12.752*	-1.25	-0.55	-7.47**
D ShanA x IR34686R	1.93	1.42	-1.92**	-0.79	20.84**	-3.84	-0.04	8.05**
D ShanA x IR10198R	-3.22	-2.45*	0.49	-0.30	10.22	-6.56*	-1.15	5.56**
- D Shan46A x Gui99R	0.10	2.35*	0.08	-0.12	-22.33**	-5.24	0.58	-5.46**
D ShanA x BR827R	0.27	-0.32	1.58**	-0.04	4.50	0.93	-0.06	3.69
D ShanA x BR736R	-1.03	-1.92	-0.87	1.07*	-11.06	6.29*	1.02	1.69
D ShanA x BR168R	1.94	0.82	-0.12	0.18	5.29	-1.84	-0.49	-1.89
- IR58025A x IR29723R	-2.82	0.51	-0.55	-0.11	21.74**	-16.67**	-0.52	7.32**
IR58025A x IR46R	-5.43**	1.51	-1.68**	-0.91	-14.94*	0.17	0.90	-5.10**
IR58025A x IR34686R	-5.77**	-7.63**	4.16**	-1.32*	2.15	-1.21	-0.84	-4.54*
IR58025A x IR10198R	7.35**	1.84	0.10	1.51**	-7.87	1.62	-0.68	-2.17
- IR58025A x Gui99R	-2.11	1.31	-0.27	-1.84**	-27.93**	9.06**	0.63	0.75
- IR58025A x BR827R	-0.13	-1.03	-1.27*	2.11**	-24.06**	4.67	-1.35*	-0.68
IR58025A x BR736R	7.47**	3.04**	0.88	0.43	82.58**	-5.72*	0.05	10.71**
- IR58025A x BR168R	1.44	0.44	-1.38	0.14	-31.67**	8.09**	1.81**	-6.29**
SE (Sij)	1.995	1.006	0.57	0.534	6.347	2.906	0.59	1.896
SE (Sij-Ski)	2.821	1.422	0.806	0.756	8.976	4.110	0.835	2.682

*p<0.05, **p<0.01

Heterosis

Nature and extent of both relative heterosis and heterobeltiosis were found to vary depending on cross combinations and character (Table 4). Based on the mean values of relative heterosis and heterobeltiosis, the highest magnitude of heterosis was obtained in grain yield followed by panicles/plant and filled grains/panicle. Most of the cross combinations produced significant positive heterosis over mid parent for grain yield, while nearly 50% of the crosses scored significant positive heterosis over better parent for the same trait. The hybrids involving Gan46A or You1A as female parent and IR34686R or IR10198R or BR827R or BR168R as male parent produced higher degree of relative heterosis as well as heterobeltiosis for grain yield indicated the potentiality of those parental lines developing heterotic rice hybrid. Most of the crosses involving BR.11A as female parent and / or, BR736R, BR168R and IR10198R as male parent showed significant negative heterosis for plant height. The maximum heterobeltiosis was observed in the cross Gan46AxBR827R for earliness. IR58025AxBR736R followed by IR58025A x IR34686R showed the highest magnitude of both relative heterosis and heterobeltiosis for filled grains/panicle.

Table 4. Relative heterosis (RH) and standard heterobeltiosis (HB) in 40 rice hybrids

Hybrid	Plant height		Days to 50% flowering		Panicles/plant		Panicle length		Filled grains/panicle		Spikelet strility		1000 grain weight		Grain yield/plant	
	RS	HB	RS	HB	RS	HB	RS	HB	RS	HB	RS	HB	RS	HB	RS	HB
Gan46A x IR29723R	13.0**	-0.6	2.1*	-9.6**	16.9*	11.2	-5.0	-17.4**	-45.9**	-54.5**	196.1**	164.8**	6.8*	0.3	-28.9**	-30.0**
Gan46A x IR46R	13.5**	1.5	-1.2	-12.2**	12.5	-0.6	4.2	-5.3	18.9**	-12.4*	-46.2**	-51.0**	5.3	1.5	66.2**	59.8**
Gan46A x IR34686R	10.4**	-1.9	0.1	-12.7**	11.6	7.7	-3.8	-14.9**	0.8	-26.9**	-34.8*	-37.6*	13.7**	2.6	95.3**	57.4**
Gan46A x IR10198R	4.6	-6.5*	1.0	-7.1**	0.7	-12.3	2.4	-7.0*	-13.4*	-31.6**	18.1	8.9	9.4	3.8	57.6**	33.0**
Gan46A x Gui99R	9.4**	-3.9	0.5	-9.0**	40.3**	34.5**	7.5*	-0.4	30.7**	0.0	-29.2	-30.1	1.7	-4.5	65.4**	61.9**
Gan46A x BR827R	5.7	-9.0**	-3.9**	-15.5**	11.0	2.8	0.2	-5.8	-9.7	-27.2**	47.4*	26.6	9.5**	-2.0	50.2**	48.7**
Gan46A x BR736R	-7.7**	-24.7**	-5.5**	-15.3**	-1.6	-7.3	-14.1**	-25.0**	-55.9**	-60.2**	82.9**	68.0**	-4.7	-8.0	-56.1**	-59.4**
Gan46A x BR168R	-1.3	-13.2**	-2.5**	-13.1**	2.0	-3.0	1.4	-7.1*	12.5*	-10.8*	-10.9	-12.8	2.1	-7.6*	93.1**	86.1**
You1A x IR29723R	15.0**	-1.2	0.9	-9.4**	30.8**	26.9**	1.5	-16.0**	13.3*	5.6	-41.2	-42.8	12.7**	6.7	27.3**	20.5*
You1A x IR46R	18.1**	3.1	-0.5	-10.2**	0.7	-9.5	6.0	-8.5**	36.3**	9.0	-17.8	-33.8*	0.9	-2.0	40.5**	36.0**
You1A x IR34686R	21.2**	5.2	2.7**	-9.1**	14.7	12.9	18.7**	-0.1	7.4	-15.7*	4.2	-12.4	20.0**	9.1**	20.5	-7.9
You1A x IR10198R	7.6*	-6.0*	-0.8	-7.4**	8.0	-4.3	3.7	-10.6**	-8.7	-20.8**	46.7*	38.1	13.3**	8.4*	38.4**	10.4

Table 4 (continued)...

You1A Gui99R	x	14.7**	-1.6	3.0**	-5.3**	13.2	10.6	10.6**	-2.8	15.3*	-3.6	12.2	-3.2	2.8	-2.7	22.4*	11.8
You1A x BR827R		11.6**	-6.1*	-2.9**	-13.4**	23.9**	16.9*	4.3	-7.2*	9.0	-3.2	18.0	15.8	7.8*	-2.8	14.1	7.3
You1A x BR736R		-5.0	-24.1**	-3.7**	-12.4**	1.1	-2.9	-5.6	-21.6**	6.6	5.6	7.2	-13.0	7.1	2.6	12.9	12.0
You1A x BR168R		5.9	-9.0**	-2.0*	-11.3**	-0.8	-3.7	9.8**	-4.6	28.7**	12.2	-50.2**	-55.7**	-2.5	-11.2**	42.9**	28.7**
BRR11A x IR29723R		-4.7	-15.4**	-5.3**	-11.4**	0.4	-5.3	-8.6**	-19.2**	-34.6**	-39.7**	185.2**	182.1**	9.0*	-5.2	-32.3**	-36.7**
BRR11A x IR46R		8.2**	-2.4	-4.2**	-10.0**	0.3	-1.9	6.1*	-1.9	14.6*	-9.2	-1.6	-18.3	2.1	-9.2*	15.7	10.7
BRR11A x IR34686R		6.3*	-4.7	-3.8*	-11.4**	-13.9	-19.9*	-2.8	-12.6**	23.2**	-4.1	-43.0*	-50.5**	10.1**	-7.7*	36.9**	3.7
BRR11A x IR10198R		-2.2	-11.8**	-1.0	-3.6**	19.1**	14.7*	-5.0	-12.2**	-6.8	-20.0**	59.7**	56.2*	20.1**	5.4	25.9*	-0.6
BRR11A x Gui99R		-0.1	-11.6**	-3.1**	-7.1**	14.8*	7.6	2.2	-3.6	32.5**	9.7	-28.1	-35.7	3.7	-9.9**	14.6	3.5
BRR11A x BR827R		2.5	-11.1**	-5.8**	-12.5**	6.5	3.3	-5.3	-9.4**	15.2*	1.3	-24.7	-28.8	0.1	-16.8**	49.0**	38.4**
BRR11A x BR736R		-17.1**	-31.8**	-10.7**	-15.3**	9.7	4.6	-4.7	-15.5**	-47.1**	-47.2**	124.9**	88.3**	-3.6	-8.3	-58.0**	-58.2**
BRR11A x BR168R		-0.8	-12.1**	-4.7**	-10.2**	8.1	2.0	1.0	-5.9	20.9**	4.4	-43.9*	-48.3*	-1.7	-17.4**	25.8**	12.0
D ShanA x IR29723R		4.1	-7.0*	-1.1	-9.2**	0.0	-8.1	-7.3*	-19.0**	-39.4**	-46.8**	273.7**	203.0**	10.4**	8.0*	-32.2**	-35.2**
D ShanA x IR46R		14.5**	4.1	-1.7	-9.3**	-5.7	-6.2	3.8	-5.0	30.7**	-0.3	-10.1	-37.0*	-1.2	-1.7	-13.2	-15.3

Table 4 (continued)....

D Shan A x IR34686R	13.8**	2.8	-1.1	-10.6**	-22.8**	-30.0**	-4.6	-15.1**	32.6**	-0.5	-41.2*	-57.4**	10.7*	3.9	81.3**	39.4**	
D Shan A x IR10198R	1.6	-7.6*	-2.5**	-6.9**	2.8	1.8	-0.9	-9.4**	-2.7	-20.0**	20.8	-4.5	3.6	2.4	59.1**	27.7**	
D Shan46A x Gui99R	7.8**	-3.8	2.5**	-3.7**	6.8	-2.5	1.2	-5.6	-8.4	-27.2**	-19.6	-40.6*	5.1	2.8	-4.8	-12.3	
D Shan A x BR827R	7.5**	-6.0*	-5.0**	-13.4**	15.9*	9.4	1.0	-4.4	0.7	-15.4**	44.7	21.7	1.7	-5.5	45.9**	38.4**	
D Shan A x BR736R	-8.0**	-23.8**	-8.0**	-14.4**	-19.2**	-25.0**	-2.7	-14.6**	-25.3**	113.3**	50.4**	4.5	-3.1	-20.8*	-22.1*		
D Shan A x BR168R	5.6	-5.7	-2.4**	-9.8**	-17.0*	-23.8**	3.5	-4.5	15.2*	-4.9	-16.9	-37.2	-2.6	-8.4*	23.8*	12.3	
IR58025A x IR29723R	1.6	-0.7	-2.0*	-5.5**	12.6	9.1	-4.3	-10.1**	17.8**	12.6	11.6	-16.6	2.2	-8.6*	14.5	1.0	
IR58025A x IR46R	4.0	3.5	-2.2*	-5.1**	-11.2	-15.4*	0.5	-0.8	39.2**	13.6	-18.6	-28.2*	2.5	-6.2	-5.0	-17.8	
IR58025A x IR34686R	2.9	1.7	-8.5**	-13.1**	62.6**	55.2**	-4.5	-8.6**	50.4**	20.4**	-45.1**	-53.8**	4.8	-9.8**	26.7	12.3	
IR58025A x IR10198R	12.3**	11.8**	-0.8	-1.4	17.0*	9.8	8.9**	7.4*	9.9	-2.6	16.8	-10.7	2.9	-7.2	29.5*	21.1	
IR58025A x Gui99R	3.6	1.1	0.1	-0.9	23.3**	18.5*	-4.4	-5.2	15.5*	-1.4	15.3	-5.3	2.6	-8.4*	24.1*	13.3	
IR58025A x BR827R	5.4*	0.5	-6.6**	-10.6**	6.0	5.6	12.5**	10.0**	4.2	-5.3	54.0**	11.6	-7.1*	-20.8**	34.7**	19.6	
IR58025A x BR736R	0.2	-10.2**	-5.6**	-7.7**	17.9*	15.4	-3.3	-8.7**	68.2**	62.4**	-14.3	-25.1*	-4.0	-5.8	14.0	-4.7	
IR58025A x BR168R	3.5	1.1	-4.0**	-6.7**	-11.9	-14.7	5.1	4.6	13.0	0.8	2.0	-18.4	4.7	-9.7**	7.3	-0.6	
Mean	5.2	-5.9	-2.5	-9.6	7.7	2.1	0.7	-8.1	7.1	7.1	-19.9	3.2	4.7	-3.8	23.1	10.7	
Range	-17.1- 21.2	-31.8- 11.8	-10.7- 3.0	-15.5- -0.9	-22.8- 62.6	-30.0- 55.2	-14.1- 18.7	-25.0- 10.0	-55.9- 68.2	-60.2- 62.4	-50.2- 273.7	-55.7- 203.0	-7.1- 20.1	-20.8- 9.1	-58.0- 95.3	-59.4- 86.1	

Association between heterosis and combining ability

The parental lines were categorized into three general combiner groups based on the assumption that the parental lines with significant gca effect in desired direction were high (H), those with significant gca effect in undesired direction were into low (L) and those with other than the above two cases were categorized into average (M) general combiners. Based on these gca class of the parental lines the heterotic crosses over one or both parents for different traits were grouped into following combinations, HxH, HxM or MxH, H x L or L x H, M x M, L x M or M x L and L x L (Tables 5 & 6). The results in table 5 showed that out of 22 heterotic hybrids for grain yield, six belonged to H x H, five belonged to H x M, five belonged to H x L and six belonged to M x L type. For plant height, one cross was H x M type and two crosses were H x L type. Similarly, of 23 hybrids showing heterosis for days to 50 % flowering, two were in H x H, three were in H x M, 11 in M x L, two in M x L and five in L x L combinations. Heterotic crosses for panicles/plant and filled grains/panicle were distributed in all the combinations except M x M. Out of 12 heterotic crosses for 1000-grain weight; nine were in H x H and three belonged to H x L class. In aggregation of all the traits, out of total 105 heterotic crosses, 43 (40%) were from H x L or L x H, 23 (22%) from H x H, 18 (17%) from H x M, eleven (10%) from M x L and ten (9.55) from L x L parental combinations. On the other hand, in case of better parent heterosis (Table 6), heterotic crosses for different characters were distributed in different classes. Out of total 94 heterotic crosses for different characters, 37.2% were H x L, 23.4% were H x H, 13.8% were H x M and 14.9% were L x L type combination of gca. These observations revealed that the maximum number of hybrids (40% and 37.2% over mid parent and better parent, respectively) were evolved form H x L combination and majority of the crosses showing high heterosis in both relative heterosis (80% cross) and heterobeltilosis (74.5% cross) included at least one of the parents with high gca effects in desired direction. This indicated that diversity in parental gca is necessary for realizing heterosis. Langham's (1961) findings regarding the success of H x L was also in agreement with this study. Better hybrid performance of H x L combiner was also reported earlier in rice by Bashar (2002), Mian and Bahl (1989) in chickpea, Shing et al (1983) in pigeon pea. Correlation coefficient between specific combining ability and relative and better parent heterosis showed highly significant relationship between sca and heterosis for almost all the fruits. (Table 7). This result implied that the heterosis of a hybrid combination could be predicted reliably by specific combining ability. Such kind of close and consistent positive relationship between heterosis and combining ability was also reported by Wang and Tang (1988) for 8 growth characters in rice.

Table 5. Significant heterotic crosses (over mid parent) in desired direction

Table 5. Significant heterotic crosses (over mid parent) in desired direction in different gca combinations for different characters in rice

Character	Parental gca combination						Total
	HxH	HxM	HxL	MxM	MxL	LxL	
Plant height	0	1	2	0	0	0	3
Days to 50% flowering	2	3	11	0	2	5	23
Panicles/plant	2	2	5	0	1	1	11
Panicle length	0	1	2	0	1	3	7
Filled grains/panicle	3	3	12	0	1	1	20
Spikelet sterility	1	3	3	0	0	0	7
1000-grain weight	9	0	3	0	0	0	12
Grain yield	6	5	5	0	6	0	22
Total	23	18	43	0	14	10	105

Table 6. Significant heterotic crosses (over better parent) in desired direction in different gca combinations for different characters in rice

Character	Parental gca combination						Total
	HxH	HxM	HxL	MxM	MxL	LxL	
Plant height	3	5	6	0	1	3	18
Days to 50% flowering	6	5	13	1	6	7	38
Panicles/plant	1	1	3	0	0	1	6
Panicle length	0	0	2	0	0	0	2
Filled grains/panicle	1	0	1	0	0	0	2
Spikelet sterility	2	0	7	0	0	3	12
1000-grain weight	3	0	0	0	0	0	3
Grain yield	6	2	3	0	2	0	13
Total	22	13	35	1	9	14	94

Table 7. Coefficient of correlation between specific combining ability (SCA) effects and heterosis (over mid parent and better parent) for different characters in rice

Character	Correlation coefficient (r)	
	SCA vs Heterosis over mid parent	SCA vs Heterosis over better parent
Plant height	0.455**	0.333*
Days to 50% flowering	0.464**	0.373*
Panicles/plant	0.765**	0.751**
Panicle length	0.662**	0.498**
Filled grains/panicle	0.651**	0.684**
Spikelet sterility	0.607**	0.604**
1000-grain weight	0.612**	0.425**
Grain yield/plant	0.642**	0.653**

* $p < 0.05$, ** $p < 0.01$

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MEASURES FOR CONSERVATION AND UTILIZATION ECHNIQUE OF PHOSPHORUS IN SOIL-PLANT MICRO-ENVIRONMENT FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

Phosphorus is one of the most important and limiting plant nutrients and its management in a sustainable manner for future agriculture is crucial. Limited reserve of rock phosphate, low availability of soil P and its immobilization under different soil conditions are the uncontrollable causes in relation to P hampering crop production in the tropics. Environmentally friendly technologies are of global concerns that strongly discourage the use and manufacture of inorganic fertilizers. It is, therefore, an urgent need to find out different on-farm and off-farm resources that could be used as a source of P and to recognize and develop suitable land and crop management practices that could efficiently conserve and recycle P in agricultural soils. Phosphorus behavior and its availability in soils vary with the cropping systems, soil type and environmental conditions, and hence, P deficiency should be addressed using specific crops and cropping systems. Phosphorus could be conserved and recycled using green manure crops, slaughterhouse and domestic and industrial wastes, sludge and fishpond sediment in agriculture. Judicious use of mycorrhiza would better help P utilization and conservation schemes. These practices, in addition to making use of P in agriculture from different sources, reducing application of inorganic P fertilizer, in turn would help reduce the multitude of environmental pollution originated from wastes. Therefore, future research programs should be planned out and launched considering these timely issues

Key words: Phosphorus, conservation, recycling, green manure, wastes, mycorrhiza.

INTRODUCTION

Phosphorus (P) is one of the key essential macronutrients making up about 0.2% of a plant's dry weight (Schachtman *et al.*, 1998). In most tropical soils, P is one of the main limiting plant nutrients, and its deficiency is a major constraint in crop production (Tchienkoua and Zech, 2003). The deficiency of P primarily occurs as a result of shortage of inherent soil P, depletion of soil P by crop removal, sorption and fixation of P with Fe and Al oxides and hydroxides (Solomon and Lehmann, 2000). Total P content

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in soils is generally less than that of total N or K, which is about one-tenth to one-fourth of N and onetwentieth of K (Brady, 2001). Total P content in surface and subsurface soils may vary from a few mg kg⁻¹ to 1 g kg⁻¹ (Prasad and Power, 1997), where the available P seldom exceeds about 0.01% of the total P in soils (Brady, 2001).

The problem of P is threefold: (i) the total P content in soil is low, (ii) the inherent soil P is mostly unavailable for plant uptake, and (i ii) if soluble sources of P such as inorganic P fertilizers and manures are added to soils, they become fixed or changed to unavailable forms in a short period of time (Brady, 2001). In contrast to N, which constitutes 79% of the earth's atmosphere and can be replenished by biological fixation, P is present as mineral deposits that are nonrenewable natural resources (Prasad and Power, 1997). Deposits of phosphate minerals as a source of P fertilizer are limited (Shibata and Yano, 2003). Hence mining P minerals and spreading P fertilizers over the landscape is not sustainable in the long run, which should be addressed by conserving P for future needs.

Therefore, this review on the forms and behaviors of soil phosphorus has been accomplished to find out P conservation strategies and how the available on-farm and off-farm resources that are enriched with P could be used to recycle P in the soil-plant microenvironment for enhancing soil fertility and thus crop productivity.

2. Forms and Behaviors of Phosphorus in Soils

Soil P exists in inorganic and organic forms and both are important to plants as a source of this nutrient element (Schachtman *et al.*, 1998; Brady, 2001). Each form is a continuum of many P compounds, existing in equilibrium with each other and ranging from solution P to very stable or unavailable compounds. Inorganic P is usually associated with calcium (Ca), aluminum (Al), and iron (Fe) compounds of varying solubility and availability to plants. Depending on soil pH, P can rapidly be fixed thus forming complex compounds, which makes P is unavailable to plants. The maximum P availability in soils for plant uptake is obtained between the soil pH 6.0-7.0 (Brady, 2001). The recovery of P in fertilizer is usually 10-30% (Roberts, 1995). In acid soils Fe, Al and Mn and their hydrous oxides are usually present and reactions with H₂PO₄⁻ immediately occur thus forming insoluble hydroxyl phosphate. If soluble P is added to this kind of soils the concentration of P in soil solution increases, however, with a set of reactions its concentration quickly decreases (Ruaysoongnern and Keeratikasikorn, 1998). While in the alkaline soils with pH 8.0 or above P becomes fixed with Ca and forms the most insoluble tri-calcium phosphate at a later stage (Brady, 2001). Conversion of unavailable to available forms of soil P usually occurs too slowly, therefore, there will be shortage of P supply for plant requirements. However, these kinds of transformations of P in soils are controlled by the physical and chemical conditions of soils, which include soil pH, clay content, exchangeable Al, and soil organic matter content, etc (Ruaysoongnern and Keerati-kasikorn, 1998).

Organic P compounds range from readily available forms, undecomposed plant residues and microbes in the soil to stable compounds that have become part of soil organic matter. The amount of organic P present in soils varies from 20 to 80% of the total P (Prasad and Power, 1997; Schachtman *et al.*, 1998). Phosphorus cycling and availability in soils is controlled by a combination of biological (i.e. mineralization-immobilization) and chemical (i.e. adsorption-desorption and dissolution-precipitation) processes. Biological processes in the soil such as microbial activities, soil-root interrelationship, soil arthropods etc tend to control the mineralization and immobilization of organic P. Phosphorus immobilization by microorganisms, turnover of microbial P, and mineralization of microbial byproducts seem to be the major processes regulating P cycling and its availability from plant residues in soils (McLaughlin *et al.*, 1988a). Arbuscular mycorrhizal (AM) association plays an important role in the plant P nutrition (Lopez-Gutierrez *et al.*, 2004). This kind of mutualistic symbiosis between plant and fungus is localized in a root or root-like structure in which energy moves primarily from plant to fungus and inorganic resources including P absorbed move from fungus to plant (Allen, 1991) can contribute greatly to plant P nutrition even at P deficient conditions (Joner and Jacobsen, 1995). AM contribution for nutrient especially P acquisition may be direct or indirect. The direct effect is the consequence of the production of extracellular phosphatases and the access to distant P sources otherwise not available to plants (Joner and Johansen, 2000). This provides additional benefits of P supply to plants in acid soils (with low pH below 5.0 to 5.5), when the P fixation becomes common due to increasing solubility of Al. Fungi become dominant at pH below 5.5, which enables arbuscular mycorrhiza to grow and develop faster than that under pH above 5.5 and to support the plant to acquire soil P. The indirect effect is due to its extraradical hyphae that are capable of absorbing and translocating nutrients, can explore more soil volume and inducing physiological changes that favor the establishment of P solubilizing and mineralizing microorganisms in the micorrhizosphere (Joner and Jacobsen, 1995; Singh and Kapoor, 1998).

3. Recycling and Conservation of Phosphorus for Sustainable Agriculture

Nutrient cycling is becoming an essential component of sustainable agriculture. The major sources of nutrients to be recycled to soils are crop residues, animal manures, domestic and industrial wastes (Brady, 2001), and fish pond sediment (Rahman *et al.*, 2004). Nitrogen and P contents of different animal manures, wastes, fishpond sediments are given in the Table 1. Incorporation of legumes and native plant residues in crop rotations is used to enhance soil fertility in many tropical agro-ecosystems. Removal of P by plants/crops is a way by which soil loses P. Reducing removal and promoting recycling of crop residue can minimize loss of soil P.

Table 1. N and P contents of different animal manures, wastes, fishpond sediment

Different wastes	N content (g kg⁻¹)	P content (g kg⁻¹)	Reference
Poultry manure	37.7	18.9	Tacon, 1987
Cattle manure	19.1	5.6	
Pig manure	28.0	13.6	
Slurry from cattle	40.4	7.6	EPA, 1999
Slurry from pigs	63.4	23.2	
Bone meal (raw)	30.0	100.0	Rosen and Bierman, 2005
Fish meal	100.0	27.3	
Sewage sludge compost	25.8	7.3	Chongrak, 1996
Domestic waste water (mg/L)	85	15	Metcalf and Eddy, 1991
Tilapia pond sediment	2.8	0.2	Rahman et al., 2004

In tropical cropping systems, a better understanding of P transportations and P cycling during decomposition of incorporated organic residues is important (Salas *et al.*, 2003). Much attention has been paid to determine plant, biological and environmental factors influencing the release and mineralization of N from plant residues (Vanlauwe *et al.*, 1996). However, little information exists on the incorporation of plant residues on P cycling, especially on biological transformations associated with the release of P from residues and subsequent accumulation and turnover of organic P during decomposition (McLaughlin *et al.*, 1988b; Umrit and Friesen, 1994).

3.1 Use of Cropping Systems Including Green Manuring Crops

Phosphorus management in acid soils is a challenge (Brady, 2001; Ranamukhaarachchi *et al.*, 2005). Acid soils exhibit considerable limitations to agricultural use (Cho *et al.*, 2002). The management of these soils includes liming, and application of phosphorus and nitrogen. Since soluble PO₄⁻³ are converted to insoluble phosphates with Mn and Fe, application of costly and soluble P fertilizers offers very little benefits in acid soils. However, planned and judicious use of cropping systems would overcome this problem to some extent. There are options for the diversification of rice-based cropping systems to include other cash crops, such as fruits and vegetables. In this regard, P availability was found to be higher under potato-rice-rice cropping system than rice-rice-rice cropping system in Bangladesh (Ranamukhaarachchi *et al.*, 2005).

Use of suitable cropping systems help increase crop productivity and soil organic matter content and hence improve soil fertility (Ranamukhaarachchi *et al.*, 2005). Cultivation of low pH tolerant crops during dry seasons in the cropping systems would offer possibilities to make use of low pH conditions on acid sulfate soils. Crops that could tolerate

Mn and Al toxicities and overcome P deficiencies would enable also to successfully utilize the dry periods. Integration of wide range of activities would be suitable in managing acid soils, such as introduction of early maturing and photo-insensitive varieties in the cropping systems so that planting time would have minimal effect on the crop duration (Rai, 1996). A crop like mungbean can be harvested in about three months from planting. It can be followed by rice for the wet season. After harvesting of rice a drought tolerant crop like sorghum could be introduced.

One of the most promising agronomic measures for P management is the integration of P mobilizing plant species into cropping systems (Vanlauwe *et al.*, 2000; Horst *et al.*, 2001). These plant species show the ability to uptake P even from less labile forms and store in the aboveground biomass even in excess of their needs (Kahm *et al.*, 1999). *Tithonia diversifolia*, which is also known as Mexican sunflower, is such kind of plant that can uptake large amounts of soil P and store in the above ground biomass. Total P content in *Tithonia* was found 3,650 mg kg⁻¹, while the soluble P was 2,560 mg kg⁻¹ of plant dry matter (Pypers *et al.*, 2005), whereas the average total P content in plant is reported 2,000 mg kg⁻¹ (Schachtman *et al.*, 1998).

Culture of such species in short rotations or fallow periods would help absorb soil P in deep layers and by returning this plant residue surface soil profiles could be enriched with P. Upon decomposition, organic P in the incorporated green manure tissues could provide a relatively labile or available P to succeeding crops, thus providing a larger pool of mineralizable soil organic P to supplement soluble inorganic P pools (Tiessen *et al.*, 1994). Along with the mineralized P, organic acids are also released during decomposition of organic matter, which may help dissolve soil mineral P (Sharpley and Smith, 1989). Carbon dioxide released (CO₂) during decomposition of green manure forms H₂CO₃ in the soil solution, which ultimately dissolves P minerals in soils, thus increasing P availability for plants (Tisdale *et al.*, 1985). Cavigelli and Thien (2003) reported from a pot study that incorporation of green manure crops into soil may increase P bioavailability for succeeding crops. Pypers *et al.* (2005) reported from a field core incubation experiment that both P deficiency and Al toxicity can be amended through green manuring. This amendment of P deficiency and Al toxicity is resulted due to organic acids and H₂CO₃ released during decomposition. Detailed field level experiments addressing these important issues are still lacking.

3.2 Use of Fishpond Sediment

Fishpond sediment is a rich source of P which can be used in agriculture as a promising option to recycle P in crop production. Inland fish culture is common in Asian countries such as Bangladesh, India, Viet Nam, Thailand, China etc. Tropical fishponds require balanced supply of nutrients for economic fish production (Li and Yakupitiyage, 2003). Regular feeding using organic manures and supplementary feeds and addition of

inorganic fertilizers are common in fish culture, which result in sedimentation and nutrient build up at the pond bottom. Accumulation of such sediment reduces the effective pond depth reducing the space available for fish and also makes the water environment unfavorable for fish growth (Stickney, 1994; Boyd *et al.*, 2001). Sediment removal is thus adopted as a remedy in pond fish culture (NACA, 1985).

Optimal rates of addition of N and P for tilapia fishponds in Thailand are 4 and 1 kg ha⁻¹ d⁻¹, respectively (Knud-Hansen *et al.*, 1993), which are equivalent to 1,460 kg N and 362 kg P ha⁻¹ yr⁻¹. In the Republic of Korea a crop land of one hectare receives fertilizers approximately 452 kg per year, which is the highest rate of fertilization for a crop land in Asia (RAPA, 1993). Accordingly, the amount of fertilizers applied for a fishpond is approximately four times higher than fertilizers applied for a cropland, of which undissolved portions of fertilizers apparently settle down in and mix with pond sediment. This makes pond sediments rich in nutrients (Boyd, 1995; Rahman *et al.*, 2004). Total and available P contents in tilapia pond sediments were as high as 195 and 89 mg kg⁻¹, respectively (Rahman *et al.*, 2004), which qualifies sediment as a P resource rather than a waste.

The nutrients in pond sediment could be utilized in integrated farming systems, which are technically feasible and economically viable (Edwards *et al.*, 1988). Integration between ponds and crops could be established through the use of crops and crop residues to fish as feeds, and pond sediments as fertilizers for crops (Ruddle *et al.*, 1983), and the use of pond water for irrigation. But the integrated agriculture and aquaculture farming systems have been adopted only a small percentage of farmers (1%) in a few countries (Edwards *et al.*, 1988). Lack of appropriate technologies, farmers' unawareness, inadequate research and dissemination of information and social and institutional problems might have barred the use of pond sediment and accruing its benefits by integrating aquaculture with agriculture. Therefore, further on-farm research is needed to develop new technologies and motivate the farmers for using such technologies.

3.3 Use of Mycorrhiza

Organic P mineralization is essential for plant P nutrition (Lopez-Gutierrez *et al.*, 2004). Mineralization of soil organic P vary with the season. In summer, faster decomposition of organic matter and increased microbial respiration due to high temperatures increase CO₂ emissions, which increase soil pH to near neutral. Under this condition, insoluble P becomes soluble and available for plant uptake (Brady, 2001).

Under low pH conditions, making use of mycorrhiza helps extract P from deep soils, since P will be in a fixed form with either Al or Fe or both. In tropical countries, leaching of basic cations during heavy rains and faster nitrification of ammonium released in the organic matter mineralization process subtend soil to be acidic so often, which promotes soil P to be fixed with Al, Fe and Mn and become unavailable to plants. As the growth of mycorrhiza is

avored at such low pH the benefit of using mycorrhiza becomes obvious. Development of mycorrhizal colonization and its effectiveness on plant growth is enhanced in nutrient deficient soils, especially P deficient soils (Azcon *et al.*, 2003). Most agricultural crops depend on or benefit substantially from mycorrhiza and the level of dependency on mycorrhiza varies greatly among varieties of crops (Janos, 1980; Brundrett 1991). Land management practices affect the formation of mycorrhiza. The number of mycorrhizal fungi in soil will decline in fallow fields or in those lands planted to crops that either do not help form mycorrhiza or inhibit its growth. Frequent tillage may reduce mycorrhizal associations (Read and Birch, 1988; Vilarino and Arines, 1991). Broad spectrum fungicides are also known to be toxic to mycorrhizal fungi. Use of very high levels of nitrogen or phosphorus fertilizer has been observed to reduce mycorrhizal inoculation of roots (Newton and Pigott, 1991; Azcon *et al.*, 2003). However, the effect of mycorrhizal colonization on acquisition of immobile nutrients by plants is still obscure (Clark and Zeto, 2000) and inconsistent experimental findings suggest further study.

3.4 Use of Meat and Bone Meal

Meat and bone meal (MBM), earlier used as animal feed, but recently banned for that purpose, contains appreciable amounts of both P and N. Recent studies on the application of MBM as a fertilizer have shown its excellent quality in terms of high N and P (Jeng *et al.*, 2004, 2005).

The efficiency of added P depends, to a considerable extent, on the quantity of residual P in soils. When MBM is added as phosphate fertilizer, the labile pool of available P is increased and the capacity of soils to adsorb additional phosphate can be expected to decrease. The MBM-P is partly present as $\text{Ca}_5(\text{PO}_4)_3\text{OH}$ in the bone fraction and in organic form in the meat fraction. Kahiluoto and Vestberg (1998) found a significantly larger P uptake from bone meal than from Kola apatite in a pot experiment. Kola apatite did not influence soil acetate-extractable P contents, whereas bone meal increased the acetate-extractable P contents significantly. However, Baker *et al.* (1989) performed different laboratory tests of P-availability of bone meal (MBM), and found considerable P-effects in green house experiments. This indicates that bone meal is a better P source than the commonly used phosphate rock. As the dissolution of $\text{Ca}_5(\text{PO}_4)_3\text{OH}$ in the bones requires H^+ ions, pH is an important factor influencing P release from bone meal. Earlier investigations indicate that bone meal may be a more effective P fertilizer in acid soils than in soils with $\text{pH} > 6$ (Bekele and Hofner, 1993; Surendra *et al.*, 1993). Novelo *et al.* (1998) found that bone meal significantly increased P-Olsen level and microbial biomass in coffee plantation soils. Compared with soluble mineral P fertilizers, MBM-P is expected to have a greater residual effect. Studies using a mixture of rock phosphate and poultry manure have indicated that one time application was able to sustain four successive cropping of maize and cowpea (Akande *et al.*, 2005). MBM containing both organic and inorganic P-fractions may be expected to possess similar properties. However, the hydroxyapatite component in

the bone fraction requires a combination of moist and relatively acid conditions to accelerate the dissolution process and release plant available P. The organic P fraction will be released during organic matter decomposition. Therefore, under tropical acid soil conditions MBM should be expected to be a good source of P. For using these research findings at the field levels, further on-farm research is needed using farmers participatory approach.

4. Conclusions and Recommendations for Future Research

Since stock of phosphate minerals and plant available P in soils are limiting, it is an urgent need to recognize and develop different agronomic management strategies that could conserve and recycle P to enhance soil fertility and satisfy plant requirements, thus for increasing crop productivity. In order to recycle and manage P the following research activities could be recommended for sustainable agriculture and friendly environment:

1. Identify cropping systems and their productivity, and measures to overcome P deficiencies or P limitations by specific cropping systems.
2. Identify green manure species/plant species that would extract and conserve soil P and that could be used as green manure and their suitable environmental conditions, and study the potential for using them to enhance P absorption.
3. Study soil P variations and environmental conditions influencing such variations, and determine the available and total P in soil under such conditions.
4. Search for other P sources such as fishpond sediment, organic P, industrial waste, sludge, meat and bone meal etc and develop measures to recycle P for agricultural uses.
5. Study P behaviors in commonly used cropping systems and ways by which crops overcome P deficiencies and maintain crop yields, and make use of such mechanisms for enhancement of P enrichment in agricultural soils,
6. Study P conservation using different cropping systems with selected crops that could conserve P for use in the succeeding cropping systems,
7. Make attempt to use of mycorrhiza for better understanding of mineralization of organic P, and its uptake by different crops in the cropping systems under different climatic conditions and soil fertility levels, and
8. Finally, development of integrated measures for overall conservation and utilization of P and sustainable food production.

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PRODUCTION AND MARKETING SYSTEM OF GUAVA IN SOME IMPORTANT GROWING AREAS OF BANGLADESH

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ABSTRACT

The present study was undertaken in three thanas namely, Swarupkathi, Patia and Gazipur Sadar under the districts of Pirojpur, Chittagong and Gazipur, respectively. Three guava varieties like swarupkathi, kanchannagar and Kazi peyara were considered for analyzing the marketing system of this fruit. A total of 60 farmers taking 20 farmers from each area and 30 intermediaries for this fruit were selected randomly from primary and secondary markets. Four important channels: (i) Farmer- Faria- Bepari- Arathdar- Retailer- Consumer, (ii) Farmer- Bepari- Arathdar- Retailer- Consumer, (iii) Farmer- Bepari- Retailer- Consumer, (iv) Farmer- Retailer- Consumer were found in guava marketing. The average marketing cost of guava was Tk 513 per ton. Transport was the major cost item in the study areas. The average price of guava at farm level was Tk 6250 per ton. The marketing margin for Faria, Bepari and Retailer were Tk 1300, 1500 and 1700 respectively. In fruit marketing, Bepari and Retailer got the highest margin and profit due to higher sale price. The post-harvest losses of guava were estimated to be 35 kg per ton. This loss was mainly due to carrying, loading and unloading, packaging, storing and delay in selling. The important marketing problems for farmers and intermediaries were low price, perishability, high transport cost, inadequate storage facility and lack of marketing information

INTRODUCTION

Bangladesh is an agro-based country. Agriculture is the main occupation of the people employing 69% of the labour force. This sector directly contributes around 32% of the gross domestic production. Total cultivated land of Bangladesh is 14.85 million ha in which different fruits occupy about 0.67% (BBS, 1998).

Guava (*Psidium guajava*) is one of the most common and popular fruits in Bangladesh. It is very tasty, nutritious and equally liked by urban as well as rural people. It is a cheap source of vitamins and minerals. It contains about 250 mg of vitamin C per 100 gm of fruit (Pandis, 1970). It also contains iron, calcium, and phosphorus (Miller *et al.*, 1945). Mukundopuri, IPSA and BARI varieties are also grown in some areas in the country. Local and indigenous varieties are grown all over the country and sole mostly

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by the farmers in retail markets. June to October is the main fruiting season and small quantity of guava is marketed in mid January to mid February. Bangladesh produces 0.04 million metric tons of guava from 0.01 million ha of land fruiting (BBS, 1998).

Every year huge amount of fruits i.e. mango, jackfruit, banana, pineapple, guava, papaya and coconut etc are grown in Bangladesh. The per capita fruit consumption is estimated at 3.3 kg per annum being the lowest in comparison with other neighboring countries. The present area under fruit cultivation is estimated at 0.18 million hectare producing 0.33 million tons per annum where mango occupies about 28 % of the total area followed by banana (22%), jackfruit (17%), pineapple (5%), guava (6%), papaya (6%) and the rest (15%) by other fruits (BBS, 1998).

The demand for different fruits are increasing day by day but the supply has remained stagnant. So, there is wide variation of price between the producers' and the consumers' level at harvesting period. It occurs due to inefficient marketing system. Very little information is available about constraints to marketing system of fruits. However, lack of marketing information of different fruits particularly guava prevents researchers from identifying and prioritizing research plan for its improvement. The specific objectives of the study were to:

- i. study the institutions and channels of guava marketing;
- ii. know the trend and seasonal variations of prices;
- iii. quantify the post-harvest losses of guava; and
- iv. explore problems in guava marketing.

MATERIALS AND METHODS

Three thanas namely, Swarupkathi, Patia and Gazipur Sadar under the districts of Pirojpur, Chittagong and Gazipur respectively were purposively selected and three guava varieties like swarupkathi, kanchannagar and Kazi peyara were considered for the study.

A total of 60 farmers taking 20 farmers from each area for each variety and 30 intermediaries for this fruit were selected randomly from the primary and secondary markets. Calculation of profits and margins for *Arathdar* were ignored in this report because they were receiving commission at a fixed rate (5-10%) from *bepari* and retailer. Two sets of pre-tested interview schedules, for survey during the period from January to December 2001 were used one for the farmer and the other for intermediaries for the collection of data. Tabular method of analysis was done throughout the study.

RESULTS AND DISCUSSION

3.1 Fruit Marketing at Farmers' Level

This chapter presents brief scenarios of guava marketing at farmers' level. At first area and

productivity of this fruit is discussed, followed by disposal patterns, fruit prices, and marketing problems.

3.1.1 Area and Productivity of Guava

The sample household used an average area of 0.33 ha for guava production (Table 1). The Pirojpur farmer owned the highest guava garden (0.46 ha/farm), compared to Chittagong (0.38 t/ha) and Gazipur (0.15 ha/farm). The average yield of guava was recorded to be 12 tons per hectare. This was highest in Gazipur area (14 t/ha) as compared to other two study areas, because of cultivating HYV guava (Kazi peyara).

Table 1. Area and productivity of Guava in the study areas

Study area	Area (ha/farm)	Yield (ton/ha)
Pirojpur	0.46	12
Chittagong	0.38	11
Gazipur	0.15	14
Average	0.33	12

3.1.2 Disposal Pattern and Marketed Surplus of Fruits

The disposal pattern and marketed surplus of guava is presented in table 2. It is evident that 2% of fruits was used for family consumption, 2% for gift to others, and 0.8% become wastage. The share of marketed surplus of this fruit was calculated at 95.2%. The farmers in the study areas usually sell their fruits just after harvesting mainly due to cash need and lack of storage facility.

Table 2. Disposal Pattern and Marketed Surplus of Guava

(Figures in %)

Fruit	Consumption	Gift	Wastage	Marketed Surplus				Total	
				Faria	Bepari	Retailer	Consumer		
Guava	2	2	0.8	15.2	45	30	5	95.2	100

3.1.3 Cost of Guava Marketing

The farmers in the study areas incurred various costs for selling their produces. These costs they mainly incurred for transportation, tax/toll, personal expenses, *Arathdars' commission*, and due to product loss. All these costs are briefly discussed below according to fruit types.

Marketing Cost for Guava: Table 3 shows that the cost of marketing for guava included transportation cost, market taxes/ tolls and others etc. It was observed in the study areas that the cost of marketing of guava was Tk.513 per ton. The highest marketing cost was found in Chittagong (Tk.760/ton) due to higher transport cost and market taxes/tolls and the lowest in

Pirojpur (Tk.305/ton). The guava from Pirojpur is mainly transported by river way. It was also observed that transport cost was the major cost in all the study areas.

Table 3. Cost of marketing for guava in different study areas

Study area	Marketing cost (Tk. /ton)			Total
	Transport	Taxes/tolls	Others	
Pirojpur	200 (66)	40 (13)	65 (21)	305 (100)
Chittagong	500 (66)	100 (13)	160 (21)	760 (100)
Gazipur	300 (63)	-	173 (37)	473 (100)
All areas	333 (65)	-47 (9)	133 (26)	513 (100)

Figures in parenthesis indicate percent of total marketing cost

3.1.4 Prices of Guava at Farmers' Level

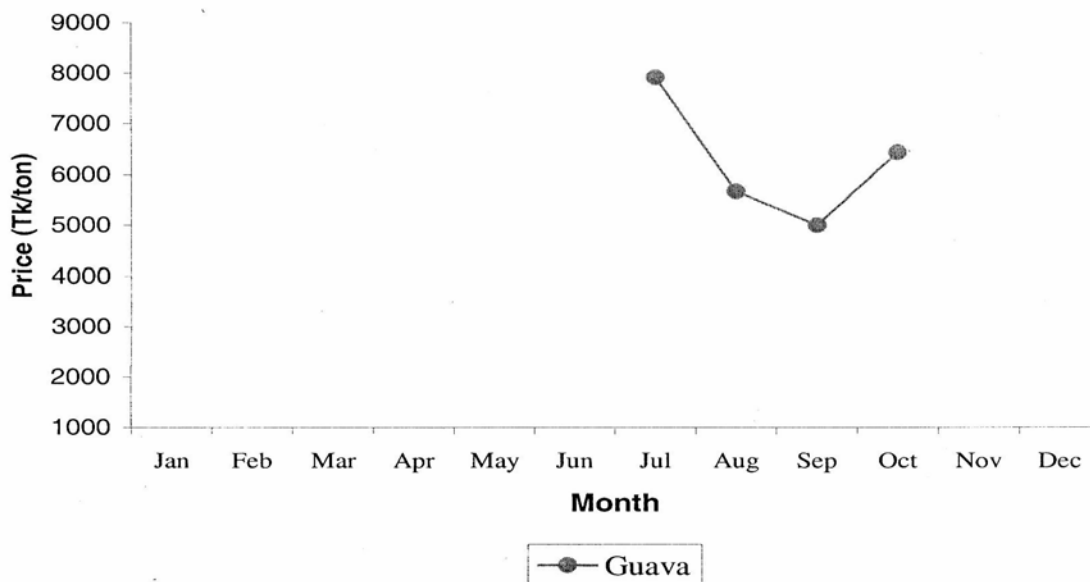
The farmers in the study areas usually sell their produces just after harvesting mainly due to immediate cash need and lack of storage facilities. Therefore, they were found to be deprived of fair prices. The prices received by the farmers by selling fruits are shown in different tables and are briefly discussed below.

Price of Guava: The price of guava varied from location to location and month after month. In all areas, it was found that the average price of guava was Tk. 6250 per ton. The price was highest in Chittagong (Tk.7375/ton) and lowest in Pirojpur (Tk.5375/ ton) (Table 4). It was highest mainly due to good variety with taste and more demand. It was also observed that in the beginning of the season the price was high but in peak harvesting period the price was gradually decreased and at the end of the season the price was again increased (Fig. 1)

Table 4. Price of guava at farm level in different study areas

Study areas	Month-wise price (Tk./ton)				Mean
	July	August	September	October	
Pirojpur	7200	4500	4000	5800	5375
Chittagong	9500	6500	6000	7500	7375
Gazipur	7000	6000	5000	6000	6000
All areas	7900	5667	5000	6433	6250

Fig. 1. Seasonal Price Variation of Guava



1.5 Marketing Problems at Farmers' Level

The farmers in the study areas encountered various problems during marketing of guava. All these problems were ranked according to the descending order of frequencies of responses. It was found that low price was ranked first in guava marketing, followed by perishability, high transport cost, inadequate storage facility and lack of marketing information. Most farmers opined that they could not get fair price for their produce due to the influence of local broker (Dalal), immediate cash need and lack of storage facilities.

3.2. Marketing of Fruits at Intermediaries' Level

This section provides brief information on marketing channels, characteristics of intermediaries, marketing cost, marketing margin and profits, post-harvest losses, price spread and marketing problems at different intermediaries' level.

3.2.1 Business Characteristics of Intermediaries

The key players involved in the process of fruit marketing are *faria*, *bepari*, *arathdar* and retailer. Their business characteristics are discussed below:

Faria: *Farias* are the petty traders who purchase comparatively smaller quantity of agricultural products from the growers in the village or in the local primary market and sell them to *Bepari* and retailer in the local market. Their volume of businesses is small because they possess little capital.

Bepari: *Beparis* are professional traders who purchase agricultural products from the farmers or *faria* in the local market or in the village and sell them to the other *bepari* and retailer through *arathdar*. Their volume of business is larger than *faria*. They operate both in primary and secondary market.

Arathdar: Arathdar Serve as a commission agent who have fixed establishment in the market and operate between *bepari* and retailer. They help *bepari* and retailer to sell their products and charge a fixed commission by providing storage facilities.

Retailer: They are the last link in the marketing channel. They buy product from *beparis* through *arathdar* and sell them to the consumer. Most of the retailers have no permanent shop usually use open market place for their sale. Their volume of business is small. In spite of being self-financed, they sometimes borrow money from non- institutional sources (friends and relatives) at time of need. They sometimes take credit from *bepari*.

3.2.2 Guava Marketing at Intermediaries' Level

Marketing Channel: Generally, guava moves from producer to ultimate consumers through a number of market intermediaries. The following four channels were found in Guava marketing in Bangladesh (Fig. 2).

1. Farmer- Faria- Bepari- Arathdar- Retailer- Consumer
2. Farmer- Bepari- Arathdar- Retailer- Consumer
3. Farmer- Bepari- Retailer- Consumer
4. Farmer- Retailer- Consumer

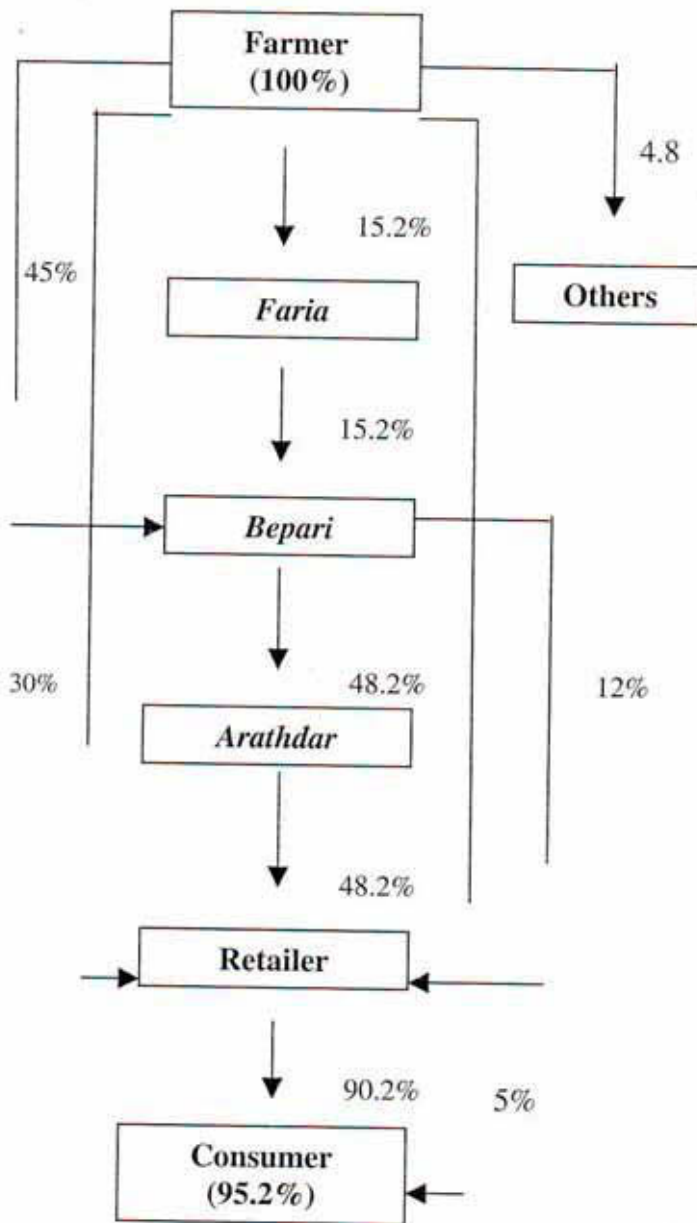


Fig. 2. Marketing Channel of Guava

Marketing Cost: Marketing cost of guava for all intermediaries included the cost of transportation, loading and unloading, commission, taxes, damage of product, and personal expenses. The average cost of marketing for *faria*, *bepari* and retailer were Tk.530, 1070 and Tk.615 per ton, respectively. The highest marketing cost was for *Bepari* (Tk.1070/ton) due to higher transport cost (Tk 300/ton), followed by loading and unloading cost (Tk 103/ton) and *arathdars* commission (Table 4).

Table 4. Marketing cost of guava at different intermediaries' level

Intermediaries	Marketing cost (Tk/ton)							Total cost
	Transport	Loading & unloading	<i>Arathdars'</i> commission	Persona I cost	Taxes/ tolls	Damage	Others	
<i>Faria</i>	360 (49)	-	-	160 (30)	33 (6)	50 (10)	27 (5)	530 (100)
<i>Bepari</i>	300 (28)	103 (10)	240 (22)	220 (21)	87 (8)	70 (6)	50 (5)	1070(100)
Retailer	150 (24)	-	-	290 (47)	50 (8)	85 (14)	40 (7)	615 (100)

Figures in parenthesis indicate the percentages of total marketing cost

Marketing Margin and Profit: Marketing margin of guava for *faria*, *bepari* and retailer were Tk 1300, Tk 1500 and Tk 1700 per ton, respectively (Table 5). Retailer (1700/ton) obtained the highest margin. The profit for *faria*, *bepari* and retailer were Tk 770, 430 and 1085, respectively. The retailer got the highest profit in guava marketing due to higher price and lower marketing cost.

Table 5. Marketing margin and profit of guava at different intermediaries' level

Intermediaries	Purchase price (Tk/ton)	Sale price (Tk/ton)	Marketing margin (Tk/ton)	Marketing cost (Tk/ton)	Profit (Tk/ton)
<i>Faria</i>	6250	8106	1300	530	770
<i>Bepari</i>	8106	10635	1500	1070	430
Retailer	10635	12935	1700	615	1085

Post-harvest Losses: On an average, the post-harvest loss of guava at intermediaries' level was estimated at 35 kg per ton. This loss mostly occurred due to transportation, followed by bad handling during selling and storage. *Bepari* generally purchase guava from assembling markets located at distant areas and transported them to the urban markets. Therefore, the post-harvest loss of guava was found highest for *bbepari* and retailer (13 kg/ton), followed by *faria* (Table 6).

Table 6. Post-harvest losses of guava at different intermediaries' level

Intermediaries	Post-harvest losses (kg/ton)					Total
	Carrying	Loading & unloading	Packaging	Storage	Selling	
<i>Faria</i>	5 (56)	-	-	2 (22)	2 (22)	9 (100)
<i>Bepari</i>	7 (54)	2 (15)	1 (8)	2 (15)	1 (8)	13 (100)
Retailer	3 (31)	1 (8)	-	3 (23)	5 (38)	13 (100)
Total	16 (46)	3 (9)	1 (3)	7 (20)	8 (22)	35 (100)

Figures in parenthesis indicate the percentages of losses

Price Spread and Farmers' Share to Consumers Prices: Two channels: *Farmer-Faria-Bepari- Arathdar-Retailer-Consumer* and *Farmer-Retailer-Consumer* were taken into consideration for measuring the price spread and farmers' share to consumer price in guava marketing. In the first, the price spread of guava was Tk.6685 per ton and the farmers' share and the farmers' net share were 48 and 28% of retail price, respectively. In the second channel, the price spread of guava was Tk.5470 per ton and the farmers' share and the farmers' net share were 53 and 30% of retail price, respectively. The findings indicated that longer the marketing channel lesser the farmers' share. Thus the consumer in the study areas get more benefit in channel II by getting fruits with lower price compared to channel-I. Therefore, the channel-II was more efficient than channel-I in terms of farmers' share to the retail price and consumers' welfare (Table 7).

Table 7. Price spread and farmers share to consumers price in guava marketing

Marketing Channels	Retail price (Tk/ton)	Farmers price (Tk/ton)	Farmers net price (Tk/ton)	Price spread (Tk/ton)	Farmers share % of retail price)	Farmers net share (%) of retail price)
I	12935	6250	3554	6685	48	28
II	11720	6250	3554	5470	53	30

Marketing Problems: Problems faced by different intermediaries in guava marketing were ranked and presented in table 8. The types of problems varied among the intermediaries. Price instability, inadequate capital, weight losses and damage, high transport cost, inadequate market facilities and storage facilities were the major problems identified in guava marketing. Storage life of different fruits such as guava, mango, papaya, banana and pineapple were 2-5, 4, 2-3, 1-5 and 1-2 weeks respectively which were not suitable for establishment of costly storages. Quick transportation may help reduce loss of fresh fruit and processing of guava may help the farmers to increase their return.

Table 8. Marketing problems of guava at intermediaries' level

Nature of problems	Rank value			
	<i>Faria</i>	<i>Bepari</i>	Retailer	All categories
Price instability	2	1	1	1
Inadequate capital	1	4	2	2
Weight losses and damage	3	3	3	3
High transport cost	4	2	4	4
Lack of processing industry	5	5	5	5
Inadequate storage facilities	6	6	6	6

CONCLUSIONS AND RECOMMENDATIONS

From the aforesaid discussion fruit marketing was found to be a profitable venture for different intermediaries, but a lot of imperfections were found in the fruit marketing in the country. The fruit growers were bound to sell major part of their produce at harvest period due to immediate cash need and high perishability. Nevertheless, the high price gap between the producer and consumer discourage them to grow more fruits. Therefore, the efficiency of existing marketing systems of fruits should be improved and this can be possible through the following measures:

- Co-operative marketing system should be developed to ensure market and better price of fruits for the farmers and intermediaries.
- Farmer's participation for direct selling to consumers should be encouraged
- Institutional credit should be made available to the farmers and traders with easy terms and conditions.
- Establishment of processing industry at major fruit growing areas to reduce the losses of fruits at peak harvesting period and to ensure better price for the producers.
- Packaging system of guava needs to be improved.
- Farmers are facing huge losses due to different diseases of guava.
- Processing industry for guava at Pirojpur, Chittagong and Rangamati should be established.

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Fig. 2. Marketing Channel of Guava

RECENT ADVANCES IN THE BIOLOGY AND MANAGEMENT OF INDIAN SHAD (*Tenualosa ilisha* Ham.)

M. J. RAHMAN¹

ABSTRACT

The Indian shad (*Tenualosa ilisha* Ham. *Clupeidae*) is an important migratory species in the Indo-Pak subcontinent and the Persian Gulf region, especially in Bangladesh and India. Bangladesh contributes about 87% of the world hilsa catch (2,23,177 t), followed by India (7.2%), Pakistan (3.4 %), Myanmar (1.3 %), Iran (0.3 %), Iraq (0.26 %) and Kuwait (0.24%). Recent developments in the biology and management of the species, with especial emphasis on Bangladesh are reviewed. The life cycle of the hilsa shad resembles American shad (*Alosa sapidissima* Wil. *Clupeidae*). Like American shad, the hilsa shad is generally termed anadromous, but it is diadromous, as it migrates frequently between fresh water and the sea. Hilsa becomes sexually mature after 1-2 years of life. The size at first maturity is around 22-25 cm for males and 28-30 cm for females. It is a highly fecund fish and does not show any parental care. It is predominantly a planktonic filter feeder. There is still controversy regarding stocks/races of hilsa in different water bodies. The hilsa fishery is mainly artisanal and is exploited from rivers, estuaries and the sea.

Different management strategies such as protection of nursery and spawning grounds, ban on obstruction on migratory routes, sustainable exploitation, rehabilitation and restoration of habitats, improvement of the socio-economic conditions of the hilsa fishers, etc. are recommended for a sound management policy for the conservation of the hilsa fishery in the region. However, community-based management would be required to implement any sustainable management initiative.

Key words: Hilsa, *Tenualosa ilisha*, fish, fishery, biology, management.

INTRODUCTION

Shads (*Clupeidae*: subfamily *Alosinae*) are a cosmopolitan group of fishes that exploit a wide range of habitats throughout the world. The hilsa shad, *Tenualosa ilisha* Ham. (commonly known as hilsa) is an important migratory alosine species in the Indo-Pak subcontinent and the Persian Gulf region, especially in Bangladesh and India. Bangladesh contributes about 87% of the world hilsa catch (2,23,177 t), followed by India (7.2%), Pakistan (3.4%), Myanmar (1.3%), Iran (0.3%), Iraq (0.26%) and Kuwait (0.24%) (Rahman, 2001). Some unrecorded catch has also been reported from Sumatra in Indonesia (Dr.D. Milton, personal communication).

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The species is an extremely popular food fish for the people of Bangladesh where it contributes about 13% of the country's total fish production of 2.1 million tonnes (Rahman, 2001; Haldar *et al.*, 2004; DOF, 2005). It is exploited from rivers, estuaries and the sea. It is popular because of its high palatability, special flavour, moderate size, attractive body shape and lucrative shiny appearance. As a result, the market demand for the species is increasing and it is becoming an export item to other countries. It occupies second position amongst the exported fish and fisheries products in Bangladesh and earns foreign currency of approximately US\$12 million (488 million Taka) through exporting some 6,000 t of frozen hilsa. The species has great socio-economic importance, as it is the single most important fishery, employing about 2% of the total population, i.e. about 2.5 million poor people of the country. It has also socio-religious significance throughout southern India and Bangladesh (Fischer & Bianchi, 1984). In Bangladesh it is the national fish. The esteem in which the hilsa is held is reflected in Sanskrit and Bengali literature, where the fish is described as '*matsyaraja*' (king of fishes) and it is said that '*illisah jitapiyusah*' (hilsa surpasses nectar) (Whitehead, 1985).

Before 1970 the hilsa fishery in most countries was mainly artisanal in nature, using traditional methods, and was mainly confined to river and estuary regions. However, due to mechanisation and development of crafts, and introduction of larger and more efficient fishing gears, the fishery has shifted gradually towards the estuary and marine environments (Hall & Kashem, 1994). Nowadays, fishing vessels travel 50-100 nautical miles into the open water of the Bay of Bengal to catch hilsa (Jafri & Melvin, 1988). A gradual decline in the abundance of the species in rivers may have also contributed to the shift in location of the main fishing effort (Mazid, 1998; Hossain, 1998).

During the last 20 years, the fishery has gradually declined in the upper reaches of rivers due to increasing fishing pressure on both juveniles and adults, loss of spawning grounds and obstruction to migratory routes by anthropogenic activities such as the construction of barrages, dams, fences, and the deterioration of habitat by industrial and agricultural pollution (Haldar & Rahman, 1998). These factors, coupled with the increasing demand for the fish for food by the rapidly growing population of the country have synergistically adversely affected the abundance of the species in the upper reaches of rivers. However, catch from marine environment seems to be increasing mostly due to greater exploitation from the sea using more efficient crafts and gears (Rahman, 2001).

Due to the migratory life style, wide distribution, great popularity, high socio-economic and socioreligious importance in the region, many fishery biologists, fishery managers and socio-economists have paid considerable attention to the hilsa shad. The importance was highlighted by Hora & Nair (1940) in 1930s and then in 1951, the Indo-Pacific Fisheries Council of the United Nation formed a hilsa subcommittee. The committee arranged a symposium in 1952, which helped to gather appropriate information about the fishery (Raja, 1985). However, before 1985, no effective or organised research on this migratory species was undertaken. In 1985, a one-year inter-country research programme was undertaken under the Bay of Bengal Programme (BOBP). Initially, the countries involved in the BOBP programme were Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka and Thailand, although India did not participate in the later stages (BOBP, 1987). Studies carried out in the past in the Bay of Bengal region were almost exclusively on the hilsa of inland waters, including estuaries; practically no attention was paid to the marine phase of the life history of the fish except for some work in Myanmar (BOBP, 1987). Nevertheless, the earliest investigations concentrated on the biological aspects, and the effects of barrages, dams, weirs and fences on the migratory movements of the species. Later, some workers concentrated on artificial propagation to supplement the stock, but this proved impractical (Rahman, 1997). Recent activities mainly concentrated on management-oriented research and socio-economic aspects of the species, as it is an important renewable natural resource of the region (Rahman & Moula, 1992).

Several review articles and bibliographical works on hilsa have already been published. Jones (1952) presented the first comprehensive listing of scientific papers, government reports and newspaper articles on hilsa from

1822-1951. Pillay (1955) provided an excellent summary of the literature on the biology and fisheries of hilsa, which was followed by a synopsis of biological data of the species (Pillay & Rosa, 1963). Sarkar & Momen (1982) and Jafri & Melvin (1988) organised bibliographies including some abstracts on all aspects of the species. Finally, Al-Hassan (1993) added some biological data to the synopsis of Pillay & Rosa (1963). However, most of the published works are not readily available and not included in the recent electronic storage media. Moreover, many recent studies are unpublished or remained as departmental reports. Therefore, it is essential to summarise all published and, wherever possible unpublished, works of this valuable species in a single compendium to help future studies on the species. This article summarised and compiled numerous recent published and important reports related to biology and management of the species.

Bionomics and life history

Life cycle

The life cycle of Indian shad resembles to American shad, *Alosa sapidissima* (Bhuyan & Talbot, 1968). It has also some similarity with European shads, *Alosa alosa* (Allis shad) and *Alosa fallax* (Twaite shad) (Aprahamian, 1982; Bristow, 1992). After spawning in fresh water, they return to the sea where they remain until the next breeding season (Fig. 1). However, this life cycle pattern is not followed by all stocks/races of the species; some do not migrate from the sea to the river or vice versa (Blaber, *et al.*, 2003).

Hilsa spawn in fresh water and deposit eggs demersally. The eggs hatch after 23-26 hours at an average temperature of 23°C (Jones & Menon, 1951). The size of the hatchlings varies between 2.3 and 3.1 mm (Kulkarni, 1950; Motwani *et al.*, 1957; Karamchandani, 1961). When the larvae can swim, they try to find suitable nursery grounds, normally in the lower region of the rivers or in coastal waters. In Bangladesh these juvenile hilsa in the nursery ground are called Jatka (Rahman & Haldar, 1998). The Jatka resembles to adult Indian river shad (*Gudusia chapra*, Hamilton-Buchanan, 1822), which is locally called Chapila, and many fishermen and many consumers generally refer to Jatka as Chapila in the market (Mazid, 1994; Rahman, 1997).

Hora & Nair (1940a) described the historical information on Jatka and confirmed that it is the young of hilsa. Using molecular genetic technology, Rahman & Naevdal (1998) confirmed that Jatka is the offspring of hilsa by comparing genotype and genotype distributions with previous analysis of hilsa. The Jatka remain around the nursery grounds for about 5-6 months and attain a maximum size of 15-16 cm (Raja, 1985; Mazid & Islam, 1991), but with a dominant size of 10-12 cm (BFRI/RS, 1994; Rahman & Haldar, 1998). However, Hossain (1975) reported that when Jatka become larger than 7 cm they may migrate to the deeper parts of the river, and finally when they reach about 12 cm they disappear from the river. Gradually the Jatka acquire the ability to tolerate saline water and move downstream to the estuary. There they spend their young life stages in brackish water. Later, the young move offshore for feeding and grow to adult size. After maturation, the adults again migrate upstream for spawning following the same pattern (Fig. 1).

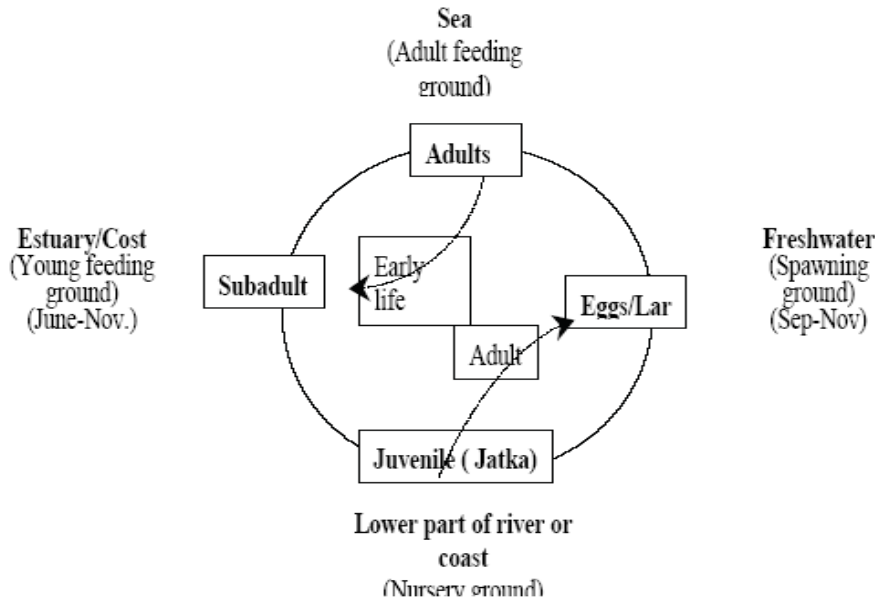


Fig. 1. Typical life cycle of the anadromous hilsa shad (*Tenuosia ilisha*). Note, all stock/race/type may not follow exactly the same cycle; some may be completely riverine, some may be completely marine (indicated by hatched line). The period shown in parenthesis indicates when the stage mostly abundant. (Modified from Rahman and Moula, 1992 and Rahman, 2001).

Migration

Like American shad, the Indian shad is generally termed anadromous, but it is diadromous, as it migrates frequently between fresh water and the sea. The adults migrate upstream to spawn at the start of the south-west monsoon and associated flooding of the rivers. During the peak breeding season the adult fish run in shoals to the estuaries and the rivers and may migrate upstream as much as 1200 km (usually 50-100 km) for spawning (Pillay & Rosa, 1963; Mazid, 1994; Rahman, 1997; FishBase, 2004). However, all races/stocks of hilsa do not migrate following the same pattern (Blaber, *et al.*, 2003). In the northern Indian Ocean there are some purely riverine stocks, anadromous stocks which migrate between the sea and the river (the river-ward migration is for spawning) and purely marine stock (BOBP, 1987). As the most important stocks/races of the species is the anadromous type, most attention has focused on this group.

In general, the anadromous type migrates upstream for spawning which is triggered by the heavy inflow of fresh water from the rivers during the monsoon (June-July). The spring and neap tide periods also trigger the migration (Rahman & Cowx, 2006). During this period the abundance of the fish increases dramatically in the upstream areas. In the peak spawning season (September-October) the catch rate in the upstream is also the greatest (BFRI/RS, 1994; Rahman & Haldar, 1998), indicating the mass migration of the species during this period. Considerable fluctuations in the abundance of brood hilsa in the estuaries and rivers of the upper Bay of Bengal may be due to variations in the intensity of the monsoon during the breeding season of the species (Rahman, 1997). A second peak migration takes place during the winter in January-February (Bhuyan & Talbot, 1968; Rao, 1969; Ghosh & Nangpal, 1970), which could be influenced by the rise in water temperature (Jones, 1957; Nair, 1958), current velocity and increase of plankton in the upstream areas (Ghosh & Nangpal, 1970).

Hilsa may also migrate upstream for feeding (Hora, 1941). Young hilsa have been found to migrate along with the brood hilsa and may travel considerable distance before they are sexually mature (Pandit & Hora, 1951).

By contrast, juveniles of the species migrate from the nursery grounds (riverine or coastal) to the estuaries during the onset of the monsoon for feeding and growth (Raja, 1985; BFRI/RS, 1994). The extent of migration varies considerably in different rivers. In the Ganges it is reported to be as far as 1287 km, reaching Agra and Delhi, but in the Purna river of India it may migrate less than 8 km (Pillay & Rosa, 1963). In the Irrawady river of Myanmar, the fish may migrate upstream to Mandalay, a distance of 724 km. In the Hooghly and Brahmaputra rivers it ascends about 300 km, but is restricted to 56-97 km in the Godavari, Krishna and Cauvery, whilst in the Indus, the migration is up to the Ghulam Mohammad Barrage, which is 161 km from the sea and as a result the Jhelum river stock become freshwater stock (Pillay & Rosa, 1963). In recent years, hilsa tagged in Bangladesh waters were recaptured in Iranian waters (Mazid, 1998).

During the last two decades natural migratory patterns of fishes have been heavily interrupted by construction of dams, barrages, dykes, regulators, fences for flood control and irrigation or fishing purposes, without any provision for the passage of fish (Ghosh, 1987; Kowtal, 1994). Al-Nasiri & Al-Mukhtar (1988) reported that water pollution in Basrah, Iraq affected the hilsa stocks remarkably. The construction of the Farakka Barrage on the Ganga in 1972 has impacted on hilsa migration and hence its abundance further upstream (Chandra *et al.*, 1987; Jhingran & Gupta, 1987; Mukhopadhyay, 1994; Chandra, 1994; Halдар and Rahman, 1998). The Ukai and Kakrapara dams in Gujarat similarly affected migration of hilsa in the Tapti River of India (Pisolkav, 1994; Dubey, 1994). Due to the construction of obstructions and dams in the Kumar, Nabaganga and Feni rivers in Bangladesh, hilsa fishery in these rivers has been lost (Halдар & Rahman, 1998). Although migration of hilsa is restricted by barrages, it still runs far up the Ganges (FishBase, 2004). Many researchers have identified barriers to hilsa migration as a major factor contributing to the decline of the species (Mazid & Islam, 1991; Rahman, 2001).

Reproduction

Hilsa is heterosexual, the females are distinguishable by the flat urinogenital opening and bulging abdomen when gravid and the males by a narrow genital opening and the presence of prominent papillae. However, hermaphroditism has also been found (Chacko & Ganapati, 1949; Swarup, 1958). The species appears to be polygamous and the fertilisation is external (Pillay & Rosa, 1963). Hilsa releases eggs demersally, where eggs fertilise externally, and after fertilisation the larvae hatch out approximately in 22-26 hours (BFRI/RS, 1994). The larvae then drift by the wave actions and tidal currents to the nursery grounds.

Maturity

Hilsa become sexually mature after 1-2 years of life. The size at first maturity is around 22-25 cm for males and 28-30 cm for females (Pillay & Rosa, 1963; BFRI/RS, 1994). In Bangladesh waters, the size at first maturity is reported as 26.5-30.5 cm for males and 30.0-35.0 cm for females (Dunn, 1982). In the River Godavari, the smallest mature male and female were 25 cm and 37 cm, respectively (Pillay & Rao, 1962). In the Hooghly river, however, the minimum size at maturity was 16-17 cm for males and 19-20 cm for females (Pillay, 1958). Pillay & Rao (1962) formulated a useful guide to determine the different maturity stages on the basis of both external and internal appearance of the gonads of both male and female hilsa and assess the period of spawning and size at first maturity. Hilsa with mature gonads are available more or less round the year (Moula *et al.*, 1991) (Table 1). Samples with immature gonads are observed only in the month of December and January (Moula *et al.*, 1991; Pillay & Rao, 1962). The percentage occurrence of males and females in different stages of maturity (Table 1) revealed that spawning of hilsa takes place in the month of August to November and subsidiary spawning in June-July and January-March (Islam *et al.*, 1987; Moula *et al.*, 1991).

Table 1. Monthly percentage of occurrence of hilsa shad (*Tenualosa ilisha*) in different stages of maturity in the Meghna River in 1987 (M, Male; F, female; n, number of specimens)

Month	Sex	N	Stages of maturity (%)							
			IIa	IIb	III	IV	V	VI	VIIa	VIIb
Jan	M	25	16.00		16.00	24.00	44.00			
	F	25	4.00		32.00	36.00	28.00			
Feb	M	26			3.85	23.08	19.23	3.85	38.46	11.54
	F	24			12.50	12.50	41.67		33.33	
Mar	M	33					27.27		41.18	6.06
	F	17			11.76	11.76	35.29		41.18	
Apr	M	14	7.14	35.71	21.43				14.29	21.43
	F	11			18.18	63.64	18.18			
May	M	35	14.29	17.14	17.14	31.43	11.43		5.71	2.86
	F	15			6.67	6.67	80.00		6.67	
Jun	M	38	21.05	13.16	34.22	23.68	2.63		2.63	2.63
	F	12		8.33	8.33	16.67	66.67			
Jul	M	37		2.7	18.92	35.14	32.43	15.38	10.81	
	F	13					69.23		15.38	
Aug	M	31	3.23	6.45	25.81	45.16	9.68	3.23	6.45	
	F	19			5.26	10.53	68.42	10.53	5.26	
Sep	M	27			4.35	25.93	40.74	7.41	7.41	3.70
	F	23			4.35	73.91	73.91	8.70		
Oct	M	28		3.57		10.71	78.57	7.14		
	F	22			4.55	31.82	59.09	4.55		
Nov	M	17		5.88	11.76	17.65	64.71		2.94	2.94
	F	34			2.94	8.82	82.35			
Dec	M	37	8.11	10.81	37.84	32.43	10.81			
	F	13	7.69	7.69	23.08	15.38	46.16			

Sex ratio

Many workers found the sex ratio in natural populations to be significantly different from that of the theoretically expected ratio 1:1, although this was not always the case (Table 2). Sizewise distribution of sexes in Bangladesh waters revealed higher percentage of females in the size group above 40 cm SL (Mazid, 1998).

Table 2. Sex-ratio of the hilsa shad (*Tenualosa ilisha*) in different water bodies

Study area/water body	Ratio (Male : Female)	Reference
The Godavari	1.00 : 9.00	Chacko & Ganapati (1949)
Indian waters	1.00 : 1.53	Pillay & Rao (1962)
The Hoogly	1.00 : 1.00 (aapprox.)	Jones & Menon (1951)
The Ganga	1.00 : 1.00 (approx.)	Pillay (1958)
The Narbada	3.50 : 1.00 (in July)	Karamchandani (1961)
	1.00: 1.00 (other season)	
The Bay of Bengal (Chittagong)	1.00 : 1.08	Islam et al. (1987)
The Bay of Bengal (Cox's Bazar)	1.00 : 1.18	Ditto
The Meghna estuary (Khepupara)	1.00 : 0.42	Ditto

The Meghna (Chandpur)	1.00 : 1.08	Ditto
The Meghna	1.00 : 0.57	BFRI/RS (1994)
The Bay of Bengal	1.00 : 1.14	Ditto
The Padma	1.00 : 0.24	Ditto
The Meghna estuary	1.00 : 0.98	Ditto
Bangladesh waters (average)	1.00 : 0.70	Ditto

Fecundity

Hilsa is a highly fecund fish and does not show any parental care. Fecundity varies with size, locality and environment (Table 3). Gravid females with a length ranging from 30-55 cm have a fecundity between 0.1 and 2.0 million eggs (Pillay, 1958; Pillay & Rao, 1962; Shamsuddoha & Abdulhaye, 1970; De, 1980). The relationship between fecundity and weight appears to be linear.

Table 3. Fecundity of the hilsa shad (*Tenualosa ilisha*) in different water bodies

Study area/water body	Size group	Fecundity (x 000)	Reference
The Hoogly	Average	250-1600	Pillay (1958)
The Hooghly estuary	Average	373-1323	De (1980)
The Godavari	910 g	1282	Chacko & Ganapati (1949)
The Narbada	2100 g	1864	Kulkarni (1950)
The Indus	Average	700-2900	Pillay & Rosa (1963)
The Godavari	300-350mm TL	100-2000	Pillay & Rao (1962)
The Indus	Average	755-2917	Bhuyian & Talbot (1968)
The Padma	273-420mm FL	348-1466	Shamsuddoha & Abdulhaye (1970)
The Padma (type A)	342-520 mm TL	660-1547	Quddus et al. (1984)
The Padma (type B)	260-470 mm TL	399-670	Ditto
The Padma	287-523 mm TL	266-1931	BFRI/RS (1994)
Bay of Bengal	325-492 mm TL	375-1423	Ditto

Spawning season

The peak spawning season for hilsa is September-October, but they may spawn in other seasons and even throughout the year (Table 4) (Bhanot, 1973; Mazid, 1994; BFRI/RS, 1994; FishBase, 2004). Swarup (1959) examined histological changes in the gonads of hilsa and concluded that hilsa spawns several times during a spawning season. By contrast, Swarup (1959) and Mitra & Ghosh (1979) found two breeding seasons, which suggested a bimodal annual spawning cycles of the species. Mathur (1964) stated the first spawning period was in February-April and the second was in October. These observations were confirmed by Pillay & Rao (1962) and Moula *et al.* (1991), but Nair (1958) found atresia in February-March and concluded this was not a true spawning season.

Raja (1985), however, pointed out two distinct spawning stocks or varieties, which were also reported by Quddus (1982), one, the broad variety spawns in the monsoon and another, slender variety, which spawn in winter. Chandra (1962) described the results of a larval fish survey of the Hooghly estuary and the information supported the belief of a prolonged spawning season. Similarly, Ghosh & Nangpal (1970) supported the hypothesis of post-winter spawning in a study of the hilsa in the freshwater section of the Ganges.

Table 4. Spawning seasons of the hilsa shad (*Tenualosa ilisha*) in different water bodies

Study area/ water body	Peak season(s)	Lean season(s)	Reference
The Hoogly	May and July-August	All other months	Hora & Nair (1940) & Hora (1941)
The Hoogly	July-November	January-March	Pillay (1958)
The Ganga	September-December	July-August	Motwani et al.(1957)
The Ganga	March and August	January-February and June-July	Nair (1958)
The Ganga	September-November	--	Chandra et al. (1987)
The Narbada	August	June-July and September	Karamchandani (1961)
The Saurashtra coast,	April-May	---	Pillay (1962)
The Godavari	August-November	---	Pillay & Rao (1962)
The Hoogly	February-March, July-August, and October-November	All other months	Bhanot (1973)
Bangladesh waters	October-November, July-August, and February-March	Ditto	Mazid (1994)
The Meghna	January-March and July-October	----	Shafi <i>et al.</i> (1978)
The Godavari	August-November	February-April	Pillay & Rao (1962)
The Meghna	October-November	All other months	Moula <i>et al.</i> (1991)
Bangladesh waters	Monsoon and winter	Ditto	Raja (1985)
The Padma (type A)	July-October	Ditto	Quddus <i>et al.</i> (1984)
The Padma (type B)	January-March	Ditto	Ditto
The Hoogly estuary	August-October	Ditto	Chandra (1962)
The Ganga (1970)	Post winter	Ditto	Ghosh & Nangpal
Bangladesh waters	October-November	June-July and January-March	BOBP (1987)
Kuwaiti waters	June	May and July	Al-Baz & Grove (1995)

Spawning ground

Hilsa spawn in all freshwater reaches of rivers (Hora, 1938; Motwani *et al.*, 1957; Chandra 1962; Quereshi, 1968; Mazid & Islam, 1991; Mazid, 1994; Mazid, 1998). Older hilsa spawn for the second and the third time in the higher reaches, while younger hilsa making their first spawning migration are more susceptible to changes in salinity and spawn in the lower portions of the river. Hora (1938) suggested that the young immature specimens below one year stay in the river for a much longer period and only spawn towards the end of the first year of their life or in the second year. Karamchandani & Pisolkar (1976) identified the location of hilsa spawning grounds in the Tapti river of India at a distance of 5-12 km upstream of Bodhan in the vicinity of Piperia (a freshwater region) situated about 56 km from the sea. Karamchandani (1961) reported the location of the freshwater spawning grounds of hilsa on the Narbada river. Pillay (1964), on the other hand, suggested that hilsa on the Saurashtra coast may be marine spawners. Mazid & Islam (1991) and BFRI/RS (1994) reported one major spawning ground in Bangladesh waters in the Hatia-Sandwip-Monpura area (Fig. 2).

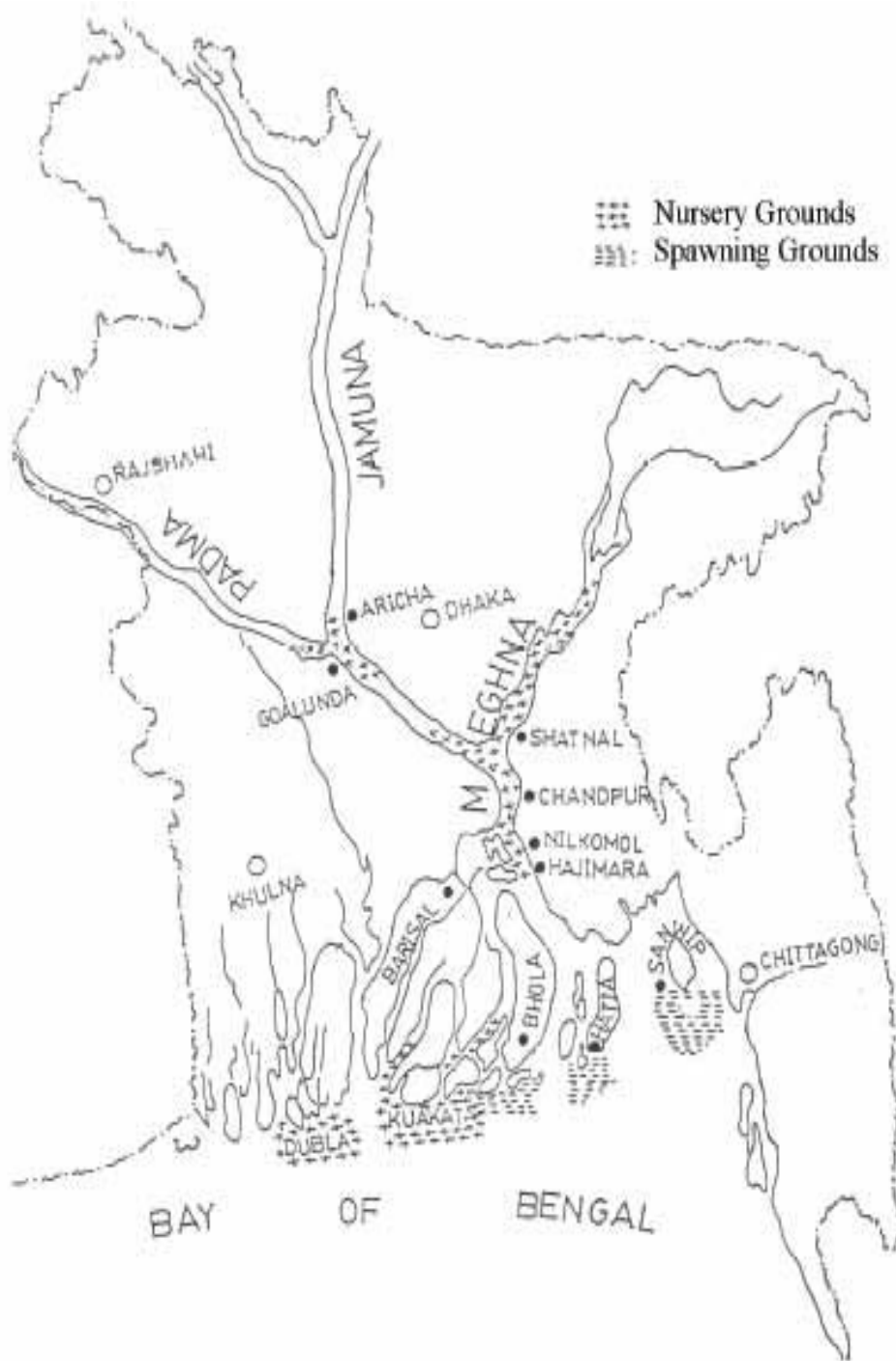


Fig. 2. Map showing spawning grounds and nursery ground of the hilsa shad (*Tenualosa ilisha*) in Bangladesh waters.

Nursery grounds

There are two main nursery grounds (Fig. 2) in Bangladesh waters (Mazid & Islam, 1991; BFRI/RS, 1994; Mazid, 1998; Rahman & Haldar, 1998). The largest riverine nursery ground is situated in the River Meghna, in and around Chandpur, from Mawa (Munshiganj) down to Hazimara. The juveniles (2-12 cm) appear in this nursery ground in November and remain up to June, but the peak period is approximately 15 February to 15 May. Another large nursery ground is situated in the coastal belt from Kuakata (Patuakhali) to the Dubla Island (Khulna). Within this area comparatively large size (11 to 15 cm) Jatka are caught during December-January. Nursery grounds in the rivers of other countries seem to be situated in their respective migratory rivers, but no specific information is available.

Food and feeding

Hilsa is predominantly a planktonic filter feeder (Rahman *et al.*, 1992), but also appears to ingest sands and debris, and possibly feeds on the benthos (Swarup, 1959a; BFRI/RS, 1994; FishBase, 2004). Gut analyses revealed the food composition of the hilsa shad to be about 42% algae, 36% debris with sands, 15% diatoms, 3% rotifers, 2% crustaceans, 1% protozoans and 1% miscellaneous (Rahman *et al.*, 1992). Twenty seven phytoplankton genera and 12 zooplankton genera were identified (Rahman *et al.*, 1992). Monthly fluctuations in the intensity of feeding are common. There appears to be a high percentage of empty stomachs in adults throughout the year, while January and April are the most active feeding months (Rahman *et al.*, 1992). However, the diet varies with season and size of the fish. Hilsa upto 20-40 mm (TL), feed mostly on diatoms and sparingly on Copepods, *Daphnia* and Ostracods. Older specimens up to 100 mm (TL) feed mainly on small crustaceans as enumerated above, insects larvae, chironomid larvae and Polyzoa, whilst bigger specimen upto 150 mm included small shrimps in their diet. Adults feed mostly on diatoms with a few *Daphnia* and Ostracods (Hora, 1938). Hora & Nair (1940) found that young hilsa are benthic feeders but Pillay & Rao (1962) and Halder (1968) indicated hilsa feeds at all depths. De & Datta (1990) described the feeding adaptations of hilsa from a digestive tract study. Absence of teeth, presence of an efficient filtering mechanism in the form of long fine gill rakers, a pharyngeal pouch and the modification of the stomach into a gizzard, and moderately long intestine indicate that the mode of feeding is of the strainer type in which food is ingested by size rather than by kind. These adaptations support the planktivorous feeding habit of the species.

Population (stocks) biology

Stock discrimination

There is still controversy regarding stocks/races of hilsa in different water bodies. Some workers (Ahmed, 1961; Das *et al.*, 1987) found a homogenous stock of hilsa in Bangladesh waters, while others (Quddus *et al.*, 1984b; Rahman & Moula, 1992; Rahman *et al.*, 1997a; Rahman & Naevdal, 1998) have found heterogeneity among hilsa in different water bodies. On the other hand, most Indian workers have suggested more than one stock in Indian waters (Pillay *et al.*, 1963; Dutta, 1966; Ghosh *et al.*, 1968; Ramakrishnaiah, 1972; Rajyalakshmi, 1973). Possible races/stocks of hilsa as found by different workers are summarised in Table 5. Genetic variation among the individuals and groups in Bangladesh waters revealed five polymorphic loci and contingency chi-square analysis showed that hilsa in Bangladesh waters belongs to more than one gene pool, rather than a single panmictic population (Rahman & Naevdal, 1998). Finally, Salini *et al.* (2004) studied the population structure of hilsa with both allozymes and morphometric analysis. Fish samples were collected from nine sites within Bangladesh and compared with samples from four other countries that covered the entire species range. No significant differences in allele frequencies were detected within Bangladesh or within the Bay of Bengal (SE India and Myanmar) samples. Significant differences in allele frequencies occurred between Kuwait, Bangladesh and Indonesia.

Table 5. Possible races/stocks of the hilsa shad (*Tenualosa ilisha*) in different water bodies

Water bodies	Parameter/ Method used	Possible races/stocks	Reference
Indian waters	Morphometric and meristic characters	Several stocks	Pillay <i>et al.</i> (1963)
Ditto	Ditto	3 types (fluvial anadromous, fluvial and marine ecotypes)	Dutta (1966)
Ganga River	Length and height	3 types (broad, broader and slender types)	Ghosh <i>et al.</i> (1968)
Chilka Lake and Hoogly River	Biological characters	2 stocks (Chilka Lake and Hoogly stocks)	Ramakrishnaiah (1972)
Godavari River	Behaviour	2 stocks (migratory and non-migratory stocks)	Rajyalakshmi (1973)
Bangladesh waters	Vertebrae counts	Single stock	Ahmed (1961)
Ditto	Morphometric and meristic characters	2 types (slender and broader types)	Quddus <i>et al.</i> (1984b)
Ditto	Ditto	Single stock	Das <i>et al.</i> (1987)
Ditto	Ditto	4 morphological groups (marine, estuarine, Padma and Meghna groups)	Rahman & Moula (1992)
Ditto	Ditto plus electrophoresis	Ditto	Rahman <i>et al.</i> (1997a)
Ditto	Genetic study	2 stocks (marine and riverine stocks) (1998)	Rahman & Naevdal
Ditto	Genetic study	Homogenous stock	Hussain <i>et al.</i> (1998)
Entire distribution range	Allozymes and morphometric analysis	No significant differences within Bangladesh or within the Bay of Bengal (SE India and Myanmar) samples, but significant differences between the samples from Kuwait, Bangladesh and Indonesia. Salini, <i>et al.</i> (2004)	

Stock dynamics

Length-weight relationship

The parameters '*a*' and '*b*' of the length-weight relationship, $w = al^b$ (where, *w* = weight of fish; *l* = length of fish; *a* = constant; and *b* = exponent) are estimated by different workers in different water bodies (Table 6). The values of the exponent (*b*) vary between 2.52 (Quddus *et al.*, 1984a) and 3.10 (Al-Baz & Grove, 1995) indicating a fairly symmetric growth rate of the fish (Table 6).

Table 6. The parameters of length-weight relationship ($w = alb$) of hilsa shad in different water bodies (w , weight of fish in g; l , length of fish in cm; a , constant; and b , the exponent)

Water bodies/area	Sex	Values of the parameters		Reference
		Constant(a)	Exponent(b)	
Meghna estuary	Male	0.0177	2.760	Islam et al. (1987)
Ditto	Female	0.0269	2.890	Ditto
Meghna River	Male	0.0280	2.740	Ditto
Ditto	Female	0.0210	2.870	Ditto
Bay of Bengal	Both	0.0305	2.730	Ditto
Bangladesh waters (broader type)	Both	0.00003	2.527	Quddus et al (1984a)
Bangladesh waters (slender type)	Both	0.00014	2.561	Ditto
Brahmaputra Rive	Both	-5.163	3.063	Chaudhury et al. (1987)
Hooghly estuary	Both	0.0315	2.800	Gupta (1989)
Kuwaiti waters	Male	0.011	2.983	Al-Baz & Grove (1995)
Ditto	Female	0.007	3.104	Ditto

Ageing

Ageing of hilsa is a problem. Chacko *et al.* (1948), Chacko & Kirshanamurti (1950), Raj (1951) proposed a direct correlation between the number of scale radii and fish length. However, Pillay (1958) concluded that the number of radii on the scales is not related to the age of fish, so, it may not be useful in determining the age and growth of the species. Similar problems were found in European populations of shad (*Alosa* sp.) but careful examination of the scales makes ageing possible (Aprahamian, 1982). Other workers (Pillay & Rao, 1962; Rajyalakshmi, 1973; De & Datta 1990a) used the length-frequency method to determine the age, which was not found reliable as the frequency distributions often overlapped due to protracted spawning periods and size selective sampling. Moreover, they did not use computer-based software such as ELEFAN or FiSAT to discriminate length modes, so, the analysis needs to be treated with caution. More recently, Quddus (1982) found otoliths are a good tool for ageing the fish. Later Quddus *et al.* (1984a) discussed the age and growth of the two types of hilsa (so called broader and slender type) from the Padma and Meghna river using otoliths. In the case of the broader type, hyaline zones appeared during June and July while in the slender type it was in January and February, i.e. during their respective spawning season. Consequently, it appears the stress of spawning may induce a growth mark. Daily growth ring on the otoliths of hilsa have also been used for ageing in Bangladesh waters, as increments were found to be visible for the first few hundred days but the microstructural pattern became unreadable thereafter (BFRI/RS, 1994; Mazid, 1998). This was because the increments were faint and very fine for extensive regions near the margin of the otoliths of the larger fish. Therefore, this method is suitable for small fish (smaller than 40 cm), but for large fish (larger than 40 cm) another method is required (Hossain, 1985; BFRI/RS, 1994; Mazid, 1998). Rahman (2001) successfully aged hilsa using otolith and validated by length-frequency. He also observed 14 days lunar cycle called lunar ring in the otolith of hilsa.

Growth and mortality

Similar to other fish, hilsa grow faster in their early life stages upto about 600 mm (BOBP, 1987). Length-frequency of hilsa in commercial catch in Bangladesh and Indian waters (Fig. 3) showed a general size range about 15-52 cm (Azad *et al.*, 1987; Gupta, 1989). Hilsa have been classified into four size groups, small (less than 30 cm), medium (30-39 cm), large (40-49 cm) and extra large (above 50 cm), but more than 90% of the catch falls within a range of 30-50 cm (Azad *et al.*, 1987). Total life span was reported to be at least 5 years (Bhuyan & Talbot, 1968), but Pillay & Rao (1962) found hilsa in Indian rivers live at least 6 years (Fig. 4).

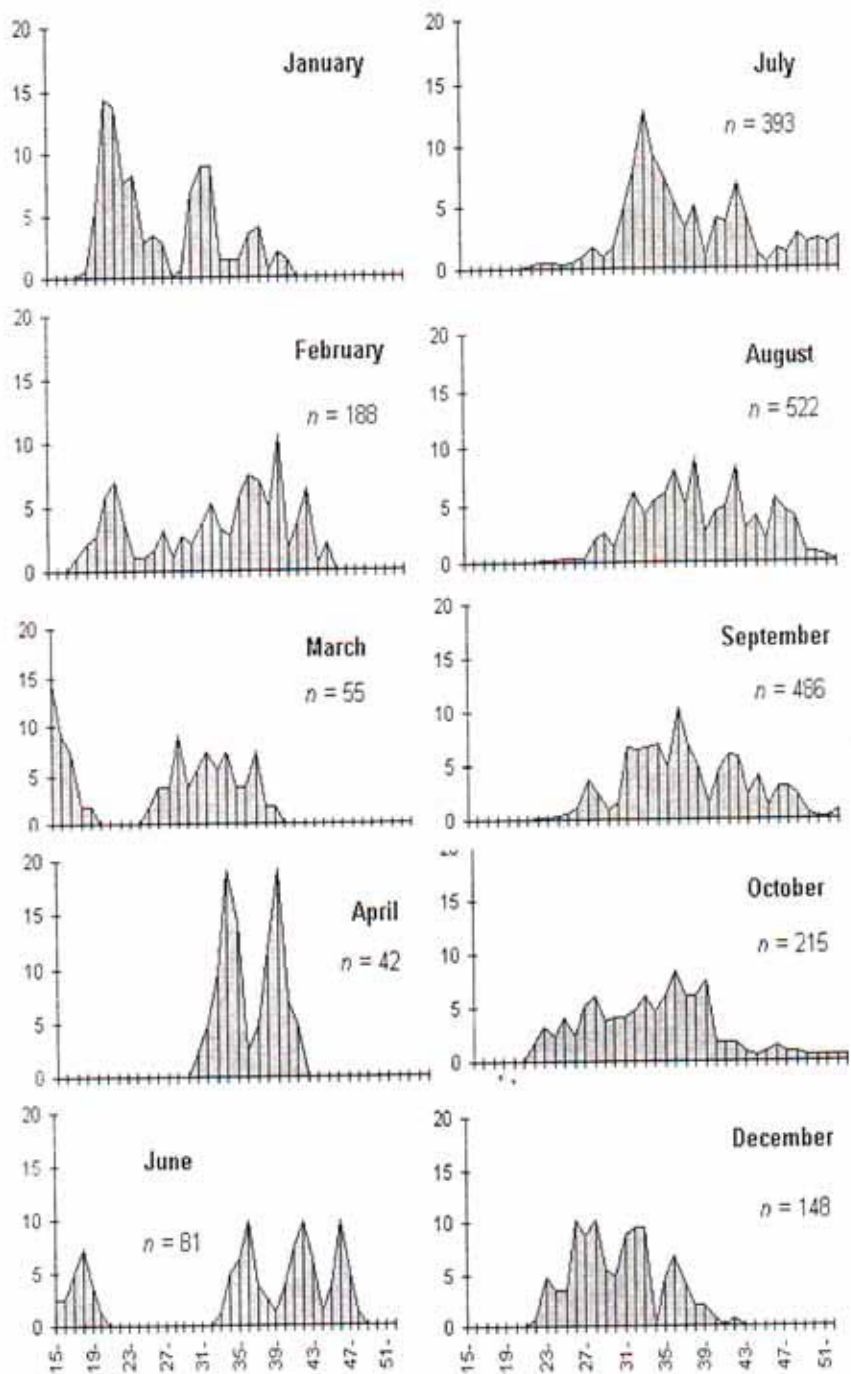


Fig. 3. Monthly length-frequency distribution of the hilsa shad, *Tenulosa ilisha*. The size class in cm along the X-axis and the percent frequency along the Y-axis (data from Gupta, 1989).

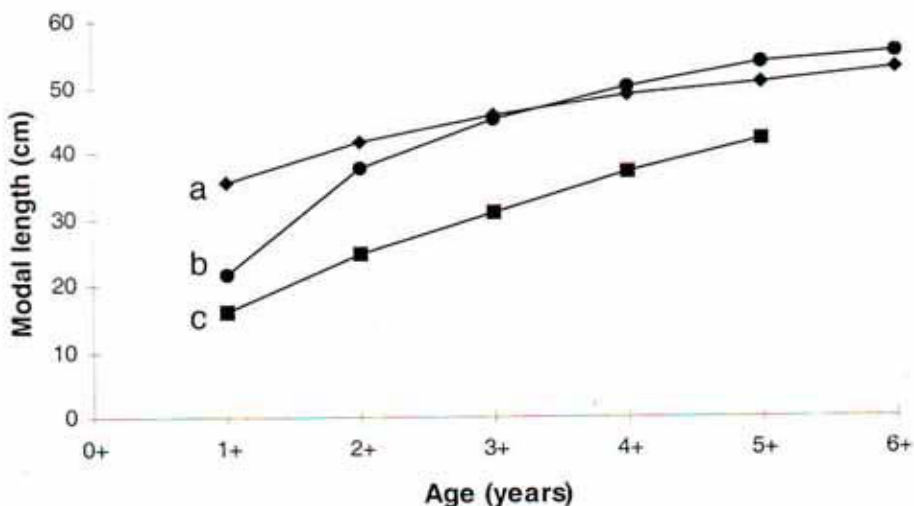


Fig. 4. Growth curves of the hilsa shad (*Tenulosa ilisha*) in different water bodies (a, Indian waters after Pillay and Rao, 1962; b, Bangladesh waters after Miah et al., 1997; and, c, Bangladesh waters after Quddus et al., 1984a).

However, in Bangladesh waters length-frequency analysis using Bhattacharya's method indicated that there were four or five modal groups, at 22, 37, 41, 47, and 50 cm within the exploited size range (BOBP, 1987; Rahman, 2001). Sujansinghani (1957) reported the details of the results of a three-year study conducted on the growth of hilsa in the Hooghly estuary. Growth increments were estimated to be 15-20 mm month⁻¹ in the first 2-3 months after hatching, thereafter decreasing to approximately 10 mm month⁻¹.

Table 7. Growth parameters of the hilsa shad (*Tenulosa ilisha*) in different water bodies (phi prime, $\phi' = \log_{10} K + 2 \log_{10} L\alpha$)

Study area/ Water bodies	$L\alpha$ (mm)	Phi prime K(year ⁻¹)	(ϕ')	Reference
Padma River (type A)	642	0.19	2.89	Quddus <i>et al.</i> (1984a)
Padma River (type B)	680	0.16	2.87	Ditto
Brahmaputra River	700	0.25	3.09	Chaudhury <i>et al.</i> (1987)
The Bay of Bengal	580	0.83	3.45	Van der Knaap <i>et al.</i> (1987)
Ditto	570	0.78	3.40	Ditto
Ditto	550	0.90	3.43	Ditto
Hoogly River	600	0.85	3.49	Gupta (1989)
Ditto	592	0.80	3.45	Ditto
Bangladesh waters	611	0.71	3.44	BFRI/RS (1994)
Ditto	583	0.74	3.40	Rahman <i>et al.</i> (1998)
Meghna River	570	0.66	3.33	Miah <i>et al.</i> (1998)
Kuwaiti waters	527	0.28	2.89	Al-Baz & Grove (1995)
Rivers of Bangladesh	588	0.82	3.45	Rahman (2001)
Marine waters of Bangladesh	610	0.80	3.47	Rahman (2001)
Coastal water of Bangladesh	609	0.66	3.38	Rahman <i>et al.</i> (1999)
Bangladesh waters	615	0.83	3.48	Rahman <i>et al.</i> (2000)
Rivers of Bangladesh (1999)	600	0.82	3.47	Haldar <i>et al.</i> (2004)
Rivers of Bangladesh (2000)	625	0.72	3.45	Haldar <i>et al.</i> (2004)

Growth and mortality parameters of hilsa in different water bodies using length-based stock assessment methods are presented in Table 7 and 8, respectively. The estimated von Bertalanffy growth parameters by different workers from different water bodies were found to differ slightly, or in some cases appreciably, from each other (Table 7). The estimated mortality parameters and exploitation rates of hilsa from different water bodies (Table 8), did not show any sign of overexploitation but all authors suggested an increase in the length at first capture

Table 8. Mortality rates and exploitation levels of the hilsa shad (*Tenulosa ilisha*) fishery from different water bodies

Water bodies	Fishing mortality (F, yr ⁻¹)	Natural mortality (M, yr ⁻¹)	Total mortality (Z, yr ⁻¹)	Exploitation level (E)	Reference
Bay of Bengal	0.62	1.27	1.89	0.33	Van der Knaap <i>et al.</i> (1987)
Ditto	0.45	1.23	1.68	0.27	Ditto
Hoogly Rivers	0.67	1.32	1.99	0.50	Gupta (1989)
Bangladesh waters	1.25	1.16	2.41	0.52	BFRI/RS (1994)
Ditto	1.43	1.18	2.61	0.55	Rahman <i>et al.</i> (1998)
Meghna River	1.14	0.89	2.03	0.56	Miah <i>et al.</i> (1998)
Kuwaiti waters	0.80	0.50	1.30	0.62	Al-Baz & Grove (1995)
Rivers of Bangladesh	1.38	1.00	2.38	0.58	Rahman (2001)
Marine waters of Bangladesh	1.32	0.98	2.30	0.57	Rahman (2001)
Coastal water of Bangladesh	2.16	1.12	3.28	0.67	Rahman <i>et al.</i> (1999)
Bangladesh waters	2.01	1.28	3.29	0.61	Rahman <i>et al.</i> (2000)
Rivers of Bangladesh (1999)	2.49	1.28	3.77	0.66	Haldar <i>et al.</i> (2004)
Rivers of Bangladesh (2000)	1.62	1.17	2.79	0.58	Haldar <i>et al.</i> (2004)

Recruitment

There are two major recruitment events each year for hilsa; these are in August and October, but there is some indication of further recruitment in April (BOBP, 1987). However, as hilsa may spawn throughout the year, the recruitment pattern is probably continuous with one or two major peaks (BFRI/RS, 1994; Mazid, 1998). It should be noted that the continuous or bi-seasonal spawning might lead to difficulties in discriminating growth parameters of hilsa from length frequency data.

Hilsa fishery management and regulations

Many workers have highlighted the need for a sound management policy for the conservation of the hilsa fishery in the region (Raja, 1985; BFRI/RS, 1994; Mazid and Blaber, 1998), and recommended different management strategies (Rahman & Moula, 1992; Mazid & Blaber, 1998). Anon (1942) provided a general review of hilsa as an important food source, and recommended different management measures including artificial propagation, protection of the young and closed fishing seasons. In addition, Dunn (1982) recommended establishment of a competent research unit to investigate many aspects of the fishery.

Anon (1995) proposed to inform fishing communities about the importance of the ban on Jatka fishing and supported a community-based programme to monitor and enforce the ban. Chai & Hossain (1997) proposed to set-up fish sanctuaries and ban fishing for juvenile hilsa in order to protect the broodstock and thereby increase recruitment.

For the management of the hilsa fishery in Bangladesh, the following four recommendations were put forwarded by the hilsa research team of Bangladesh (BFRI/RS, 1994). Rahman (1997) also redescribed these recommendations and included the importance of a socio-economic survey and distribution of loans to the fishermen. He also emphasised the need for global genetic/racial studies. The main recommendations are as follows:

- 1) Protect juvenile hilsa (Jatka) on the Chandpur nursery ground (Shatnol to Nilkomol) (Fig. 2) during March-April or at least in March by banning "Jagat Ber" (beach seine net), "Mashary Jal" and "Current Jal" having mesh sizes smaller than 100 mm. coastal nursery grounds (Kuakata to Dublar char) should also be protected during December-January or at least January by banning beach seine nets and set bag nets (Behundi Jal).
- 2) Protect identified spawning grounds in the lower stretches of the Meghna river (Hatia-Sandwip-Monpura) (Fig. 2) in the peak spawning season, i.e. September-October or at least mid September to mid October, or if not possible at least 3 days in the new moon and 3 days in the full moon by totally banning hilsa fishing in and around the spawning grounds.
- 3) Impose a ban on the erection of all "Gara Jal" (bamboo fencing) in the river, especially in the Padma river (from Munsiganj via C & B Ghat to Aricha) and in the Megna river (Mehendiganj-Hijla- Muladi region of the Barishal district) during the winter season.
- 4) Prevent catching of hilsa below 350 mm by banning all nets having mesh size smaller than 90 mm. In the case of the Current Jal the smallest acceptable mesh size must be 100 mm.

The team also suggested the following two ways to implement the recommendations mentioned above:

- 1) A joint task force should be established, including scientific personnel from Fisheries Research Institute, Extension Personnel from Department of Fisheries, Police Force, Naval Forces and administrative personnel to implement the rules and regulations established on the basis of the above recommendations.
- 2) Improving peoples awareness through publicity in mass media (radio, television, newspaper, etc.), training and demonstration. In addition to the above recommendations, the following policy issues were also formulated (Mazid & Blaber, 1998):
 - 1) Establish a proper system to monitor the effect of the ban on juvenile (Jatka) and gravid hilsa fishing.
 - 2) Register both inland and marine hilsa fishing gears and regulate fishing effort according to the present stock status.
 - 3) Before undertaking different water development projects their impacts on hilsa and other fishery should be studied.
 - 4) Alternate options for hilsa migration such as, fish passages/locks, should be commissioned wherever needed and their efficacy needs to be tested.
 - 5) Income sharing arrangements among the fisherfolk should be made more equitable by enacting laws.
 - 6) Establish separate institute for hilsa research and management and its work should be coordinated through a National Hilsa Management Steering Committee.
 - 7) Hilsa fisheries resources assessment and monitoring systems need to be strengthened to obtain data required for the regulation and conservation of hilsa stocks.

Finally, Rahman (2001) suggested a comprehensive management plan for the hilsa fishery in Bangladesh considering all interactive issues such as biological, commercial, environmental and socioeconomic issues and included all stakeholders with their respective role in the management. Implementation strategies of the hilsa fisheries conservation and management plans have formulated by Haldar *et al.* (2004). Nevertheless, if any sustainable management initiative is to be implemented it would require some sort of community-based management. Consequently, development of responsibility for the fishery in various regions should be passed to the communities but overseen and supported by Governments.

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STUDIES ON THE PERFORMANCES OF SOME NEW GENOTYPES OF AMERICAN UPLAND COTTON (*Gossypium hirsutum L.*)

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ABSTRACT

Three-years field study on assessment of planting, yield, yield contributing characters and fiber quality of seven new cotton genotypes with control cultivar CB-9 were studied at the Central Cotton Research, Training & Seed Multiplication Farm, Sripur, Gazipur, Bangladesh. The result showed that higher yield (2583 kg/ha) was obtained from genotype SR-05 which was closely followed by SR-01 (2422.12 kg/ha). Significant variations among the genotypes were also observed for node number of 1st fruiting branches (NFB), days to 50% flowering, days to 50% boll split, plant height at harvest, weight of seed cotton/boll, and seed cotton yield. Beside seed cotton yield, weight of seed cotton/ boll as well as quality were found superior. The pooled data showed that genotype SR-05 produced 40.57% more seed cotton yield than control variety CB-9. Results revealed that the superior performance of SR-05 was mainly due to its highest seed cotton / boll. Beside, only SR-05 bears okra-leaf type and others normally shaped leaves.

Key words: Cotton, Cultivar/ genotype, Okra-leaf, Seed cotton yield, GOT, Quality

INTRODUCTION

Cotton, the White Gold is one of the most important commercial fibre crops. It plays a prominent role in the national and international economy. In spite of severe competition from synthetic fibres, cotton continues to enjoy a place of prime importance in the textile industry. In recent years, cotton apparels are being preferred to the synthetic ones due to the increasing health consciousness among the people (Kairon et al., 2002).

Bangladesh produces 2400 (Mt) seed cotton and 5990 Hectogram/ Hectare (Hg/Ha) yield of seed cotton among the SAARC Countries (Statistical Bulletin of SAARC Agricultural Data, 2003). Whereas, Pakistan produces 433811(Mt) seed cotton and 1399 (Hg/Ha) yield of seed cotton among the SAARC Countries. As cotton is a very sensitive crop so its yield performance is influenced by many genetic and environmental factors. Yield variation in cotton was observed through variety to variety. To develop high yielding cotton variety, Sripur cotton farm developed 7 cotton genotypes from crosses under variety development programme since 1993.

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The fundamental way to realize the target of high yield and good quality was to regulate the time of flowering and boll position to coincide with the optimum period under the local climatic and ecological conditions. Boll size, boll weight and fibre properties were positively correlated with flowering date and boll retention (Fan et al., 1989). Thomson, et al., (1987) showed that, under the light spray regime, against *Heliothes*, genotypes with the okra leaf and / or nectariless mutant genes had higher yields than the normal, while genotypes with glabrous leaf and / or frego bract had lower yields than the normal. Okra leaf, a deeply divided and reduced leaf form, enhances earliness, reduces boll rot and provides resistance to boll weevil (Jones, 1982), pink bollworm (Wilson and George, 1981), banded-wing whitefly (Jones et al., 1975), and mites (Brettell, 1980).

Solis et al., (1989) showed that the mean maturity date based on number of harvested bolls was the most highly correlated. It was concluded that days to first flower from sowing provided a reliable estimation of earliness of maturity and the mean maturity date gave the best yield estimate. In cotton shorter plant height, lower number of days to flower and boll split are desirable (Alam et al., 1996). High yield and quality are obtained by the optimum combination of boll wt. and boll number (Tan, 1993). Stoilova & Nikolov (2003) showed that, boll weight and seed cotton yield were positively correlated.

Alfaqeh et al., (2002) showed that the number of fruiting branches, the number of flowers, the number of bolls, and yield per plant decreased with an increase in plant density. Begum et al., (2005) also reported that, the highest yield of seed cotton produced only due to the highest weight of seed cotton/boll.

So, the study of trial is aimed to test the yield and quality performance of that line through comparing the agronomic and ginning characteristics with the existing CDB varieties as control. Effects on yield and quality associated with the glabrous leaf, okra-leaf and normally shaped leaves were studied in field experiments repeated over three seasons.

Whenever a crop variety is evolved, field trials are needed to examine its yield performance and quality for several years. Information on seed cotton yield, yield attributes and quality of new cultivars are available /obtained from Replicated Progeny Row Trial (RPRT) site specific technology needs to be developed to increase and sustain crop productivity and quality. It is, therefore, intended to evaluate the yield performance and quality of cultivars with existing cultivar CB-9.

MATERIALS AND METHODS

Experiments were conducted at the Central Cotton Research, Training & Seed Multiplication Farm, Sripur, Gazipur during seasons of three consecutive years i.e., 2002-03, 2003-04 and 2004-05. In each season the isogenic lines and control variety were sown in mid to last week of July. The experimental design was randomized complete block with three replications. Plot size was 10 m x 3.6 m.

The 7 (seven) cotton genotypes obtained from 7 crosses (seed parent X pollen parent) included as treatment materials:

- 1) SR-01= (P₁ x P₃) = (DL-90 X DL-41)
- 2) SR-02= (P₁ x P₄) = (DL-90 X K-502)
- 3) SR-03= (P₁ x P₆) = (DL-90 X BAC-159)
- 4) SR-04= (P₂ x P₃) = (DL-50 X DL-41)
- 5) SR-05= (P₂ x P₆) = (DL-50 X BAC-159)
- 6) SR-06= (P₃ x P₄) = (DL-41 X K-502)
- 7) SR-07= (P₃ x P₅) = (DL-50 X BAC-81)

Seven lines were derived from an initial hybridization of some Deltapine-related experimental line and one cultivar (CB-9) used as local check. Among the 6 parent lines, only BAC-159 was okra-leaf.

Three or four seeds were sown at a spacing 90cm row to row and 60cm hill to hill during planting, but after final thinning one seedling per hill was allowed.

Chemical analysis of the soil of the experimental site according to BRAC soil analytical laboratory (April, 2003), Gazipur are given below:

Table 1. Chemical analysis of the soil of the experimental site.

Soil parameters	Characteristics & value	Critical value*
Soil type.....	Clay loam	-
PH.....	6.08 (acidic)	-
OM (%).....	2.19 (medium)	-
N (%)	0.109 (low)	0.12
P (µg/g)	7.85 (low)	10.0
K (meq/100)	0.170 (low)	0.12
S (µg/g).....	44.0 (very high)	10.0
B (µg/g)	0.76 (very high)	0.2

*Source: Fertilizer recommendation guide-2005.

Green manuring and decomposed cowdung (2t/ha) were applied before final land preparation. All chemical fertilizers such as TSP, MP, Gypsum, Borax, ZnSO₄ and Urea were applied at the rate of 175, 175, 100, 10, 10 and 50 kg/ha, respectively, during final land preparation as basal dose. Only Urea @50kg/ha was applied 3 times as side dressing at 3, 6 and 9 weeks after planting. Recommended agronomic practices were followed during the period. Heavy shower during August and September 2004 were 554 and 6 plant growth. Each year data were analyzed separately.

Data on plant characters were recorded from the middle two rows (10m x 1.8m) from every unit plot in order to avoid border effects. Yield data were converted from the plot area (10m x 1.8m) to kg/ha.

Ten plants were chosen at random from each plot to observe node number of 1st fruiting branches (NFB), plant height at harvest and average weight of seed cotton / boll. Days to 1st flower and days to 1st boll split were recorded when 50% plants have an flower and an open boll, respectively. All the genotypes and cultivars were short hairy type, except SR-05. SR-05 produced glabrous leaves. All the genotypes and cultivar produced normally shaped leaves, but only SR-05 showed okra leaf type leaves among the eight genotypes. Statistical analysis was performed for all characters according to Zaman et al., (1982).

RESULTS AND DISCUSSION

Plant, seed cotton yield, yield attributes, GOT and seed index were found statistical identical in three years, so pooled analysis was done and data is shown in Table 2. Seed and lint characteristics of different cultivars /genotypes are given in Table 3 and fibre qualities are shown in Table 4.

Plant characters and yield of cotton:

Significant variations among the cultivars on node number of 1st fruiting branches (NFB), days to 50% flowering, days to 50% boll split, and weight of seed cotton/boll, plant height at harvest and seed cotton yield was observed (Table 2).

In case of node number of 1st fruiting branches (NFB), SR-06 was lowest (5.37) and CB-9 was highest (6.52). Moreover, in case of days to 50% flowering, SR-02 showed earliness in flowering (49 days) and CB-9 showed late (57days). On the other hand, in case of days to 50% boll split, SR-02, SR-04 and SR-05 showed earliness in boll split, 113, 116 and 116 days, respectively on the contrary SR-07 showed late (128 days). Plant height at harvest are significant on different cultivars/genotype. The cultivar SR-04 showed shorter plant, but statistically identical to SR-07 and SR-03 whereas taller plant from existing cultivar CB-9 which was closely followed by SR-01.

Table 2. Performances of the cultivars/ genotypes for different plant characters and yield of cotton (pooled)

Cultivars/ Genotypes	NFB	Days to 50% flowering	Days to 50% boll split	Plant height at harvest (cm)	Weight of seed cotton /boll (g)	Yield of seed cotton	
						(kg/ha)	Increase yield over CB-9 (%)
SR-01	6.34	56	119	118.22	5.51	2422.14	131.81
SR-02	6.28	49	113	108.67	4.82	1836.48	99.94
SR-03	6.48	52	117	102.39	5.20	1721.35	93.68
SR-04	6.02	54	116	99.22	4.78	1886.65	102.67
SR-05	5.90	52	116	105.61	5.68	2583.07	140.57
SR-06	5.37	53	121	107.06	4.84	1841.03	100.19
SR-07	5.87	55	128	100.39	5.28	1838.38	100.05
CB-9	6.52	57	126	120.39	5.81	1837.55	100.00
CV (%)	4.92	4.20	2.23	4.00	4.34	9.76	-
LSD (0.05%)	0.51	3.95	4.68	7.55	0.41	161.26	-

Higher weight of seed cotton/ boll was recorded from cultivar CB-9 which was statistically at par to SR-05 and SR-01. It is noted that though higher weight of seed cotton/ boll from CB-9 but it fails to show higher yield. Though slightly lower weight of boll was obtained from cultivar SR-05 and SR-01 but it showed higher seed cotton yield than the existing cultivar CB-9. Both the cultivar/ genotype reveal 40.57 and 31.81% higher yield than the CB-9.

Lint characteristics:

In case of lint yield, the mean yield of the trial ranged 618.65-981.45 kg/ha, whereas highest yield of lint was found in SR-01 (981.45kg/ha). The lowest yield of lint was found in SR-03 (618.65kg/ha). In case of ginning outturn (GOT), the highest was found in SR-01 (40.52%) followed by SR-07 (39.57%) and the lowest was found in SR-03 (35.94%) followed by SR-05 (36.33%) okra leaf habit. Though one of its parent beared okra leaf but SR-03 did not show okra leaf habit. As only SR-05 showed dominant okra-leaf habit, so, it could be concluded that okra genes have some effects on ginning outturn and it is in agreement with that of William et al., (1983).

Table 3: Seed and lint characteristics of the cultivars/ genotypes (average of 3 years)

Cultivars/ Genotypes	Yield of lint		GOT (%)	Seed Index (g)	Lint Index (g)
	(kg/ha)	As % of CB-9			
SR-01	981.45	146.45	40.52	11.17	7.61
SR-02	678.21	101.20	36.93	10.10	5.91
SR-03	618.65	92.32	35.94	9.83	5.51
SR-04	716.36	106.90	37.97	9.33	5.71
SR-05	938.43	140.03	36.33	10.63	6.07
SR-06	711.19	106.12	38.63	9.67	6.09
SR-07	727.45	108.55	39.57	10.77	7.05
CB-9	670.15	100.00	36.47	11.93	6.85

Table 4: Fibre quality characteristics of the cultivars in 2002-03 season

Cultivars/ Genotypes	Staple 2.5% span length (mm)	50% span length (mm)	Fibre bundle strength X10 ³ psi
SR-01	27.94	11.18	86.10
SR-02	28.45	11.68	85.35
SR-03	27.94	12.70	85.57
SR-04	28.45	12.19	86.44
SR-05	26.92	11.68	87.41
SR-06	29.46	12.70	86.32
SR-07	26.42	12.19	86.21
CB-9	27.18	12.95	84.93

The highest seed index was found in CB-9 (11.93g). The lowest seed index was found in SR-04 (9.33g). The second highest produced in SR-01 (11.17g). The third highest produced in SR-05 (10.63g). In case of lint index, the highest (7.61) was found in SR-01 and the lowest (5.51) was found in SR-03. It revealed that the highest seed index and /or highest GOT (%) produced highest lint index (Table 4).

Fibre quality:

In case of staple 2.5% span length, SR-06 produced longest (29.46 mm) staple and SR-07 produced shortest (26.42 mm) staple. But SR-02 and SR-04 produced second longest staple and it were 28.45 mm. SR-05 produced the second shortest (26.92 mm) staple. In case of staple 50% span length, SR-03, SR-06 and CB-9 produced approximately same length (Table 4). In case of fibre bundle strength, all the cultivar produced the approximately same strength of the fibre. Although Table 5 indicated that SR-06 had good fibre properties.

CONCLUSION

Remarkable differences of yield and quality were found among the various characteristics of 7 genotypes and one cultivar during the experimentation. Genotype SR-05 produced the highest seed cotton yield followed by SR-01, which were 40.57% and 31.81%, respectively, higher than genotype CB-9 (control). Boll weight of the cultivar was comparable to that of the commercial check CB-9. Beside, average weight of seed cotton/ boll (5.68g) was higher which resulted highest seed cotton yield. Farmers prefer this cultivar because of its high yield. Though bundle strength of all the genotypes were same but fibre length was highest in SR-06. The

genotype SR-05 proved itself as a high yield potential cultivar over the existing variety (CB-9). Some desired plant characters eg., 50% flowering days, 50% boll split days, weight of seed cotton/ boll, seed cotton yield and fibre bundle strength were possessed better by this genotype.

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TOXIC EFFECTS OF INSECTICIDES AGAINST RICE BROWN PLANTHOPPER AND ITS PREDATORS

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ABSTRACT

An experiment was conducted in a net house and a laboratory to determine the effect of cypermethrin (Cymbush) and carbofuran (Brifer) against the rice brown planthopper (*Nilaparvata lugens* (Stal)) and its predators, *Micraspis discolor* (lady bird beetle) and *Lycosa pseudoannulata* (Spider). Toxic effect of the insecticides was assessed on the basis of percentage corrected mortalities of brown planthopper and the predators under laboratory condition at 24, 48 and 72 hours after treatment. *Cypermethrin* @ 0.05 kg a.i./ha caused 100% mortality of insect populations at different time intervals. All the doses of carbofuran caused a good mortality of *N. lugens* at different time intervals and was effective at higher dose. *Cypermethrin* @ 0.04 kg a.i./ha and carbofuran @ 0.5 kg a.i./ha were very effective against *N. lugens*. The effectiveness of cypermethrin decreased and carbofuran increased with increasing time interval. The former at 0.05 kg a.i./ha was highly toxic and 0.01 kg a.i./ha was less toxic to both the predators. Carbofuran at 0.5 kg a.i./ha was least toxic to the predators. Between the two predators, *L. pseudoannulata* was more susceptible to the insecticides than *M. discolor*.

Key words : Cypermethrin, carbofuran, *Nilaparvata lugens*, *Micraspis discolor*, *Lycosa pseudoannulata*.

INTRODUCTION

Rice is the main staple food for more than two billion people in Asia and four hundreds of millions in Africa and Latin America (Anon, 1985). Rice covers about 74.35 % of the total cropping area is grown throughout the year in Bangladesh. It is an ideal host for many species of insect pests. In Bangladesh, 175 species of insect pests have been recorded on rice (Kamal, 1998). This crop suffers heavy loss every year from insect pests. Of them, the rice brown planthopper (BPH), *Nilaparvata lugens* (Stal), is widespread and a threat to rice production in many parts of Bangladesh. The BPH was formerly a minor pest in most tropical countries of Asia. Following the introduction of insecticides and modern semi-dwarf rice varieties in the 1960's, it became the most devastating pest of rice in Asia. Large scale

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damage by the pest has been reported from India, Indonesia, Philippines, Sri Lanka and Bangladesh since the early 1970's (Sogawa & Cheng, 1979). The BPH has become a major problem for rice production in several parts of Bangladesh in recent years. *N. lugens* is mainly a pest of irrigated rice, but it can also become abundant in rainfed environments. It is also a pest in upland rice (Reissing *et al.*, 1985). It infests rice at all stages of its growth. Low infestation causes reduced plant height, vigour and tiller production, while heavy infestation turns the plants yellow which dry up rapidly. At early infestation, round yellow patches appear in the field which soon turn brownish due to drying up of the plants.

N. lugens is a vascular feeder and damages plants by sucking sap from the mesophyll and blocking the xylem and phloem by laying egg masses in the midribs of leaf blade and the leaf sheath. This feeding damage is commonly referred to as hopper burn. The patches of infestation may spread out and cover the entire field. It also acts as a vector of the virus diseases viz. grassy stunt, ragged stunt and wilted stunt (Chen & Chiu, 1981).

Natural enemies are often important biocontrol agents of BPH in nature. More than 100 species of natural enemies of leafhoppers and planthoppers have been reported (Dyck & Orlido, 1977). Predation is common among insects and some of the most successful cases of biological control have been possible through predators. The predacious coccinellid beetles, commonly known as lady bird beetles are considered to be of great economic importance in the agroecosystems. They have been successfully employed in the control of many injurious insects (Agarwala *et al.*, 1988; Nasiruddin & Islam, 1979). *Micraspis discolor* is one of the most important species of coccinellids which is found as a predator of nymphs and adults of BPH (Samal & Misra, 1985). Although it is widely distributed in Bangladesh and successfully survives and develops on BPH in rice field, the activity or performance of this predator on this pest has not been evaluated properly. The wolf spider, *Lycosa pseudoannulata* (Boesenberg et Strand) is one of the most important predators of BPH and can consume 15-20 adult planthoppers per day (Samal & Misra, 1975). The feeding efficiency of it has been estimated to be 24 nymphs or adults of *N. lugens* per day. It may serve as an effective biocontrol agent of BPH in Bangladesh.

The most commonly used method of controlling BPH in Bangladesh is the application of insecticides which cause several problems such as development of insecticide resistance to pest insects, environmental pollution and undesirable effects on non-target organisms including the natural enemies of the target pests (Kiritani, 1979). Some insecticides have disrupted natural enemy complexes and induced resurgence of the target pests and outbreak of secondary pests (Heinrichs, 1994). In contrast, use of selective insecticides that are less toxic to natural enemies than to pests should conserve natural enemy populations and the surviving natural enemies may suppress the pest populations, which in turn will reduce the rate of insecticide application. Considering the above facts the present study was undertaken to evaluate the effectiveness of two insecticides in controlling BPH under laboratory condition and to find out the doses of insecticides least toxic to the predators, *M. discolor* and *L. pseudoannulata* under laboratory condition.

MATERIALS AND METHODS

The experiment was carried out in a net house and a laboratory of the Entomology Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh from March to July, 2002. Two insecticides, carbofuran (Brifer 5G) and cypermethrin (Cymbush 10EC) were selected for their evaluation on adult stages of the predatory lady bird beetle, *M. discolor* and wolf spider, *L. pseudoannulata* in association with BPH.

Collection and rearing of BPH

Gravid females of BPH were collected with the help of an aspirator from infested rice fields of Bangladesh Agricultural University (BAU), Mymensingh. Immediately after collection, the insects were placed in test tubes of medium size (15 cm). The mouth of the test tubes were then closed with pieces of fine nets and

fastened with rubber bands. The collected insects were then brought to the net house of BINA and reared in a net house to build up a large population. The gravid females were immediately released on 30-40 days-old rice plant of TN 1 variety grown in pots and then the pots were placed in a tray (0.75 x 0.5 x 0.2 m) filled with water to one third of its height, so that the soil could not dry. The potted rice plants were covered with rearing cages (0.9 X0.5 m). The plants were observed for egg laying everyday. For a continuous supply of 30-40 days-old rice plants, TN 1 seeds were sown in seed beds at an interval of 15 days regularly starting well ahead of commencement to the experiment. Then 15-20 days-old seedlings were transplanted in pots (35 cm height and 25 cm diameter) and containing 3.0-3.5 kg soil. The TN 1 plants (3 hills/pot transplanted at the rate of 2 seedlings/hill) were allowed to grow for 30-40 days under net house condition. The pots were kept in another same size tray filled with water as previously described. All recommended cultural practices including fertilizers and insecticide applications were followed for optimum plant growth. carbaryl (Sevin 10 %) dust was used whenever necessary to protect the BPH from ants.

For egg laying purpose, adults of BPH were released in caged fresh rice plants on every Sunday and Wednesday. The gravid females were transferred from one used plant to another fresh plant with the help of an aspirator. After removal of the adults, the plants were kept under cages for sufficient time so that the eggs could hatch and the nymphs could reach the adult stage. Moreover, before using the plants for egg laying, the outer leaf sheaths of each tiller were removed to eliminate any BPH populations from the plants. After hatching of eggs into nymphs, they were provided with sufficient food plants for their growth and development. As soon as most of the insects from the new hatching became adults, the females and the males were transferred to another cage with fresh plants twice a week as mentioned earlier. These insects were preserved in new cages with dates of egg laying marked on them. The BPH were provided with fresh plants for their food as and when necessary. In this way, its populations of uniform age were established and within 3-4 generations, sufficient number of insects became available for the production of required number of nymphs and adults for the experiments.

Collection and rearing of the lady bird beetle

The lady bird beetle was maintained in the net house. For this purpose adult beetles were collected from rice field of BAU farm and reared in earthen pots (20 cm height and 25 cm diameter) covered with Mylar cage. Hard plastic cylindrical device, length 45 cm and diameter 16 cm. the upper portion of the cage covered with nylon net, the net was attached with the cage by gum). Third instar BPH nymphs on 30-40 days-old potted rice plants were offered to the beetles for their food. Mating of the beetles occurred inside the cage and they laid their eggs on those plants. The eggs were separated in Petri-dishes (11 x 2 cm). After hatching of eggs, grubs were transferred into test tubes (20 cm). Only one grub was reared in a test tube providing the same food as supplied to their parents. The newly emerged adults were sexed and confined in pairs in separate test tubes for mating and egg laying.

Collection and rearing of wolf spider

Some sexually mature adults of the wolf spider and adult spiders with egg sac were collected from the seed bed of the experimental rice plots of BINA by using an aspirator. The collected spiders were kept immediately in test tubes individually. Since the spiders are strongly cannibalistic in nature, they were confined individually in 15 x 7 cm glass pots and supplied with different stages of BPH on one or two 12 cm long rice stem wrapped with wet cotton. When all of the spiderlings detached from the mother after 2-3 days of hatching, they were transferred to other pots of the same size. To minimize cannibalism, small pieces of rice straw were put inside the pots, thus giving chance to separate the spiderling from one another. Since, wolf spiders prefer to live at comparatively low temperature and shady areas, they were reared in the laboratory at room temperature (27± 20 C).

Net house screening

To determine the toxic effect of insecticides on BPH, lady bird beetle and wolf spider, an experiment was conducted in a net house of BINA. Seeds of TN1 rice variety were shown in a pot on 3rd March 2002. Seedlings of 30-40 days-old were transplanted in plastic pots and kept in a net house. Cypermethrin was sprayed on these potted plants @ 0.05, 0.04, 0.03, 0.02 and 0.01 kg a.i./ha and carbofuran was applied in the soil @ 0.5, 0.4, 0.3, 0.2 and 0.1 kg a.i./ha at 20 days after transplanting from seed bed. The experiment was laid out in a completely randomized design with three replications.

Toxicities of carbofuran and cypermethrin were determined at five dosages as mentioned above to adult stages of lady bird beetle and wolf spider and 3-4 instars of brown plant hopper. Water was applied as control.

Ten adults of the predators per replication were treated separately at 24,48 and 72 hours after treatment (HAT) with insecticides. The adult beetles and spiders were sprayed in caged TN1 rice plants in plastic pots infested with BPH in the net house. There were 2 hills (each hill contains 3 seedlings) in each pot. Twenty days after planting of the seedlings, BPH in different numbers (100-120) were released on the plant in the pot. Adult predators were released on to the BPH infested plants in separate pots 2-3 days after infesting and then insecticides were sprayed. The control pots with TN1 rice plants with BPH and predators were sprayed with water only. Mortality of adult predators was recorded at 24, 48 and 72 HAT. At every time interval mortality of BPH sprayed with insecticides without association of adult predators in the net house was also obtained in the same way. All three parameters were considered separately.

Recording of insect mortality under laboratory condition

The insect mortalities were converted into corrected mortalities with the help of the following formula (Abbott, 1925) :

$$\text{Corrected mortality (\%)} = \frac{P - P'}{P - T} \times 100$$

Where,

P is the total population used

P' is the mortality in treated area

T is the mortality in control

Statistical analysis

Data obtained from the net house experiment in the laboratory were analyzed for two factors completely randomized design (CRD). The means were compared according to Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Effect of insecticides on the mortality of BPH

The corrected mortalities of BPH among various treatments ranged from 30 to 100 % at 24 HAT, 36.7 to 100 % at 48 HAT and 53.3 to 100 % at 72 HAT (Table 1). Cypermethrin gave the highest mortality (100%) of BPH after 24 HAT at both 0.05 and 0.04 kg a.i./ha and the lowest mortality (73.3%) at 0.02 and 0.01 kg a.i./ha. In case of carbofuran, the highest mortality (73.3%) was recorded from 0.5 kg a.i./ha and lowest mortality (30%) was recorded from 0.1 kg a.i./ha. In all the treatments, mortalities (%) were statistically dissimilar from each other in respect of high and low doses but identical mortalities were found between low doses of cypermethrin and high carbofuran.

Table 1. Mortality of brown planthopper at different doses of insecticides

Insecticides	Rate (kg or lit/ha)			Corrected mortality (%)		
	Formulated	a.i.	24 HAT	48 HAT	72 HAT	
Brifer 5G	10	0.5	73.3 c	93.3 b	100.0	
	8	0.4	70.0 c	d 80.0 c	83.3	
	6	0.3	63.3 d	66.7 d	73.3	
	4	0.2	43.3 e	40.0 f	53.3	
	2	0.1	30.0 f	36.7 f	53.3	
Cymbush 10EC	0.5	0.05	100.0 a	96.7 a	100.0	
	0.4	0.04	100.0 a	96.7 ab	76.7	
	0.3	0.03	83.3 b	76.7 c	66.7	
	0.2	0.02	73.3 c	63.3 d	63.3	
	0.1	0.01	73.3 c	53.3 e	53.3	
	LSD at (0.05)			7.617	5.501	NS

Means followed by same letter in columns are not significantly different

Values are averages of three replications

HAT=Hours after treatment

Both the insecticides caused mortalities of BPH in 48 HAT. Although they had remarkable effects on BPH, the overall effect of cypermethrin at all the doses was found to be similar to carbofuran at high doses. A low dose of cypermethrin gave better performance than the lower dose of carbofuran. Cypermethrin caused mortalities ranging from 63.3 to 100 % and carbofuran caused mortality ranging from 36.7 to 93.3 %. In all the treatments mortalities were statistically dissimilar from each other in respect to high and low doses but identical results were found between low doses of carbofuran and higher doses of cypermethrin.

Mortalities of BPH at 72 HAT at different doses of both the insecticides did not differ significantly. The highest mortalities were observed as 100 % at 24,48 and 72 HAT of cypermethrin and for this reason it may be said that this insecticide was highly effective to BPH. Carbofuran was also effective to control this insect at 72 HAT. The effectiveness cypermethrin against BPH decreased considerably with the increase of time but mortalities increased by carbofuran. These results have been supported by Krishnaiah et al. (1982) and Anonymous (1988 and 1991) by using various types commercial formulations of cypermethrin and carbamate insecticides including carbofuran.

Effect of insecticides on the mortality of lady bird beetle

Corrected mortalities (%) of the lady bird beetle among various treatments ranged from 6.7 to 100 % at 24 HAT, 10 to 76.7 % at 48 HAT and 10 to 60 % at 72 HAT (Table 2). At 24 HAT, corrected mortalities were highest (100%) at 0.05 kg a.i./ha of cypermethrin which were statistically dissimilar with all other treatments. There was no remarkable difference on the mortality of the beetle among the doses of carbofuran. Lowest mortalities were obtained from carbofuran at 0.1 kg a.i./ha. Cypermethrin caused mortalities ranging from 53.3 to 100 % and carbofuran from 6.7 to 26.7%.

At 48 HAT, cypermethrin caused the highest mortality (76.7%) at 0.05 kg a.i./ha and lowest mortality (33.3%) at 0.01 kg a.i./ha. On the other hand, carbofuran caused the highest mortality (33.3%) at 0.5 kg a.i./ha and lowest mortality (10 %) at 0.1 kg a.i./ha. In all the treatments, mortalities were significantly different from each other in respect of high and low doses but identical results were found in first and second highest doses of cypermethrin. In case of carbofuran, first and second highest doses, and second, third and fourth doses were identical.

At 72 HAT, the highest mortalities were found from higher doses of cypermethrin and lowest mortality from the lowest dose of carbofuran. The highest mortalities were recorded 100 % at 24 HAT, 73.3 % at 48 HAT and 60 % at 72 HAT from cypermethrin. From the above findings it may be said that cypermethrin was highly toxic to the predatory lady bird beetle but carbofuran did not reduce it to that extent. It was also found that the toxic effect of cypermethrin was reduced with the increase of time but this effect was evident in case of carbofuran. Sharma et al. (1991) found high toxicity of the cypermethrin at 0.04 kg a.i./ha to the predatory beetle. Rabbi et al. (1993) found 70 % mortality of the same by Fastac 2 EC at 1 day after treatment and Rajendram (1994) showed that carbofuran did not appreciably reduce the insect predator population. This findings of these workers support the result of this study.

Table 2. Mortality of *M. discolor* at different doses of insecticides

Insecticides	Rate (kg or lit/ha)		Corrected mortality (%)		
	Formulated	a i. 24	HAT 48	HAT 72	HAT
Brifer 5G	10	0.5	26.7 e	33.3 d	33.3 d
	8	0.4	26.7 e	30.0 de	30.0 e
	6	0.3	23.3 e	23.3 e	26.7 f
	4	0.2	23.3 e	23.3 e	26.7 f
	2	0.1	6.7 f	10.0 f	10.0 g
Cymbush 10EC	0.5	0.05	100.0 a	76.7 a	60.0 a
	0.4	0.04	83.3 b	73.3 a	53.3 b
	0.3	0.03	63.3 c	63.3 b	46.7 c
	0.2	0.02	63.3 c	46.7 c	46.7 c
	0.1	0.01	53.3 d	33.3 d	26.7 f
	LSD at (0.05)		9.329	8.795	2.109

Means followed by same letter in columns are not significantly different

Values are averages of three replications

HAT=Hours after treatment

Effect of insecticides on the mortality of wolf spider

Corrected mortalities (%) of the wolf spider, among the treatments differed significantly and ranged from 16.7 to 100% at 24 HAT, 20 to 83.3% at 48 HAT and 23 to 63.3% at 72 HAT. Mortality data of wolf spider at 24 HAT, cypermethrin showed a significant difference among the treatments. No insect survived when cypermethrin was sprayed at 0.05 kg a.i./ha. The lowest number of wolf spider's mortality was found at 0.1 ka a.i./ha of carbofuran. Most of the doses of Brifer 5G had given statistically identical results (Table 3).

At 48 HAT, cypermethrin significantly reduced the number of wolf spider. The highest mortality (83.3%) was recorded from 0.05 kg a.i./ha and lowest (36.7%) was recorded from 0.01 kg a.i./ha of cypermethrin. On the other hand, carbofuran caused the highest mortality (33.3%) at 0.5 kg a.i./ha and lowest (20.0%) at 0.1 kg a.i./ha. Similar and dissimilar results were found between high and low doses in both the insecticides. Most of the doses of carbofuran (0.5, 0.4, 0.3 and 0.2 kg a.i./ha) and 0.03 and 0.02 kg a.i./ha of cypermethrin were similar and showed dissimilar mortalities.

Table 3. Mortality of *L. pseudoannulata* at different doses of insecticides

Insecticides	Rate (kg or lit/ha)			Corrected mortality (%)	
	Formulated	a.i. 24	HAT 48	HAT 72	HAT
Brifer 5G	10	0.5	30.0 e	33.3 de	40.0 b
	8	0.4	30.0 e	33.3 de	36.7 bc
	6	0.3	26.7 e	30.0 de	36.7 bc
	4	0.2	26.7 e	26.7 ef	30.0 cd
	2	0.1	16.7 f	20.0 f	23.3 d
Cymbush 10EC	0.5	0.05	100.0 a	83.3 a	63.3 a
	0.4	0.04	86.7 b	73.3 b	60.0 a
	0.3	0.03	73.3 c	56.7 c	43.3 b
	0.2	0.02	70.0 c	56.7 c	36.7 bc
	0.1	0.01	53.3 d	36.7 d	36.7 bc
	LSD at (0.05)		7.167	8.795	8.227

Means followed by same letter in columns are not significantly different.

Values are averages of three replications

HAT=Hours after treatment

Toxicity of cypermethrin and carbofuran on wolf spider varied significantly at 72 HAT. Highest mortality was recorded from the highest dose of cypermethrin and lowest was recorded from lowest dose of carbofuran. In all the treatments, most of the results were statistically similar. From cypermethrin recorded highest mortalities 100%, 83.3% and 63.3% at 24, 48 and 72 HAT respectively. From the above findings it may be said that cypermethrin was highly toxic to wolf spider but carbofuran did not do so. It was also found that the toxic effect of cypermethrin was reduced with the increase of time but this effect was not evident in case of carbofuran. Similar results were obtained by Rahman and Uthamasamy (1983), Heinrichs et al. (1984), Fabellar and Heinrichs (1984), Thang et al. (1987) and Tanaka et al. (2000) by using the same groups of different insecticides. A contradictory result was found by Khusakul et al. (1979).

Comparative effects of insecticides on mortality of the pest and predators at 24 hours after treatment

Cypermethrin caused 100 % mortality of all BPH, lady bird beetle and spider (Fig.1). Carbofuran caused 70 % of BPH and less than 30% mortalities of lady bird beetle and wolf spider (Fig.2). These results indicated that both the insecticides were highly toxic against BPH but carbofuran was more acceptable in respect of pest mortality and predator survivability as well as environmental safety.

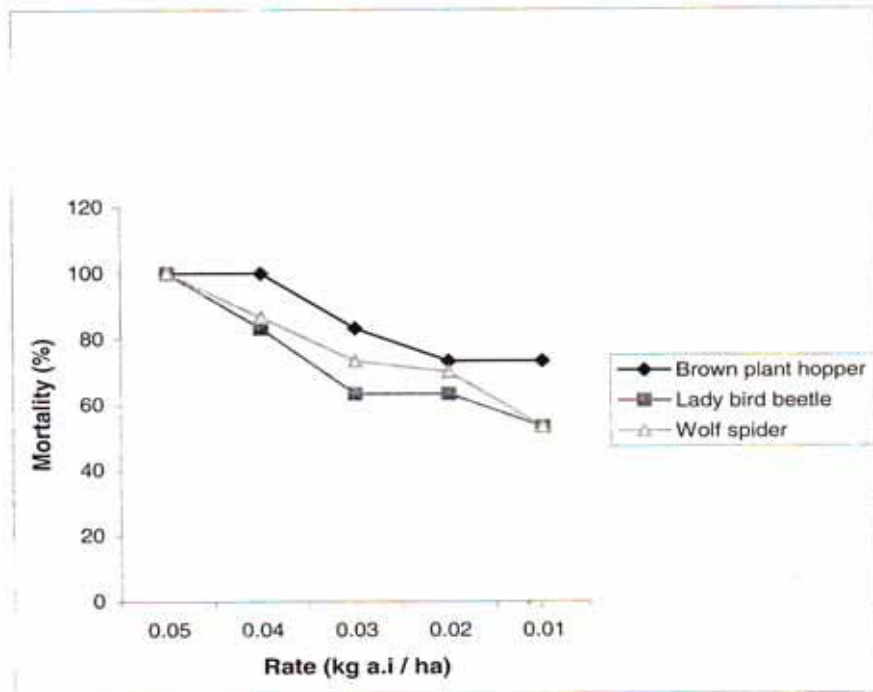


Fig.1 Effect of cypermethrin on brown planthopper, predatory lady bird beetle and wolf spider at 24 hours after treatment

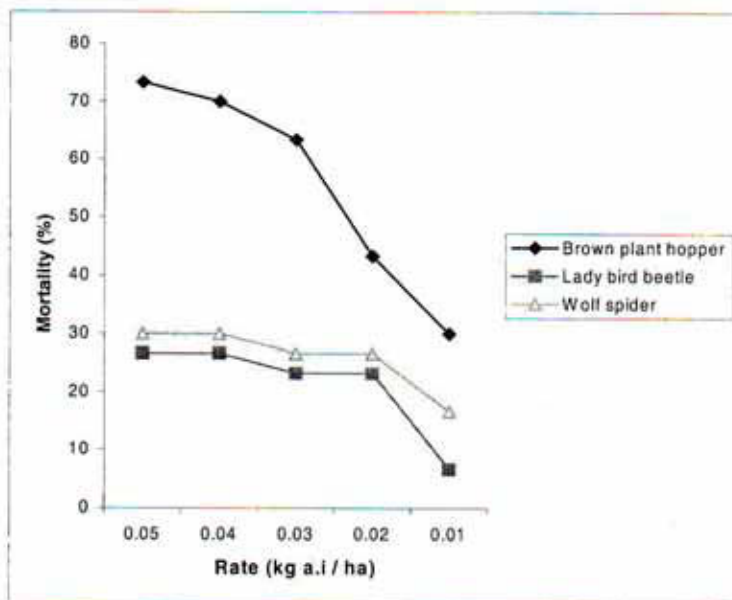


Fig.2 Effect of carbofuran on brown planthopper, predatory lady bird beetle and wolf spider at 24 hours after treatment

Comparative effects of insecticides on mortality of the pest and predators at 48 hours after treatment

Cypermethrin caused 100% mortality of BPH, less than 80% mortality of lady bird beetle and more than 80% mortality of wolf spider (Fig. 3). Carbofuran caused above 90% mortality of BPH, less than 30% mortality of both the predators (Fig. 4). All the doses gave significant response against BPH.

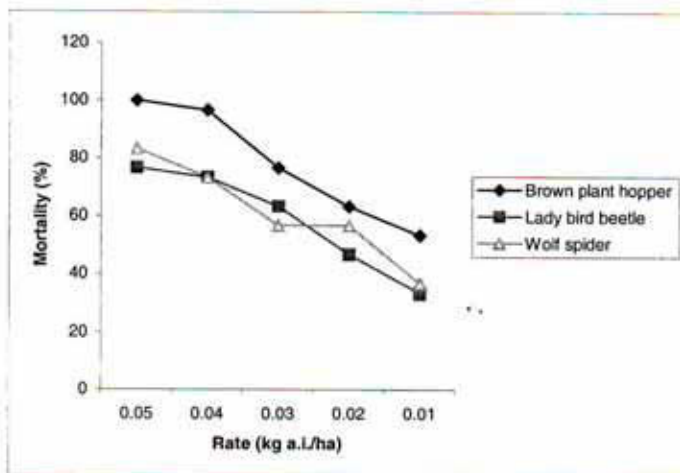


Fig.3 Effect of cypermethrin on brown plant hopper, predatory lady bird beetle and wolf spider at 48 hours after treatment

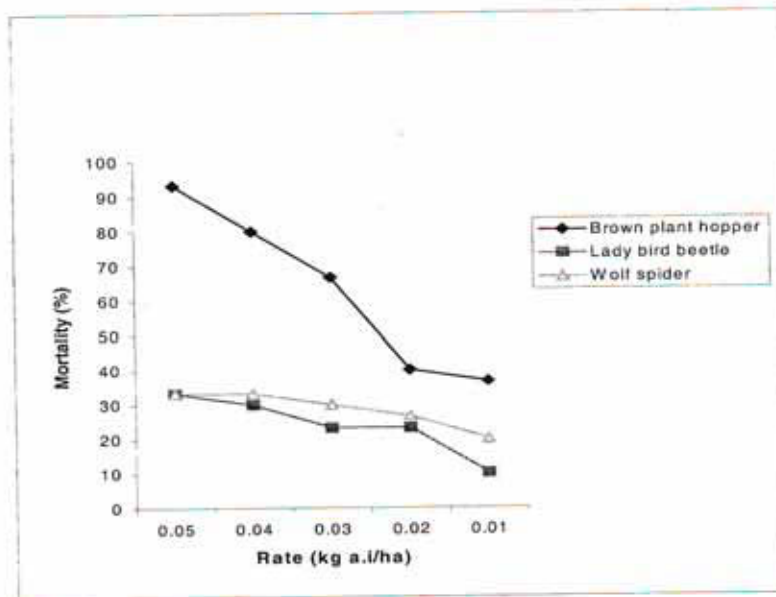


Fig.4 Effect of carbofuran on brown plant hopper, predatory lady bird beetle and wolf spider at 48 hours after treatment

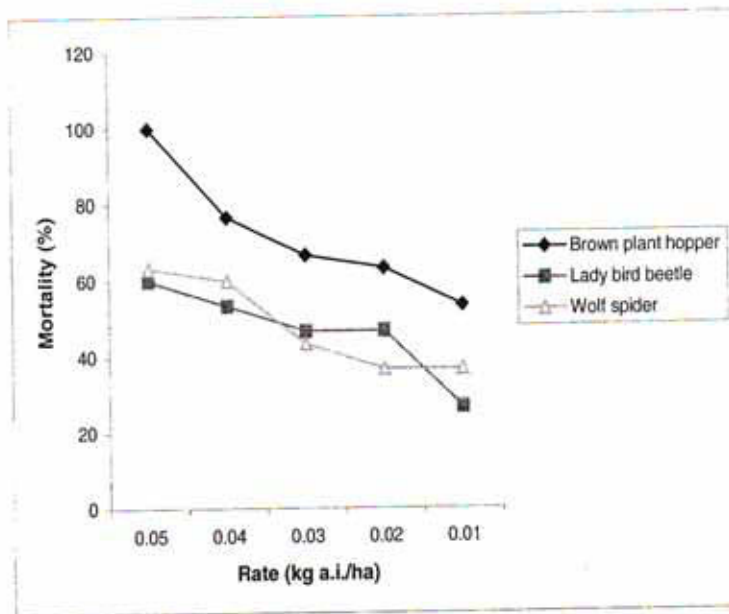


Fig.5 Effect of cypermethrin on brown plant hopper, predatory lady bird beetle and wolf spider at 72 hours after treatment

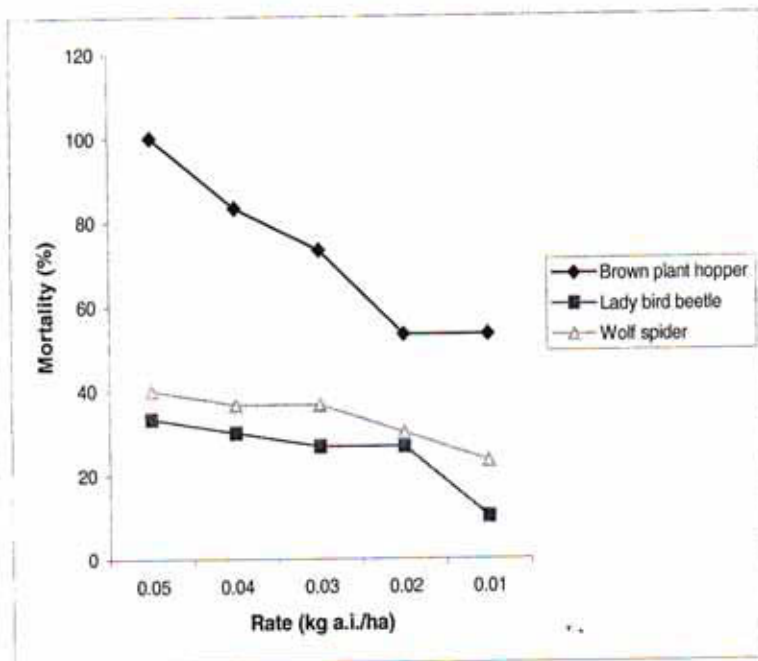


Fig.6 Effect of carbofuran on brown plant hopper, predatory lady bird beetle and wolf spider at 72 hours after treatment

Comparative effects of insecticides on mortality of the pest and predators at 72 hours after treatment

Cypermethrin caused 100% mortality of BPH, more than 50% mortality of the predator lady bird beetle and 60% mortality of wolf spider (Fig. 5). Carbofuran caused 100% mortality of BPH, above 30% mortality of lady bird beetle and 40% mortality of wolf spider (Fig. 6). At 72 HAT cypermethrin and carbofuran were highly effective to control BPH but the former was slightly more toxic to predators than the later. These findings show that wolf spider is more susceptible to insecticides than lady bird beetle.

The present study results revealed that carbofuran and cypermethrin @ 0.4 kg a.i./ha and 0.01 kg a.i./ha were effective in killing BPH. But carbofuran @ 0.4 kg a.i./ha was most effective against this pest in respect of predator survivability as well as environmental safety and it could be recommended at the farmers level.

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SWINE RESOURCES IN THE HINDU KUSH HIMALAYAS REGION: A NEED FOR MOLECULAR GENETIC CHARACTERIZATION

K.NIDUP¹

ABSTRACT

This paper briefly reviews swine (domestic and wild pigs) genetic resources of the Hindu Kush Himalayas (HKH) region and proposes a need for molecular genetic characterization of these important animal genetic resources using microsatellites and mitochondrial DNA (mtDNA) technologies. The HKH region considered in this paper includes whole or part of Afghanistan, Bangladesh, Bhutan, north and north-east India, Nepal and Pakistan. Bhutan has approximately 41,401 heads of indigenous pigs constituting about 86% of the total pig population in the country. India has total domestic pig population of 12.8 millions of which 85% are indigenous breeds. Nepal has over 550,000 heads with 81% of the population as indigenous breeds. This rich and broad distribution of both domestic and wild pigs can provide unique opportunity to analyze the origins of modern domestic pig lineages. However, beside molecular genetic study conducted on Desi pigs of north and north-east India using FAO data recommended microsatellites, there is no other evidence of such or similar studies. Use of microsatellites and mtDNA technologies to study both domestic and wild pigs in the HKH region would be interesting and important research for consideration. Microsatellites are best markers for evaluating the genetic diversities of domestic animals because of their abundance, even distribution in the genome, high polymorphism and ease of genotyping. To complement microsatellites method, mtDNA is often used. mtDNA is particularly useful in inferring phylogenetic relationship between closely related species within the same family or even within the same species. In short, mtDNA is used to make inference about population structure and recent population history. The information collected from such studies could help devise an appropriate mechanism for conservation of biodiversity and sustainable use of swine genetic resources in the HKH region.

Key Words: HKH region, domestic and wild pigs, phylogenetics, microsatellites, mtDNA

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INTRODUCTION

The Hindu Kush-Himalayan (HKH) region stretches 3,500 km from Afghanistan in the west to Myanmar in the east. The HKH region considered here include whole or part of six countries (See Figure 1): Afghanistan, Bangladesh, Bhutan, north and north-east India, Nepal and Pakistan.

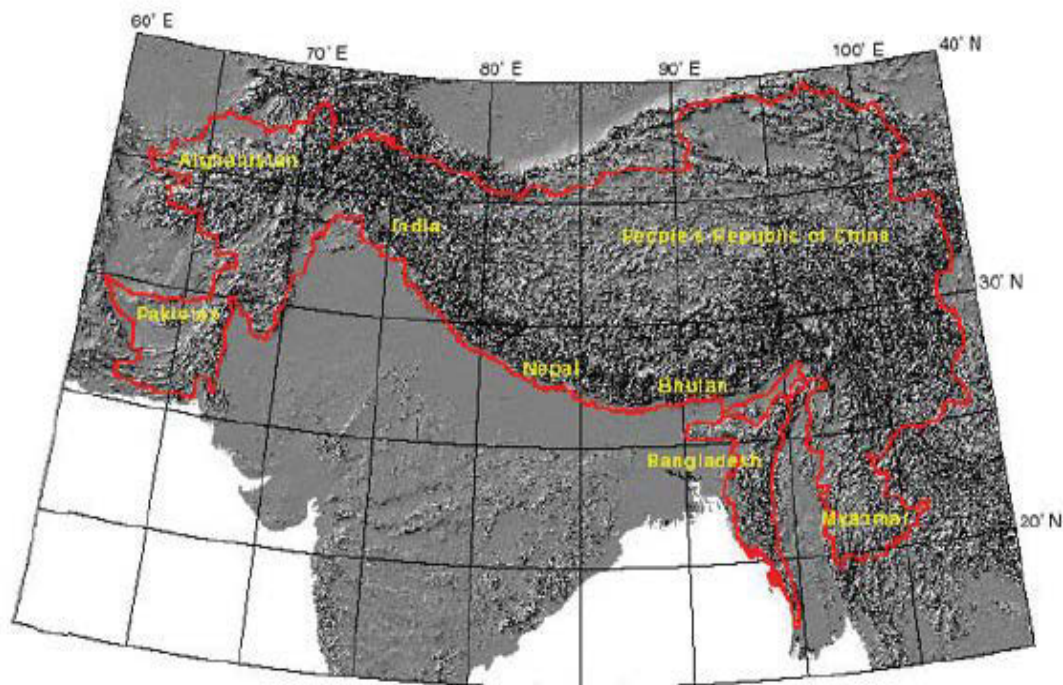


Figure 1: HKH region as identified by ICIMOD. (Source: ICIMOD)

Farming in HKH region is predominantly mixed crop-livestock farming systems. Geographic and topographic variations have combined to provide a microcosm of the earth's vegetation types and farming systems. Livestock research and development have been focused mainly on large ruminants (Abington, 1992). There is limited scientific information available on small animals especially on the pigs.

Resource Status and Study of Domestic Pigs in HKH Region

The pig was one of the first animals likely to have been domesticated over 5,000 years ago (Rothschild & Ruvinsky, 1998) and it is now the most abundant and widely distributed of all domestic animals (Ollivier et al., 2001). Several lines of evidence suggest that domestic pigs were derived from wild pigs (*Sus scrofa*). To date there are likely over 600 breeds or lines of pigs worldwide (Ollivier et al., 2001) and large numbers of these are now in danger of extinction and others are threatened by inefficient use and loss due to cross breeding (Rothschild, 2003).

Bhutan has approximately 41,401 head of indigenous pigs (MoA, 2001) constituting about 86% of the total pig population in the country. The two main types of indigenous pigs recorded are *Sapha* and *Dompha* (Figure 2).

Sapha is smaller than Dompha, and both are black in colour. The College of Natural Resources and the Renewal Natural Resources Research Centre are working on physical characterization of these pig breeds (Tshewang, 2004; Yuden, 2005).

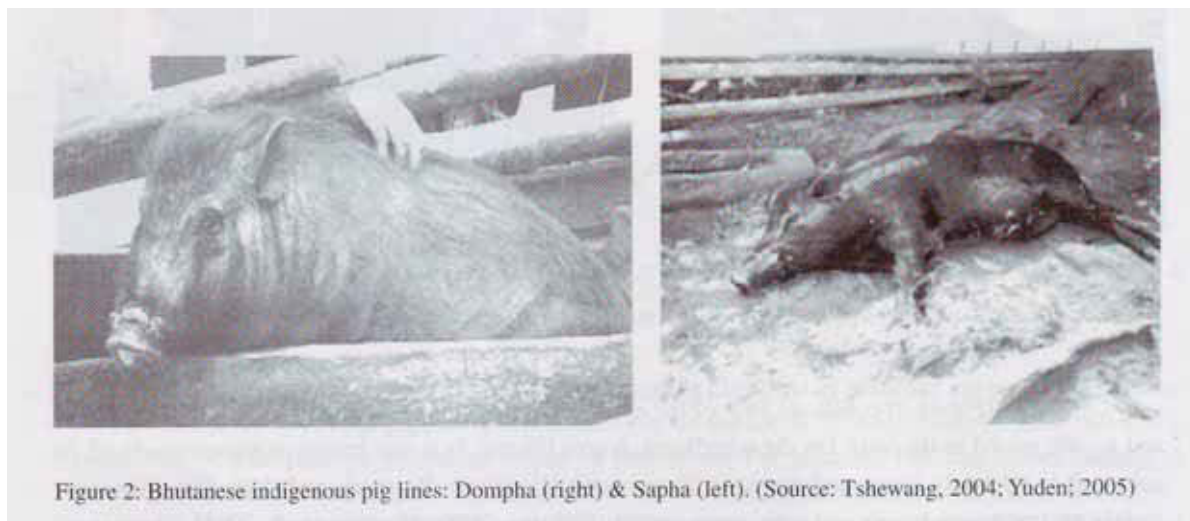


Figure 2: Bhutanese indigenous pig lines: Dompha (right) & Sapha (left). (Source: Tshewang, 2004; Yuden, 2005)

As of now, there is no genetic or molecular data available on Bhutanese pigs. Therefore, the urgent need is to genetically characterize and build necessary molecular data for promotion, use, and conservation of pig genetic resources in Bhutan.

India has a total domestic pig population of 12.8 million of which approximately 85% are indigenous breeds (CI, 2001). The areas under HKH region of the Indian sub-continent are North India and north-east India. The two main indigenous *Desi* pigs of North India and North-east India were genetically characterized using the panel of 23 FAO recommended microsatellites (Kaul et al., 2001; ICAR, 2005). However, there is no record of mitochondrial DNA sequences generated (ICAR, 2005). Therefore, there is a need to generate mitochondrial DNA sequences for these two populations of pigs to validate and compare with the findings of Kaul et al. (2001) and other related studies (Huang et al., 1999; Li et al., 2000; Martinez et al., 2000; Jiang et al., 2001; Kim et al., 2001; Fan et al., 2002; Zhang et al., 2003; Li et al., 2004; Larson et al., 2005) across the world.

In Nepal, there are no current official data on pig population (Joshi, *Personal communication*) but records from 75 districts suggests 550,000 heads with 81% of the population as indigenous breeds (Dhaubhadel, 1992). According to Dhaubhadel (1992), Nepal has two main types of indigenous pig breeds, namely *Chwanche* and *Hurra*.



Figure 3: Indigenous pigs of Nepal. Left: Chwanche; Right: Hurra. (Source: Courtesy of Joshi, 2005)

Chwanche (Figure 3) constitute 58% of the entire pig population. It is small in size, black in colour, and mostly reared in the hills. On the other hand, *Hurra* (Figure 3) is rust brown or sometimes black in colour. It is relatively larger and reared in Terai region (Figure 4). Research and studies on pigs were mainly on improving breeds and their management (Shrestha, 2000; Shrestha et al., 2001). There is no molecular or genetic data generated so far. Therefore, it is important to generate both microsatellite and mitochondrial sequences data through this study for judicious use and conservation of pig genetic resources in Nepal.

Domestic pig farming in Afghanistan, Pakistan, and Bangladesh is virtually non-existent. There are very few or negligible minority ethnic groups in these countries rearing pigs (Afzal & Habib, *Personal communication*, 2005). Because of religious edict, the issue of pig rearing in these parts of HKH region has always been very sensitive, even among animal scientists (Afzal, *Personal communication*).

Resource Status and Study of Wild Pigs in HKH Region

Wild pigs (*Sus scrofa*) include both feral hogs (domestic swine that have escaped captivity) and wild boar believed to be native to Eurasia. Wild boar and feral hogs (Figure 4) have been found to hybridize freely (Barrett & Birmingham, 1994), therefore, the term wild pig is appropriate as a generic term for these animals. *Wild pigs* can cause a variety of damage including the destruction of crops, pastures, farm ponds and native plants, and they can cause soil erosion (Barrett & Birmingham, 1994). There is also a report of wild pigs preying on lambs (Pavlov & Hone, 1982) in New South Wales, Australia. In western Punjab state of India, wild pigs have been wreaking havoc on the cultivated fields and have been described by the locals as a "perennial menace" (Bedi, 2002).

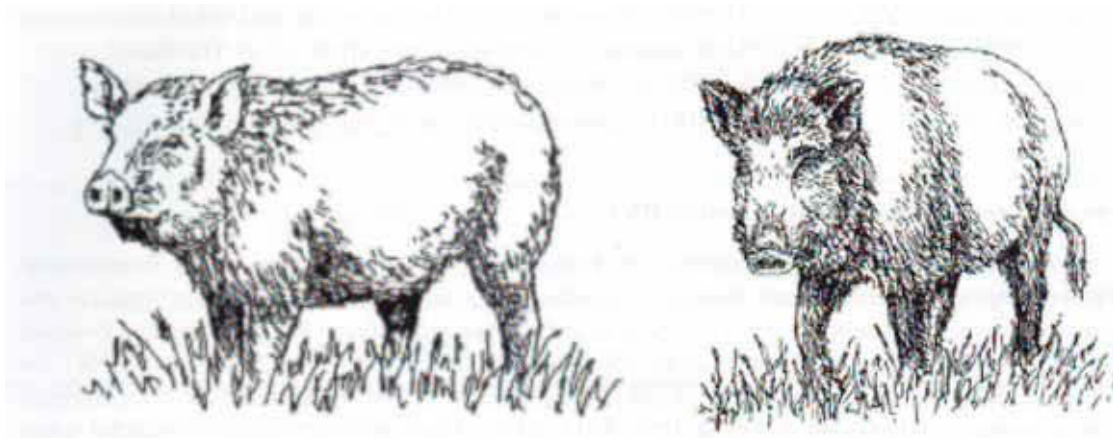


Figure 4: Feral hog (left) and European wild boar (right). Both are the species *Sus scrofa*. (Source: Barrett & Birmingham, 1994)

In Muslim countries of the HKH region, wild pigs are classified as pests and are a total nuisance to the farmers. Therefore, wild pigs are not protected nor do the locals in these countries hunt them. The population of wild pigs are increasing inspite of limitations. For instance, Pakistan allows hunting to wild pigs (Humme, 2005). There is also a report of wild boar being chased across the "Line of Control" toward the Indian Territory by the Pakistani army and the paramilitary border rangers (Bedi, 2002), and sometimes in exchange for culled cattle.

In Bhutan, wild pigs are protected by the Nature Conservation Act (DoF, 2003). However, farmers are allowed to shoot wild pigs if found in their agricultural fields. Once the pig leave the farmers land, they are again protected from hunting by the national act. However this strategy has not maintained a steady wild pig population growth. The general observations over the last few years shown an increased wild pig population, although there are no quantitative or qualitative records. Wild pigs are found in all the four regions (east, west, north and southern regions of Bhutan) because of Bhutan's diverse agroecological zones.

Nepal seems to have sound strategy for the conservation of wild pigs (locally called "Boudyel"). Since 2003, Nepal has launched wildlife farming, breeding and research policies to conserve their very rich biodiversity and bring improvement in the livelihood of the Nepalese people (HMG, 2003; Gajural, 2004). According to this, individuals, groups, and institutions can farm wild pigs. The cost to obtain each seed animal is NRS 10,000 (" US \$ 150.00). An effective mechanism to avoid negative impacts on natural population is also in place (HMG, 2003; Gajural, 2004). There is also a report of farmers in Limitar, Hadikhola region of Nepal, taming wild boar to herd the cattle effectively (Bista, 2003). The meat of wild boar is a rare and costly (NRS 250 per kg) delicacy in Nepalese cuisine.

Across the HKH countries, genetic or molecular studies on wild pigs do not exist. However, this rich and broad distribution of wild pig populations can provide unique opportunity to analyze the origins of modern domestic lineages. Previous morphological and genetic evidence principally place pig domestication in the East (Epstein & Bichard, 1984) and Far East (Giuffra et al., 2000). In additional to this, a recent genetic study suggested multiple centres of porcine domestication across Europe, Asia, and Island Southeast Asia (Larson et al., 2005). Therefore, it will be interesting and worth investigating the origin and relationship of indigenouse domestic and wild pigs across HKH region. The findings would be able to compare and further substantiate the finding of Giuffra et al. (2000), Kim et al. (2002), and Larson et al. (2005). It could also make HKH region as another site of origin of swine domestication.

Use of Microsatellites and Mitochondrial DNA

Microsatellites have been proposed as the best markers for evaluating the genetic diversities of domestic animals because of their abundant, even distribution in the genome, high polymorphism and ease of genotyping (Hammond, 1994; Paszek et al., 1998). The International Society of Animal Genetics and the FAO have recommended a set of 25 microsatellite loci (CGRFA, 2004; FAO, 2004) for evaluating the genetic diversities of pigs as part of the global strategy for the management of farm animal genetic resources (Hammond & Leitch 1998; FAO, 2004). There are many studies conducted using microsatellites on Chinese pigs (Li et al., 2000; Zhang et al., 2003; Li et al., 2004), Iberian pig breed (Martinez et al., 2000), and on Mexican hairless pig (Flores et al., 2001). Several similar studies are underway in many laboratories around the world.

To complement microsatellites studies, mtDNA is often used. mtDNA is an extranuclear genetic material and one of the most frequently used markers in molecular systematics because of its maternal inheritance, haploidy, and rapid rate of evolution (Hartl & Clark, 1997; Sorenson et al., 1999; Nidup, 2003; Nidup et al., 2005). mtDNA is particularly useful in inferring the phylogenetic relationship between closely related species with the same family or even within the same species. In short, mtDNA is used to make inference about population structure and recent population history (Hartl & Clark, 1997; Larson et al., 2005). There are several records of mtDNA sequences being used in pig phylogenetic relationship and genetic diversity studies (Huang et al., 1999; Jiang et al., 2001; Kim et al., 2002; Larson et al., 2005)

CONCLUSION

The HKH region has good resources of both domestic and wild pigs. Employing microsatellites markers and mitochondrial DNA sequences technologies will help to assess genetic relationship between domestic and wild pigs. It will also further extend the molecular genetic analysis of the origin of domestic pigs by analyzing wild and domestic pigs in the HKH region and other parts of the world. In other words, HKH region could be one of the potential sites of the origin of domestic pigs, and microsatellites and mtDNA could unveil this mystery. In addition to this, information collected from such study could help to devise an appropriate mechanism for conservation of biodiversity and sustainable use of wild and domestic pig genetic resources in the HKH region.

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COMBINING ABILITY STUDIES OVER SEASONS IN BRINJAL (*Solanum melongena L.*)

Y. SUNEE THA¹, K.B. KATHIRIA² AND T. SRINIVAS³

ABSTRACT

Combining ability analysis of a 10 x 10 diallel, excluding reciprocals was undertaken for fruit yield per plant, yield components, quality and physiological characters in egg-plant during summer, rainy and late summer seasons. Non-additive gene action was noticed to be preponderant for all the traits studied, during all the seasons. A perusal of the gca effects revealed the lines PLR 1 and JBPR 1 to be good general combiners for fruit yield per plant, during all the seasons studied. These parents had also recorded high per se performance for these trait, during all the seasons, indicating their suitability and importance in breeding programmes for the development of widely adaptable and high yielding hybrids. PLR 1 was also noticed to be a good general combiner for total soluble sugars during all the seasons indicating its potential in the development of adaptable and high yielding hybrids with high total soluble sugars, greatly desired by the consumers. Among the 45 hybrids studied, 22 crosses during summer, 14 crosses during rainy season and 22 crosses during late summer had exhibited significant and desirable sca effects for fruit yield per plant. Of these, eight crosses during summer, nine crosses during rainy season and nine crosses during late summer season had recorded desirable sca effects in addition to high per se performance for the trait. An analysis of these crosses revealed the involvement of a good and a poor general combiner parent for the majority of the crosses; and both good or poor in few cases. The hybrid, PLR 1 x JBPR 1, involved both good combiner parents for fruit yield per plant was identified as a potential and widely adaptable hybrid for commercial cultivation during all the three seasons, while KS 224 x PLR 1 was identified for specific cultivation during contingency situations of late summer

Keywords : Brinjal, Combining Ability, Over seasons, Yield, Yield Components, Quality, Physiological characters

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INTRODUCTION

Brinjal is one of the most common, highly productive and popular vegetable crops. It is quite popular and is widely cultivated as the poor man's vegetable crop, mostly in the rainy season. However, the crop is being increasingly grown during summer season, as an off-season vegetable for its premium price during the season. The summer crop is normally sown during first week of February. However, under contingency conditions of extreme and prolonged winter, sowing of the crop gets delayed, as low soil temperatures adversely effects germination and, therefore, a late summer crop, sown in the second fortnight of February is raised.

Average productivity of the crop is reported to be low, mainly due to non-availability of suitable high yielding varieties/hybrids for the different crop growing seasons (Varghese & Vahab, 1994). Improvement in the productivity levels of the crop is being attempted through the exploitation of hybrid vigour. Egg-plant hybrids with high fruit dry matter and total soluble sugars in addition to low seed weight and total phenols are highly desired by the consumers and, therefore, attract premium price in the market.

Information on combining ability of these traits is, however, a pre-requisite for development of superior hybrids, since it helps in the identification of superior parents with better gca and crosses with high sca effects. Knowledge on the nature of gene action governing quantitative traits is also essential for planning systematic crop improvement programmes. Biometrical estimation of genetic parameters governing yield and yield component characters in egg-plant has been reported by several workers (Chadha, 1993; Wadnerkar et al., 1985; Kumar & Ram, 1987; Patil & Shinde, 1989). Both additive and dominance gene effects, were found to be important, their relative importance varying from character to character and study to study. These studies were based on a few lines in a single environment and hence, are of restricted applicability, as combining ability of the genotypes has been reported to vary with the season and location (Rojas & Sprague, 1952; Baig & Patil, 2002). This is more so in egg-plant, which is grown round the year and is highly influenced by varied agro-climatic conditions (Chadha & Singh, 1982). In this context, the present investigation was undertaken to elucidate information on the nature of gene action and combining ability of round egg-plant genotypes over environments with regards to fruit yield, yield components, quality and physiological characters. The additional aim was to identification of potential round egg-plant hybrids for cultivation during the different crop growing seasons.

MATERIALS AND METHODS

The experimental material comprised of ten elite homozygous lines, namely, KS 224, JB 64-1-2, AB 98-10, AB 98-13, PLR 1, Gandhinagar Local, Bombay Gulabi, Morvi 4-2, Surati Ravaiya and JBPR and their 45 hybrids derived from 10 x 10 diallel mating (excluding reciprocals) of these lines. The hybrids and parents were evaluated along with the check, GBH 1 in a randomized block design with three replications for fruit yield and yield component characters namely, days to first picking, plant height, primary branches per plant, fruit length, fruit diameter, fruit weight and number of fruits per plant at the Main Vegetable Research Farm, Anand, Gujarat during 2004.

Seeds were sown in the nursery during the first week of February 2001 for summer crop, last week of July 2001 for rainy season crop, and last week of February 2002 for late summer crop. Seedling were transplanted 35-40 days after sowing, depending on the growth of seedlings. The normal, healthy and vigorous seedlings of each genotype were transplanted in a single row plot of 6 m length, with a spacing of 90 x 60 cm and the crop was raised following recommended package of agronomical production practices.

Data were recorded on five random, competitive plants tagged for each entry, in each replication and the average values were computed. Observations for plant height and plant spread were recorded at the last picking time. In contrast, data on fruit yield per plant were obtained for each picking (harvest) and the totals were

computed, while data on leaf area per plant were recorded at 90 DAT. The observations on fruit drymatter, total soluble sugars and total phenols were recorded on five random fresh fruits, taken from each genotype in each replication and the mean values were calculated. However, for 1000-seed weight, five random mature fruits were taken for seed extraction and weighing. Further, observations on days to first picking were recorded on plot basis. Estimates of total soluble sugars and total phenols were obtained following the procedures outlined by Dubois *et al.* (1956) and Malik & Singh (1980), respectively; and the values were computed utilizing the formula provided by Sadasivam & Manickam (1992). The estimates of combining ability variances and effects were obtained for each season, using Diallel analysis, Method 2 of Model I, suggested by Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance for combining ability (Table 1) revealed significant mean squares due to *gca* and *sca* for fruit yield per plant, yield components, quality and physiological characters studied during all the seasons, indicating the importance of both additive and non-additive gene actions for these traits. Several workers had also reported similar results for fruit yield (Das & Barua, 2001; Baig & Patil, 2002); days to first picking (Vaghasiya *et al.*, 2000); plant height (Baig & Patil, 2002); plant spread (Singh *et al.*, 1991); fruit dry matter and total soluble sugars (Dahiya *et al.*, 1985); total phenols (Chadha & Sharma, 1991) and leaf area per plant (Chaudhary & Malhotra, 2000). However, *gca* mean squares alone were noticed to be significant for 1000-seed weight during rainy season, while *gca* and *sca* mean squares were both significant during the two summer seasons studied. The studies of earlier workers (Warade, 1986; Barbind, 1990; and Baig & Patil, 2002) also revealed a variation in the estimates of additive and non-additive gene effects with the environment.

Non-additive gene action was, however, found to be pre-ponderant for all the traits studied, during all the seasons indicating the need for heterozygosity in the population and heterosis exploitation for improvement of these traits. The predominant role played by non-additive gene action in egg-plant for fruit yield and yield component characters has also been reported earlier (Patil & Shinde, 1989). Predominance of non-additive gene action for the quality traits studied namely, fruit dry matter (Kapadia, 1995), total soluble sugars and total phenols (Patel, 2003) has also been reported earlier.

A perusal of the general combining ability (*GCA*) effects for parents (Table 2) revealed that none of the parents was good general combiner for all the characters studied, during all the seasons. However, KS 224 was found to be a good general combiner for earliness; AB 98-10 for earliness and fruits drymatter; Morvi 4-2 for earliness and total soluble sugars; Bombay Gulabi for plant height and leaf area per plant; Surati Ravaiya for plant spread and total soluble sugars; Gandhinagar Local for 1000-seed weight; and JB 64-1-2 for fruit drymatter, during all the seasons studied. These parents may, therefore, be used in egg plant breeding programs aimed at improvement of the respective traits.

Details of the good general combiners identified for fruit yield per plant during the different seasons studied are presented in Table 3. The genotypes, PLR 1 and JBPR 1 were observed to be good general combiners for fruit yield during all the seasons studied. These parents had also recorded high per se performance for the trait, compared to the general mean, during all the seasons studied in the present investigation. Further, their hybrid, (PLR 1 x JBPR 1) was identified as one of the most promising hybrids during all the seasons studied. Hence, these parents may be used in the crop improvement programs aimed at enhancing the yield levels and development of widely adaptable hybrids. PLR 1 was also noticed to be a good general combiner for total soluble sugars during all the seasons indicating its potential in the development of adaptable and high yielding hybrids with high total soluble sugars, greatly desired by the consumers. Further, KS 224 and Surati Ravaiya were noticed to be good general combiners for fruit yield per plant during summer season; AB 98-13 during rainy season; and KS 224 and Morvi4-2 during late summer season, indicating their utility in the development of high yielding hybrids for the respective seasons.

Table 1. Combining ability ANOVA for fruit yield, yield components, quality and physiological characters during different brinjal growing seasons

Source	d.f	Fruit yield plant			Days first picking			Plant height			
		Summer	Rainy	Late Summer	Summer	Rainy	Late Summer	Summer	Rainy	Late Summer	
		gca	sca	Error	s2gca	s2sca	s2gca/s2sca	gca	sca	Error	s2gca
	9	0.15**	69.01**	7.53**	42.49**	0.91**	0.69**	323.25**	408.40**	492.50**	
	45	0.11**	28.40**	5.77**	16.66**	0.23**	0.12**	51.50**	81.26**	214.92**	
	108	0.01	0.07	0.07	0.08	0.03	0.02	17.09	17.69	0.20	
		0.01	5.75	0.62	3.53	0.07	0.06	25.51	32.56	41.03	
		0.10	28.33	5.70	16.58	0.20	0.10	34.41	63.57	214.92	
		0.10	0.20	0.11	0.21	0.35	0.60	0.74	0.51	0.19	

Source	d.f	Plant spread			1000-seed weight			Fruit drymatter			
		Summer	Rainy	Late Summer	Summer	Rainy	Late Summer	Summer	Rainy	Late Summer	
		gca	sca	Error	s2gca	s2sca	s2gca/s2sca	gca	sca	Error	s2gca
	9	2471.10**	1611.98**	2928.53**	0.68**	0.76**	0.91**	1.45**	1.05**	1.43**	
	45	736.36**	587.33**	937.37**	0.51**	0.16	0.50**	0.61**	0.43**	0.58**	
	108	45.68	47.88	21.48	0.02	0.11	0.01	0.13	0.01	0.11	
		202.12	130.34	242.25	0.06	0.054	0.08	0.11	0.09	0.11	
		690.68	539.45	915.89	0.49	0.055	0.49	0.48	0.42	0.47	
		0.29	0.24	0.26	0.12	0.98	0.16	0.23	0.21	0.23	

Source	d.f	Total soluble sugars			Total phenols			Leaf area per plant			
		Summer	Rainy	Late Summer	Summer	Rainy	Late Summer	Summer	Rainy	Late Summer	
		gca	sca	Error	s2gca	s2sca	s2gca/s2sca	gca	sca	Error	s2gca
	9	58.13**	6.92**	20.68**	0.008**	0.007**	0.59**	17521440**	96504984**		
	45	56.21**	6.90**	24.42**	0.01**	0.016**	0.41**	16134548**	55010832**	81870496**	
	108	0.04	0.001	0.002	0.00	0.000	0.001	204641	240.19	249653	
		4.84	0.58	1.72	0.00	0.00	0.05	1443066	8042061	8926432	
		56.17	6.90	24.42	0.01	0.01	0.41	15929907	55010591	81620843	
		0.09	0.08	0.07	0.00	0.00	0.12	0.09	0.15	0.11	

*, ** Significant at 5 and 1 per cent levels, respectively

Table 2. Good general combiners for fruit yield, yield components, quality and physiological characters during different brinjal growing seasons

Character	Good combiners identified		
	Summer	Rainy	Late summer
Fruit yield per plant	KS 224, PLR 1, Surati Ravaiya, JBPR 1	AB 98-13, PLR 1, JBPR 1	KS 224, PLR 1, Morvi 4-2, JBPR 1
Days to first picking	KS 224, AB 98-10, PLR 1, Gandhinagar Local, Morvi 4-2	KS 224, JB 64-1-2, AB 98-10, AB 98-13, Bombay Gulabi, Morvi 4-2	KS 224, AB 98-10, PLR 1, Gandhinagar Local, Morvi 4-2, JBPR 1
Plant height	Bombay Gulabi, Surati Ravaiya	KS 224, Bombay Gulabi, JBPR 1	KS 224, Gandhinagar Local, Bombay Gulabi, Morvi 4-2, Surati Ravaiya
Plant spread	Surati Ravaiya, Bombay Gulabi, JBPR 1	AB 98-10, Surati Ravaiya, JBPR 1	Bombay Gulabi, Surati Ravaiya, JBPR 1
1000-seed weight	AB 98-10, AB 98-13, PLR 1, Gandhinagar	PLR 1, Gandhinagar Local	AB 98-10, AB 98-13, Gandhinagar Local PLR 1, Local
Fruit dry matter	JB 64-1-2, AB 98-10, PLR 1, Bombay Gulabi, JBPR 1	JB 64-1-2, AB 98-10, Gandhinagar Local, JBPR 1	JB 64-1-2, AB 98-10
Total soluble sugars	KS 224, PLR 1, Gandhinagar Local, Bombay Gulabi, Morvi 4-2, Surati Ravaiya	KS 224, JB 64-1-2, PLR 1, Bombay Gulabi, Morvi 4-2, Surati Ravaiya, JBPR 1	PLR 1, Morvi 4-2, Surati Ravaiya, Gandhinagar Local
Total phenols	AB 98-10	PLR 1	KS 224, JB 64-1-2, AB 98-10
Leaf area per plant	KS 224, Bombay Gulabi, JBPR 1	JB 64-1-2, AB 98-10, AB 98-13, Bombay Gulabi, Surati Ravaiya, JBPR 1	AB 98-10, Bombay Gulabi, Surati Ravaiya

Table 3. Details of the good general combiners identified for fruit yield per plant, during the different seasons studied

Season/Good combiner	<i>Per se</i> performance	Fruit yield per plant Characterization w.r.t <i>per se</i> performance	<i>gca</i> effect	Desirable <i>per se</i> and <i>gca</i> effects noticed for yield components, quality and physiological characters
Summer				
JBPR 1	1.47	High	0.13**	Plant spread, fruit drymatter and leaf area per plant
PLR 1	1.22	High	0.13**	Days to first picking, 1000-seed weight, fruit drymatter and total soluble sugars
Surati Ravaiya	1.62	High	0.09**	Plant height, plant spread and total soluble sugars
KS 224	1.29	High	0.07*	Days to first picking, total soluble sugars and leaf area per plant
Rainy				
JBPR 1	3.01	High	0.54**	Plant height, plant spread, fruit drymatter, total soluble sugars and leaf area per plant
AB 98-13	2.92	High	0.23**	Days to first picking and leaf area per plant
PLR 1	2.87	High	0.14**	Total soluble sugars, total phenols and leaf area per plant
Late Summer				
PLR 1	1.61	High	0.36**	Days to first picking, 1000-seed weight and total soluble sugars
KS 224	1.53	High	0.22**	Days to first picking and total phenols
Morvi 4-2	1.70	High	0.19**	Days to first picking and total soluble sugars
JBPR 1	1.23	High	0.12**	Days to first picking and plant spread

*, ** Significant at 5 and 1 per cent levels, respectively

The study of specific combining ability effects (Table 4) revealed significant and desirable effects for several hybrid with regard to yield and yield components. In total, 22 hybrids during summer, 14 hybrids during rainy season and 22 hybrids during late summer season had exhibited significant and desirable *sca* effects for fruit yield per plant. Among these, eight hybrids during summer (KS 224 x AB 98-10, JB 64-1-2 x AB 98-13, JB 64-1-2 x PLR 1, PLR 1 x Bombay Gulabi, PLR 1 x JBPR 1, Morvi 4-2 x Surati Ravaiya, Morvi 4-2 x JBPR 1 and Surati Ravaiya x JBPR 1), nine hybrids during rainy season (KS 224 x Bombay Gulabi, JB 64-1-2 x AB 98-13, JB 64-1-2 x Morvi 4-2, AB 98-10 x JBPR 1, AB 98-13 x Bombay Gulabi, AB 98-13 x JBPR 1, PLR 1 x Morvi 4-2, PLR 1 x JBPR 1 and Morvi 4-2 x Surati Ravaiya) and nine hybrids during late summer season (KS 224 x AB 98-10, KS 224 x AB 98-13, KS 224 x PLR 1, KS 224 x Gandhinagar Local, AB 98-10 x PLR 1, PLR 1 x Gandhinagar Local, PLR 1 x Morvi 4-2, PLR 1 x JBPR 1 and Morvi 4-2 x Surati Ravaiya) had recorded significant and desirable *sca* effects, coupled with high *per se* performance for fruit yield per plant.

An analysis of the *gca* effects of the parents for these elite crosses with regards to fruit yield per plant revealed maximum number of elite hybrids to be of high x low type (62.5% during summer, 44.4% during rainy season and 66.7% during late summer). The production of superior hybrids with the combination of high and low *gca* parents has also been reported earlier (Chaudhary & Malhotra, 2000). It was inferred that such crosses would throw up desirable transgressive segregants, if the additive genes present in the good combiner and complementary epistatic effects, present in the cross, act in the same direction so as to maximize the desirable plant attributes (Das & Barua, 2001). In a few cases (25% during summer, 22.2% during rainy season and 33.3% during late summer), crosses with both good general combiner parents had also exhibited high *sca* effects, indicating the role of additive x additive type of gene action and hence, a good scope for fixation of the heterotic effects through the isolation of high yielding homozygous lines in advance generations.

Crosses involving two good combiners were also reported to be of particular merit, in practical eggplant breeding programs. ®- parental mating among the F₂ progenies was suggested for evolving of better genotypes through the combination of desirable attributes (Das & Barua, 2001). Further, superior hybrids were also noticed to result with both poor combiner parents (12.5% during summer and 33.3% during rainy season), indicating the presence of dominance x dominance type of gene action and hence their exploitation as hybrids only. The findings are in conformity with the reports of earlier workers (Varshney *et al.*, 1999). Among the above hybrids, PLR 1 x JBPR 1 and Morvi 4-2 x Surati Ravaiya had recorded desirable *per se* and *sca* effects for fruit yield per plant, during all the seasons and hence, are identified as widely adaptable and potential round egg-plant hybrids for commercial exploitation during all the egg-plant growing seasons. The hybrid, PLR 1 x JBPR 1 was also proved to be the most promising hybrid (Table 5), during summer and rainy seasons. It was also observed to be relatively early, dwarf and compact with low 1000-seed weight, during all the seasons and is therefore, highly suitable for egg-plant based inter-cropping systems. Further, KS 224 x PLR 1, an early, dwarf and compact hybrid with low 1000-seed weight and high leaf area in addition to fruit dry matter had recorded maximum fruit yield per plant during late summer and hence, holds potential for cultivation under contingency situations of late summer.

Table 4. Specific combining ability of the hybrids for fruit yield, yield components, quality and physiological in round brinjal, during different seasons studied

Character	Number of hybrids with significant and desirable sca effects		
	Summer	Rainy	Late summer
Fruit yield per plant	22	14	22
Days to first picking	26	28	26
Plant height	15	23	25
Plant spread	22	24	22
1000-seed weight	19	9	22
Fruit dry matter	15	19	14
Total soluble sugars	18	20	18
Total phenols	11	14	23
Leaf area per plant	17	19	17

Table 5. Details of the best round brinjal hybrid identified for fruit yield per plant, during the different seasons studied

Season/Best Hybrid	Per se	Fruit yield per plant		Desirable <i>per se</i> and <i>gca</i> effects noticed for yield components, quality and physiological characters
		sca effect	Characterization of parents w.r.t <i>gca</i> effects	
Summer				
PLR 1 x JBPR 1	2.53	0.80**	High x High	Days to first picking and 1000-seed weight
Rainy				
PLR 1 x JBPR 1	4.18	0.85**	High x High	Days to first picking, total soluble sugars and total phenols
Late Summer				
KS 224 x PLR 1	2.64	0.40**	High x High	1000-seed weight, fruit dry matter and leaf area per plant

*, ** Significant at 5 and 1 per cent levels, respectively

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EFFECT OF SALT STRESS ON BIOCHEMICAL PARAMETERS IN RICE (*Oryza sativa L.*) GENOTYPES

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ABSTRACT

Rice is the most important food crop cultivated mostly in South and South-east Asian countries. The present investigation employing ten rice cultivars was aimed to determine the physiological basis of salt tolerance with particular reference to sodicity. The field experiment was conducted under sodic soil condition prevailing at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirapalli in India. Biochemical parameters like soluble protein, proline and nitrate reductase enzyme recorded higher values in the salt tolerant cultivars. Soluble protein content was estimated in order to find out the phytosynthetic capacity of the genotypes under salt stress condition. The genotypic difference in soluble protein content could be related to grain yield. The genotypes like CORH 2, TRY(R) 2, APMS 5B and TRY 1 registered comparatively higher values for the soluble protein implying their salt tolerance behaviour. Proline, an amino acid, has been shown to accumulate in plant tissues in many species when subjected to salt and water stresses. Cultivars such as CORH 2, TRY(R) 2, TRY 1 and CO 43 had recorded higher proline content. The hybrid CORH 2 followed by APMS 5B, TRY 1 and TRY(R) 2 established their superiority over other cultivars for the enzyme NRase. The decreased NRase activity in salt sensitive rice cultivars is possibly due to the inhibition of enzyme induction under salt stress condition and uptake of NO₃ by the plants is reduced.

Key words: *Oryza sativa L.*, salt stress, sodic soil, soluble protein, proline and nitrate reductase enzyme

INTRODUCTION

In India, rice is cultivated in about 44.6 mha under varied eco-systems, which contributes 23 per cent of total world rice production and 45 per cent of total food production in India. In India, an area of nearly 4 mha of rice is affected by soil salinity (Paul and Ghosh, 1986). Therefore, there is a great deal of urgency for developing rice genotypes, which can sustain and set seed under high salt stress condition. Efforts to improve productivity of rice under salt stress condition need understanding of the mechanism to identify traits required for productivity improvement programme.

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Understanding of adaptive mechanism for salt stress in rice is complex due to presence of ionic and osmotic compounds. Identification or development of suitable genotypes that can come up well under saline/alkaline soil is one of the immediate requirements. The crop response studies particularly of tolerance mechanism and yielding ability under saline/alkali soil condition are the major efforts for the improvement of rice productivity under salt stress condition. Rice is considered to be a salt sensitive crop (Flowers and Yeo 1981). However, considerable variability for salinity resistance among rice varieties is also apparent (Yeo and Flowers 1982). This paper reports the effect of salt stress on biochemical parameters like soluble protein, proline and nitrate reductase enzyme in rice genotypes.

MATERIALS AND METHODS

Field experiments were conducted under sodic soil condition at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirapalli. Ten rice genotypes were raised in the nursery under moderate level of soil sodicity. Transplanting of seedlings was done 28 days after sowing in the main field under sodic soil condition. Two to three seedlings hill-1 were planted in the main field in the spacing of 20cm ´ 10 cm. The study was conducted in the wet season (2002-2003) in Randomized Block Design replicated thrice. The physical and chemical properties of the soils of the experimental field are given in Table 1. Plant samples were drawn at transplanting, tillering, panicle initiation, and flowering stages for assessing the biochemical characters. Soluble protein content was determined by the procedure described by Lowry et al. (1951) and expressed as mg g-1 on fresh weight basis. The amino acid proline content was estimated in fully expanded leaf at transplanting, tillering, panicle initiation and flowering stages following the method of Bates et al. (1973) and expressed on µg g-1 on fresh weight basis. The nitrate reductase activity was estimated as per the method suggested by Nicholas et al. (1976) and expressed as µ moles NO₂ g-1 h-1 fresh weight. The mean values of the above mentioned observations were subjected to the statistical analyses and the genotypes were tested for their significance by adopting the procedure of Panse and Sukhatme (1961).

Table 1. Effect of salt stress on soluble protein content (mg g-1) in 10 rice genotypes at different phenological stages

Soluble protein content mg g-1						
Sl. No.	Genotypes	Transplanting	Tillering	Panicle Initiation	Flowering	Mean
1	IR 62829B	6.20	7.00	7.52	9.35	7.52
2	IR 68885B	5.94	7.84	9.20	11.60	8.65
3	IR 68281B	5.80	4.40	5.84	7.38	5.86
4	APMS 5B	6.43	9.20	9.70	11.00	9.08
5	TRY 1	6.38	9.28	10.00	10.43	9.02
6	TRY (R) 2	6.57	9.30	10.08	11.75	9.43
7	CO 43	6.72	8.38	8.56	11.33	8.75
8	ADT 39	6.10	7.21	7.28	9.44	7.51
9	CORH 2	6.82	9.30	10.10	12.10	9.58
10	WHITE PONNI	5.41	5.84	6.12	8.00	6.34
	Mean	6.24	7.78	8.44	10.24	
		SED			CD (P=0.05)	
	S	0.06			0.12	
	G	0.14			0.29	
	SXG	0.29			0.57	

RESULTS AND DISCUSSION

Soluble Protein Content

Soluble protein content was estimated in order to find out the photosynthetic capacity of the genotypes under salt stress condition. The genotypic difference in soluble protein content could be related to grain yield. The total soluble protein content determines the dry matter accumulation of crops since it represents the efficiency of the RuBPase, the carboxylating enzyme in C₃ plants (Plaut, 1974). A strong positive correlation between soluble protein and grain yield has been established in this study (0.742**). Vijayaraghavan (1994) had reported a reduction in soluble protein content under salt stress situation. However, the genotypes like CORH 2, TRY(R) 2, APMS 5B and TRY 1 registered comparatively higher values for the soluble protein implying their salt tolerance behaviour. Protein contents in leaves were found to be correlated with plant growth rate, leaf area index, tillers and panicle number (Jayabalan et al., 1995). Jha and Singh (1997) reported higher protein content of stressed seedlings of tolerant rice cultivars as compared to susceptible cultivars.

Proline

Proline, an amino acid has been shown to accumulate in plant tissues in many species when subjected to salt and water stresses (Mukerjee, 1974). The loss of turgor due to salt stress triggers proline accumulation in plants contributing to osmotic adjustment and stress tolerance (Aslam et al., 1989; Pessarakkali, 1999). Besides this, proline can serve as a protector of enzyme denaturation, a reservoir of nitrogen and carbon or as a stabiliser of the machinery for protein synthesis (Hamada and Khulaef, 1995). Hence, proline accumulation in plants can be taken as an index to identify the tolerant genotypes. Pessarakkali (1999) reported that accumulation of proline depend on the extent of stress. Proline was considered as salt tolerant mechanism and serve in osmotic regulation (Aslam et al., 1989). Significant variation in proline content was recorded in the 10 rice genotypes. Cultivars such as CORH 2, TRY(R) 2, TRY 1 and CO 43 had recorded higher proline content. The positive association of proline with grain yield (0.483*) exhibits the tolerant nature of the above mentioned genotypes under salt stress. The proline accumulation may be due to either non-incorporation of free amino acid proline into protein synthesis due to salt stress or the breakdown of the existing protein molecules into various constituent amino acids with proline being predominant (Somani, 1991 and Mukerjee, 1974).

Nitrate Reductase (NRase)

The pathway of NO₃ assimilation is considered as the major route of conversion of inorganic N into a biologically useful organic compound. The primary step in NO₃ assimilation involves reduction of NO₃ to NO₂ catalysed by the enzyme, NRase. Nitrite is subsequently reduced to NH₄⁺ by the enzyme nitrite reductase. These two enzymes reduce NO₃ to the end product NH₄⁺, which is then incorporated into amino acids. Activity of NRase in plants gives a good estimate of the N status of plants and is very often correlated with growth and yield of crops (Srivastava, 1980). The hybrid CORH 2 followed by APMS 5B, TRY 1 and TRY(R) 2 established their superiority over other cultivars for the enzyme NRase. The positive association of the enzyme with grain yield (0.542**) and also soluble protein (0.698**) explained the higher yield of these genotypes under salt stress. The decreased NRase activity in salt sensitive rice cultivars is possibly due to the inhibition of enzyme induction under salt stress (Katiyar and Dubey, 1992). Under salt stress condition, uptake of NO₃ by the plants is reduced. This leads to limited NO₃ availability in the plant tissues and thereby NRase is suppressed, which results in decreased NRase activity (Lacuesta et al., 1990). This decreased NRase activity has been partly attributed to the enhanced degradation of NRase enzyme itself (Plaut, 1974). Several possible explanations have been suggested for the decreased NRase activity in salt sensitive plants under saline stress. The plausible reason appears to be inhibition of enzyme induction under salinization. NRase is a substrate-inducible enzyme. Under saline conditions, NO₃ uptake by the plants is reduced. This causes a limited NO₃

availability in plant tissues and thereby, NRase induction is suppressed, which results in decreased NRase activity (Lacuesraet al., 1990).

Table 2. Effect of salt stress on proline ($\mu\text{g g}^{-1}$) in 10 rice genotypes at different phenological stages

Proline content ($\mu\text{g g}^{-1}$)						
Sl. No.	Genotypes	Transplanting	Tillering	Panicle Initiation	Flowering	Mean
1	IR 62829B	425	635	510	680	563
2	IR 68885B	480	670	590	830	643
3	IR 68281B	400	590	410	630	508
4	APMS 5B	500	725	520	1050	699
5	TRY 1	480	710	700	980	718
6	TRY (R) 2	485	780	680	1000	736
7	CO 43	510	850	810	1150	830
8	ADT 39	450	750	630	820	663
9	CORH 2	590	830	850	1100	843
10	WHITE PONNI	350	670	700	900	655
Mean		467	721	690	914	
		SED		CD (P=0.05)		
S		5.10		10.07		
G		11.96		23.61		
SXG		23.93		47.23		

Table 3. Effect of salt stress on enzyme Nitrate Reductase activity ($\mu\text{ moles NO}_2\text{ g}^{-1}\text{ hr}^{-1}$) in 10 rice genotypes at different phenological stages.

Nitrate reductase activity ($\mu\text{ moles NO}_2\text{ g}^{-1}\text{ hr}^{-1}$)						
Sl. No.	Genotypes	Transplanting	Tillering	Panicle Initiation	Flowering	Mean
1	IR 62829B	21.5	23.3	22.4	26.0	23.3
2	IR 68885B	25.1	27.2	23.0	28.5	25.9
3	IR 68281B	21.0	22.5	25.2	26.7	23.9
4	APMS 5B	32.0	35.4	37.3	39.3	36.0
5	TRY 1	29.6	33.4	34.4	35.3	33.2
6	TRY (R) 2	28.4	32.4	32.8	33.5	31.8
7	CO 43	31.2	32.5	36.4	40.3	35.1
8	ADT 39	23.8	26.0	27.5	28.5	26.4
9	CORH 2	35.0	34.1	36.0	40.1	36.3
10	WHITE PONNI	18.3	20.4	19.5	21.9	20.0
Mean		26.6	28.7	29.5	32.1	
		SED		CD (P=0.05)		
S		0.02		0.04		
G		0.05		0.10		
SXG		0.10		0.19		

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PRODUCTION AND POST-HARVEST MANAGEMENT OF VEGETABLES IN WESTERN REGION OF UTTAR PRADESH

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ABSTRACT

The vegetable crops, characterized by high productivity, much higher return, employment generating with export potentials, have attracted the farming community in general, small and marginal farmers in particular. In the present study an attempt has been made to examine the present status of technology adoption, production and post-harvest management in the Western Region of Uttar Pradesh. The study is based on primary data collected from a sample of 80 randomly selected vegetables growers of Bareilly district of the Western region of U.P. The Multiple Regression Analysis as well as simple statistical tools was used to accomplish different objectives of the study. The study revealed that there is a wide gap between the recommended and adoption level of technologies in all the sample vegetables. The yield was also found far below the potential level. The net returns were positive over Cost C₂ in all the sample vegetables except in okra and pumpkin. The marketed surplus varied between 98.53 in tomato to 84.14 percent in potato. The post-harvest activities were not performed properly resulting in loss of quality and quantity of the produce. The study suggests for providing financial assistance with provision of crop insurance. The post-harvest management needs to be integrated with the present extension services. The small scale processing units in the areas of concentrated production would avoid the crash in prices and loss of produce. For modernization of the vegetable industry, a professional body on the lines of MAHAGRAPES/NDDDB is a urgent need of the day.

INTRODUCTION

The role of horticultural crops in India nutritional security, poverty alleviation and employment generation is becoming increasingly important. The sector contributes 24.5 percent to GDP and 54.55 per cent to agricultural export. India is the second largest (next to China) in area and production of vegetables contributing 13.38 percent to world production. The estimated area under vegetables is 58.70 lakh ha with a production of 875.30 lakh tones in India.

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The vegetable crops constitute an integral part of horticultural sector. They are characterized by high productivity, much higher return, employment and export potentials. But being highly concentrated with small and marginal farmers inefficient use of various technological inputs is a common feature resulting in low productivity of these crops. Further with low quantity of marketed surplus and perishable nature of these results in inability on the part of producers to manage their supply in assembling markets. The production of the vegetables is seasonal and localized in favored agro-climatic situation and each of the agro-climatic regions differs from others in terms of land use, cropping pattern, infrastructure, institutional structure and other socio-economic factors. Therefore, there is a need to conduct comprehensive studies in each region. Against this backdrop, this study was undertaken with the following objectives:

1. To study the economics and cost of production of sample vegetables.
2. To examine the resource use efficiency in vegetable production.
3. To examine the status of post-harvest management of sample vegetables.

METHODOLOGY

Sampling Design: The Western region of U.P. has strategic importance in terms of production and export potentials of vegetables. Therefore, the region was purposively selected for the present investigation. The vegetable growers were selected through the following Multistage Sampling Technique:

Stage I: One biggest secondary vegetable market (in terms of quantity of vegetables traded in a year), the APMC, Bareilly, was selected from the region.

Stage II: Two primary feeding markets, namely Devchara and Naryaval (out of 8), were selected on the basis of volume of vegetable trade.

Stage III: Four villages (2 near pucca road and two at least 4 kms away from pucca road) were selected from the area of each of the selected primary markets.

Stage IV: Finally 10 vegetable growers were randomly in proportion to their size group. Thus the sample includes 80 vegetable growers.

The vegetables were selected on the basis of their share (2 per cent or more) in total quantity of vegetables traded in the year. The selected vegetables were potato, onion, tomato, cabbage, cauliflower, carrot, radish, brinjal, okra, bottle gourd and pumpkin.

The primary data were through survey method with the help of pre-tested schedule-cum-questionnaire. The data relate to crop year 1998.

Analytical Tools: The economic analysis of vegetable production has been performed using various cost concepts adopted by the Commission for Agricultural Costs and Prices (CACP), Ministry of Agriculture, G.O.I. as explained below:

Cost C3 = Cost C2 + 10 percent of Cost C2 on account of managerial functions performed by the farmers.

Cost C2 = Cost B1 + imputed of family labour by taking into account the statutory minimum/actual wages whichever is higher.

Cost C1 = Cost B1 + imputed of family labour.

Cost B1 = includes actual cost incurred (cash/kind) on hired labour, machinery, bullock labour, seed, manure/fertilizers, irrigation, depreciation, land revenue, interest on operational cost and interest on value of owned capital assets (excluding land).

The resource use efficiency in production of vegetable had been examined through production function approach. The following type of function had been analyzed for sample vegetables separately:

$$Y = A.X_1^{b_1}. X_2^{b_2}. X_3^{b_3}. X_4^{b_4}. X_5^{b_5}. X_6^{b_6}. X_7^{b_7}.U$$

Where, Y = Yield (q per ha)

X₁ = Human labour (days)

X₂ = Land preparation (Rs per ha)

X₃ = FYM (q per ha)

X₄ = Chemical fertilizers (kg per ha)

X₅ = Plant Protection Chemicals (Rs per ha)

X₆ = Seeds (kgs per ha) or seedling (Rs per ha)

X₇ = Irrigation (no.)

b_i = Output elasticity of ith recourse

U = Random disturbance term.

Initially the presence of multicollinearity was tested between explanatory variables and the variables were transformed on per hectare basis, as the area under the crop was found highly correlated with all the explanatory variables. The model was estimated through regression technique using Ordinary Least Square (OLS) Technique, which is the most powerful and popular method of regression analysis.

Marketed Surplus: The marketed surplus is the actual quantity of a produce sold by a farmer. It had been estimated by using the following formula:

$$M_s = (M_p - M_c) * 100 / M_p$$

Where, M_s = Marketed Surplus (per cent)

M_p = Production of vegetable (quintals)

M_c = On farm consumption of vegetables (quintals)

Post-harvest Management: Profitability in commercial vegetable production depends on proper harvesting, handling and marketing. Unless the growers have grown the varieties market demand, protected the crop from diseases, insects and pests, graded them carefully and properly, packed them in container suited to the products and method of handling, they have not done all that is expected of them. Therefore, the post-harvest management of sample vegetables has been analyzed in terms of grading, packing, transportation and storage at producers' level.

RESULTS AND DISCUSSION

The district of Bareilly of the Western region of U.P. is conducive for production of wide range of vegetables throughout the year. The district is also among one of the districts of the state selected under Hybrid Vegetable Production Programme by the Directorate of Horticulture, U.P. There was high degree of inequality in distribution of land holding in the district. The marginal and small farmers constitute about 89 per cent of the farming community. The average size of land holding is 0.89 ha (1991 census) in the district. The average size of land holding of sample vegetable grower was 1.42 ha, constituting 85 percent of marginal farmers.

Cropping pattern: The season wise cropping pattern on sample vegetable farms presented in table 1, shows that the share of vegetable crops in gross cropped area was 57.51 per cent while it was 15.99, 25.18 and 16.35 percent in *kharif*, *rabi* and *zaid* respectively. The cropping intensity had been found as 245 percent on the

sample vegetable farms. Some of the vegetables like, bottle gourd, pumpkin, okra and brinjal were grown in more than one season, and therefore the analysis had been performed superlatively for them.

Level of technology adoption: Vegetable crops are considered as high feeder crops on account of their much higher level of input requirement. The productivity as well as their profitability depends upon the extent of adoption of technology. Vegetable wise per hectare use of technological inputs and yield gap presented in the table 2.

Table 1. Cropping pattern on the sample vegetable farms in Western U.P.

<i>KHARIF SEASON</i>		<i>RABI SEASON</i>		<i>ZAID SEASON</i>	
Crop	Area (ha)	Crop	Area (ha)	Crop	Area (Ha)
A. Vegetable Crops		A. Vegetable Crops		A. Vegetable Crops	
Okra	0.099 (3.26)	Brinjal	0.091 (3.00)	Pumpkin	0.074 (2.44)
Bottle gourd	0.090 (2.96)	Carrot	0.010 (0.33)	Bottle gourd	0.087 (2.90)
Ridge/Ribbed gourd	0.091 (3.00)	Radish	0.016 (0.53)	Brinjal	0.091 (2.91)
Bitter gourd	0.054 (1.78)	Green chilli	0.044 (1.45)	Bitter gourd	0.040 (1.32)
Pumpkin	0.027 (0.92)	Pea	0.029 (0.96)	Okra	0.066 (2.17)
Brinjal	0.080 (2.64)	Potato	0.363 (11.96)	Ridge/Ribbed gourd	0.023 (0.78)
Other vegetables	0.044 (1.43)	Onion	0.046 (1.52)	Other vegetables	20.094 (3.76)
Total vegetables	0.485 (15.99)	Garlic	0.012 (0.40)	Total	0.496 (16.35)
B. Foodgrain crops	0.698 (23.00)	Tomato	0.069 (2.27)	C. Other crops³	0.077 (2.54)
C. Other crops ¹	0.046 (1.52)	Cauliflower	0.04 (1.55)	Total zaid	0.573 (18.89)
Total Kharif	1.229 (40.50)	Cabbage	0.037 (1.22)		
		Total vegetables	0.764 (25.18)		
		B. Foodgrain crops	0.415 (13.68)		
		C. Other crops	0.053 (1.75)		
		Total Rabi	1.232 (40.61)		

Note: 1. includes cucumber, chilli, greenchilli, radish, cucumber, ash gourd etc.

2. include mentha, MP cherry, muskmelon, watermelon etc.

D. Average net cropped area of sample vegetable farms = 1.23 hectare

E. Gross cropped area under vegetable = 1.745 hectare (57.51 per cent of GCA)

F. Grossed cropped area of sample vegetable farms = 3.024 hectare

G. Cropping Intensity = 245.04 per cent.

Table 2. Economics of vegetable production in Western U.P.

Particulars	Bottle gourd (Kharif)	Bottle gourd (Zaid)	Pumpkin (Kharif)	Pumpkin (Zaid)	Okra (Kharif)	Okra (zaid)	Brinjal (Kharif)	Brinjal (rabi)
Yield (q/ha)	189.20	167.05	279.93	323.86	56.96	51.02	170.50	147.47
Average price (Rs/q)	331.67	442.19	53.31	61.49	380.62	419.61	234.67	305.38
Marketing Cost (Rs/q)	17.70 (9.68)	18.09 (10.23)	2.23 (2.45)	5.21 (6.02)	30.74 (6.90)	27.21 (5.20)	30.09 (28.88)	29.99 (24.00)
Net price (Rs/q)	313.37	424.10	51.08	56.28	349.88	392.40	204.58	275.39
Production Cost (Rs/q)								
i. Cost B ₂	114.75	131.30	63.42	68.01	318.56	362.33	81.51	98.34
ii. Cost C ₁	128.87	160.98	80.89	73.02	398.94	470.03	88.64	106.98
iii. Cost C ₂	142.87	176.84	90.35	81.20	445.45	521.96	104.18	124.94
iv. Cost C ₃	157.16	194.52	99.39	89.32	489.99	574.15	114.60	137.44
Net return over (Rs/q)								
i. Cost B ₂	198.62	292.80	-12.34	-11.73	31.32	-30.07	123.07	177.05
ii. Cost C ₁	184.50	263.12	-29.81	-16.74	-49.06	-77.63	115.94	168.41
iii. Cost C ₂	170.50	247.26	-39.27	-24.92	-95.57	-129.56	100.40	150.45
iv. Cost C ₃	156.21	229.58	-48.31	-33.04	-140.11	-181.75	89.98	137.95
Net return over (Rs/ha)								
i. Cost B ₂	37578.90	48912.24	-3454.34	-3798.88	1783.99	1534.17	20983.44	26109.56
ii. Cost C ₁	34907.40	43954.20	-8344.71	-5421.42	-2794.46	-3960.68	19767.77	24835.42
iii. Cost C ₂	32258.60	41304.78	-10992.85	-8070.59	-5443.67	-6610.15	17118.20	22186.86
iv. Cost C ₃	39554.93	38351.34	-13523.42	-10700.33	-7980.67	9272.89	15341.59	20343.49

Contd

Continued from Table 2

Particulars	Tomato	Onion	Potato	Cauliflower	Cabbage	Carrot	Radish
Yield (q/ha)	196.51	135.02	352.82	149.65	220.95	249.64	279.75
Average price (Rs/q)	507.43	383.28	288.92	281.52	280.84	238.00	191.00
Marketing Cost (Rs/q)	62.91 (60.14)	31.89 (14.08)	35.10 (29.39)	33.79 (24.36)	13.12 (13.99)	38.78 (47.00)	33.93
Net price (Rs/q)	444.52	351.39	253.82	24.73	267.72	199.22	157.07
Production Cost (Rs/q)							
i. Cost B2	85.34	167.67	94.11	102.65	62.96	56.62	60.12
ii. Cost C1	91.13	206.91	180.66	121.01	81.76	71.89	71.97
iii. Cost C2	104.61	226.53	119.41	138.72	93.75	82.51	81.44
iv. Cost C3	115.07	249.18	131.35	152.59	103.13	90.76	69.58
Net return over (Rs/q)							
i. Cost B2	359.16	183.72	159.71	145.08	204.76	142.60	96.95
ii. Cost C1	353.39	144.48	73.16	126.72	185.96	127.33	85.10
iii. Cost C2	339.91	124.86	134.41	109.01	173.97	116.71	75.63
iv. Cost C3	329.45	102.21	121.47	95.14	164.59	108.46	67.49
Net return over (Rs/ha)							
i. Cost B2	70582.46	24805.87	56348.88	21711.22	45241.72	35598.66	27121.76
ii. Cost C1	69449.67	19507.69	52812.31	18963.65	41087.86	31786.66	23806.73
iii. Cost C2	66795.67	16858.60	47422.54	16313.35	38438.67	29135.48	21157.49
iv. Cost C3	64740.22	13800.39	42587.05	14237.70	36366.16	27075.95	18880.33

Note: Figures in parentheses show percent of Cost of production (C2)

The table indicates that seed was used in excess in most of the crops except onion and bottle gourd (*kharif*). The maximum difference (110 percent) was observed in Okra (*kharif*) while the minimum (7.25 percent) in bottle gourd (*zaid*). As far as use of FYM was concerned it was used less than the recommended level in most of the sample vegetable crops. The nitrogenous and phosphatic fertilizers were used in lower quantities in most of the sample vegetable crops except in potato and okra. The potash was not at all applied in any sample vegetable crops. Irrigation and plant protection were also below the recommended level except in potato. The table also indicates that none of the sample vegetable grower could achieve the potential yield of any of the sample vegetable. The maximum yield gap of 58.46 percent was observed in onion followed by brinjal (58.46 percent) while minimum (5.40 percent) in bottle gourd (*kharif*).

ECONOMICS OF PRODUCTION OF VEGETABLES

The profitability of sample vegetable have been analyzed by considering various cost concepts, viz. Cost B₂, Cost C₁, Cost C₂ and Cost C₃ and have been presented in Table 3.

Bottle gourd: It is one of the most important cucurbit crop grown in *kharif* as well as in *zaid* season in the study area. The Cost C₂ has been estimated as Rs 27031 and Rs 29734 per ha respectively for two seasons. The net returns were higher in *zaid* season crop the *kharif* (Table 3) though *kharif* crop yielded about 12 qtl per ha higher yield, which was due to price difference in two seasons. The vegetable was also exported to Delhi, Lucknow, Kolkota and Guwahati by road transportation

Pumpkin: It is also one of the most important cucurbit vegetable crops grown in the study area during *kharif* as well as in *zaid* season. The cost of production per ha was higher (Rs 30,000) in *zaid* than the *kharif* crop (Rs 27,822). The table indicates that pumpkin production in the study area was not profitable even at Cost A in both seasons. The productivity of summer crop (324 q/ha) was higher than the *kharif* crop (279 q/ha).

Okra: The crop was grown during *kharif* and *zaid* seasons in the study area. The cost of production of *zaid* okra was higher (Rs 29293 per ha) than the *kharif* crop (Rs 27910 per ha), which was due to higher irrigation expenditure in the season. The yield of *kharif* crop was higher (57 q ha⁻¹) as compared to *zaid* crop (51 q ha⁻¹). While considering net return over different crops the crop yielded loss on Cost C (Table 3).

Brinjal: Brinjal is the only crop grown through out the year in study area. The table 4 reveals that the cost of production was over 19,20 and 22 thousand per hectare in *kharif*, *rabi* and *zaid* seasons respectively. The *kharif* crop yielded about 171 qtls per ha while *rabi* and *zaid* crops 147 and 140 q ha⁻¹, respectively (Table 3). The reverse trend was found while considering net return per ha. The *rabi* crop yielded highest net return per ha of Rs 22187 over Cost C₂ followed by *kharif* (Rs 17118) and *zaid* crop (Rs 16538).

Tomato: Tomato is principally an important *rabi* season crop though it is now being cultivated in other seasons also. The cost of production was estimated at about Rs 22612 per ha (Cost C₂). The crop was found as highly profitable crop in the area. The net return over Cost C₃ was Rs 64740 per ha. The marketing cost was found as Rs 62.91 (over 60 percent of Cost C₂) per quintal of the produce.

Onion: The cost of production of onion was estimated as Rs 33544 per ha in the study area. The average yield was found as about 135 quintal per ha. The cost of production (Cost A₁=Cost A₂) was estimated as Rs 146 per quintal while Cost C₃ as Rs 249 per quintal. The cost and return at Cost C₃ were estimated as Rs 35186 and Rs 13800 per hectare respectively.

Potato: It is revealed from the table 3 that average yield of potato was 353 quintal per ha in the study area. The crop was found to be highly profitable on sample vegetable farms, yielding a net return of Rs 47422 per ha (on Cost C₂). The cost of production (Cost C₂) was estimated as Rs 119.41 per quintal.

Table 3. Estimated production function and marginal value productivity (MVP) of inputs of vegetables in Western U.P.

Vegetable	Item	Constant	X ¹	X ²	X ³	X ⁴	X ⁵	X ⁶	X ⁷	R ²
Bottlegourd (kharif)	SE (b)	2.8224	0.4051***	0.0575					-0.3205*	0.47
	MVP		0.1995	0.1622					0.1159	
	A.C.		122.364**						-200.397**	
Bottlegourd (zaid)	SE (b)	5.6312	0.2561	0.5552**	-1.3265**	0.9833**			0.4364**	0.25
	MVP		0.2464	0.2923	0.6453	0.5447			0.3149	
	A.C.			-1.90.86**	-42.5.21**	-319.97**	1.00	1.00	323.47	515.9915
Pumpkin (Kharif)	SE (b)	-7181.45	1252.257	0.232***	0.9300**				0.3494***	0.47
	MVP		1143.446	0.1359	0.3173				0.2467	
	A.C.			9.254***	35.86*				-61.70*	330.73
Pumpkin (Zaid)	SE (b)	5.0106	1.5620*	-0.2985*	0.3918***	-0.359***				0.87
	MVP		0.2516	0.0615	0.2733	0.2452				
	A.C.		94.9111*	-21.7489*	-17.83***	-15.71***				
Okra (Kharif)	SE (b)	15.6476	10.00	1.00	1.00	1.00			0.0568	0.50
	MVP		-0.6488**	-0.416**					0.3519	
	A.C.								127.96**	
Okra (Zaid)	SE (b)	12.1422	10.00	1.00	1.00	1.00				0.51
	MVP		-0.1863	0.301***	1.2150*				-0.1246	
	A.C.		0.2813	0.1848	0.3898				0.1565	
			62.35***	-25.5207*						
			1.00	1.00						

Contd.

Cauliflower and Cabbage: Table 2 shows that the Cost C₂ of cauliflower was 199 rupees per qtl while that of cabbage as 94 rupees. The yield per ha of cabbage was obtained as about 221 quintal per ha while that of cauliflower as only 150. The net return in cabbage over Cost C₂ was obtained as Rs 38439 per ha and that of cauliflower Rs 16313 (Table 2).

Carrot and Radish: The cost of production (Cost C₂) of carrot and radish was estimated as Rs 20597 and Rs 22783 per ha respectively. The average yield of these crops was about 250 and 280 quintal per ha. Carrot fetched market price Rs 238 per quintal while radish Rs 191 per quintal, which resulted in higher net return over Cost C₂ in carrot (Rs 29135 per ha) than the radish (Rs 21157 per ha). The marketing cost was estimated as 47 and 42 percent of cost C₂ for the two crops, respectively.

RECOURSEUSE EFFICIENCY

The analysis has been performed separately for the vegetables grown in different season. The results are presented in Table 3.

Bottle gourd: The value of coefficient of multiple determination (R₂) for *kharif* and *zaid* season crop had been found as 0.47 and 0.25 respectively indicating that variation in per ha yield of crop is explained by the explanatory variables included in the model. The low R₂ value of *zaid* season crop may be due to the other factors, e.g. weather during the crop season, which may have influenced the crop yield. The regression coefficients of FYM and irrigation in *kharif* crop; while fertilizers, plant protection, seed and irrigation in *zaid* were found significantly influencing its yield. The negative value of the coefficient shows excessive use of the resource; therefore, by reducing its' use yield can be increased while the positive value of the coefficient shows under use of the resource. For example, the regression coefficient of irrigation in *kharif* crop is negatively significant, which indicates the excess use of irrigation in *kharif*.

Pumpkin: The value of R₂ for *kharif* and *zaid* seasons was found as 0.47 and 0.87, respectively. The production elasticity of fertilizer, plant protection and irrigation were positive in *kharif* crop. The difference of MVP from its acquisition cost was also found significantly different implying that by increasing the level of these resources profitability level could be increased. Fertilizers, plant protection and irrigation significantly affected the *zaid* crop. The coefficient of FYM and plant protection were positive while that of fertilizer and seed was negative Their MVPs were also significant.

Okra: The regression coefficient of FYM, fertilizer and seedling were negatively significant in *kharif* crop indicating excessive use of the inputs. The MVPs of FYM and seedling were also statistically different from their A.C. suggesting their excessive use. However optimal use of fertilizer is indicated. The results of *zaid* crop show that the regression coefficient of chemical fertilizer was positively significant while that of plant protection was negatively significant. The coefficients of multiple of determination (R₂) for two seasons were 0.50 and 0.51 respectively.

Brinjal: About 38 percent variability in yield of *kharif* brinjal was explained by the variables included in the model whereas 32 percent in *rabi* and 22 percent in *zaid* season crop. The value of R₂ of summer crop was lower than the *kharif* crop, which may be due to severity of weather during the season. It was further observed that the production elasticity of expenditure on land preparation was negative and significant in *kharif*, implying thereby that yield in *kharif* brinjal could be increased by reducing the cost of land preparation. The regression coefficient of human labour, FYM and seedling had positive and significant impact on the yield of *rabi* crop. Their MVPs were also significantly different from their AC indicating excessive use of these inputs in *rabi* season. The perusal of *zaid* season model indicates that the coefficients of fertilizer and seeding were significant and positive.

Onion: The regression coefficient of irrigation was only found statistically significant in onion showing diminishing return. However, the MVP of irrigation was not significantly different than its acquisition cost (AC), indicating optimal use of the input.

Potato: The elasticity coefficients of FYM, plant protection and irrigation were positive and significant. The magnitude of these being less than unity indicates decreasing return to scale. The MVP of these variables were also significantly different from their ACs except that of irrigation, indicating the optimal use of irrigation and sub-optimal of plant protection and FYM.

Cabbage: The FYM was only found influencing the production of cabbage significantly. The MVP was also significantly different from its AC thereby implying that productivity of cabbage could be increased economically by increasing the use of FYM.

Carrot and radish: The values of R^2 for the two crops were 0.53 and 0.69 respectively. Among different variables only seed was found influencing the yield of carrot significantly, while seed and irrigation in radish. The MVPs were also significantly different from their ACs implying their sub-optimal use. In general low R^2 value of zaid season crop was observed, which may be due to other factors, like severity of weather during the crop season in the study area, influencing the crop yield adversely.

POST-HARVEST MANAGEMENT

The vegetables come in indifferent forms, e.g. fruit, leaf, tuber etc in terms of parts used thereof. Therefore, the most important aspect of understanding vegetable production lies in comprehending the pre and post-harvest status of each vegetable crop. If the producers are unfamiliar with the requirement of the next, pre and post-harvest stage their production efforts may be in vein. Thus the skillful post-harvest management of these is of great significance in order to maintain quality of produce which intern affects the profit level which had been analyzed in terms of marketed surplus grading, packing, transportation etc performed by the sample growers.

Marketed Surplus: From the marketing point of view the marketed surplus is more important. The results have been presented in Table 4. The table reveals that the marketed surplus was more than 95 percent in most of the sample vegetables except in potato and pumpkin, which is justifiable as the on-farm consumption of these vegetables is expected to be more. The maximum quantity of marketed surplus (98.37) was recorded in tomato because of its highly perishable nature (Table 4).

Grading: Though the Agricultural Produce (Grading and Marketing) Act was enacted way back in 1937 in India the scientific grading in vegetables (except potato) is yet to introduced. The farmers sort their produce according to varieties they grow, stage of ripeness, size, insect-pest affected etc before disposing to the market.

About 79 percent of sample growers were found grading vegetables. The cost of grading (Table 5) includes wages paid to hired labour and family labour (imputed value). The highest cost of grading was estimated in cauliflower (Rs 19.58 per quintal) followed by potato (Rs. 19.18 per quintal) and tomato (Rs. 17.57 per quintal).

Table 4. Marketed surplus of vegetables on sample vegetables farms in Western U.P.

Sl. No.	Vegetable	Production (qtl)	<u>Consumption</u>		<u>Marketed Surplus</u>	
			Quantity (qtl)	Percent	Quantity (qtl)	Percent
1.	Bottle gourd (<i>kharif</i>)	16.33	0.38	2.29	16.25	97.21
2.	Bottle gourd (<i>Zaid</i>)	14.76	0.24	1.63	14.52	98.37
3.	Pumpkin (<i>Kharif</i>)	7.48	0.94	12.57	6.54	87.43
4.	Pumpkin (<i>Zaid</i>)	25.46	0.87	3.42	24.59	96.58
5.	Okra (<i>Kharif</i>)	5.83	0.77	13.21	5.06	86.79
6.	Okra (<i>Zaid</i>)	3.47	0.45	12.97	3.02	87.03
7.	Brinjal (<i>Kharif</i>)	13.50	0.33	2.80	13.17	97.20
8.	Brinjal (<i>Rabi</i>)	11.20	0.32	2.86	10.68	97.14
9.	Brinjal (<i>Zaid</i>)	12.68	0.33	2.61	12.35	97.39
10.	Onion	5.41	0.45	8.32	4.96	91.68
11.	Potato	126.82	20.11	15.86	106.71	84.14
12.	Tomato	13.57	0.20	1.47	13.37	98.53
13.	Cauliflower	7.19	0.31	4.31	6.88	95.69
14.	Cabbage	8.34	0.30	3.60	8.04	96.40
15.	Carrot	2.61	0.12	4.60	2.49	95.40
16.	Radish	4.52	0.14	3.10	4.38	96.90

Table 5. Economics of post-harvest management of vegetables on sample farms in Western U.P. (Rs per quintal)

Sl. No.	Vegetable	Grading	Packaging	Transportation	Total cost
1.	Bottle gourd	10.49	Unpacked	23.23	33.72
2.	Pumpkin	4.76	Unpacked	17.29	22.05
3.	Brinjal	15.33	26.13	7.20	48.66
4.	Okra	9.82	24.82	17.28	51.92
5.	Tomato	17.57	43.58	21.97	83.12
6.	Onion	11.36	18.04	21.81	50.21
7.	Potato	19.18	20.21	27.05	66.44
8.	Cauliflower	19.58	24.21	20.06	63.85
9.	Cabbage	17.47	21.06	18.72	57.25
10.	Carrot	5.81	12.42	28.19	46.42
11.	Radish	6.94	20.64	17.64	45.22

Packing: The packing of vegetables is another most important post-harvest activity. The vegetables being highly perishable to semi-perishable in nature require specific packages. The sample growers were found using following type of packages to pack vegetables:

Types of packages	Vegetables packed therein
1. Gunny bag	Potato, onion, brinjal and carrot
2. Baskets	Tomato and okra
3. Wooden box	Tomato
4. Jute bag	Cauliflower, cabbage and brinjal
5. Unpacked	Bottle gourd, pumpkin and radish

The cost of package and nature of vegetables were the important criteria in selection of a particular package. The cost of packing of vegetables has been presented in Table 5. The cost varied between Rs 12.42 (carrot) to Rs 43.58 (tomato) per quintal. The cost of packing included cost of labour and package used. The number of packages used varied across vegetables. The problem of insufficient availability of packing materials at harvesting time and their high cost were most important problems faced by the growers.

Transportation: The transportation of vegetables is the most important post-harvest activity involving movement of vegetables from farm to the primary, secondary and terminal markets. The perishable nature of vegetables requires specific and quick transportation. The vegetable growers of study area used different types of transport, such as head load, horse cart, rickshaw, tractor, truck etc. Large quantities of different vegetables were also transported to different parts of the state as well as the country by truck and rail transport. The cost of transportation incurred by the sample vegetable growers has been presented in Table 5. The maximum cost of transportation was estimated as Rs 27.05 per quintal for potato while the minimum of 7.20 rupees per quintal for brinjal. The maximum cost of transportation on potato may be due to selling it to distant markets. The problem of non-availability of suitable mode of transportation at harvest time, improper loading-unloading were the important problems faced by the growers resulting in economic losses.

Storage: Storage is of great significance since it stabilizes the prices. None of the sample vegetable growers were found storing vegetable except potato and onion, and that also in unutilized space of their house for a very short period. Therefore, analysis on this aspect was not performed.

Price Spread: It was analyzed by decomposing the consumers' price among producer, WCA and retailer and results are presented in Table 6. The maximum producers' share was observed in bottle gourd (72.84 percent) while the minimum of 16.06 percent in pumpkin. The WCA (Wholesaler-cum-Commission Agent) received maximum share of 31.48 percent from onion and the retailers from pumpkin (67.76 percent).

Table 6. Marketing cost and margin as a share of producers' price.

Sl. Vegetable No.	Consumers' Price (Rs/q)	Producers' Price (Rs/q)	Present share in Consumers' Price		
			Producer	WCA	Retailers
1. Bottle gourd	486	354	72.84	9.82	17.34
2. Pumpkin	330	53	16.06	16.18	67.76
3. Brinjal	529	286	54.06	12.44	33.50
4. Okra	650	447	68.77	9.58	21.65
5. Tomato	770	473	61.43	20.53	18.04
6. Onion	666	389	58.41	31.57	10.11
7. Potato	425	268	63.06	23.70	13.24
8. Cauliflower	525	270	51.43	21.52	27.05
9. Cabbage	427	282	66.04	12.52	21.44

CONCLUSIONS

From the foregoing analysis following conclusions can be drawn which suggest for the strategies to be initiated for promotion of vegetable trade in the state so as to enhance the productivity, profitability and export level thereof:

The level of technology adoption was much lower than the recommended level, which resulted in low productivity and efficiency of resources in most of the vegetables. Although the appropriate technological management has been developed their transfer seems to be inadequate. Therefore, the transfer of technology needs to be given priority.

The sector, being highly concentrated with small and marginal farmers (more than 89 percent), has resulted in sub-optimal use of crucial inputs like fertilizers, plant protection measures etc. Therefore, financial assistance with the provision of crop insurance will encourage the growers in increasing use of technological inputs in vegetable production.

The marketing cost forms a considerable part of total cost of production. Therefore, there is a need to create an alternate marketing channel to improve the marketing efficiency and increase the profitability level.

The perishable nature of vegetables, lack of processing and canning facilities, inadequate storage techniques, non-availability of suitable transportation etc are also responsible for the deplorable situation of the sector. Therefore, to ensure better return to the producers, these facilities need to be established in the area of concentrated production so that the surplus vegetables are either processed or exported to deficit areas.

There is an urgent need of training of vegetable growers on the Scientific Post-harvest techniques, if the vegetable production is to be sustained on a profitable basis.

Though the Agriculture Produce (Grading & Marketing) Regulation Act was enacted in the state in 1961 its' effective implementation and monitoring is required to be ensured. There is also need of amendment in the act in the present economic environment globalization and commercialization.

Finally for modernizing and organizing the vegetable trade, a professional body on the lines of HOPCOMS/NDDDB/MAHAGRAPES is urgently required to cater to the needs of producer as well as the consumers.

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RELATIVE ABUNDANCE OF SPIDER FAUNA IN RICE ECOSYSTEM

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ABSTRACT

A survey on the relative abundance of spider fauna was made at fortnightly interval in six rice growing districts Viz., Varanasi, Chandauli, Deoria, Basti, Sant Kabirnagar and Siddarthnagar of Uttar Pradesh. A total of 39 species belonging to 18 genera under 9 families were recorded. Out of these, 11 species of Lycosidae, 5 species of Salticidae, 3 species of Clubionidae and 5 species of Oxyopidae were hunting spider. Four species of Thomisidae were ambushing spider. Five species of Araneidae, one species of Theridae, 4 species of Tetragnathidae, one species of Uloboridae were web building. Among the total spider species, 33 species in Varanasi, 29 species in Chandauli, 23 species in Deoria, 32 species in Basti, 30 species in Sant Kabirnagar and 26 species in Siddarthnagar rice ecosystem were recorded. The relative abundance of *Lycosa pseudoannulata* was found highest followed by *Arctosa himalayensis* in Chandauli, Basti, Sant Kabirnagar, Siddarthnagar and in Deoria followed by *Araneus inutus* and *Tetragnatha mandibulata*. Only *Arctosa himalayensis* was found most abundant in Varanasi. Here the number of spider species and number of individuals were recorded highest followed by Basti rice ecosystem. The species richness was also greater in Varanasi but the species diversity was greater in Basti rice ecosystem.

Key words: Spider fauna, quantitative estimate, species diversity and species richness.

INTRODUCTION

Many field experiments performed over the last 35 years have demonstrated that spiders can reduce insect populations and crop damage they cause (Reichert and Lawrence, 1997). The effect of spiders on pest population may be enhanced if their population increase rapidly in response to rich supply of nutritious alternative preys (Axelsen *et al.*, 1997; Khan and Misra, 2003a). These are indications from the literature that there are many mechanisms whereby spiders can affect of invertebrate pests. Direct predation, pest dislodgment and wasteful killing reduce pest abundance (Barbosa, 1998). Successes with spider, suppression of pest in rice ecosystem is correlated most frequently

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with increased predator densities, though recent studies indicate that species richness may be important component as well (Heong *et al.*, 1991b; Riechert, 1999). In recent years, there has been a realisation by ecologists that components of rice ecosystems are tractable to manipulate and those spiders are convenient model organisms (Riechert and Bishop, 1990; Khan and Misra, 2002). Consequently, there are growing numbers of investigations in which spiders in rice ecosystems are used as tools to gain insights into the role of generalist predators in community and ecosystem function (Sunderlan, 1999; Khan and Misra, 2003). Study on abundance of fauna is a prerequisite for any kind of attempt for study of spiders and their role as biological control agent in rice ecosystem.

MATERIALS AND METHODS

Diversity of spiders

Spider samples were collected from six rice-cultivated districts of Uttar Pradesh viz., Varanasi, Chandauli, Deoria, Basti, Sant Kabirnagar and Siddarthnagar at 15 days intervals from the vegetative stage (Second week of transplanting) to flowing stage (fifteenth week of transplanting) during Kharif 2000 to 2002 (for three years). A mylar enclosure having a dimension of 1.0 × 1.0 × 1.0 meter trapped all spiders on 36 hills. The spiders were sucked up by using a FARMCOP suction device (Barrion and Litsinger, 1981). Five samples from each site were taken, for a total of 540 samples. The species first seen were collected and preserved in Oudemans's fluid (85 part, 70 % alcohol, 5 parts, glycerine, 5 part, glacial acetic acid) for identification. In the laboratory, specimens were identified on the basis of criteria given by various workers (Barrion and Litsinger, 1980; Tikader and Bal, 1981; Tikader and Biswas, 1981).

Quantitative estimation of spider abundance

Quantitative estimation of individual species under above six ecosystems was made by using the data derived from field survey. Species diversity (H') was based on Shannon-Wiener function as detailed by Margalef (1957) while using information theory

$$H' = -\sum p_i \log_{10} p_i$$

Where,

$$p_i = N_i/N$$

N_i = Total number of individual in a species

N = Total number of individuals in all the species

Evenness (J') was also calculated to estimate the equitability component of diversity using the formula (Pielou, 1975).

$$J' = H' / \log_{10} S$$

Where, S = Species richness

Richness (ma) was computed by using the following formula (Pielou, 1966)

$$ma = \frac{S-1}{\log_{10} N}$$

Where,

S = Total number of species collected.

RESULTS AND DISCUSSION

The spiders encountered in rice ecosystems of Uttar Pradesh were grouped on the basis of their behavioural characteristic Viz., hunting, ambushing and web building (Table 1).

A total of 39 species belonging to 18 genera under 9 families were recorded. Out of these, 11 species Lycosidae, 5 species under Salticidae, 3 species under Clubionidae and 5 species under Oxyopidae were hunting spider. Four species under Thomisidae were ambushing spiders. Five species under Araneidae, one species under Theridae, 4 species under Tetraganathidae, one species under Uloboridae were web building. Earlier, Khan and Misra (2003a) was reported 14 species belonging to 10 genera under 7 families from eastern Uttar Pradesh. Similar diversity was also recorded by Ghode *et al.* (1985). They were found 21 species of spiders belonging to 8 families in wetland rice ecosystem of Orissa.

Of 24 species of hunting spiders, *Lycosa pseudoannulata* (Lycosidae) (16.74 %) *Salticidae*(4.49%); *Clubiona japonicola* (Clubionidae) (4.82 %) and *Oxyopes javanus* (Oxypidae) (5.37 %) were relatively most abundant. Among the 4 species of ambushing spiders of family (Thomisidae), *Thomisus sp.* (3.27 %) was dominant in abundance. Of 11 species of web building spiders, *Araneus insutus* (Araneidae) (6.38 %) *Tetraganatha mandibulata* (Tetraganathidae) (8.05%) were most abundant. *Theridion sp.* (Theridae) (0.09 %) and *Uloborus sp.* (Uloboridae) (0.24 %) were found poor in abundance among web building spiders. Among the total spider species, 33 in Varanasi, 29 in Chandauli, 23 species in Deoria, 32 in Basti, 30 species in Sant Kabirnagar and 26 in Siddarthnagar rice ecosystem were recorded (Table 1 and 2).

Of these total species, *Arctosa himalayensis* (18.56 %) was very abundant in Varanasi followed by *Lycosa pseudoannulata* (13.41 %) and *Tetragnatha mandibulata* (8.46 %). Similarly, Khan and Misra (2003a) recorded that the *Arctosa himalayensis* was dominant followed by *pseudoannulata* and *mandibulata* in the same ecosystem. *L. pseudoannulata* was found very abundant in rest of the ecosystems, Chandauli (15.04 %), Deoria (20.20 %), Basti (16.23 %), Sant Kabirnagar (17.40 %) and Siddarthnagar (18.18 %); The present findings are in consonance with that of Heong *et al.* (1991) and Sahu *et al.* (1996). According to them, *a pseudoannulata* was dominant predator in rice ecosystem. *Theridion sp.* followed by *T. pugifis* was found poorest in abundance. These were noted only in Varanasi (0.09 % followed by 0.12 %) and Chandauli (0.42 % followed by 0.99 %), respectively. The total composition of *Lycosidae* (43.56 %) was dominant over the population of remaining families of spiders.

The composition of abundant spider species in Sant Kabirnagar (68.17 %) followed by Varanasi (68.03 %) were predominant over the population of 65.49 % in Chandauli, 57.87 % in Siddarthnagar, 56.65 % in Basti and 55.64 % in Deoria rice ecosystems. Out of these compositions, 8 species in Varanasi, 7 species in Chandauli and also in Basti, 6 species in Deoria and also in Siddarthnagar and 6 species in Sant Kabirnagar were abundant. Among these abundant species, 3 in Varanasi and also in Deoria, 4 in Chandauli, Basti and also in Sant Kabirnagar, 2 species in Siddarthnagar and were very abundant. The present findings are in consonance with that of Bhardwaj and Pawar (1986) and Heong *et al.* (1991). According to them, 2 species were very abundant in Madhya Pradesh and 3 were in the Philippines; respectively.

Table 1. Relative abundance of spider species for 6 rice growing districts in U.P., India during Kharif season, 2001 to 2003

Sl. No.	Spider species	Relative abundance (%)						Mean
		Varanasi	Chandauli	Deoria	Basti	Kabir-nagar	Siddarth-nagar	
A.	HUNTING SPIDER							
I	Family Lycosidae							
1.	<i>Arctosa himalayensis</i>	18.56 ¹	13.97 ²	5.24	9.36 ²	7.22 ⁴	6.21 ⁵	10.092 ²
2.	<i>A. indicus</i>	1.27	0.00	2.27	1.98	0.00	0.00	0.92
3.	<i>Hippasa holmerae</i>	0.00	0.00	0.00	2.43	3.55	4.39	1.73
4.	<i>Lycosa pseudoannulata</i>	13.41 ²	15.04 ¹	20.20 ¹	16.23 ¹	17.40 ¹	18.18 ¹	16.74 ¹
5.	<i>L. mackenziei</i>	1.12	2.29	0.00	0.00	0.64	0.00	0.67
6.	<i>L. geotubalis</i>	0.76	0.00	0.00	0.00	0.10	0.40	0.21
7.	<i>Lycosa sp.</i>	4.22 ⁸	5.64 ⁵	3.20	3.28	3.20	2.25	3.63
8.	<i>Pardosa birmanica</i>	3.42	4.22 ⁶	6.43 ⁵	4.20	5.02 ⁹	3.93	4.54
9.	<i>P. fletcheri</i>	0.49	0.00	0.00	1.20	0.08	0.00	0.29
10.	<i>P. sutherlandi</i>	0.77	1.10	3.12	5.49 ⁶	5.71 ⁵	4.07	3.38
11.	<i>Pardosa sp.</i>	0.98	1.00	1.61	2.31	0.00	2.26	1.36
II	Family-Salticidae							
12.	<i>Marpisa sp.</i>	1.78	0.64	2.76	1.43	2.34	0.54	1.58
13.	<i>Phidippus pateli</i>	4.72 ⁵	3.94	2.48	2.71	2.26	5.39	3.58
14.	<i>P. indicus</i>	0.26	0.00	0.00	1.03	0.90	0.00	0.37
15.	<i>Plexippus paykulli</i>	1.29	2.42	0.00	0.76	0.45	2.13	1.76
16.	<i>Salticus sp.</i>	4.48 ⁶	3.82	6.49 ⁴	3.65	3.98	4.52	4.49
III	Family Clubionidae							
17.	<i>Castianeira indica</i>	0.80	0.00	0.00	0.36	0.40	0.00	0.26
18.	<i>Clubiona japonicola</i>	4.38 ⁷	3.02	5.24	5.43 ⁷	5.67 ⁷	5.20	4.82 ⁷
19.	<i>C. ludhianensis</i>	0.00	0.26	0.00	1.22	0.00	0.00	0.25
IV	Faimly Oxyopidae							
20.	<i>Oxyopes chittrae</i>	0.19	0.00	0.00	0.13	0.38	1.12	0.31
21.	<i>O. javanus</i>	5.32 ⁴	3.08	6.02	6.21 ⁵	5.47 ⁸	6.14 ⁶	5.37 ⁶

Continued from Table 1

22.	<i>O. pandae</i>	1.23	0.22	0.00	1.60	0.86	0.39	0.72
23.	<i>O. ratane</i>	0.92	0.00	0.76	0.00	0.00	0.00	0.28
24.	<i>O. shweta</i>	1.38	2.39	1.23	0.93	2.64	2.66	1.87
B AMBUSHING SPIDERS								
V Family- Thomosidae								
25.	<i>Thomisus elongates</i>	0.00	0.00	0.00	1.10	0.36	0.00	0.24
26.	<i>T. pugifis</i>	0.25	0.99	0.00	0.00	0.00	0.00	0.20
27.	<i>T. pugulis</i>	0.49	0.76	1.02	0.00	0.13	0.31	0.45
28.	<i>Thomisus sp.</i>	3.53	4.327	2.33	2.68	2.91	3.86	3.27
C. WEB-BUILDING SPIDERS								
VI Family- Araneidae								
29.	<i>Araneus inustus</i>	4.48 ⁶	7.23 ⁴	8.12 ²	6.61 ⁴	5.68 ⁶	6.24 ⁴	6.38 ⁴
30.	<i>Argiope sp.</i>	1.20	2.41	3.21	2.01	0.92	1.29	1.84
31.	<i>Larinia sp.</i>	0.08	0.00	0.26	0.42	0.00	0.90	0.28
32.	<i>Neoscona mukherjei</i>	0.00	0.12	0.00	0.30	1.02	0.00	0.24
33.	<i>Neoscona sp.</i>	0.00	1.23	0.00	0.61	0.93	0.00	0.46
VII Family- Therididae								
34.	<i>Theridion sp.</i>	0.12	0.42	0.00	0.00	0.00	0.00	0.09
VIII Family- Tetragnathidae								
35.	<i>Tetragnatha javana</i>	3.24	5.64 ⁵	8.02 ³	4.16	8.24 ²	6.72 ³	6.00 ⁵
36.	<i>T. mandibulata</i>	8.46 ³	9.43 ³	6.38 ⁶	7.32 ³	7.76 ³	8.99 ²	8.05 ³
37.	<i>T. maxillosa</i>	1.28	2.21	1.90	2.37	2.43	0.19	1.73
38.	<i>Tetragantha sp.</i>	3.12	2.16	1.73	0.48	0.00	0.80	1.38
IX Family-Uloboridae								
39.	<i>Uloborus sp.</i>	0.00	0.13	0.00	0.00	1.34	0.00	0.24
	Very abundant spider sp. (No.)	3	4	3	4	4	2	3.33
	Abundant spider sp. (No.)	8	7	6	7	6	6	7.16
	Composition of abundant spider sp.(%)	68.03	65.49	55.64	56.65	68.17	57.87	61.98
	Total spider collected (No.)	2860	2238	1221	2619	1802	1294	2005.67

* Numbers in superscript represent ranking of relative abundance

Table 2. Parameter of abundance of spider fauna in 6 rice growing districts of Uttar Pradesh, India during 2001 to 2003

Dictriacts	N	S	J'	H'	ma
Varanasi	2860	33	0.8159	1.2391	9.2584
Chandauli	2238	29	0.8311	1.2154	8.3587
Deoria	1221	23	0.8915	1.2140	7.1273
Basti	2619	32	0.8803	1.3249	9.0694
Sant Kabir- nagar	1802	30	0.8535	1.2608	6.8142
Siddarth-nagar	1294	26	0.8511	1.2242	8.0336
Total species		39			
Mean			0.8539	1.2464	8.1102

Where,

N= Total number of individual in all species

S = Number of species

J'= Indices of evenness

ma = species richness

H= Species diversity

Quantitative estimates of spider abundance

The average mean of species diversity of spider was observed 1.2464 and species richness was 8.1102 in rice ecosystems of Uttar Pradesh (Table 2). The highest species diversity was recorded in Basti (1.3249) followed by Sant Kabirnagar (1.2608). The species richness of spiders was greater in Varanasi (9.2582) followed by Basti rice ecosystems. The poorest species diversity was observed in Deoria (1.21402) followed by Candauli (1.2154) rice ecosystems. The species richness of spider was observed poorest in Siddarthnagar (6.8142) followed by Deoria (7.1273) rice ecosystem. Kamal *et al.*(1992) studied the abundance of spiders fauna in rice ecosystem of Bangladesh. They computed the species richness of spider in field, which was 7.2 as compared to 4.4 in weedy fallow, 4.0 in seedbed and 3.5 in ratoons. The species diversity and richness of spiders in field were 1.2 and 0.8, respectively. Similarly, Kumar and Velusamy (1996) also stated that rice field possessed a more diverse and richer population of spiders than the border weeds at Coimbatore, Aliyarnagar and Karaikal.

Overall results indicates that the species richness was greater in Varanasi due to highest number of spider species and their population and species diversity was varied due to the variation of total number of spiders and number of species in particular rice ecosystems. This is in agreement with the report of Heong *et al.*, (1990a) who was found the diversity greater at IRRI farm and poorest in Cabanathuan followed by Banaue sites of the Philippines and richness was also high at IRRI than other sites.

CONCLUSION

Our study indicate that the knowledge of relative abundance of generalist spiders was a prerequisite as a tool of biological control and high species diversity and species richness of spider fauna also help in ecological based management in rice ecosystem.

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EVALUATION OF SPRING WHEAT [*Triticum aestivum* (L.) em Thell] GERMPLASM FOR VARIOUS FLORAL CHARACTERISTICS

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ABSTRACT

The genetic variability, heritability and genetic advance involving six floral characteristics related to outcrossing behavior in 400 spring wheat genotypes were investigated with a view to explore the possibility of improvement in the yielding ability and stability by increasing the level of heterozygosity. A significant quantitative variation existed for floral characteristics. High heritability coupled with high genetic advance in stigma length, openness of florets, anther extrusion and duration of floral opening indicated that selection for these characteristics may be effective. The adapted cultivars genotype were found promising compared to exotic and indigenous germplasm. Among the genotype HD 2329, HP 1633, PBW 54 were found promising for multiple floral characteristics. The character association studies indicated that most of the characteristics showed significantly positive correlation with each other but high correlation was observed between anther length and stigma length, and anther extrusion and duration of floral opening. The results indicated that selection for the characteristics that promote out crossing (high anther extrusion, and longer anthers and stigmata) may result in the genotypes with more open pollination ability and these genotypes may be utilized as parents in improvement programme to improve yielding ability through enhanced heterozygosity

Key words: *Spring wheat, floral characteristics, outcrossing, pollen viability.*

INTRODUCTION

The Indo Gangetic plains of northern India, the most productive area for wheat crop includes two major wheat growing zones namely north-western plains zone (NWPZ) and north-eastern plains zone (NEPZ). NWPZ was the seat for green revolution in India and considered as wheat bowl of the country whereas NEPZ is the future potential area of wheat production. Indian, wheat programme has achieved a remarkable position globally due to its rich wheat biodiversity and their effective utilization in wheat improvement programme. India has maintained a large number of indigenous as well as exotic wheat germplasm in repositories / gene banks at national level and also at institutional level. Besides, more than 200 cultivars of spring wheat have been adapted for commercial cultivation in various zones. In the predominantly wheat-growing areas particularly in NWPZ, the productivity has reached to a saturation

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level. It has been demonstrated that increasing the level of heterozygosity can enhance the yielding ability and stability in cereals (Mayer et. al., 1995). Selection of floral characteristics that enhance magnitude of out crossing such as duration of flower opening, greater anther extrusion in the male parent, openness of florets and stigma receptivity in the female parent is crucial in this regard.

Previous studies indicated that floral structure; anthesis and anther dehiscence patterns in wheat [*Triticum aestivum* (L.) em Thell] make this crop strictly autogamous with natural outcrossing rates ranging from 0.0 to 6.05 per cent (Martin, 1990; Hucl, 1996). Important floral characteristics that influence outcrossing in wheat are stigma size, anther size, anther extrusion, pollen number and pollen viability. Based on the studies and inheritance studies in cereals, Ceccarelli (1978); Sarkar & Miah (1983) proposed that out crossing, and consequently the level of heterozygosity, might be increased by selecting for large, protruding anthers and vigorous stigma. Thus, the extent of variability present in the germplasm, their heritability pattern and character associations among various floral characteristics were of utmost importance. The main aim of the present study was to estimate the range of genetic variation along with selection parameters like heritability and genetic advance for out crossing related floral characteristics in a representative sample of three different categories of wheat germplasm namely, exotic germplasm, indigenous germplasm and the adapted cultivars in India. In addition, the trends of correlations among those characteristics were of great interest.

MATERIALS AND METHODS

Four hundred genetically diverse genotypes were taken from the spring wheat [*Triticum aestivum* (L.) em Thell] germplasm maintained at Banaras Hindu University, Varanasi, India and these were categorized in three classes on the basis of their origin. These classes are-

- I. Exotic germplasm obtained from various countries through introduction or through various international nurseries and trials (90),
- II. Indigenous germplasm developed from various research centers within the country through selection following hybridization having improvement over land races for different yield components (205) and
- III. Adapted cultivars released for commercial cultivation in different agro climatic conditions of the country. (105).

Field experiments were conducted during two consecutive crop season (1996-98) at Agricultural Research Farm, Banaras Hindu University, Varanasi (25° 18' N latitude and 82° 03' longitude). The climate that falls under sub humid with annual average rainfall of 1081.4 mm and mean relative humidity of 62%. The maximum and minimum temperatures range between 23.2°C - 46.4°C and 9.3°C -24.5°C, respectively. The above classes of genotypes were sown in three different experiments for each class of genotypes in randomized block design with three replications. The plot size was double row of 3m lengths with spacing of 23 cm between the rows and 10 cm between the plants. All the recommended agronomic practices were adopted to raise a good crop.

The data were recorded for six floral characteristics and subjected to statistical analyses. Anther length (Atashi-Rang & Lucken, 1978) was measured in mm using a dissecting microscope and ocular micrometer scaled to 0.1 mm increments and was recorded as the average of three anthers belonging to a lateral floret of the three central spikelets of a spike. Stigma length (mm) was also measured by using a dissecting microscope and ocular micrometer. The average from two stigma of one lateral floret from three central spikelets of a spike was recorded. The anther length and stigma length was also recorded on five randomly selected spikes in each replication. Anther extrusion (%) was measured after counting the extruded anthers of two lateral florets of five central spikelets from each of the ten spikes / replication (Atashi-Rang & Lucken, 1978). Openness of floret was measured in degree using divider and protractor. It was taken as the separation angle between the glumes

of first two florets of a spikelet. Duration of floral opening was recorded in minutes from the time of opening to closing of florets. The data was recorded on five florets of each of the three randomly selected spikes in each replication. The observations were made on three consecutive days on five florets of the same spike. The anthers from each of the three central spikelets of five randomly selected spikes per replication were collected to examine the pollen viability (%) as per Joppa et al. (1966); Hucl (1996). For the purpose, the spikes were collected at Zadoks growth stage 60 (ZGS 60) and were fixed in 3:1 solution of 95% ethanol:acetic acid. Anthers from central spikelets were assayed for the pollen staining. Each determination was based on a count of 100 pollen grains. The anthers were placed on a microscope slide with three drops of potassium iodide, gently crushed to extract the pollen and the debris removed. A cover slip was placed over the pollen grains. Unstained or partially stained but shriveled pollen grains were rated as unviable. The dark stained pollen grains, which were due to starch particles, were taken as viable pollen grains. The percentage was calculated from dividing the dark stained pollen grain by total count.

The data of both the years were pooled and analyzed to work out the variance (Panse & Sukhatme, 1967; Knapp et al., 1985), coefficients of variability, genetic advance (Johnson et al., 1955), heritability in broad sense (Knapp et al., 1985) and correlation coefficients (Robinson et al., 1951).

RESULTS AND DISCUSSION

Pooled analysis of variance was done for all the characteristics to determine the pattern of existing variability in the wheat germplasm of three different groups and the expression of characteristics over the years (Table.1). Highly significant differences were observed among genotypes for all the characteristics in all the three experiments, which show existence of variability among the genotypes / germplasm for the characteristics under study. The year x genotype interactions were non significant in all the cases except for pollen viability in exotic germplasm which indicated almost similar trend of the expression of character in wheat germplasm over the year.

Table 1. Analysis of variance (ANOVA) for floral characteristics in different categories of spring wheat

Source of variation	Degree of freedom	Mean sum of squares				Duration of Floral Opening (minutes)	Pollen Viability (%)
		Anther Length (mm)	Stigma Length (mm)	Anther Extrusion (%)	Openness of Florets (o)		
<i>Exotic germplasm (EX)</i>							
Year	1	0.35*	0.45	78.94	38.42	24.36	12.10*
Replication	2	0.28*	0.32	16.25	9.85	10.08	7.00
Year x Replication	2	0.14	0.16	13.50	4.82	6.26	5.50
Genotype	89	1.16**	0.99**	857.64**	89.94**	116.18**	33.40**
Year x Genotype	89	0.10	0.16	9.49	2.11	4.58	4.47*
Error	356	0.09	0.13	38.91	14.64	7.82	3.13
Total	539						

Continued from Table-1

<i>Indigenous germplasm (IN)</i>							
Year	1	0.29*	0.88**	552.50**	72.88	22.84	64.40*
Replication	2	0.18*	0.13	12.87	6.25	14.21	4.50
Year x Replication	2	0.14	0.16	9.25	5.78	3.88	7.50
Genotype	204	0.57**	0.57**	917.82**	128.31**	124.67**	60.56**
Year x Genotype	204	0.06	0.07	6.74	4.96	3.38	5.62
Error	816	0.05	0.06	57.66	23.70	7.13	12.53
Total	1229						
<i>Adapted cultivars (RC)</i>							
Year	1	0.30*	0.32*	85.28	32.76	22.29*	14.30*
Replication	2	0.12	0.06	18.56	10.17	4.80	5.00
Year x Replication	2	0.12	0.11	16.75	7.16	3.13	4.25
Genotype	104	0.70**	0.459**	676.44**	103.67**	102.06**	31.67**
Year x Genotype	104	0.04	0.07	9.41	9.07	6.39	3.74
Error	416	0.05	0.06	39.45	15.05	5.61	3.35
Total	629						

*, ** - Significant at P=0.05 and P=0.01 level, respectively.

3.1 Variability for floral characteristics

A wide range was observed among the genotypes in different classes for all the characteristics (Table.2). The expression of variability for different characteristics was measured in terms of range and coefficient of variability. The frequency distribution of the genotypes in exotic, indigenous accessions and adapted cultivars was done for different classes of the floral characteristics and the percentage of genotypes in each class was worked out for making comparisons (Figure 1).

Anther length ranged from 2.91 to 5.00 mm. Although the mean of anther length was the highest among adapted cultivars, longer range was observed among exotic genotypes. Similar trend of high values in adapted cultivars was also observed for stigma length, anther extrusion and duration of floral opening. The stigma length ranged from 1.89 to 3.47 mm. whereas a range of 9.22 to 88.43% was observed for anther extrusion and 8.67 to 39.33 minutes for duration of floral opening. The floral openings of 12.02 to 35.85% were observed in the study in which indigenous germplasm showed wider range as well as higher mean values for this character. The pollen viability ranged from 83.64 to 97.31%. On an average, higher pollen viability was observed in adapted cultivars but the range was more among indigenous accessions. Comparison of exotic and indigenous germplasms indicated higher range of anther and stigma length, anther extrusion and duration of floral opening among exotic germplasm but it was noted from the mean values for these characteristics that indigenous germplasm had longer anthers and stigma along with more extruded anthers and the flowers remained open for longer duration than the exotic germplasm. In addition, adapted cultivars that have improved genotypes developed either by selection from exotic / indigenous germplasm or through hybridization between exotic and/or indigenous germplasm followed by further selection in segregating generations, showed improved values for these floral characteristics.

Table 2. Range, mean, coefficients of variability, heritability and genetic advance for floral characteristics in spring wheat

Character	Category	Range	Mean	Coefficient of variability		Heritability [BS] (%)	Genetic Advance**	Genetic Advance as % of mean
				Phenotypic	Genotypic			
Anther Length (mm)	EX	2.91-4.89	4.03+ 0.03	12.89	10.44	91.23	0.97	24.06
	IN	3.19-4.99	4.14+ 0.02	8.97	7.04	89.47	0.68	16.42
	AC	3.21-5.00	4.22+ 0.02	9.38	7.86	91.66	0.74	17.53
Stigma Length (mm)	EX	1.89-3.38	2.85+ 0.05	18.56	13.03	83.64	0.92	32.28
	IN	2.13-3.42	2.96+ 0.02	12.91	9.73	87.36	0.68	22.97
	AC	2.13-3.47	3.02+ 0.02	11.84	8.44	84.41	0.62	20.53
Anther Extrusion (%)	EX	9.22-86.96	48.15+ 0.11	27.13	24.69	98.79	26.37	4.76
	IN	11.10-84.52	48.36+1.10	28.69	25.48	99.22	28.30	58.51
	AC	12.15-88.43	51.49+0.34	23.03	20.47	98.60	23.93	46.47
Openness of florets (%)	EX	12.02-34.57	21.66+0.74	23.13	17.66	97.39	10.01	46.21
	IN	12.65-35.85	24.01+1.17	25.67	18.88	96.07	12.19	50.77
	AC	13.53-34.25	23.89+0.05	22.47	16.62	91.20	10.06	42.10
Duration of floral opening (Minutes)	EX	10.33-39.33	20.52+0.39	24.53	21.02	96.07	9.96	48.53
	IN	8.67-34.17	19.93+0.33	25.63	22.55	97.25	10.21	51.22
	AC	9.50-37.83	21.69+0.32	21.53	18.41	93.70	8.95	41.26
Pollen Viability (%)	EX	85.97-94.99	90.62+0.11	3.20	2.42	86.53	5.13	5.66
	IN	83.64-97.31	90.98+1.25	4.84	3.32	90.68	8.16	8.96
	AC	86.63-95.85	91.60+0.25	3.11	2.36	88.06	5.17	5.64

*EX = Exotic germplasm; IN = Indigenous germplasm; AC = Adapted cultivars,

** Genetic advance at 5% selection intensity.

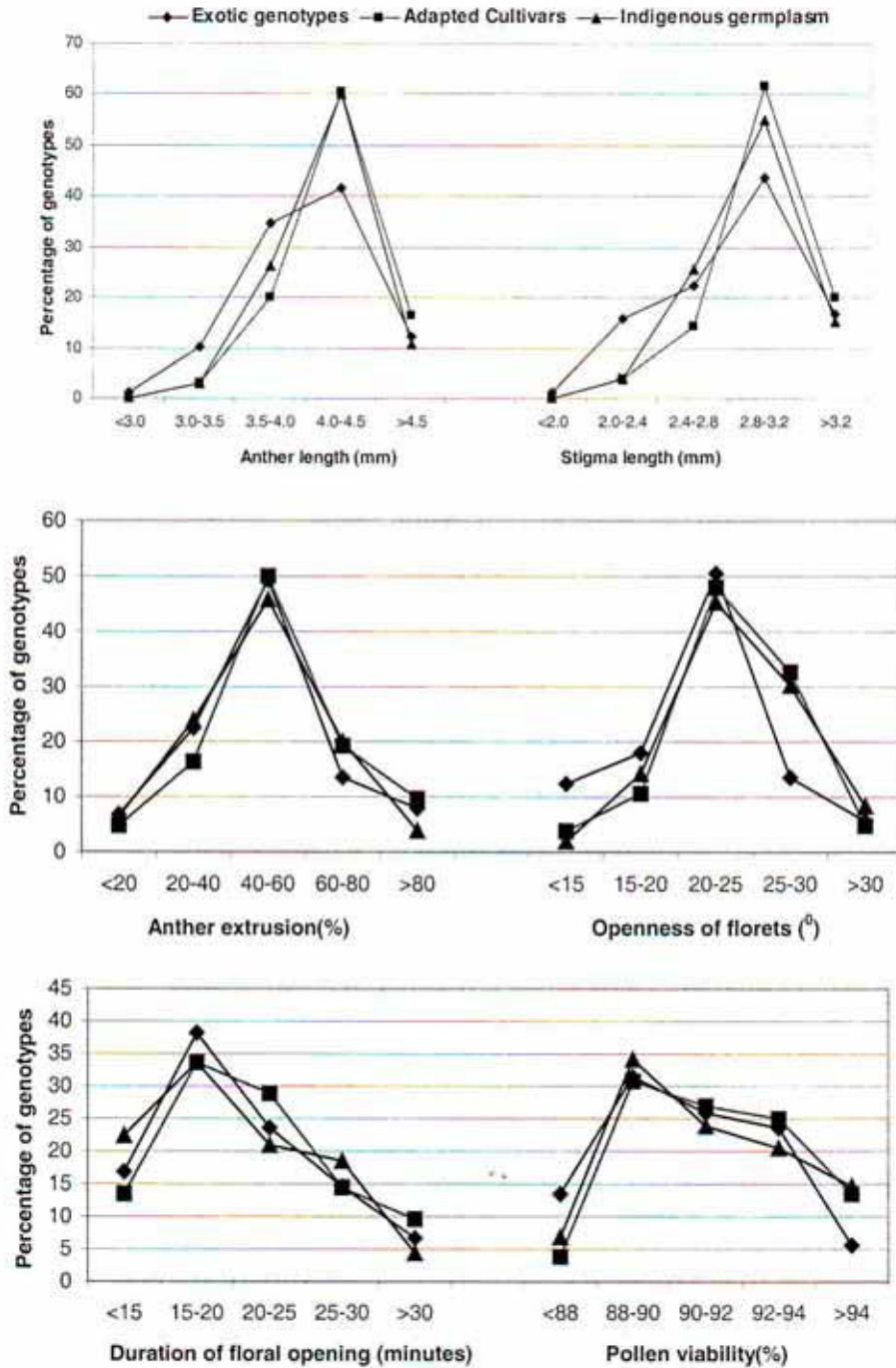


Fig.1: Frequency distribution for floral characteristics in spring wheat [*Triticum aestivum* (L.) em Thell]

All the six characteristics varied continuously in exotic and indigenous accessions as well as in adapted cultivars. Among the genotypes that contributed to different classes of these floral characteristics, about 60% indigenous germplasm and adapted cultivars showed 4.0-4.5 mm anther length and 2.8-3.2 mm stigma length. Similarly, half of the exotic germplasm and adapted cultivars showed 40-60% anther extrusions and 20-25% of floral opening. For duration of floral opening and pollen viability, all the germplasm groups had shown similar trend. More than 30% germplasm had floral opening of 15-20 minutes and pollen viability ranging from 88-90% in all the three groups. Similar findings were also reported by other workers (Atashi-Rang and Lucken, 1978; Komaki and Tsunewaki, 1981). Taken into consideration the percentage of genotypes that fall into the class representing the higher values of these characteristics, it was found that very small proportions of the exotic and indigenous germplasm (less than 10% on average) showed high values for these floral characteristics. Among adapted cultivars, comparatively more proportion of the genotypes (about 12%) was observed with higher values. The less proportion of the germplasm in higher classes has indicated the possibility of improvement in average genotypes for these characteristics through breeding techniques so that more genotypes can be included in this elite group. The promising germplasm for higher values of these characteristics can be further utilized in wheat improvement programme that focus on increasing heterozygosity through more out crossing.

Some promising genotypes for multiple floral characteristics were also screened on the basis of their *per se* performance (Table.3). These included HD 2329, HP 1633, PBW 54, WL 711, HD 2009, Sonalika, UP 2121, WH 147 and WH 157 among adapted cultivars; Gumachil, V 22, CIMMYT 244 and SUZHOE//10-31B-0Y among exotic germplasm and AKW 1390, BW 11259, K 9310, PBW 389, WG 2878 and WH 638 among indigenous germplasm. These genotypes possessing longer anther and stigma, more extruded anthers and open florets for longer duration and more pollen viability may be effectively utilized as parents in wheat improvement programme for enhancing outcrossing as well as increasing heterozygosity.

Coefficient of variability shows the extent of variability present for the characteristics. The highest coefficient of variability either at phenotypic or at genotypic levels was recorded for anther extrusion in all the three groups. Higher values were also found for openness of florets and duration of floral opening (Virmani & Edwards, 1982; Singh, 1992; Hucl, 1996). On the other hand it was lowest for pollen viability. Larger coefficient of variability expresses the quantum of variability present for the particular character and the characteristics having higher values have a better chance for selection. Similar trend was observed in all the groups but more values of coefficient of variability among exotic germplasm indicates the possibility of exploiting more variability from these genotypes through direct selection or use them in hybridization programme. The out crossing related characteristics in cereals have been reported to be affected by environmental factors. Hammer (1984) states that the expression of out crossing related characteristics in barley greatly depends on environmental conditions. It was observed from the results that the character expression was stable in different environmental condition during two crop seasons. This suggests the good chances for transferring the gene into other genotypes by back crossing.

Table 3. Promising spring wheat genotypes for multiple floral characteristics

Sl. No.	Genotypes	Category*	Characteristics
1.	HD 2329	AC	AL (4.59 mm), SL (3.78 mm), AE (88.43 %), DFO (34.83 minutes), PV (94.97 %)
2.	HP 1633	AC	AL (4.88 mm), SL (3.26 mm), AE (84.44 %), OF (32.870), DFO (36.50 minutes)
3.	PBW 54	AC	AL (4.60 mm), SL (3.24 mm), OF (34.250), DFO (33.83 minutes), PV (94.17 %)
4.	WL 711	AC	SL (3.21 mm), AE (85.37 %), OF (33.070), DFO (36.17 minutes)
5.	HD 2009	AC	AL (4.75 mm), SL (3.34 mm), AE (82.29 %), DFO (31.50 minutes)
6.	Gumachil	EX	AL (4.58 mm), SL (3.38 mm), AE (80.92 %), DFO (33.00 minutes)
7.	V 22	EX	AE (85.50 %), OF (32.580), DFO (35.17 minutes), PV (94.71 %)
8.	SONALIKA	AC	SL (3.24 mm), DFO (30.33 minutes), PV (95.85 %)
9.	UP 2121	AC	AL (4.64 mm), SL (3.38 mm), DFO (33.33 minutes)
10.	WH 147	AC	AL (4.58 mm), SL (3.38 mm), PV (95.69 %)
11.	WH 157	AC	SL (3.24 mm), DFO (30.50 minutes), PV (94.63 %)
12.	CIMMYT244	EX	AL (4.63 mm), OF (30.320), PV (94.99 %)
13.	SUZHOE//10-31B-0Y	EX	SL (3.26 mm), AE (81.55 %), DFO (39.33 minutes)
14.	AKW 1390	IN	AL (4.99 mm), DFO (30.67 minutes), PV (97.15%)
15.	BW 11259	IN	AL (4.60 mm), AE (81.10 %), OF (31.480)
16.	K 9310	IN	AE (80.88 %), OF (32.020), DFO (33.00 minutes)
17.	PBW 389	IN	AE (84.46 %), DFO (31.17 minutes), PV (95.55 %)
18.	WG 2878	IN	AL (4.73 mm), SL (3.42 mm), PV (95.60 %)
19.	WH 638	IN	AE (84.52 %), DFO (31.33 minutes), PV (95.03 %)

* EX = Exotic germplasm; IN = Indigenous germplasm; AC = Adapted cultivars

AL- anther length (mm), SL- Stigma length (mm), AE- anther extrusion (%), OF- Openness of florets (0), DFO- Duration of floral opening (minutes) and PV- Pollen viability (%)

3.2 Heritability and genetic advance

Heritability and genetic advance are important selection parameters. Heritability estimates are index of the transmission of the characteristics from parents to their offspring. Heritability in broad sense was estimated from total genetic variability that consists of additive, dominance and epistatic variances which expressed high values in most of the characteristics. Anther extrusion was found highly heritable character in all the categories of germplasm. High heritability was also observed for duration of floral opening, openness of florets and anther length (Atashi-Rang & Lucken, 1978, Komaki & Tsunewaki, 1981). The genetic advance, which is expressed as improvement in the mean genotypic value of selected individuals over the parental population,

was also estimated at 5% selection intensity. The genetic advance was further estimated as percentage of mean for getting a clear idea about improvement for the characteristics after selection. Higher genetic advance was found for anther extrusion, duration of floral opening and openness of florets in exotic and indigenous germplasm as well as in adapted cultivars.

Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson et al., 1955). Anther extrusion, duration of floral opening and openness of the florets showed high heritability coupled with high genetic advance in all the three groups but the extent of genetic advance (genetic gain under selection) was more than 50% than their mean values among exotic group. This indicated that these characteristics showed high heritability due to additive gene effects and selection for these characteristics may be effective. On the other hand, lowest heritability values were recorded for stigma length that indicated that stigma length is more influenced by environmental conditions compared to other characteristics under study. Although pollen viability had high heritability but low values of genetic advance indicated that the characteristics is governed by non-additive gene action and the high heritability is being exhibited due to favourable influence of environment rather than genotype.

3.3 Correlation coefficients

Correlation coefficient is a statistical measure to find out the degree (magnitude) and direction of relationship between two or more variables. This information may be used in the prediction of correlated response to directional selection and detection of characteristics (Robinson et al., 1951). Most character combinations showed significant positive correlations (Table.4). Very high association of anther length with stigma length and anther extrusion with duration of floral opening was observed in all the three groups of wheat germplasm. In addition most of the floral characteristics showed moderate but significant correlation with each other (De Vries, 1974; Komaki and Tsunewaki, 1981). Some character combinations viz., anther extrusion with openness of florets and pollen viability, and openness of florets with duration of floral opening also had shown weak but significant associations. Among indigenous germplasm, negative correlations although non significant were also observed for anther length and stigma length with openness of florets and pollen viability. Openness of florets and pollen viability also showed negative correlation among indigenous germplasm.

The positive correlations among most of the floral characteristics enhance the outcrossing rate by selection. It was suggested that selection for long anthers and high rate of anther extrusion should be effective in promoting natural cross-pollination (Chowdhary et al., 1994). It has also been reported that hybrid seed production in rice was improved by selecting for floral characteristics that increase cross pollination such as stigma length and the proportion of extruded stigmata (Virmani and Athwal, 1973; Taillebois et al., 1988). The present results corroborate the observations of other workers who reported positive correlations among floral characteristics (Zukov, 1969 and Hammer, 1975). Taken together, there is evidence that the outcrossing rate has positive correlation with floral characteristics in cereals (Martin, 1990, Hucl, 1996 and Abdel-Ghani et al., 2003). Thus, recurrent selection for high anther extrusion and long anthers and stigma may gradually enhance the level of outcrossing in wheat. The resultant genotype that has better outcrossing ability may be used for combining more variability from distinct genotypes through hybridization and thus increased heterozygosity for the characteristics under consideration.

From the above discussions, it can be concluded that wheat germplasm has a greater variability for various floral characteristics. The Indian adapted cultivars have advantage over exotic and indigenous germplasm but these germplasm may be efficiently utilized as a genetic resource in wheat improvement programmes through hybridization and other techniques for increasing heterozygosity and ultimately improved yielding ability. The character association between these floral characteristics in desirable direction may also be rewarding during

selection for enhanced outcrossing. The promising genotypes for various characteristics may also be used as parent in hybrid development programmes.

Table 4. Phenotypic correlation coefficients (rp) among various floral characteristics in different categories of spring wheat.

Characteristics	Category #	Stigma Length	Anther Extrusion	Openness of Florets	Duration of Floral Opening	Pollen Viability
Anther Length	EX	0.834**	0.328**	0.127*	0.294**	0.182**
	IN	0.824**	0.350**	-0.060	0.324**	-0.066
	AC	0.800**	0.306**	0.305**	0.275**	0.065
Stigma Length	EX		0.268**	0.004	0.241**	0.226**
	IN		0.381**	-0.049	0.364**	-0.025
	AC		0.357**	0.147**	0.339**	0.191**
Anther Extrusion	EX			0.227**	0.863**	0.322**
	IN			0.249**	0.900**	0.159**
	AC			0.195**	0.914**	0.268**
Openness of florets	EX				0.133*	0.127*
	IN				0.244**	-0.014
	AC				0.250**	0.185**
Duration of floral opening	EX					0.314**
	IN					0.225**
	AC					0.338**

#EX = Exotic germplasm; IN = Indigenous germplasm; AC = Adapted cultivars

*, ** - Significant at P= 0.05 and P=0.01 level, respectively.

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FARMERS' PREFERENCE FOR RICE VARIETIES IN NEPAL: THE ROLE OF ATTRIBUTES

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ABSTRACT

The effort of the research system of Nepal since mid 60's has resulted into the development of about 50 modern rice varieties. Farmers have adopted these varieties at varying degrees. Farmer's selection criteria for varieties to adopt encompass many attributes other than yield potential, which is often regarded as the sole criteria for evaluating the performance of a variety. The main objective of this paper is to assess farmers' preference for rice varietal attributes in the Tarai region of Nepal by using ordinal ranking method. The results show that farmers attached great importance to drought tolerance and pest resistance rather than yield, as this could be a reflection in the rainfed ecosystem. In terms of individual criteria, the results indicate that farmers in general perceived the modern varieties as supplying the yield, straw for fodder and marketability better than the traditional varieties. However, traditional varieties were superior in supplying taste attribute. There is no single variety that can supply all the attributes farmers' value. Hence, they mix several varieties to meet their attributes preference. Farmers are also capable of commenting on the design of particular technologies and suggesting changes as per their needs. Taking farmers' input on technology design seriously would accelerate the ultimate technique of varietal development vis a vis adoption of new technology.

Key words: Attributes, importance, Nepal, preference, rice, variety.

INTRODUCTION

Rice is the staple food crop of Nepal. It occupies about 50 percent of the total area under food crops of 3.4 million hectares and its contribution to the total food supply is more than 50 percent. In Nepal, the area under modern varieties (MVs) has increased from about 40 percent in 1993/94 to about 83 percent in 2003/04 (MOAC,2004). Compared to other ecological regions, this proportion is higher in *Tarai** region where irrigation, roads and market infrastructures are well developed.

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The *Tarai* region is considered as the granary of the country which accounts for about three-fourth of the country's rice output. The hill area produce 22 percent, and the mountain about 3 percent. In 2003/04, out of the total rice production of about 4.5 million tons in the country of which 3.3 million tons were from the *Tarai* region alone.

During 1974/75 to 2003/04 periods, rice production grew by 2.33 percent annually (2.18 % for *Terai*, 2.80 % for hills and 2.91 % for mountains). In the first half of this period, there was a small growth in the production of rice because of almost stagnated growth in yield. However, in the second half the production increased mainly because of yield growth. This might be due to the improvement in irrigation availability and the adoption of improved technologies.

The research system of Nepal has already developed about 50 MVs since mid 60's. Farmers have adopted these varieties to varying degrees. But low productivity of rice continues as a major constraints for increasing the rice production in Nepal. Comparing to the wider agro-ecological diversity of Nepal, the number of varieties released so far are very low. Also much of the efforts of breeding programs have been focused on creating varieties with high yield potential. It is now a well-established fact that farmers' selection criteria for varieties to adopt encompass many varietal attributes other than yield potential. This explains why one finds many subsistence farmers mixing several varieties in a small plot because of the impossibility to find all desired varietal attributes in one single variety. However, no combination varieties can be optimal for all desirable varietal attributes and all varietal choices involved some tradeoffs. Thus, any portfolio of adopted varieties implies some preference for particular varietal attributes relative to others.

Any technology or practice used by farmers represents a particular way to solve one or several problems. Each technology or practice responds to farmers' concerns in specific ways, which may be regarded as the traits or attributes that define the technology or practice. Farmers can view some attributes as positive and others as negative. The choice of one technology over others is greatly influenced by the balance between these two types of attributes. Depending on the preferences, resources, and constraints that individual farmers face, a beneficial attribute for one farmer may be a negative one for other, or the balance between positive and negative traits may be acceptable for one farmer but not for another (Bellon, 2001).

Farmers may assess a new technology such as crop variety, grain quality, straw yield, and input requirements, in addition to grain yield (Traxler and Byerlee, 1993). Crop improvement could potentially benefit from farmers' assessments of the relative performance of different varieties under their management. Information on the attributes desired by farmers and their knowledge of the production system could be invaluable in setting the goals of breeding program, delineating the target environment, identifying the parents for breeding and defining the management treatment for breeding work (Sperling , 1996; Eyzaguirre and Iwanaga, 1996).

It is an established fact that farmers' are also capable of commenting on the design of particular technologies and suggesting changes that would make such technologies and innovations more appropriate for their needs. Taking farmers' input on technology design seriously would accelerate the ultimate adoption of new technologies (Pingali et al., 2001). Most of the experimental works in crop improvement evaluate the rice varieties often using yield as the sole criterion. Most often these varieties have either not been adopted or were used only for a short period. As rice is the main staple food of Nepal and shares more than 50 percent to the total cropped area, understanding farmers' attribute preference serves as an input to both on-farm conservation and variety development and diffusion. Hence, the main objective of this paper is to assess the attributes preferred by the farmers and the extent of the supply of those attributes by the rice varieties.

MATERIALS AND METHOD

Data Collection

The required sample size was determined using a multistage sampling technique. In the first stage, Village Development Committees (VDCs) in each district where large proportion of area under rice is unirrigated (rainfed) were chosen in consultation with District Agriculture Development Office. In the second stage, three rainfed VDCs from each district were selected. At the third and final stage, the required number of sample was randomly drawn from the list of the farmers cultivating rice in each VDCs.

The household growing rice in rainfed areas constituted the sampling frame of this study. Thirty five farming household from each VDC were selected totaling to 210 samples (105 from each district). However, extra samples of 8 from Banke and 4 from Nawalparasi were included (in order to compute for some missing information in the sample). Thus, the total sample size in Banke District was 113 where as it was 109 in Nawalparasi district. The villages where survey was carried out are Manikapur, Bethani and Bageswori from Banke district and Kushma, Deurali and Ramnagar villages from Nawalparasi district.

The survey included collection of data on number and types of rice varieties grown, farmers' preference for attributes, the attributes supplied by major varieties, agro-hydrological information and associated socio-economic and demographic characteristics of the farm household. Using a set of pre-tested questionnaires collected the relevant data for the cropping year 2001/02.

Analytical methods

Rice varieties are often described in terms of attributes (maturity days, yield) and by the presence or absence of other attributes (e.g. drought tolerant, pest resistance). Other attributes are more difficult to express on a cardinal scale since they are very dependent on farmers' perceptions (e.g. taste, cooking quality). Hence, the starting point for the study was to elicit farmers' perceptions on the attributes of the variety. These perceptions were elicited with the help of an empirical approach developed and applied by Reed et al (1991) in industry.

This approach uses a relatively simple index that provides an indication of how well certain variety attributes meet farmers' preferences. Implementation involves application of quasi-arbitrary ordinal weights in which farmers rank the importance of each attribute and how well these specific attributes are being embodied in different varieties. Reed et al. (1991) showed that by choosing weights meeting certain conditions, the proposed indices become and when calculated under different sets of weights, these indices than show high correlation.

Each farmer was asked to judge each attribute along two scales: first, what is the level of importance of the attribute to them (very important, some what important and not important) and second, how they judged the quality of the attribute being supplied by the selected modern and the traditional varieties (very good, good, poor).

Attainment Index (AI) is a measure of the extent to which the overall performance of a particular variety or technological option meets all the interests and needs of a farmer or group of farmers (Bellon, 2001). Therefore, AI combines the two types of ratings - demand of attributes by the farmers and the supply of attributes by the variety.

The maximum value carried by AI is 1, and implies a perfect match. In such a situation, all farmers rank the particular attribute as very important and rank the attribute supplied of it by the variety as very good. It is obvious that a variety that performs very well for many important attributes should be more desirable than one

that performs very well for attributes that are only somewhat important. Conversely, a variety that is poorer with respect to many important attributes should be less desirable than one that is poor with respect to less important attributes. Hence, it is necessary to devise a way by which both types of ratings can be combined to generate an ordinal measure that makes it possible to rank the different varieties from more to less desirable.

The farmers' preference for attributes was determined following the two steps procedure. In the first step, farmers' concerns and preferences with regard to variety attributes were identified. The farmers were requested to make an ordinal rank for each attribute based on their perceived importance. Appropriate ranking was done or weights were assigned.

For ratings of the importance of characteristics, the scores/weights remain between 1 and zero (1 for "very important" and zero for "not important"). "Somewhat important" was assigned an intermediate weight such as 0.4. These scores maintain the order of importance, and the zero takes into account that it does not matter how a variety performs for an attribute that is irrelevant.

For ratings of the performance of a variety for an attribute, the scores/weights remained between 1 and -1 (1 for "very good" and -1 for "poor"). The "intermediate/acceptable" rating was assigned an intermediate weight, such as 0.5. These numbers maintain the order of performance, and the -1 takes into account that a poor performance has a negative impact on the well being of a farmer.

For each cell in the matrix, the scores in the column and row are multiplied, generating an index that varies between 1 and -1. The ordinal scale is as:

Very important-very good (1) > very important-regular performance (0.5) > somewhat important-very good performance (0.4) > somewhat important-regular performance (0.20) > not important-any performance (0) > somewhat important-poor (-0.5) > very important-poor (-1). It is more important or desirable to have an intermediate performance for a very important attribute than to have a very good performance for an attribute that is "somewhat important." Clearly it is more desirable to have (1) a variety that has an intermediate rather than a poor performance for a very important attribute, rather than (2) a variety that has a very good rather than an intermediate performance for a somewhat important attribute, or a variety that has an intermediate rather than a poor performance for a somewhat important attribute.

Some farmers may consider some attributes to be unimportant (therefore they will have a zero score), whereas other farmers may not. To take these differences into account, it is necessary to normalize the index. Otherwise, when two scores are compared, one may be very large - not because one of the varieties was more satisfactory, but simply because the farmer who rated it considered many attributes to be very or somewhat important, whereas another farmer rating the same variety might consider fewer attributes to be important (and may even have found the variety to be more satisfactory). It is important to divide the score by a "perfect" score (i.e., the score that would have been obtained if the variety had scored very well for all relevant attributes, weighted by the importance of the attribute). This means that the perfect score is simply the summation of all demand scores and that unimportant attributes are not taken into account.

RESULTS AND DISCUSSION

General characteristics of rice production system

The basic characteristics of the production systems in the two sampled districts are summarized in Table 1. The average farm size, the area under TVs and the percentage area irrigated in both the districts are higher than the national average. However, compared with the national average, the cropping intensity and yield of TV is much lower in Banke.

The table also shows that the farm size is much larger in Banke than in Nawalparasi. While rice is the dominant crop in both the locations, the share of MV is higher in Banke than in Nawalparasi. The cropping intensity and the proportion of irrigated area are higher in Nawalparasi than in Banke. On an average about 23 percent of the rice area is under TVs.

Table 1. General characteristics of the production system in the study area, Nepal

Indicators	Districts		National figure a
	Banke (n=113)	Nawalparasi (n=109)	
Average area owned per household (ha)	2.3	1.1	0.80
Cropping Intensity (%)	151	185	183
Area under rice (% of total cropped area)	53	52	36
Area under MV of Rice (%)	81	73	83
Area under landraces of Rice (%)	19	27	17
Average Yield of MV (t/ha)	3	3	3.04
Average Yield of TV (t/ha)	1.6	2.3	1.99
Percentage Area Irrigated (including seasonal)	35	72	32

Source: Field survey MOAC, 2004

Description of the Varieties Grown

Evaluating by the number of named varieties being grown by the farmers, the varietal diversity in the study area appeared to be quite high. The sample farmers grew as many as 25 MVs and 19 landraces (TVs). Most of the farmers grew more than one rice variety on their farms, with a number of varieties ranging from one to nine. The percentage of farmers growing two to three varieties was about 72 percent (Table 2).

Table 2. Percentage of farmers growing one or more varieties of rice, Nepal

No. of varieties	Percentage distribution		
	Banke	Nawalparasi	Both
One	12.4	8.3	10.4
Two	40.7	41.3	41.0
Three	29.2	33.0	31.1
Four	12.4	12.8	12.5
Five and above	5.3	4.6	5.0

Source : Field survey

Also about 53 percent households grew both modern varieties and landraces. About 39 percent of the farmers grew only MVs whereas only about 9 percent grew only landraces. The result indicated that majority of the farmers still grow landraces (although in a small area) in combination with MVs.

Any product of the breeding program is termed as MV. Farmers in the survey area grew 25 MVs. Among them, Radha-4 ranked number one in terms of area coverage followed by Janaki, Masuli and Radha-17. Radha-4, Masuli, and Radha-17 are popular in both Banke and Nawalparasi districts, whereas Janaki is popular among the farmers in the Banke district alone. Farmers have also cultivated Indian variety such as Sarju-52 (Table 3). Based on the quality of the grains, the varieties such as Radha-4, and Janaki are considered as coarse rice; Sabitri as medium rice; and Masuli, and Radha-17 as fine rice. Discussions with the District Agricultural Development Office, Banke revealed that the area under Janaki is decreasing in this district. This is mainly because of the difficulty in pulling of seedlings for transplanting and threshing of the grains. This variety is being replaced by Radha-4. In terms of maturity days, the varieties such as Radha-4, Radha-17 and Sabitri are early maturing, Sarju-52 and Janaki are medium maturing and Masuli is a late maturing variety. In the survey area, the Masuli is grown as high as for 30 years since its release in 1973. Sabitri is also being cultivated for 23 years since it was released in 1979. National Agricultural Research System of Nepal and India released Janaki and Sarju-52, respectively, in 1979. These varieties are cultivated for about 20 years. Radha-4 released during 1995 and recommended for western/mid-western *Terai* has been cultivated for seven years.

The farmers are cultivating TVs for many years. In the survey area, farmers grew as many as 19 landraces. Among them, the Satha is popular in Banke that accounted for about 62 percent of the total TVs area. According to the farmers, this variety is directly seeded, and also suitable to grow in areas where there is late monsoon. Hence, it is most suitable for rainfed area. In case of Nawalparasi, Makarkodo ranked number one occupying 34 percent of the total TV area. This variety is most suitable for making fried rice (*Murahi/Bhujiya*). Shyamjira, Gauria and Jhinuwa are considered to be fine aromatic rice. Shyamjira was cultivated in Banke whereas Gauria and Jhinuwa were cultivated in Nawalparasi (Table 3). According to the farmers, all of them require high amount of water to grow. This means they are more suitable to lowland fields.

Almost all of the varieties (except Satha and Padhani) are late maturing. The name for Satha variety is based on its maturity days. It is an early maturing variety, which matures on an average of 90 days. This variety has religious and medicinal value, hence has been cultivated for about 50 years. Most of these varieties have good taste, some of them are aromatic too, and have religious and cultural significance; hence, they have been cultivated for many years inspite of low yield.

Table 3. Area share (%) of popular MVs and TVs, in the sample households, Nepal

Variety	Distribution		
	Banke	Nawalparasi	Total
MVs			
Radha-4	55.9	23.5	45.0
Janaki	28.7	0.7	19.3
Masuli	3.5	19.2	8.8
Radha-17	2.0	7.5	3.8
Sabitri	0.0	6.0	2.0
Sarju-52	0.2	17.6	6.1
Others	9.7	25.5	15.0
Total MVs	100	100	100
TVs			
Satha	61.5	0.0	31.1
Shyamjira	19.8	0.0	10.0
Gauria	0.0	15.7	7.1
Jhinuwa	0.0	11.3	5.7
Anadi	0.3	12.2	6.5
Makarkodo	0.0	32.3	16.7

Others	17.6	28.5	22.9
Total TVs	100	100	100

Source : Field survey

Demand for attributes

What farmers wanted in terms of the different varietal attributes is reflected in demand indices presented in Table 4. The demand indices for drought tolerance was the highest followed by the pest resistance and higher yields. This shows that farmers attached great importance to drought tolerance rather than yield, as this could be a reflection in the rainfed ecosystem. In fact concerns about the ability of rice to survive under lower rainfall conditions was reflected not only in the importance attached to the drought tolerance criteria but also in the high degree of demand attached to the growing cycle criteria. This means earlier maturity or shorter growing cycle is viewed as desirable in addition to yield. The farmers also showed concern about the threshability of the grains. The varieties that require less number of beatings is preferred as threshing operation is often carried out manually. However, the farmers showed less concern about the consumption attributes such as taste, uses of grains for fried rice and beaten rice and quality of straw as fodders.

Table 4. Demand indices for the major variety attributes of rice, Nepal

Sl. No.	Variety attributes	Indices
1	Yield of grains	0.790
2	Straw quality for fodder	0.194
3	Drought tolerance	0.846
4	Pest resistance	0.827
5	Less fertilizer requirement	0.293
6	Early maturity	0.714
7	Easy threshing	0.633
8	Usage of grains for other purposes	0.309
9	Marketability	0.394
10	Taste	0.378

Source: Author's own calculation

Supply of attributes

The supply of attributes by the improved varieties and local varieties is presented in Table 5. Only 6 varieties for each MV and TV categories are considered for the analysis. In terms of individual criteria, the results indicate that farmers in general perceived the modern varieties as supplying the yield, straw for fodder and marketability better than traditional varieties. Farmers, in general perceived the Janaki variety as superior in supplying yield, straw for fodder and marketability attribute. However, this variety is poor (inferior) in supplying threshability and early maturity attributes. Farmers perceived Radha-4 variety as superior in terms of drought tolerance, pest resistance, early maturity, threshing and preparation for beaten rice. It is moderate yielder but poor in terms of taste.

In general, TVs are inferior in supplying attributes such as yield and early maturity. Among the TVs, Satha is superior in supply the attributes like drought tolerance, low fertilizer requirement, early maturity, easy threshing but is inferior in terms of yield, uses of grains for other purposes (preparations) and straw for fodder. Shyamjira, Gauria and Jhinuwa are superior in terms of supplying taste and marketability attributes but inferior

in yield, maturity and drought tolerance. The varieties like Anadi and Makarkodo are superior in terms of marketability, taste and other preparations but poor in yield.

The Normalized Attainment Index (NAI) presented in Table 5 describes the overall desirability of a variety to the farmers considering the selected attributes. The Table shows that farmers' expectations are being better met by Radha 4 with NAI of 0.829. With respect to individual criteria, this variety is not satisfactory in supplying marketability and taste attribute. Other varieties such as Sarju-52, Janaki and Radha-17 seem moderate in acceptability. There is always trade off in the supply of attributes by different varieties. Hence, the farmers are cultivating several varieties to meet their demand for attributes, as there is no single variety that can supply all the attributes the farmers value.

Three sets of weights were used to calculate the indices and the robustness of the results were verified. The three sets used were: demandA (1, 0.4, 0) and supplyA (1, 0.5, -1); demandB (2, 1, 0) and supplyB (1, 0.5, -1); and demandC (2, 1, 0) and supplyC (2, 1, -1). The results were found to be consistent across all three weighting schemes for all the varieties and attributes tested. To test the robustness of the results with respect to the sets of the weights chosen, following the suggestion of Reed et al. (1991) the results of the attainment index and normalized index using the different combinations of the weights were compared calculating Pearson and Spearman correlation coefficients for each set. The Spearman correlation coefficients measure the consistency in ordering the scores while the Pearson correlation coefficients measure the linear relationship between the different scores. The correlation coefficients were highly significant at 1 percent level, indicating a high degree of robustness and confidence in the results. The result presented here reflects the use of the first combination of the weights listed above.

Table 5. Supply indices for attributes and Normalized Attainment Index (NAI)

Varieties	Attributes										NAI
	1	2	3	4	5	6	7	8	9	10	
Janaki	0.959	0.936	0.368	0.581	0.320	0.186	-0.215	0.308	0.808	0.659	0.489
Radha 17	0.214	0.558	0.384	0.140	0.337	0.663	0.779	0.012	1.000	1.000	0.475
Radha 4	0.754	0.596	0.982	0.936	0.771	0.993	0.964	0.861	0.414	0.243	0.829
Sabitri	0.794	0.206	0.559	0.338	0.368	-0.157	-0.691	0.029	0.544	0.191	0.255
Masuli	0.733	0.694	-0.075	-0.053	0.192	-0.445	0.993	-0.205	0.993	0.904	0.306
Sarju 52	0.593	0.593	0.500	0.546	0.574	0.593	0.389	1.000	1.000	0.944	0.617
Satha	-0.917	-0.354	0.819	0.785	0.813	1.000	0.861	-0.646	-0.208	0.563	0.325
Shyamjira	-0.591	0.386	-0.114	0.159	0.477	-0.795	0.864	0.386	1.000	1.000	0.071
Gauria	-0.667	0.611	-0.500	0.500	0.500	-0.167	0.778	-0.556	1.000	1.000	0.262
Jhinuwa	-0.679	0.571	-0.036	0.643	0.536	-0.893	0.571	-0.464	1.000	1.000	0.173
Anadi	-0.786	0.571	-0.036	0.821	0.500	-0.679	-0.036	1.000	1.000	0.964	0.317
Makarkodo	0.140	0.520	0.500	-0.220	0.500	0.500	0.480	1.000	1.000	1.000	0.446

Source: Author's own calculation

Notes on Attributes:

- | | | |
|----------------------|--|-----------------------|
| 1 = Yield of grains; | 2 = Straw quality for fodder; | 3 = Drought tolerance |
| 4 = Pest resistance; | 5 = Less fertilizer reqt.; | 6 = Early maturity |
| 7 = Easy threshing; | 8 = Usage of grains for other purposes | |
| 9 = Marketability; | 10 = Taste | |

CONCLUSION

The yield level of modern varieties (MVs) is significantly higher than those of traditional varieties (TVs). Despite this, about 53 percent of the households still cultivate TVs because some of them are suitable for direct sowing when there is late monsoon, can tolerate drought, most of them have better taste than MVs, and possess cultural values.

Farmers' ranking of technology attributes is considered a simple and cost-effective mechanism for eliciting farmers' preferences and these could be used as an input in research priority setting. Moreover, ranking is also considered an effective method for quantitatively assessing the large number of choices faced by farmers across a wide range of agro-climatic and socio-economic conditions.

Farmers are the eventual consumers of the products of agricultural research such as variety. They critically assess the attributes of new technologies against those of existing local technologies and only adopt the former if they are judged superior to the latter based on certain critical attributes. The results indicate that farmers have strong preference for a range of varietal attributes. In most cases, their preferences are driven by the need for tolerance to stress such as drought tolerance and the pest resistance. Also they have concern for the high yield, early maturity and easy threshing. Farmers are capable of commenting on the design of particular technologies and suggesting changes that would make such technologies and innovations more appropriate to their needs. Taking farmers' input such as attributes preference on new variety development would accelerate the ultimate adoption of generated technology. Hence, farmers' participation in crop breeding and varietal selection needs to be emphasized in a greater scale.

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PARTIAL SUBSTITUTION OF F₁ HYBRID WITH OPEN POLLINATED VARIETY FOR GRAIN YIELD AND YIELD ATTRIBUTES OF MAIZE (*Zea mays* L.)

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ABSTRACT

Adoption of hybrid maize technologies led to a substantial increase in maize production. Nevertheless, small farmers in developing countries are constrained with high inputs requirement of hybrids. A field experiment was conducted to find out effects of partial substitution of seeds between F₁ hybrid and open pollinated variety (OPV) of maize. The variety DK 909, an F₁ hybrid was substituted with USM var 5, an OPV at different proportions of seed substitution on seed count basis. Grain yield obtained from the mixed stands of 75:25 and 50:50 between F₁ hybrid and OPV was not significantly different from that of the pure stand of hybrid. On the other hand, grain yield was significantly higher in the mixed stands of 75:25 and 50:50 between hybrid and OPV than the grain yield of the pure stand of the OPV. Substitution of 75% of F₁ hybrid seeds with OPV, however, resulted into significantly lower grain yield than that of the pure stand of the hybrid. Differences in the agronomic traits except days to 50% silking were not significant. Linear regression analysis revealed that shelling recovery accounted for 42% of the variations in grain yield. Frequency distribution showed dynamics of the productivity of individual plant and ear traits in the different stands indicating the occurrence of yield compensation mechanism at varying magnitudes. Partial economic analysis showed that gross return was higher in the 75:25 mixed stands of hybrid and OPV than in the pure stand of the F₁ hybrid. The pure stand of the OPV gave the lowest returns for return above variable cost, gross return, and cost of seeds

Key words: Seed substitution, Attributes, Frequency distribution, Partial economic analysis, Open Pollinated Varieties (OPV)

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INTRODUCTION

Maize is the world's most widely grown cereal and is the staple food in many developing countries. Almost half of the agricultural area in developing countries is planted to local varieties or landraces of maize (Morris *et al.*, 1999). In terms of world grain production, maize is ranked second after wheat while rice is third (Pingali, 2001). Maize is used as food, feed, and largely utilized in many industrial purposes such as maize or corn oil which is gaining popularity in the developed and developing world. As a result, it has become one of the important cash and industrial crops (Paudel, 2002; Koirala, 2002).

In developing countries farmers prefer maize to rice and wheat because of its adaptability to diverse agro-climatic conditions. In South and Southeast Asia, most of the farmers have small land holding and poor resources base which do not permit the adoption of improved maize technology of high input requirement. In these countries, maize is largely grown under rainfed condition. As a result the average productivity is very low (less than 2.0 tons ha⁻¹). Multi-line culture or growing more than one variety on a farm is a low cost technology which can be performed by seed mixing in different ratios and planting at specific row proportions. Seed mixing may include open pollinated varieties (OPV) and hybrids or both hybrids having different canopy architecture. Seed mixing can create unevenness in the canopy surfaces of the plants because of height difference among OPV and hybrids. This unevenness of canopy surfaces can increase carbon dioxide availability to the plants as compared to monoculture of varieties or hybrids. To date the impact of hybrid seed substitution with OPV on maize productivity is not known. In developing countries, OPV and hybrid maize could be mixed to boost productivity because the grains are largely used for home consumption and animal feed which do not require to pass strict marketing standards of quality parameters.

To reduce the production cost, partial substitution of F₁ hybrid seeds with OPV is a possible option, however, the optimum combination of seed substitution needs to be determined. Crop yield attained from the cultivation of OPV might be increased by partial substitution with F₁ hybrid seeds. Partial substitution of hybrid seeds with OPV is perceived to be cost-reducing and production-enhancing strategies for maize production in the subsistence farming conditions. Hence this study was undertaken to achieve the above mentioned objectives.

MATERIALS AND METHODS

The experiments were conducted in 2004 at the Central Experimental Station, University of the Philippines at Los Banos (14 ° 11 'N latitude, 121 ° 15 'E longitude, and 21 m above sea level), Laguna, the Philippines. The experiment was done on February 19 and harvested on June 20, 2004. The varieties grown were USM var 5 and DK 909. USM var 5 is open pollinated variety (OPV) developed by the University of Southern Mindano, Philippines. The variety has a yield potential of 6.8 tons ha⁻¹, attains a height of 177-193 cm and matures in about 97 days. Variety DK 909 is a commercial hybrid developed by Monsanto, the Philippines, and has a yield potential of 7.6 tons ha⁻¹, matures in about 100 days and attains a height of 183- 200 cm (National Seed Industry Council, Philippines, 1993 and 1994).

The experiment was laid out in randomized block design in three replications separated by 1.50-m alleys and planted in 70 cm row spacing and 20 cm plant spacing. There were six treatments based on seed count viz: 100% F₁ hybrid (pure stand), 75% F₁ hybrid +25% OPV, 50% F₁ hybrid +50% OPV, 25% F₁ hybrid +75% OPV, 100% OPV (pure stand), and 3 rows F₁ hybrid+ 3 rows OPV. The treatments were randomly assigned to six 22-m² plots in each block. Each plot had 6 rows of 5.0-m long.

A fine seed bed was prepared by ploughing once and harrowing twice. Two seeds were sown per hill to assure germination. Twenty five Days After Planting (DAP), a single plant was retained per hill. A basal dose of 60 kg ha⁻¹ each of N, P, and K through compound fertilizer (14:14:14) was drilled. A second dose of 60 kg N ha⁻¹

through urea was top dressed 30 DAP, thereafter hilling up was done. Manual weeding was carried out 25 DAP. Spot weeding was also done two weeks after hilling up to preventing crop-weed competition. *Carbofuran 3G (2,3 dihydro 2, 2-dimethylbenzofuran methylcarbofuran)* was applied in the whorl of leaves at 0.5 kg a.i. ha⁻¹ 30 DAP to control corn borer. The plots were irrigated 1 DAP using pressurized overhead irrigation system. Subsequent overhead irrigations were applied twice a week up to one month after planting, thereafter, irrigation was applied through gravity system at weekly intervals in the absence of sufficient rains.

For grain yield determination, the inner four rows in each plot were harvested, ears were counted. Grain yield at 15% seed moisture content (measured by seed moisture tester) was recorded from the net harvested area of 14.0 m² per plot. Individual plants and ears in the central row of each plot were numbered consecutively, e.g. 1, 2, 3,...25 for the frequency distribution analysis of grain weight per plant, length and diameter of individual ears, percent ear fill, shelling recovery and Leaf Area Index (LAI). Grain yield, yield attributes, and other plant parameters were recorded as per the standard procedure described by the International Maize and Wheat Improvement Program (CIMMYT), Mexico and analysed by SAS General Linear Model (GLM). Least significant difference was used compare means.

The soil of the experimental field contained 0.09-0.11% total N, 9.02-12.44 ppm available P and 0.59-0.71 meq 100⁻¹ g exchangeable K, and a.pH ranged from 6.23-6.3. Bulk density of the soil was 1.12 to 1.2 g cc⁻¹ and the sand, silt, and clay contents were 9.3, 19.3, and 71.3%, respectively.

Meteorological parameters such as solar radiation, total evaporation, total rainfall, temperature, and relative humidity were recorded during the experimentation period from the Meteorological Station of International Rice Research Institute (IRRI), Philippines 100 m away from experimental site. Solar radiation was 18 MJm⁻² at the time of planting and increased up to about 23 MJm⁻² in the third decade (10 days' interval) of March and the second decade of April. Thereafter solar flux density decreased to 15 MJ m⁻² in the first decade of June. Rainfall during the second week of February was 5 mm and 18 mm in the third week of February. March and first week of April were rainless. Rainfall started in May and it was recorded 80 mm in the first and second week of June near physiologically maturity. Because of the high evaporation in March-April, irrigation was applied twice a week. The average maximum temperature was 32^oC in April and May and the minimum was about 22^o C in February. Relative humidity was the lowest (79%) in the third week of April and the highest (88%) in the first week of June.

RESULTS AND DISCUSSION

Grain Yield and Yield Attributes

Grain yield significantly differed among the treatments while the differences in yield attributes were not significant (Table 1).

The highest grain yield was obtained from the 75:25 mixed stands of the hybrid and OPV which was statistically at par with the grain yield obtained in the pure stand of hybrid. Hybrid seed substitution with OPV was permissible up to 50% in which grain yield was similar to that of the pure stand of the hybrid. Substituting 75% of the hybrid seeds with OPV, led to significantly lower yield to that of the hybrid in pure stand. Substituting 25% of the OPV with F₁ hybrid seeds did not significantly increase grain yield, whereas, increasing the level of seed substitution to 50% led to significantly higher grain yield to that of OPV in pure stand. Studies done by Hoekstra *et al.*, (1985) and Midmore and Alkazar (1991) showed that varietal mixture in maize gave higher yield than their pure stands. In mixed cultivar cultures, each cultivar tends to express their competitive ability which may result in high yields (Hoekstra *et al.*, 1985). Work of Zambezi *et al.* (1997), Jensen (1952), Jensen (1965), Probst (1957), Brim and Schutz (1968), Schutz and Brim (1971), Paudel and Lales, (2006), and Panse *et al.* (1989) also likewise have shown that yield obtained from mixed cultivar culture

was higher than in pure stands. In this study, the mixed stand that out-yielded the pure stand of the hybrid was the 75:25 level of substitution between F₁ hybrid and OPV.

Table 1. Grain yield and yield attributes of maize as affected by partial substitution of F₁ hybrid seeds with OPV

Treatment ^a	Grain yield	Grain weight	100-grain weight	Ear diameter	Ear length	Ear fill	Shelling recovery
	(kg ha ⁻¹)	(g plant ⁻¹)	(g)	(cm)	(cm)	(%)	(%)
1	5951	104.1	22.0	4.2	17.3	87.0	83.0
2	6112	99.8	23.4	4.2	16.7	87.0	81.0
3	5622	91.7	22.4	4.2	16.4	84.0	79.0
4	4093	88.2	23.5	4.3	15.7	84.0	76.0
5	4069	83.6	22.2	4.2	15.7	83.0	79.0
6	5181	93.6	23.4	4.3	16.2	81.0	80.0
CV%	16.0	19.8	6.1	2.7	8.5	4.8	4.0
LSD	1509	34.7	2.5	0.7	2.5	7.7	5.8

a1=100% F₁ hybrid (pure stand) 2=75% F₁ hybrid + 25% OPV

3=50% F₁ hybrid + 50% OPV 4=25% F₁ hybrid + 75% OPV

5=100% OPV (pure stand) 6= 3 rows F₁ hybrid + 3 rows OPV

b *, **, and ns indicate significant at P<0.05, 0.01 and, not significant, respectively

Agronomic Attributes

Plant and ear height, Number of Leaves Above the Ear (NLAE), stalk diameter, and days to 50% tasseling did not respond to the treatments (Table 2). However, days to 50% silking varied significantly whereby the pure stand of the hybrid and the 50:50 mixed stand reached this stage significantly earlier by about one day than the other treatments.

Table 2. Agronomic attributes of maize as affected by partial substitution of F₁ hybrid seeds with OPV

Treatment ^a	Plant height	Ear height	NLAE ^c	Stalk diameter	Days to 50% tasseling	Days to 50% Silking
	(cm)	(cm)	(No)	(cm)	(day)	(day)
1	181	100	5.6	3.1	47.7	52.0
2	183	99	5.6	3.0	47.7	53.3
3	188	103	6.0	3.0	47.3	52.3
4	200	104	5.8	2.9	48.7	54.0
5	199	107	6.0	3.0	48.0	53.0
6	204	110	5.6	3.0	47.7	53.7
CV%	5.4	9.9	18.8	7.4	1.2	1.0
LSD	ns	ns	ns	ns	ns	

a1=100% F₁ hybrid (pure stand) 2=75% F₁ hybrid + 25% OPV

3=50% F₁ hybrid + 50% OPV 4=25% F₁ hybrid + 75% OPV

5=100% OPV (pure stand) 6= 3 rows F₁ hybrid + 3 rows OPV

b *, **, and ns indicate significant at P<0.05, 0.01 and, not significant, respectively

cNLAE = Number of leaves above ear at 65 DAP

Differences in LAI measured at 10-day interval starting from 45 to 65 DAP were not significant (Table 3) indicating similar leaf area developed and stay-green characteristics. Ten days later (55 DAP); the 25:75 mixed stands had the highest LAI. At 65 DAP; the pure stand of the OPV had the highest LAI (3.8) although the difference from the other stands was not significant. Apparently, the slight differences were linked to the moderately leafy characteristic of the OPV. The results likewise showed slight differences in LAI dynamics among the stands which has reflected the unique characteristic of the hybrid and the OPV in terms of leaf size, rate of leaf development, and ability to maintain chlorophyll integrity over time having stay-green characteristic. Apparently, the OPV had slightly larger leaves than the hybrid but the two varieties appeared to have similar rate of leaf development and stay-green characteristics.

Table 3. Leaf area index of maize as affected by partial substitution of F₁ hybrid seeds with OPV

Treatment ^a	Leaf area index		
	45 DAP	55 DAP	65 DAP
1	2.5	3.3	3.5
2	2.5	3.2	3.6
3	2.2	3.4	3.4
4	2.4	3.7	3.4
5	2.3	3.6	3.8
6	2.6	3.5	3.7
CV%	9.0	12.3	18.8
LSD	ns	ns	ns

a1=100% F₁ hybrid (pure stand) 2=75% F₁ hybrid + 25% OPV
 3=50% F₁ hybrid + 50% OPV 4=25% F₁ hybrid + 75% OPV
 5=100% OPV(pure stand) 6= 3 rows F₁
 hybrid + 3 rows OPV

b *, **, and ns indicate significant at P<0.05, 0.01 and, not significant, respectively

Relationship between Grain Yield and Yield Attributes

A linear regression analysis ($Y = \alpha + \beta X$) was carried out to establish a basis for determining the yield component(s) that might explain the differences among the treatments of grain yield. The regression model was

$$Y = \alpha + \beta X$$

Where, Y =dependent variable

α =intercept of the line on Y axis (i.e. the value of Y when the value of X is zero)

β =the linear regression coefficient, the slope of line or the amount of change in Y for each unit change in X

X = independent variable

The results of the regression analysis showed that among the six important yield attributes, only shelling recovery was significantly (P<0.004) related to grain yield (Table 4) which exhibited up to 42% variation in grain yield. However, the differences in shelling recovery were not significant, therefore, shelling recovery alone cannot fully account for the differences in grain yield (Table 1). The probability values (Table 4) indicate that ear length may explain 19.5% (P<0.067) of the variation in grain yield while ear fill percentage may account for 17.7% of the variations (P<0.082). Hence, these two yield attributes were considered potential

sources of variation in grain yield. In the study 100-grain weight, grain weight per plant, and ear diameter were poorly related with grain yield.

Table 4. Relationship between bulk grain yield and yield attributes as affected by partial substitution of F1 hybrid maize with OPV (n=18)

Variable	Intercept	Coefficient	P-value	R ²
100- grain weight	5791	-27	0.903	0.001
Grain weight plant	3062	22	0.159	0.120
Ear diameter	-6105	266	4 0.583	0.019
Ear length	-1259	393	0.067	0.195
Ear fill	1166	288	0.082	0.177
Shelling recovery	-11400	208	0.004	0.420

Ear Length

The frequency distribution of ear length was skewed to the left (lower-value categories) with the highest frequency of each stand noted in the 17-18 cm category (Fig. 1). Skewness was higher in the 50:50 mixed stands, 75:25 mixed stands, and the pure stand of the hybrid than other treatments. These crop stands appeared to have higher propensity than the other stands to produce ears ≥ 18 cm long. The 25:75 mixed stand, 100% OPV, and 3:3 row proportion had higher tendency to produce ears ≥ 19 cm long. Numerical differences among the stands in the < 16 cm class ranged from 1 to 5% while frequencies in the 21-22 cm category ranged from 0 to 2%. Since the differences in these extremes were small, the dynamics of ear length alone as influenced by the various stands could not explain the trend in grain yield.

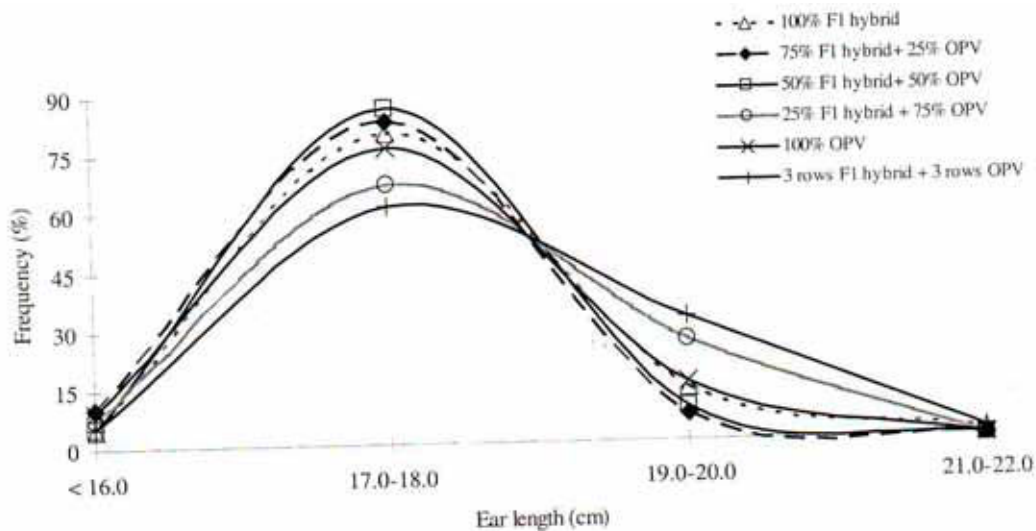


Fig. 1. Frequency distribution of ear length of maize as affected by hybrid seed substitution with OPV

Ear Fill Percentage

The frequency distribution of ear fill percentage was skewed to the right with the peak noted in the 81-90% ear fill category (Fig. 2). In this category where the treatments were apparently divided into two clusters, the 50:50 mixed stands had the highest frequency. The same stands had lower tendency to attain ear fill percentage of > 91% than the pure stand of the hybrid. The 75:25 mixed stands and the pure stand of the hybrid were clustered with the 50:50 mixed stands. In the 91-100% category, the pure stand of the hybrid had the highest frequency followed by the 75:25 mixed stands. The 25:75 mixed stands had the highest frequency followed by the 50:50 mixtures in 3:3 row proportions in the 71-80% category. The pure stand of hybrid had the lowest frequency both in the 71-80% and <70% categories. The trends indicate the influence of mixed variety cultivation on ear filling which was hypothesized to be insensitive to changes in the micro-environment in pure and mixed variety stands. The results of the study showed the dynamics of ear fill percentage.

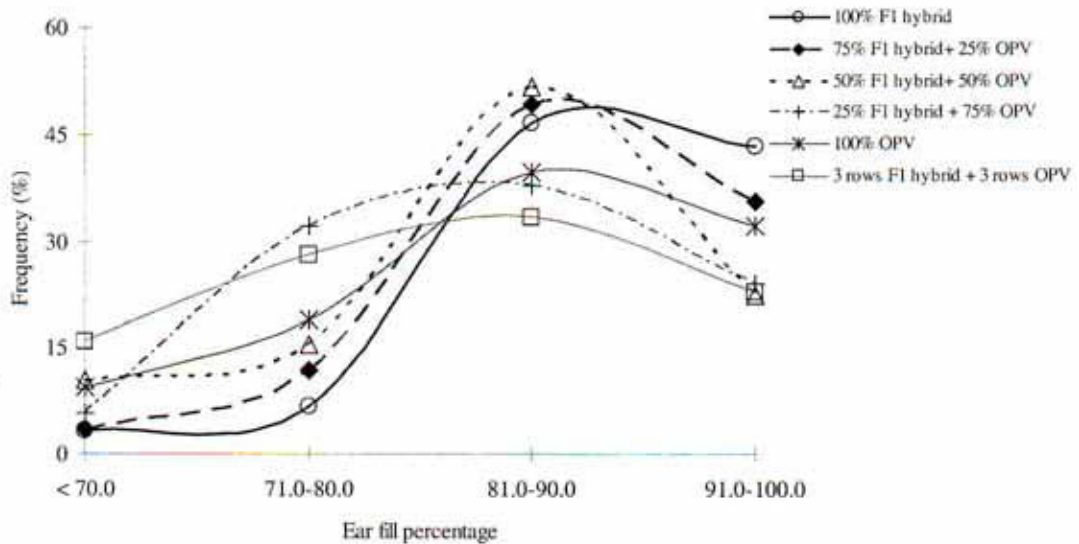


Fig. 2. Frequency distribution of ear fills percentage of maize as affected by hybrid seed substitution with OPV

Shelling Recovery

The frequency distribution of shelling recovery was skewed to the left sharply declining to the <70% and 81-90% categories followed by a gradual decline to the 91-100% category (Fig 3). Shelling recovery 90% was considered unusually high. Although the frequencies noted in the 91-100% category were low (0 to 3%) obtained from the pure stand of the hybrid and the OPV. The 75:25 and 50:50 mixed stands indicated that variations in grain yield could be partly attributed to the differences among stands in this category. Variations in grain yield can also be partially linked to the differences among stands in the <70% category in which the pure stand of the hybrid had the lowest frequency. Thus, increasing the level of hybrid seed substitution with OPV magnified the adverse effect of low shelling recovery on grain yield

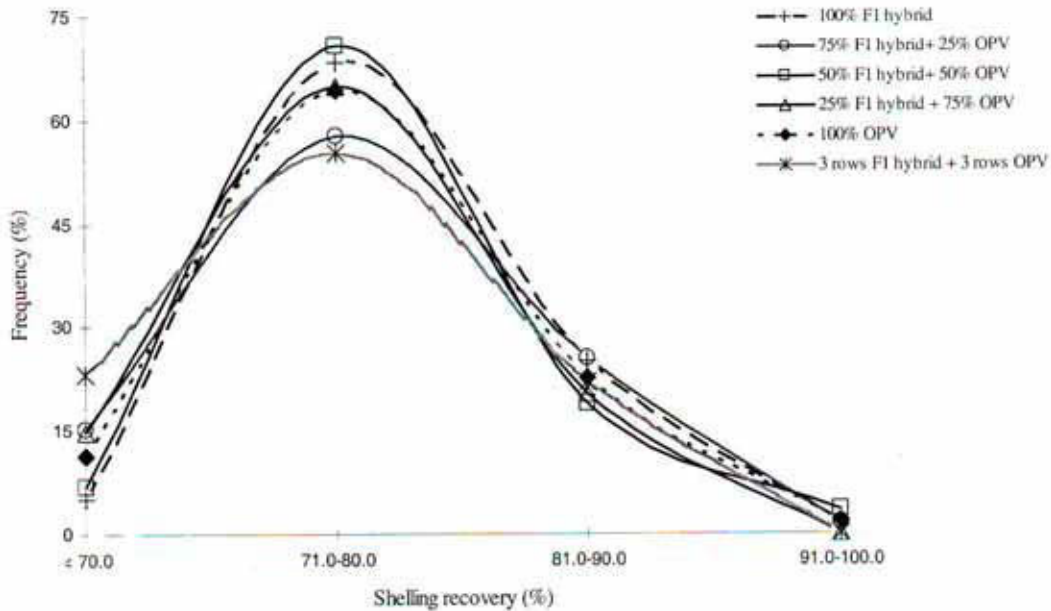


Fig. 3. Frequency distribution of shelling recovery of maize as affected by hybrid seed substitution with OPV

Partial Analysis of F₁ Hybrid Seed Substitution with OPV

Villegas *et al.*, (2004) established for the Philippines that Total Variable Cost (TVC) to produce a kilogram of maize grain was Philippine Peso 4.87, which was equivalent to around US\$ 0.087. This was considered as a basis to convert gross grain yield into TVC in the study. Partial analysis of hybrid seed substitution with OPV showed that gross return was the lowest in the pure stand of OPV (Table 5). The results also indicated that the gross return obtained from the pure stand of the hybrid was lower than that of the 75:25 mixed stands of hybrid and OPV. Gross return, decreased with the increase level of hybrid seed substitution, which indicated that OPV was ineffective to compensate for the diminishing contribution of the hybrid to gross income. As indicated earlier the OPV has inferior yield potential compared to the hybrid but the cost of hybrid seed is 12-fold higher than the cost of OPV which could even be higher under actual production. Usually farmers in South and Southeast Asia save some seeds from the previous harvest for next planting, the cost of OPV seeds become negligible. However, despite seed cost advantage of OPV, the Return Above Variable Cost (RAVC) was higher in the pure stand of hybrid and in mixed stands where the hybrid seed substitution level was 25-50%. Accordingly, on the basis of gross return and RAVC, hybrid substitution up to 50% with OPV either on seed weight or row proportion basis were economical for cultivation (Paudel, 2005).

Table 5. Partial economic analysis of costs and returns (per hectare basis) for maize as affected by the magnitudes of F₁ hybrid seed substitution with OPV

Treatment ^a	Grain yield	Gross return (GR) ^b	Seed cost (SC) ^e	Total variable cost (TVC)	Return above variable cost (RAVC) ^d
	(kg ha ⁻¹)	(UD\$)	(UD\$)	(UD\$)	(UD\$)
1	5951	851.00	42.86	518.00	376.00
2	6112	874.00	34.82	532.00	377.00
3	5622	804.00	23.21	489.00	338.00
4	4093	585.00	11.61	356.00	241.00
5	4069	582.00	3.57	354.00	232.00
6	5181	741.00	23.21	451.00	313.00

a1=100% F₁ hybrid (pure stand)

2=75% F₁ hybrid + 25% OPV

3=50% F₁ hybrid + 50% OPV

4=25% F₁ hybrid + 75% OPV

5=100% OPV(pure stand)

6= 3 rows F₁ hybrid + 3 rows OPV

^bFarm gate price per kilo maize ~ US\$ 0.143, August 2004

^cSC for F₁ hybrid per hectare ~US\$42.86; SC for OPV per hectare ~US\$ 3.56, August 2004

^dRAVC=GR-(TVC-SC);

Buying rate of 1 US\$ ~ Philippines Peso 56.0 as of August 2004

CONCLUSION

The study revealed that F₁ hybrid seed substitution with OPV up to 50% produced grain yield comparable to that obtained from the pure stand of F₁ hybrid. Partial economic analysis showed that despite seed cost advantage of OPV, the return above variable cost was higher in the pure stand of the hybrid and in mixed stands where hybrid seed substitution was 25-50%. Gross return and return above variable cost for hybrid seed substitution up to 50% with OPV either seed weight or row proportion basis was economical. Therefore, hybrid seed substitution up to 50% with OPV either seed weight or row proportion basis is a feasible maize production technology.

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PEST WEATHER INTERACTION OF MAJOR INSECT PEST IN RICE ECOSYSTEM

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ABSTRACT

Studies showed that the populations of leaf folder (*Cnaphalocrosis medinalis*) Gn. and stem-borer (*Scirpophaga incertulas*) Wlk. attained their peak in September (74 and 7.75 larvae per 20 hills, respectively). However, the maximum population of whitebacked planthopper (*Sogatella furcifera*) Horv., green leafhopper (*Nephotettix cincticeps* Uhl.) and white leafhopper (*Cofana spectra* Dist.) recorded to be 88.25, 25.50 and 1.50 insects/ 10 net sweeps, respectively, in October. So far as the effect of environmental factors is concerned, it was found that the maximum and minimum temperature (except stem-borer having positive effect) and rainfall (except green leafhopper having positive effect) are vital for bringing a change in the population of green leafhopper, leaf folder, stem-borer, whitebacked planthopper and white leafhopper while relative humidity has shown a positive response on the population. As a whole, 85.30, 82.99, 78.09, 66.50 and 57.00 percent changes in the population of aforesaid insect pests were found to be due to environmental factors.

Key Words: Population dynamics, paddy, *Cnaphalocrosis medinalis*, *Scirpophaga incertulas*, *Sogatella furcifera*, *Nephotettix cincticeps*, *Cofana spectra*.

INTRODUCTION

Rice (*Oryza sativa*) is by far the leading kharif annual cereal crop. Its importance can hardly be overstated. It is mainly used for human consumption. Rice grain is a source of protein, oil, sugar (Ahmad, 1989) and its outer layer is rich in thiamin (vitamin B₁), deficiency of which results in a disease called "Beriberi" in human beings (Montgomery et al., 1980).

It is more extensively grown in tropical and sub-tropical regions of the world. Basmati rice grown in "Kallar Tract" of the Punjab province is of international repute and valued for its cooking quality and aroma and, hence, is very much in demand at an appreciable premium in the world market (Chaudhry, 1976).

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It is a major source of our national income and merits next to cotton, in export of major agricultural commodities. It is a staple food article of Pakistanis with per capita availability of 21.81 Kgs/ annum and comes next to wheat in consumption (Statistics, 1991).

Of the various factors contributing to low yield of rice unimproved methods of cultivation, low yielding varieties, lack of proper irrigation methods, less use of fertilizers, the ravages by pest insects is very important. It has been estimated that each year, about 25-30 % losses are caused by insect pests (Ashraf et al., 1986). A number of insect pests damage rice crop from nursery to harvest causing considerable yield losses. As many as 128 different species of insects have been reported to attack this crop (Ahmad, 1981a) out of them 15-20 insect pests are of major economic importance (Ahmad, 1981b). The major insect pests include borers, which were the only accepted terrors of this crop in the past (Majid et al., 1979). According to Inayatullah et al., (1989), the incidence of rice stem borers, *Tryporyza incertulas* and *T. innotata* was 25% and 17% in 1986 and 1987, respectively in the Punjab but its devastation may even go up to 90% at the time of heavy infestation (Janjua, 1957). Its damage caused by larvae right from seedling stage till harvest (Salim & Masih, 1987), which feed within the stem, severing the vascular system resulting entire panicle to dry, forming "deadheart."

The infestation of rice leaf folder which is a dominant pest insect of summer rice (Panda and Shi, 1993) in certain cases may go up to 60 % (Kushwaha and Singh, 1985) resulting in a yield loss of 80% (Ragendran et al., 1986). In this case damage is done by the larvae, feeds on leaf tissues. As, they become older, fold the leaf to form a tube and scrap the green matter inside it, which hinders photosynthetic activity. Its damage can be spotted as white feeding areas in a field (Atwal, 1991).

Leafhoppers which include green leafhopper (*Nephotettix cincticeps* Uhl.) and white leafhopper (*Cofana spectra* Dist.) have also become regular insect pests of rice throughout the rice growing tract of the Punjab (Majid et al., 1979). Green leafhopper is one of the most serious pests of rice both in the tropics and temperate zone and known to be a vector of rice viruses and MLO'- mycoplasma like organisms (Kawabe, 1986).

Whitebacked planthopper caused tremendous loss by sucking phloem sap from the plant resulting in retardation of plant growth rate. Some times the plant does not form panicle. Moreover, the feeding and ovipositional marks predispose plants for bacterial and fungal infections. The honeydews secreted by the whitebacked planthopper, demonstrate its sign of feeding, encourage development of sooty mould, which hinders photosynthesis of the plant. "Hopperburn" was observed on more than 8000 hectares in Haryana (India) alone during 1984 (Kushwaha and Singh, 1986).

This research programme was designed to study population dynamics of some paddy insect pests and will play a pivotal role in their prediction and emergence, affected by temperature, relative humidity and rain fall directly or indirectly and will also help to develop effective control measures.

MATERIALS AND METHODS

The experiment was carried out at village Bhannoke Cheema under Sialkot District with the purpose of studying population dynamics of rice (Basmati-385) during 2001- 2003.

Population of rice-stem borer and leaf folder was recorded weekly by counting the number of larvae per 20 hills selected randomly, while the populations of rice leaf and planthopper were recorded at weekly interval by taking 10 hand net sweepings from the field walking diagonally across the plots. Meteorological data were taken from Daska observatory, which was nearby the experimental site. Population density was correlated with different environmental factors like minimum, maximum temperature, relative humidity and rainfall.

The data thus collected, analyzed statistically by using MSTAT package. The treatment means were compared by DMR test at $P= 0.05$ (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

a. Leaf folder:

The perusal of the population data (Fig. 1) recorded from the experimental field showed that the pest was appeared in August and was recorded through out the season. Its population started increasing from the second week of August (2.50 larvae per 20 hills being first peak) and reached the maximum level (74 larvae per 20 hills, the second peak) during the last week of September. A gradual decline in population was observed thereafter till end of October. These finding are in line with those of Wada and Shimazu (1978) who reported its presence from July to October. But according to the studies of Kushwaha and Singh (1985) the infestation of this pest begins in August and continued until mid October. According to Nazir (1986) population of this pest started increasing from the fourth week of August, reaching peak during the last week of September and then after, it started decreasing. Sachan (1992) also reported its appearance in July- October and peak population from early August to late September.

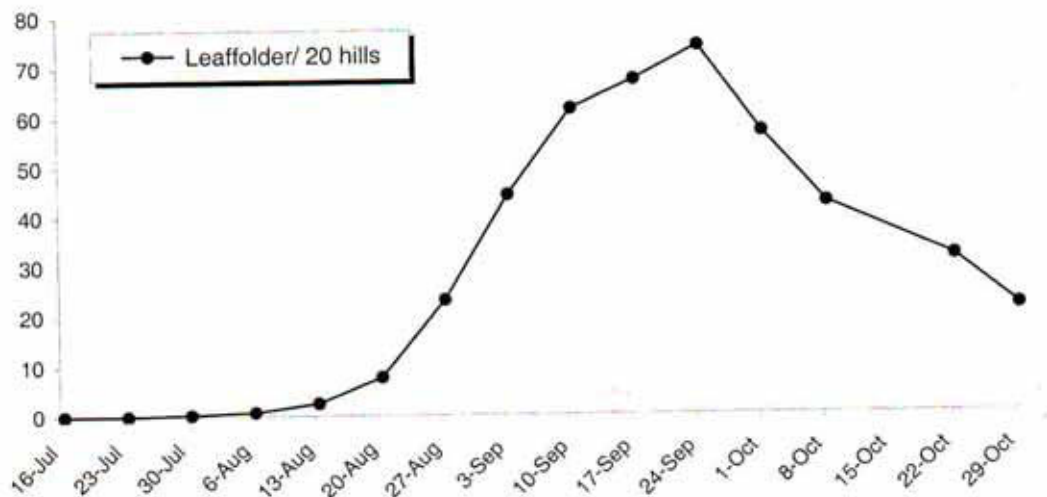


Figure 1: Population fluctuation of rice Leaf folder (*Cnaphalocrosis medinalis* Gn.).

The multiple regression equation (Table 1) showed that the 78.09 % changes in the population of leaf folder were because of the environmental factors. A negative but non- significant relation was observed in case of minimum and maximum temperature and rainfall but the correlation with relative humidity was highly significant and positive. According to Ram (1986) the infestation of this pest favoured by long period of humid weather.

Table 1. Multiple regression equation between the population of rice pest insects and maximum, minimum temperature, relative humidity and rainfall

Pest insect	Multiple regression equation	R	R ²	100R ²
Leaffolder	$Y = -68.3 - 0.32X_1 - 1.42X_2 + 2.04X_3 - 0.113X_4$	0.8837	0.780	78.09
Stem-borer	$Y = -2.93 + 0.0205X_1 - 0.0108X_2 + 0.0469X_3 - 0.00308X_4$	0.9110	0.8299	82.99
Whitebacked planthopper	$Y = 56.8 - 3.70X_1 - 2.12X_2 + 1.60X_3 - 0.012X_4$	0.8154	0.6649	66.50
Green Leafhopper	$Y = 11.0 - 1.47X_1 - 0.828X_2 + 0.783X_3 + 0.0088X_4$	0.9235	0.8529	85.30
White Leafhopper	$Y = 2.33 - 0.0586X_1 - 0.0382X_2 + 0.0077X_3 - 0.00054X_4$	0.7549	0.5699	57.00

Y = Population, X₁= Minimum Temperature, X₂= Maximum Temperature, X₃= Relative Humidity
X₄= Rainfall

b. Stem-borer:

The data regarding the population dynamics of stem-borer recorded per 20 hills are given in the Fig. 2 showed that the population remained very low up to the last week of August. High population was observed in the first week of September (5.25 larvae per 20 hills) and it reached the maximum level during the third week of September (7.75 larvae per 20 hills). These are in conformity with those of Suwongwan and Catling (1987) who reported that the larvae were more in September-October than in April-June. However, these are partially coinciding with those of Qadeer et al., (1992) who reported the peak activity period in August-September

The multiple regression equation (Table 1) indicated a positive and non-significant effect of minimum temperature on the population of stem-borer. Positive relation was also observed with relative humidity but maximum temperature and rainfall had a negative effect on population. However, collective effect of environmental factors (100R) was found to be 82.99%. The findings of Nandihalli et al., (1994) coincide with the present results. They reported a negative correlation between population and average maximum temperature and positive correlation with relative humidity. Alam et al., (1994) reported that the stem-borer infestation decreased with the increase in maximum temperature and rainfall and decreased with minimum temperature.

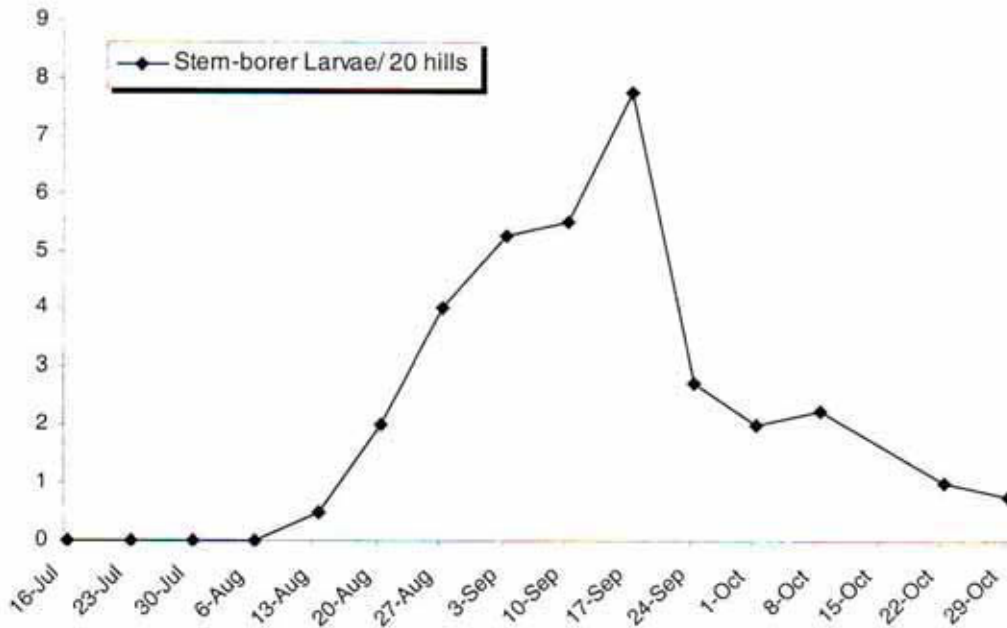


Figure 2: Population fluctuation of rice Stem-borer (*Scirpophaga incertulas* Wik.)

c. *Whitebacked Planthopper:*

The population data of WBPH in Fig. 3 shows that the population started increasing by the end of August and reached the maximum (88.25 insects/ 10 net sweeps) during the second week of October which are in agreement with those of Vardharajan (1980), Sathiyandanan and Subramanian (1983), Shrivastava et al., (1982) and Mohsin (1985) who reported its maximum population during September and October.

The multiple regression (Table 1) showed a non-significant negative correlation with minimum and maximum temperature and rainfall but the correlation with relative humidity and population was positive and significant with 66.50% collective effect of environmental factors (100R). These results partially correlate with those of Bajwa (1985) who concluded that the changes in the population of this pest insect were significantly affected by the changes of relative humidity as well as of sunshine. Akram (1986) reported a non-significant correlation between minimum temperature and its population density. It was also found the relative humidity have also some effect on the population. Kumar (1992) also studied the physical factors affecting outbreak of this pest and found that variation in relative humidity during the evening, < 200 mm rainfall and < 45 rain days from 10 to 20 August, controlled the population.

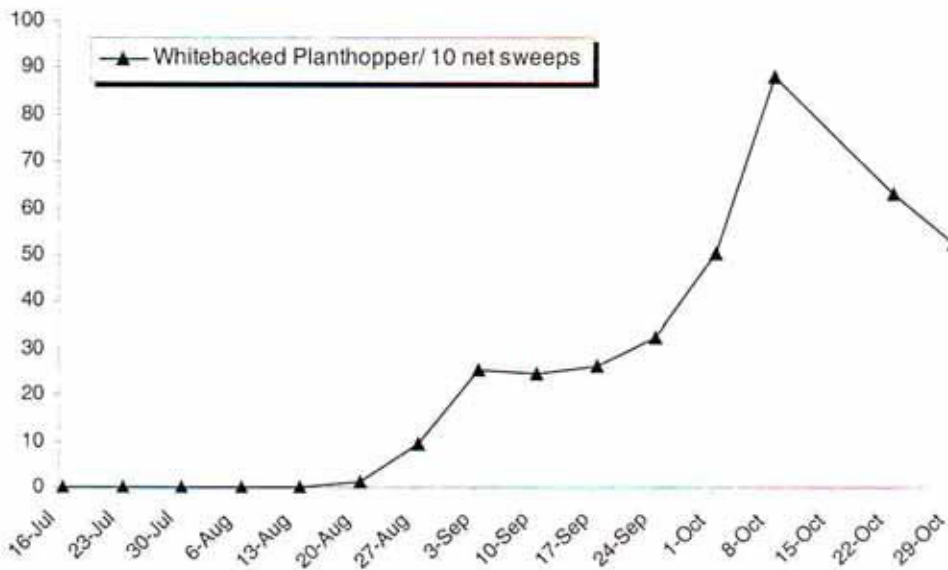


Figure 3: Population fluctuation of rice Whitebacked Planthopper (*Sogatella furcifera* Horv.)

d. Green Leafhopper:

The data regarding the population of GLH (Fig.4) indicated that the pest was present round the season but its population remained very low up to the last week of August. High population was observed in the third week of September and reached the maximum level (25.50 insects/ 10 net sweeps) during the third week of October. Lowe and Nandy (1984), Mishra et al (1984), Ammar et al (1975), Chakravarti and Mukhopadhyay (1978), Mukhopadhyay et al (1979), Sathiyandam and Subramanian (1983) and Mohsin et al (1990) also observed its peak activity period during October- November.

The multiple regression equation (Table 1) indicated 85.30% changes in the green leafhopper population due to the environmental factors. It further showed that the population of GLH was negative correlated with minimum temperature significantly but a non-significant negative correlation was observed in case of maximum temperature. A highly significant positive correlation was observed between the GLH population and relative humidity. Likewise the effect of rainfall was significant and positive. These results are partially in agreement with those of Reddy et al (1983). They reported a negative correlation between population of GLH and relative humidity but rainfall had a significant positive effect.

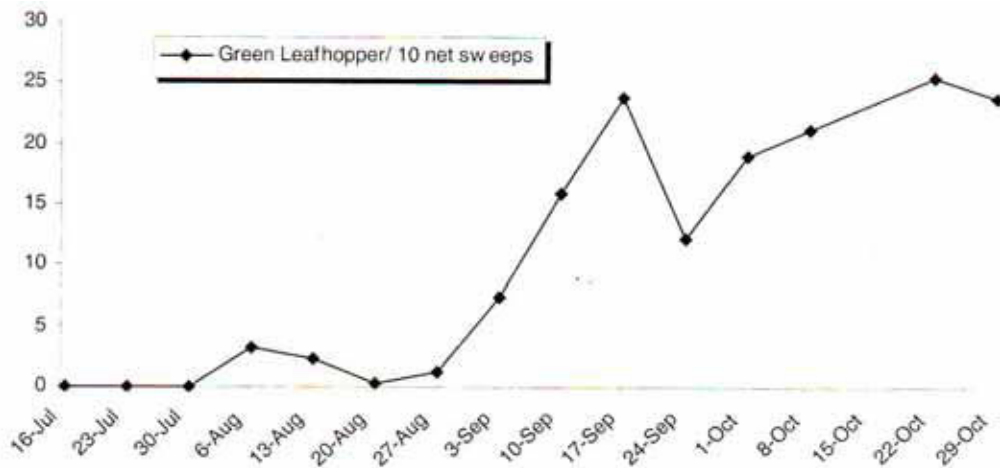


Figure 4: Population fluctuation of rice Green Leafhopper (*Nephotettix cincticeps* Uhl.)

White Leafhopper:

Its population (Fig 5) remained very low up to the last week of September. High population was observed in the third week of October and it reached the maximum level (1.50 insects/ 10 net sweeps) during the last week of October, which is in line with the findings of Mohsin (1985) who observed its highest population (42 insects/ 10 net sweeps) during the last week of October.

The multiple regression equation (Table 1) showed a negative but non-significant correlation between the population of WLH and maximum, minimum temperature and rainfall. But the correlation with relative humidity was positive and non-significant. However, collective effect of environmental factors (100R) was found to be 57%. Sam and Chelliah (1984) and Mohsin (1985) reported a negative correlation with environmental factors and its population. Farooq et al., (1988) also reported a significant negative correlation between its population and temperature.

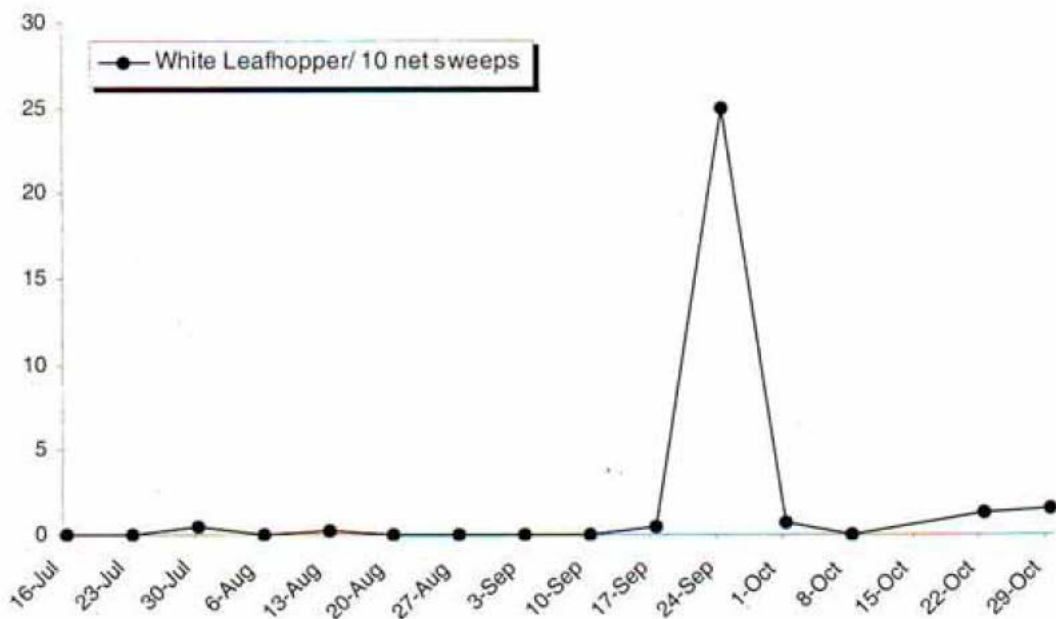


Figure 5: Population fluctuation of rice White Leafhopper (Cofana spectra Dist.)

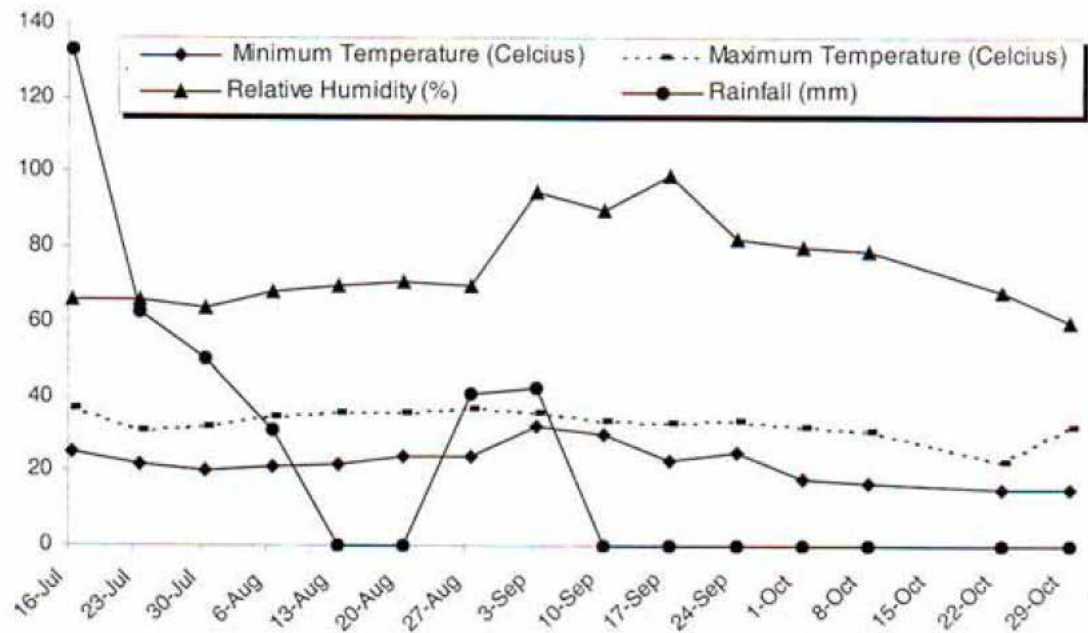


Figure 6: Meteorological data showing minimum temperature, maximum temperature, relative humidity, rainfall

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ROLE OF INFORMATION SOURCES, EXTENSION SERVICES AND AGRICULTURAL CREDIT TOWARDS RICE PRODUCTION IN DERA ISMAIL KHAN, PAKISTAN

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ABSTRACT

The results of a survey comprising 50 randomly selected farmers revealed that information sources, extension services and credit has a role in explaining rice production in Dera Ismail Khan of North West Frontier Province (NWFP), Pakistan. The frequency of the sampled population for getting information from nearby growers was very high mainly due to uncertain and insufficient knowledge provided by the other sources. A large chunk of society is devoid of effective extension service, though, among extension method, farm visits were considered as effective channel. Fifty-four percent of the farmers needed loan for the purchase of fertilizers, insecticides etc for rice crop and thirty-two percent declared banks as the suitable source of credit in the area

Key words: Rice, *Oryza sativa*, farmers, socio-economic conditions, Pakistan

INTRODUCTION

Rice (*Oryza sativa* L.) is the major summer crop of Dera Ismail Khan, the extreme southern district of NWFP, Pakistan. Out of total cultivated area (0.308 million hectares) of Dera Ismail Khan, rice is sown on 6044 ha with total production and average yield of 16366 tones and 2707 kg ha⁻¹, respectively (Anonymous, 2002a). The per hectare rice yield in this part of the country, although, exceeds the national average rice yield of 1836 kg ha⁻¹ (Anonymous, 2002b), the growers are not exploiting the potential rice yield up to the mark.

Keeping in view the importance of the subject, a survey was undertaken in the rice growing areas of Dera Ismail Khan to asses the role of information sources, efficacy of agricultural extension as well as looking into the role of economic institutions in providing credit facilities and role of agricultural extension in educating rice growers of the area.

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MATERIALS AND METHODS

The present endeavor was conducted by a survey research. A total of 50 farmers were interviewed from 25 villages of Dera Ismail Khan. Simple random sampling technique probability was adopted. The respondents were selected on the basis of their acreage under rice cultivation. Farmers having 5 acres or more under rice cultivation were included in the final interview schedule. The wealth of the information obtained from interviews was compiled. Frequencies and percentages were calculated and tabulated across respondents for comparison (Dowdy and Wearden, 1991).

Limitation of the study

The researcher has faced difficulty in conveying a number of questions dealing with the information access, extension services and credit. The researcher came to know that only the respondents who were illiterate were unable to understand the format of the questions. It is, therefore, suggested to concentrate on the format of the questions and attention should be paid in how to phrase and ask such type of questions in future investigations of the same kind. This will certainly improve response rate and drawn of valid conclusions.

RESULTS AND DISCUSSION

A. Information access

Sources of information and their effectiveness: The trend of the sampled population towards getting information on rice from different sources is given in Fig. 1. The frequency of the sampled population in getting information from nearby growers was very high i.e. 26%, as compared to other sources of information. Similarly, 20% growers did not want to get information from the Agricultural Research System because of the low intensity of the visits to farmer's field. Out of the total surveyed population, 36% rice growers indicated the Agricultural Research System as their preferential source in getting information about rice crop as compared to other sources (Fig. 2). The rest of the farmers showed variable responses in selecting their favourite source towards rice cultivation. Among the farmers interviewed, 32% farmers had the view that the information provided by nearby growers was most effective, followed by the Agricultural Research System. Radio, although, is a powerful medium of communication in the present era of information technology, but 20% pointed out that this medium is less effective as it provides only information not the practical demonstration (Fig. 3). Response of growers towards the effectiveness of other sources of information was quite inconsistent. Thirty-two percent growers did not respond to these questionnaires.

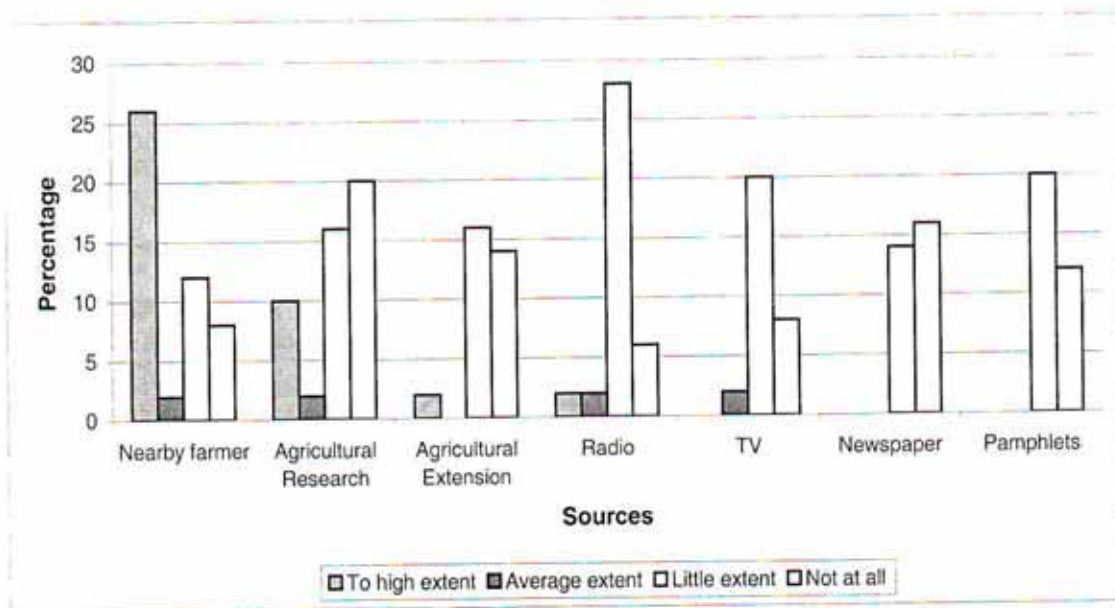


Fig. 1. Sources of information of rice growers in sampled area

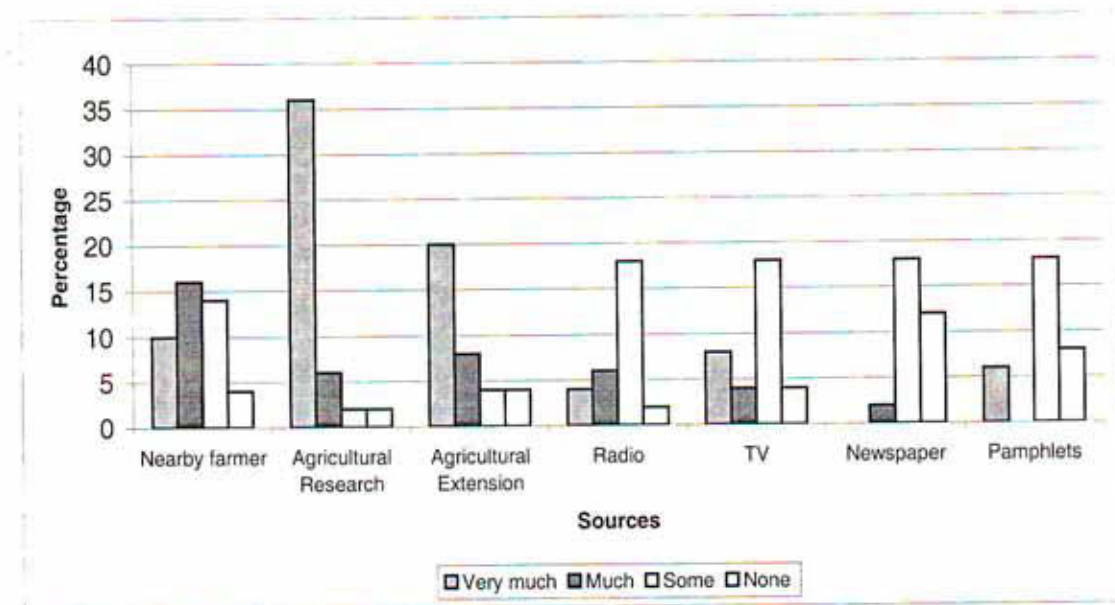


Fig. 2. Favourite source of information of rice growers in sampled area

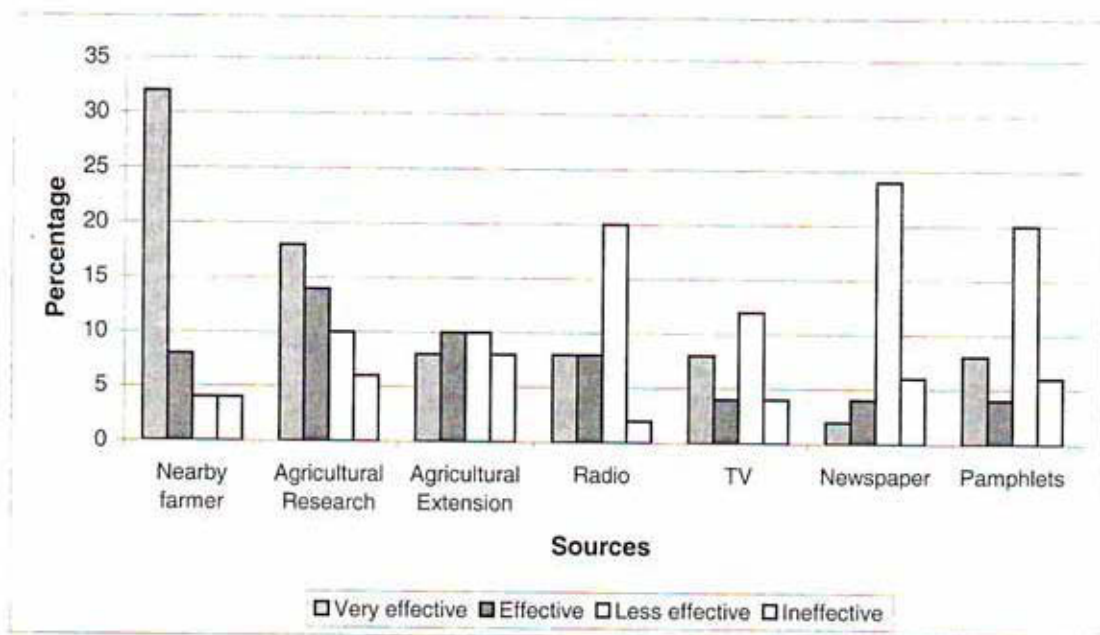


Fig. 3. Effective source of information for rice crop in sampled area

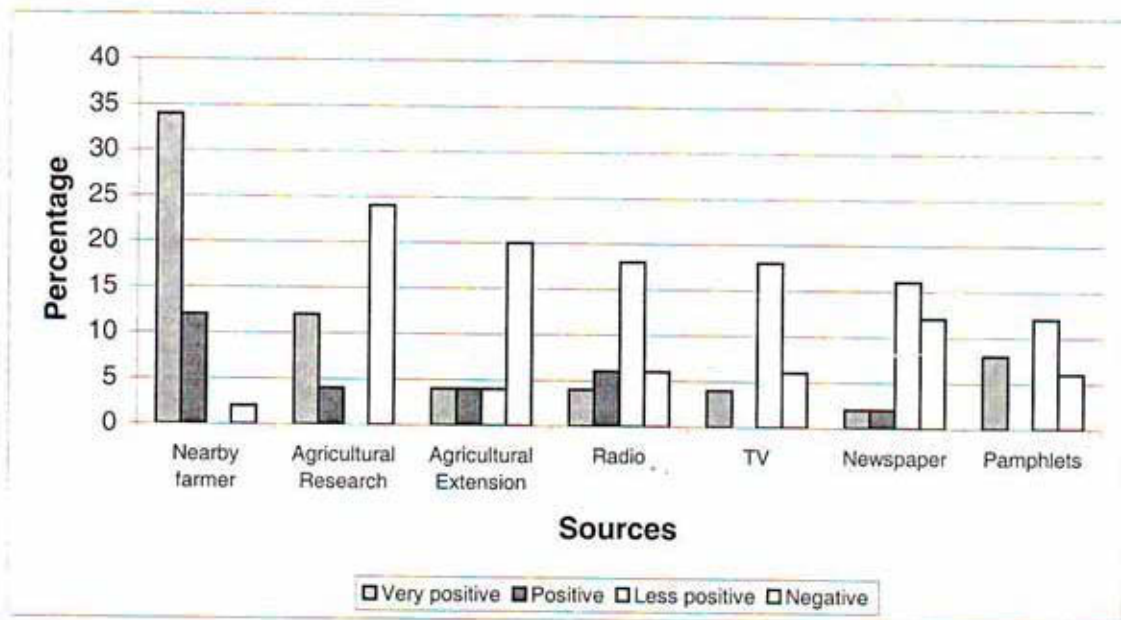


Fig.4. Role of information sources for transfer of technology in sampled area

Role of information sources: About one-third (34%) growers of the sampled population agreed that the role of nearby growers in providing information about rice crop was very positive (Fig. 4). Similarly, 12% had the view that the role of Agricultural Research System is also very positive. Unlikely, 24 and 20% growers of the surveyed population reported negative role of Agricultural Research System and Agricultural Extension department. The trend of the population interviewed towards the role of Radio was similar as they responded to previous questionnaires. The role of pamphlets in providing information and dissemination of improved technologies was also recognized by 8% of the growers. However, 32% growers did not respond to this questionnaire.

B. Extension services

A number of channels (farm visits, exhibitions, field days and demonstrations) were examined regarding their role in dissemination of rice technology. Out of the sampled farmers, 58% showed complete dissatisfaction on the performance of Extension department in educating farmers and providing sufficient information about rice crop. Only 10% farmers were satisfied with their performance. While, 32% growers did not respond to this questionnaire.

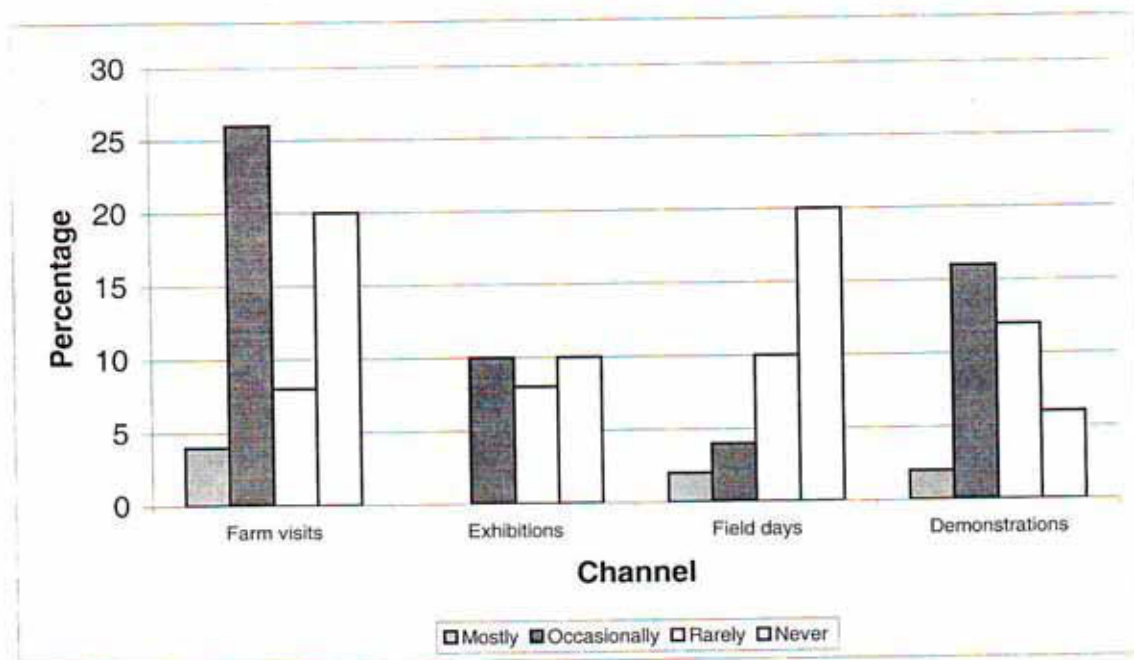


Fig. 5. Channels used by extension workers for dissemination of technology in sampled area

Channels of extension services: Among sampled population, 26% farmers reported occasional visits of extension workers while 16% had the view that the extension workers transmitted no practical knowledge through demonstration. Twenty percent growers replied that none of the extension worker transmitted knowledge either through field visits or field days (Fig. 5). Thirty-two percent growers did not respond to this questionnaire.

Effective channel: A big segment of the sampled population agreed that farm visit was the most effective channel, followed by demonstration plots and field days (Fig. 6). The farmers' were of the view that they could learn a lot in the field, if the extension workers paid visits to them frequently. Kamruzzaman *et al.* (2001) examined the extent of modern technology and knowledge gap of the farmers about the technology. It was

found that the demonstration farmers of the farming system research sites and multi-location testing sites had less knowledge gap than the other farmers.

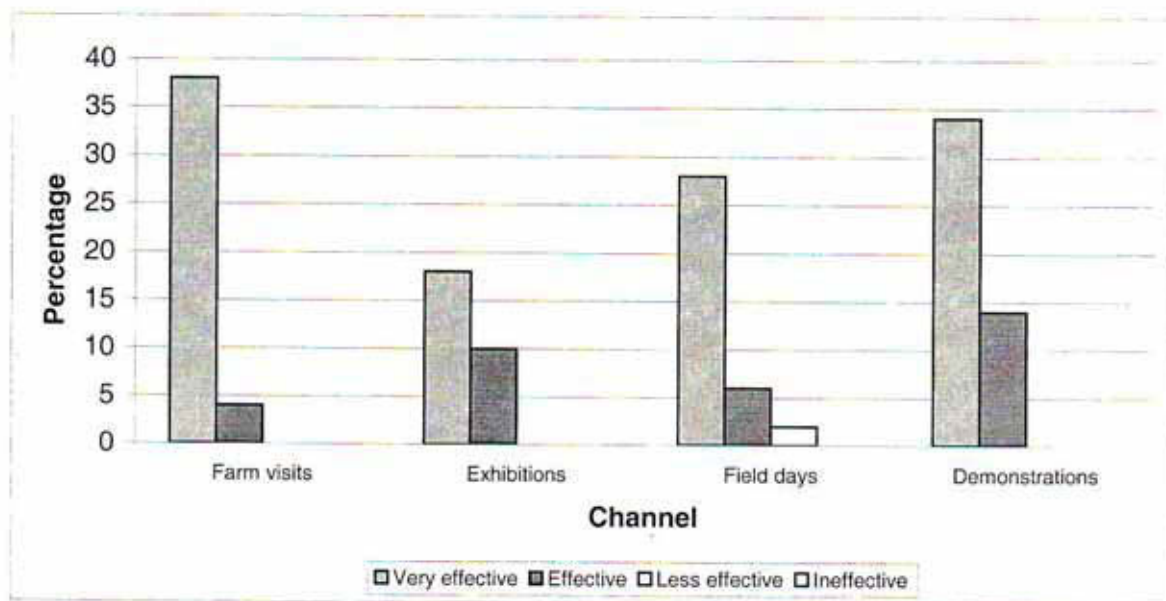


Fig. 6. Effective channels used by extension workers for dissemination of technology in sampled area

C. Credit

Fifty-four percent of the farmers interviewed needed loan for the purchase of fertilizers and insecticides etc for rice crop. The population not using the credit put forth the reasons that credit is not available when needed and interest rate is high. However, 32% growers did not respond to this questionnaire.

Suitable source: Out of the three sources available for credit, thirty-two percent of the population declared banks as the suitable source of credit, followed by friends. Twenty percent farmers having smaller holdings were dependent on Broker because of their convenience. They can take loan from the Broker for the cultivation of crops and repaid after harvesting (Fig. 7). Thirty-two percent growers did not respond to this questionnaire. Previously, Gurmani *et al.* (1988) conducted a survey in the same region and reported 32% of the sample population using credit from Agriculture Development Bank of Pakistan. Also, Muhammad *et al.* (2002) examined the relationship of farmer's age, educational qualification and social status with the timely availability of loan. The analysis showed that age and educational qualification had a highly significant negative relationship with the timely availability of loan. There was also a non-significant relationship between social status and timely availability of loan.

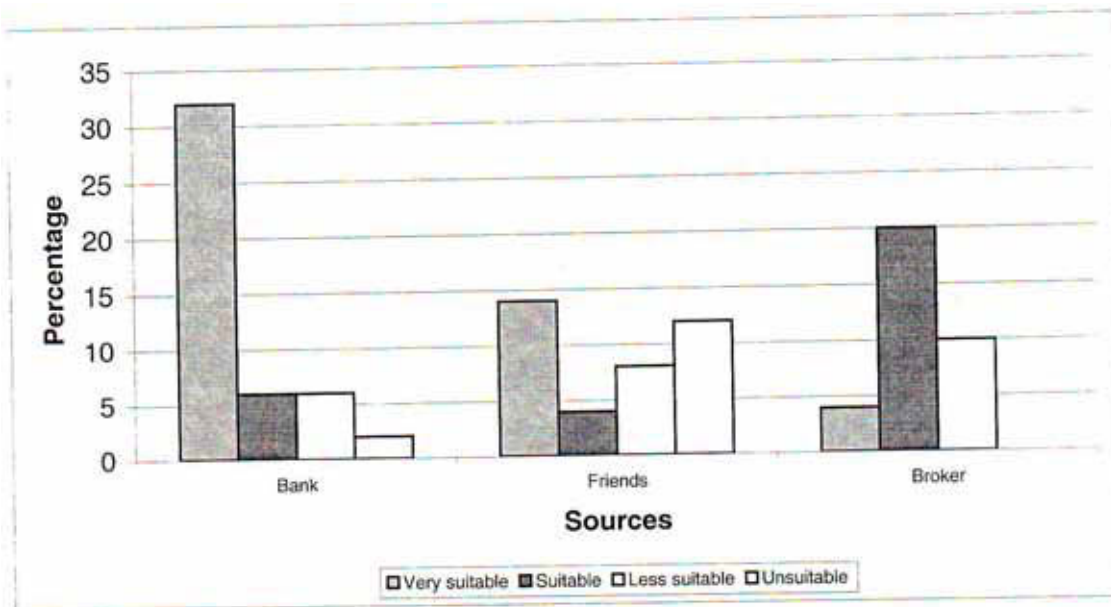


Fig. 7. Suitable source of credit for rice growers in sampled area

CONCLUSION

The study aimed at exploring the influence of information sources, extension services and credit facilities associated with rice production in Dera Ismail Khan, NWFP, Pakistan. High reliance on fellow farmers regarding information access and usage has provided an insight into the role of extension services, which requires reorientation and increased contacts for effective results. The access and repayment of credit attainment should be made easy for successful rice production in the area. Hence, an integrated effort is needed by all stakeholders involved in rice production in order to mark increased returns.

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CROP AREA ESTIMATION IN MAHAWELI SYSTEM C, SRI LANKA USING REMOTELY SENSED DATA

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ABSTRACT

Estimation of agricultural crop area is essential in predicting the harvest and deciding on imports. Remote sensing provides frequent and up-to-date information to monitor crops and also facilitates area estimation of crops.

This study was carried out to estimate crop area in Mahaweli System C using multi-temporal satellite images. IRS-1A LISS II (March 1992), IRS-1C LISS III, IRS-1C, PAN (February 1998) and ASTER (July 2000) were used to extract crop area in Mahaweli System C. Visual interpretation, supervised classification and unsupervised classification were employed to identify land use classes and to extract crop area to compare with the available field statistics. The most accurate area estimation was used to assess total yield in Mahaweli System C for a particular period. The study shows the ability of remotely sensed data to estimate crop areas. A set of multi temporal images acquired from the same sensor within a crop cultivation season will be more helpful to improve the accuracy. According to the study the estimated crop area by visual interpretation of IRS-1C PAN was 28011 ha and it was identified as the best method for crop area estimation with comparison of field data. Supervised classification of ASTER image was identified as the best for rice area estimation. The estimated rice area was 23428 ha.

Key words: Crop Area Estimation, Yield Forecasting, Remote Sensing, Mahaweli System C, IRS, ASTER.

INTRODUCTION

Agriculture resources are among the most important renewable, dynamic natural resources. Comprehensive, reliable and timely information on agricultural resources is very much necessary for a country like Sri Lanka whose mainstay of the economy is agriculture. Timely information of agricultural farming is one of the basic requisites for planning and management.

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The staple food of the people in Sri Lanka is rice hence the major cultivated crop is paddy. Therefore, economical status and food security of Sri Lanka are mainly depended on rice production. A main component of the agricultural monitoring is the pre-harvest assessment that is undertaken at the end of the growing season when harvesting starts. Due to lack of information about national level food production at accurate time, many governments try to import supplementary food from other countries. However, these food imports may be overlapping with national crop harvesting period. This makes conflicts on local level food chain, which leads to low prices to farmer, wastage of food etc.

Remote Sensing is a technique of acquiring information about objects, areas or phenomena by means of sensors mounted on the aircrafts & spacecrafts, is proven to have a great potential for earth resources survey applications. Remotely sensed data are used for the assessment water resources, topographical and land use mapping, yield estimation of crops etc (Chandrasekar, 1986). It has the potential to provide real-time analysis of the attributes of a growing crop that can assist in making timely management decisions that affect the outcome of the current crop. The information gained from remote sensing is more meaningful when combined with other available data. For this reason, even historical photographs can take on new value (Casady & Palm, 2005).

Satellite based crop yield estimation attains greater importance, as it provides information on smaller real units such as distributaries, before the harvesting season. TM image of six bands was classified covering paddy area according to yield variability obtained through interviews of cultivators in the study area and obtained a good correlation between actual grain yield and reflectance values in some bands of the images taken during maturity state of rice (Tennakoon et al., 1992).

RADAR remote sensing can be used to rice area estimation successfully. Using seasonal RADARSAT data, characteristics of backscatter coefficient in agricultural area were investigated. As the result, paddy field has low backscatter in flooded season. Backscatter of paddy field increases as rice grows. However, it is impossible to monitor rice fields precisely due to speckle noise of SAR data. Combining Geographical Information System with SAR data might help solve this problem (Ogawa & Saito, 2005).

MATERIALS AND METHODS

Study area

Mahaweli System C is one of the command areas that were developed under the accelerated Mahaweli development program in 1977. Mahaweli System C is located in the Eastern, Uva and North Central Provinces and on the right bank of the Mahaweli River and downstream of the Randenigala and Rantembe reservoir between latitudes 08°49'07" N, 09°27'36" N and longitudes 82°36'28" E, 82°49'00" E. The extent is about 63000 ha and the topography is sloppy and irregular (ILRI, 1986). Figure 01 shows the location of the Mahaweli System C and the system boundary.

There is only 42 percent or 26000 ha area suitable for irrigation out of the total area. The mean annual rainfall is 2100 mm which is mainly received from North East monsoon or from Maha rains between October and April. The dry season or Yala coincide with South West monsoon from May to September. The major crops are paddy, banana, black gram, B'onion, cowpea etc. There are former settlements based on tanks such as Horabora, Dambarava and Mapakada Wewa. The Minipe right bank channel has made new settlements based on reservoirs; Ulhitiya and Rathkinda. Before the accelerated Mahaweli project began, most of the lands were covered by forest and later converted to paddy land and home gardens.

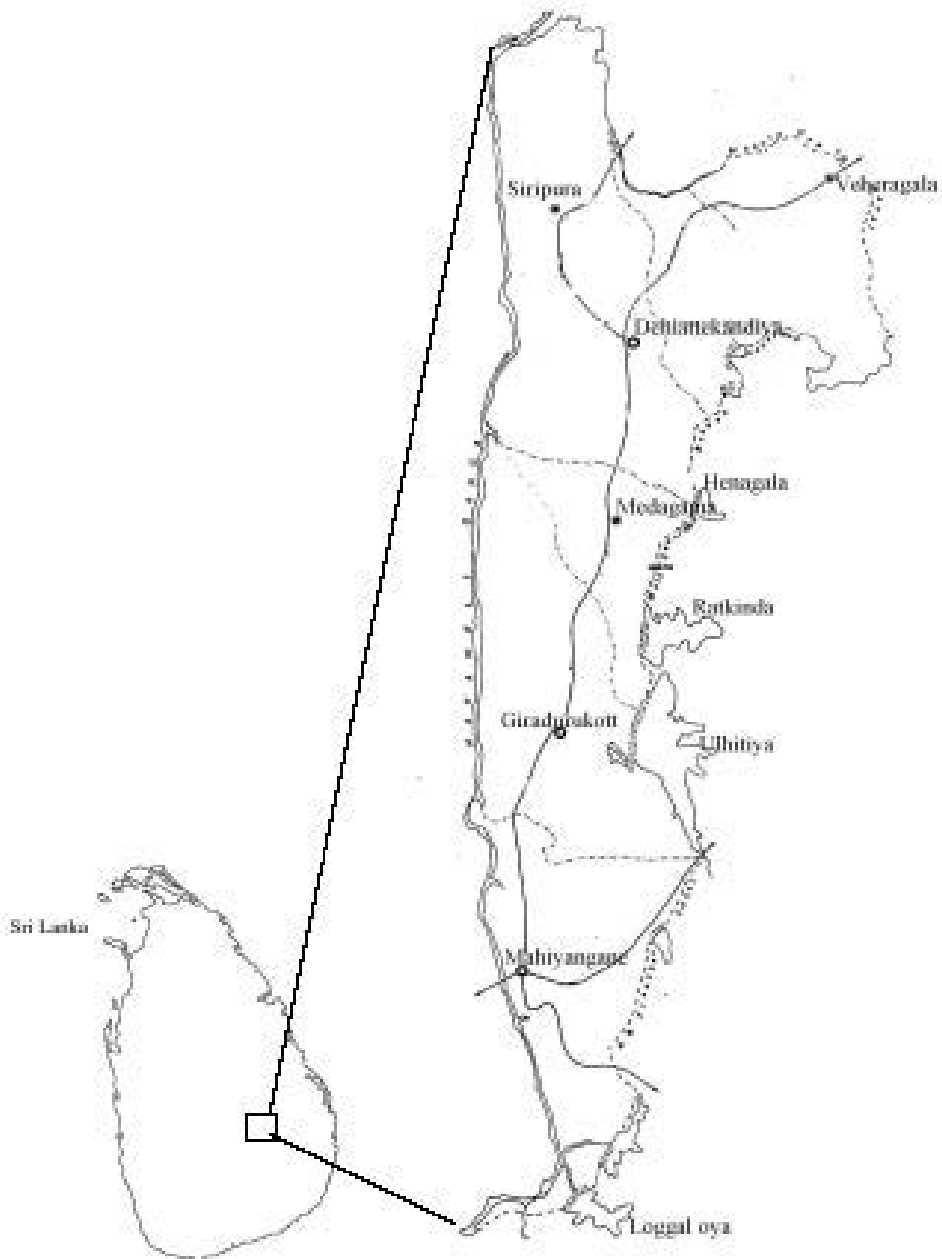


Figure 1. Location of Mahaweli System C

Data and other Information

Medium resolution, multi-temporal satellite images were used in the study. The information on digital satellite data used in the study is given in Table 1.

Table 1. Specifications of satellite images

Satellite and sensor	Acquisition date resolution (m)	Spatial (μm)	Sepectral band
IRS LISS II	March 1992	36.25	0.45-0.52, 0.52-0.59, 0.62-0.68, 0.77-0.86.
IRS LISS III	22 FEB 1998	23	0.52-0.59, 0.62-0.68, 70 0.77-0.86. 1.55-1.70.
IRS Pan	22 FEB 1998	5.8	0.50-0.75
ASTER	JULY 2000	15	30 0.52-0.60, 0.63-0.69, 30 0.76-0.86. 1.60-1.70.

Source: Lillesand & Kiefer (2004).

Other data/ information used are

- Topographical maps of 1:50000, prepared by Survey Department of Sri Lanka that covers the Mahaweli System C area.
- Crop statistics collected by Mahaweli Authority of Sri Lanka according to the dates of image acquisition (March 1992, February 1998 and July 2000)
- Land use maps and ground truth information of Mahaweli System C.

Processing of data

Image pre-processing

Geometric correction was applied to IRS LISS II, IRS LISS III and IRS Panchromatic images. Two image scenes were required to cover the entire system C with IRS data. Those images were geometrically corrected using reference coordinate obtained from 1: 50000 topographical maps of the Survey Department of Sri Lanka. The ASTER images had already been geometrically corrected by using GPS data. The geometrically corrected images were mosaiced to cover the entire system C. Finally, vector layer of Mahaweli System C boundary was overlaid on each mosaic to extract the study area.

Identification and extraction of crop area

Identification of the crop area was carried out using three different image interpretation techniques namely; visual interpretation supervised and unsupervised classifications. First, best band combinations were identified to extract the different land uses present in the area. Then the image interpretation techniques were applied separately. Visual interpretation was applied to the IRS LISS II, IRS Pan and ASTER images to extract the crop area using screen digitization with ARC View software. Here, crop area was visually identified and polygons were made. IRS Pan Vector polygon layer was used to extract the crop area from the IRS LISS III image.

Best band combination was identified to select the training samples. High priority was given to identify the crop area training samples as much as possible. Supervised classification was performed using selected training samples. Maximum likelihood classification was the statistical decision criteria to assist in the classification overlapping. Signature pixels were assigned to classes of high probability. Furthermore, IRS LISS II image was classified into five classes, IRS LISS III image was classified into six land use classes and ASTER image was classified into five classes using maximum likelihood classification algorithm. The number of classes was based on the image's ability to provide information. IRS LISS III and ASTER images were used to identify general land use patterns and these images are in proper resolution to provide general information of the study area. The classified images were imported to Arc View GIS 3.3 software and the crop area was isolated from other land use classes as a vector layer.

IRS LISS II and IRS LISS III images were subjected to unsupervised classification and categorized into 50 classes using ERDAS Imagine software. Then the categories which are having similar statistical characteristics were combined together to identify the crop areas from other land uses. Unsupervised classification of ASTER image into twelve classes was better for identification of land use classes and for the extraction of crop area.

Comparison of the techniques with real field statistics and yield assessment

The effectiveness of the three techniques was compared with the real time statistics of the Mahaweli System C obtained from the Mahaweli Authority of Sri Lanka. Subsequently, the most suitable method and the images for total crop area and paddy area extraction were identified by this comparison. Furthermore, estimated area and average yield per ha was used to estimate the total yield.

RESULTS AND DISCUSSION

Crop area extraction from satellite data

Agriculture fields are obviously dynamic and one crop cycle can be divided into two phases basically such as vegetative phase and reproductive phase. The rice plant shows more greenish colour at vegetative phase and slightly off brown colour at reproductive stage. Due to that, spectral signature of crop vary with the growth phase of the plant but there are significant differences of pixel value in digital image of forest, scrubs, human settlements, water bodies and agricultural crops. Agricultural crops can be extracted with the help of different classification methods with set of frequent images of same field.

Visual interpretation

Result from visual interpretation depends on resolution of the image, layer compatibility of image, interpreter's prior knowledge etc. Out of the images, IRS LISS II and III and ASTER were used to produce band combinations because those are multi-layer images.

IRS LISS II image

Visual interpretation is one of the standard methods for crop area extraction. IRS LISS II has low resolution compared with other images (LISS III, ASTER) and is about 36.25 m. With a prior knowledge, crop field can roughly be identified to draw polygons which sometimes lead to errors due to spectral confusion of objects (urban, paddy) and wrong identification of objects. However, water bodies, dense forest and water channels can be demarcated easily. The problem with low resolution images is that when a pixel is missed out a considerable area will be counted as crop area. As an example, when one pixel of IRS LISS II image is lost, the final result will have an area loss of $36.25 * 36.25 \text{ m}^2$.

IRS LISS III image

IRS Pan and LISS III images have been acquired on the same day. Due to that, the boundary file was made by using Pan image and that file was taken as the area of interest to extract the crop area from LISS III image. Pan has high resolution (5.8 m) which is suitable for visual interpretation with high accuracy. Figure 02 shows crop area in LISS III extracted with the help of IRS Pan

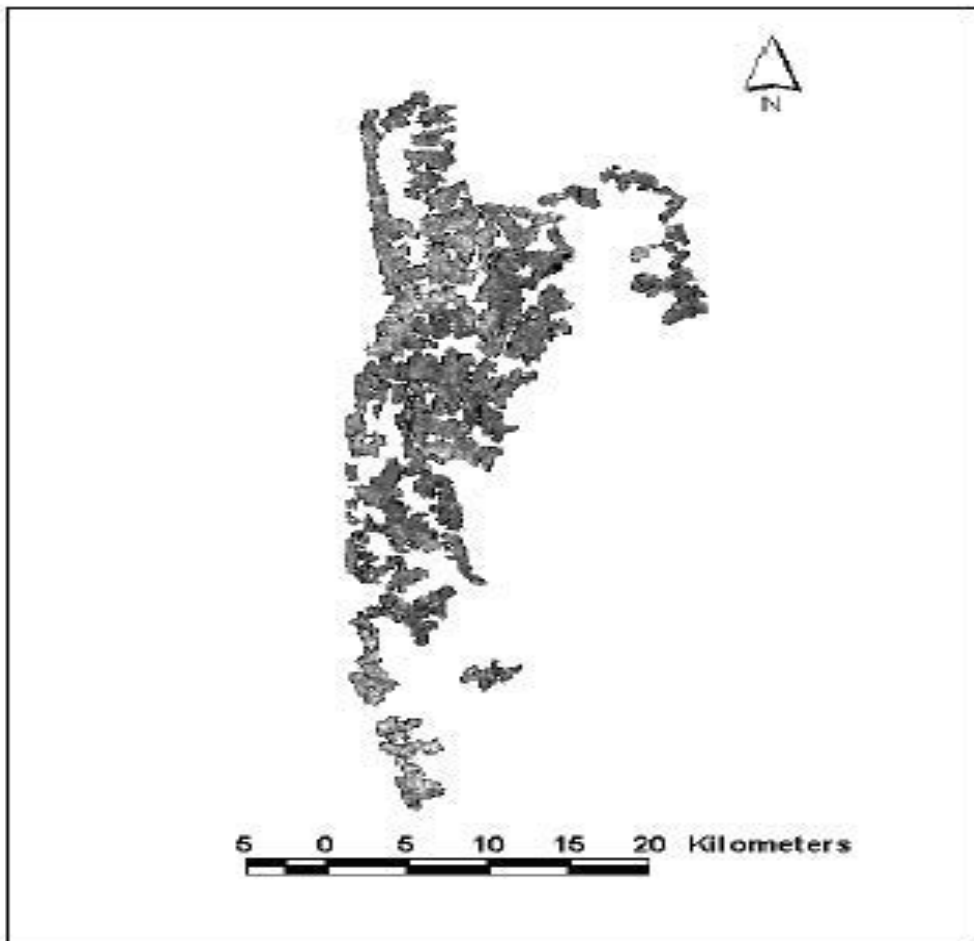


Figure 2. Crop area extracted by visual interpretation of IRS LISS II

ASTER image

ASTER images have medium resolution (15 m) which is moderately preferable for visual interpretation. Multi-spectral bands help to change colour composites which further enhance the visual interpretation ability of the image. As an example, under Standard False Colour Composite, green vegetation shows more in red colour. It helps to demarcate vegetation from other objects. Upland paddy fields can be clearly identified in the Pan image but it is difficult to identify in ASTER image.

Supervised classification

IRS LISS II image

IRS LISS II gives a fairly good land cover classes by supervised classification. To get a quantitative value, supervised classification may not be the proper method. However, it is useful for qualitative assessment of crop area due to low resolution. The signatures selected as crop area overlapped with scrub and grassland due to spectral confusion. Also pixels belongs to well grown paddy fields were similar to forest. Classifying LISS II image into several classes such as paddy, scrubs, water body, forest and unknown was given a fairly reliable land use map of Mahaweli System C. Compared to the visual interpretation output, this over estimates the crop area.

IRS LISS III image

According to the supervised classification of LISS III image, it shows six land use types namely, marginal lands, dense forest, scrubs, water, paddy and gardens. IRS LISS III image shows reliable classification results based on given training samples. Agricultural lands can be extracted to a considerable extent, though there are some confusions with forest. Figure 03 shows the crop area extracted by supervised classification of LISS III image.

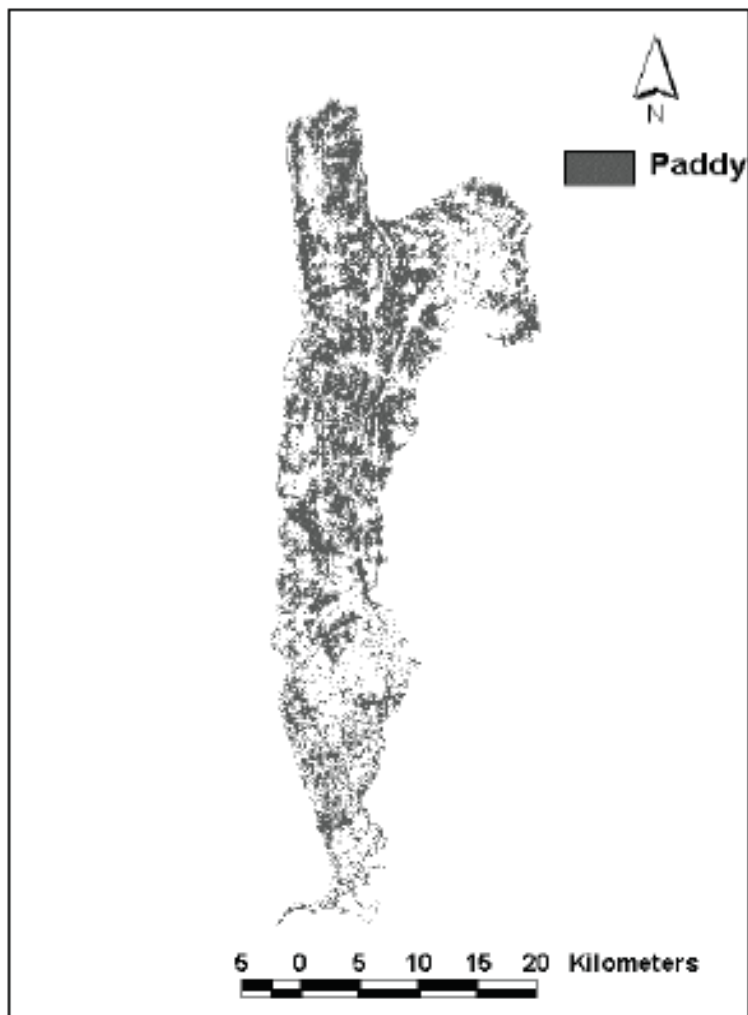


Figure 3: Crop area extracted by supervised classification of IRS LISS III image

ASTER image

Paddy fields were very clear in false colour composites in the ASTER image due to unique reflectance characteristics. ASTER image shows a significant difference in reflectance pattern in paddy fields compared to the other land uses. Supervised classification of ASTER image was good in identifying the paddy cultivated area. Figure 04 shows paddy area extracted by supervised classification of ASTER image.

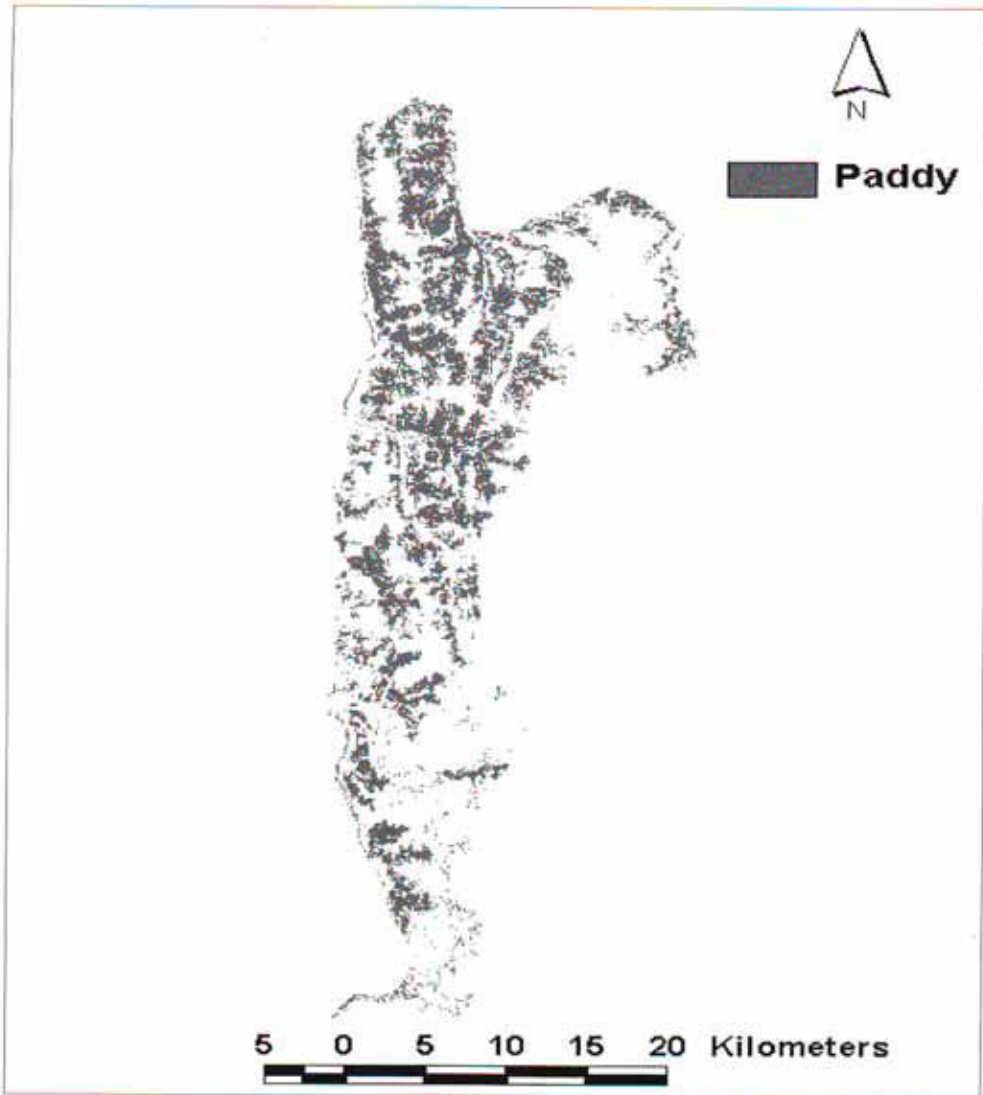


Figure 4. Paddy area extracted by supervised classification of ASTER image

Unsupervised classification

IRS LISS II image

IRS LISS II has been acquired at the end of the Maha season in 1992. At the maturity stage, rice plant shows brownish colour which is similar to the reflectance of dried grassland. Also, harvested paddy land show very bright white colour in standard false colour composite which is again similar to the reflectance of urban areas. This made it difficult to extract the paddy lands accurately. Due to the spectral confusion and relatively low spatial resolution, LISS II image is suitable in identifying general land use of Mahaweli System C.

IRS LISS III image

IRS LISS III has a moderate spatial resolution (23.5 m) which again gave problems with unsupervised classification. Spectral confusion was the major problem in this image too. However, this problem was minimized by classifying the image into large number of classes and then merging them.

ASTER image

Classification of ASTER image into six classes gives sharply demarcated crop areas. Small scattered pixels are minimum in this classification. This result mainly gives the total paddy cultivated areas. This result can be further verified with field visits. Figure 05 shows crop area extracted by unsupervised classification of ASTER image.



Figure 5. Crop area extracted by unsupervised classification of ASTER image

The summarized problems and constrains of each method can be shown as given in Table 2.

Table 2. Summarized Problems and Constrains of each Method

Classification Method		Problem's Associated
Visual Interpretation	<i>IRS LISS II image</i>	The problem with low resolution images is that when a pixel is missed out a considerable area will be counted as crop area. Further lead to errors due to spectral confusion of objects (urban, paddy) and wrong identification of objects.
	<i>IRS LISS III image</i>	It is easy to classify this image with help of IRS Pan on same day. Otherwise it leads to miscalculations.
	<i>ASTER image</i>	It is difficult to distinguish other lands other than rice land.
Supervised Classification	<i>IRS LISS II image</i>	To get a quantitative value, this method may not be the proper method
	<i>IRS LISS III image</i>	Agricultural lands can be extracted to a considerable extent, though there is some confusion with forest lands.
	<i>ASTER image</i>	It is not suitable for identification of minor non agricultural lands within major non agricultural lands.
Unsupervised Classification	<i>IRS LISS II image</i>	It is difficult to extract the paddy lands accurately due to the spectral confusion and relatively low spatial resolution.
	<i>IRS LISS III image</i>	Spectral confusion was the major problem in this image.
	<i>ASTER image</i>	This result mainly gives the total paddy cultivated areas. To improve clarity of result field visits will be helpful.

Comparisons with field statistics

Table 3 shows the values estimated using each method and the real field statistics obtained from the Mahaweli Authority of Sri Lanka. Total cultivatable agricultural crop area is 29300 ha (MASL, 2000). The closer values for crop area to the field statistics is given by visual interpretation technique. IRS Pan and ASTER images give close values to the field statistics due to their relatively high spatial resolution. Out of them, IRS Pan is the most suitable image for visual interpretation because most of crop fields and their boundaries can be identified easily in the image due to its high spatial resolution of 5.8 m. It gives crop area extent of 28011 ha. Though it

is not possible to identify individual fields in the ASTER image, total crop area can be easily separated from the other land uses. ASTER image has a lower resolution than the IRS Pan image. However, the multi spectral nature helps to enhance the image using band combinations and it helps to improve the visual interpretation. IRS LISS II image is not suitable for crop area estimation and it only gives an idea about the land use pattern in the area due to its low spatial resolution of 36.25 m.

With IRS LISS III, supervised classification is mostly suitable for agricultural area estimation when compared with the field statistics. Unsupervised classification and visual interpretation do not give acceptable results when compared with field statistics. Supervised classification of ASTER image gives 23428 ha of agricultural land, which is closer to the paddy area estimated by Mahaweli Authority of Sri Lanka. Unsupervised classification of ASTER shows close value to the field statistics out of all unsupervised classified images. To get more accurate value of crop area, there must be larger collection of secondary data about the study area. Field statistics are also estimated values and therefore it is very difficult to come to a firm conclusion. However, since the IRS Pan image is good in identifying the individual fields, the area estimated by it can be considered as more accurate. Further, by classifying one image crop area cannot be extracted accurately, therefore, there should be several images acquired during the same crop season and in different seasons to estimate crop areas accurately.

Table 3. The area (ha) estimated by different methods and images

	1992	1998		2000
	IRS LISS II	IRS LISS III	Pan	ASTER
Visual interpretation	34782		28011	28713
Supervised classification	29647	30132	27790	23428*
Unsupervised classification	43758	30841		25631
Real time statistics		24925		20712

(*-paddy area only)

Yield assessment

Yield forecasting is an essential component to identify food security of the country and to decide on imports. Crop area estimation and forecasting of yield are closely related to the capability of identifying crop species and certain agronomic variables such as maturity, density, vigor, and disease which can be used as yield indicators. Yield is influenced by a large number of factors such as crop genotype, soil characteristics, cultural practices, weather conditions and biotic influences, such as weeds, diseases and pests. Two approaches are adopted for yield modeling using remotely sensed data; first is the use of remotely sensed data to estimate crop area which was covered by this study and the second is the estimation of yield per unit area. The satellite data based crop yield models such as NDVI, is used to measure the yield and combine that with the field location using a global positioning system (GPS) receiver. Yield, together with the longitude and latitude coordinates can be used to create a yield map, which is a visual indicator of the yield variation within the field. The yield map can immediately provide two important pieces of information. Those are yield variability within field and yield production that helps to understand what is going on the field. So better management decisions such as low yielding locations are not planted and to evaluate the most productive land for potential (change seeding rate, increase management of pests, etc.) can be practiced.

Problems occurred in crop area extraction

Spectral confusion

Different objects types sometimes produce similar reflectance characteristics, which leads to a condition called 'spectral confusion'. According to the results of this study, spectral confusion has mainly affected paddy and urban areas. The harvested paddy lands show similar reflectance to that of urban areas. Since IRS LISS III in 1998 has a comparatively low spatial resolution of 23.5 m, it causes similar reflectance pattern of these ground covers and poses difficulties in differentiating. ASTER image has unique reflectance for paddy fields and hence, there is low spectral confusion with other land cover types. However, other land cover classes such as scrubs, urban area and gardens have similar reflectance and it leads to difficulties in differentiating.

Time gap between image data acquisition and the reference data.

The topographical map sheets of Mahaweli System C produced before 1986 and IRS LISS III and ASTER acquired in 1998 and 2000 respectively, provided the background for geometric correction and supervised classification. During the time gap between the image acquisition date and the reference data, there may be changes on the land surface. It would result in errors identifying the training samples for supervised classification. However, this can be improved with ground information collection and referring high resolution IRS Pan images because IRS Pan and LISS III images have been taken on the same day.

Poor accessibility for ground truth collection

The geometric correction, land use classification, field visits should be done at the same time but it is not possible to conduct frequent field observations due to practical limitations.

CONCLUSIONS

According to the study, visual interpretation of IRS Pan is the best technique to estimate total crop area in Mahaweli System C. Supervised classification of ASTER is highly suitable to estimate paddy cultivated area and IRS LISS II and III images provide an idea about the land use condition of Mahaweli System C. However, the inadequate resolution of images is the main limitation in accurate identification of crop area. It is difficult to estimate crop area accurately with a single image. Therefore, it is essential to have two or more images of the same season for better interpretation. It was not possible to verify the results due to lack of field investigations. Again, it was not possible to do field investigations due to the old acquisition dates of the images. Since, rice is a short term crop, field investigations are needed at the time of image acquisition.

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