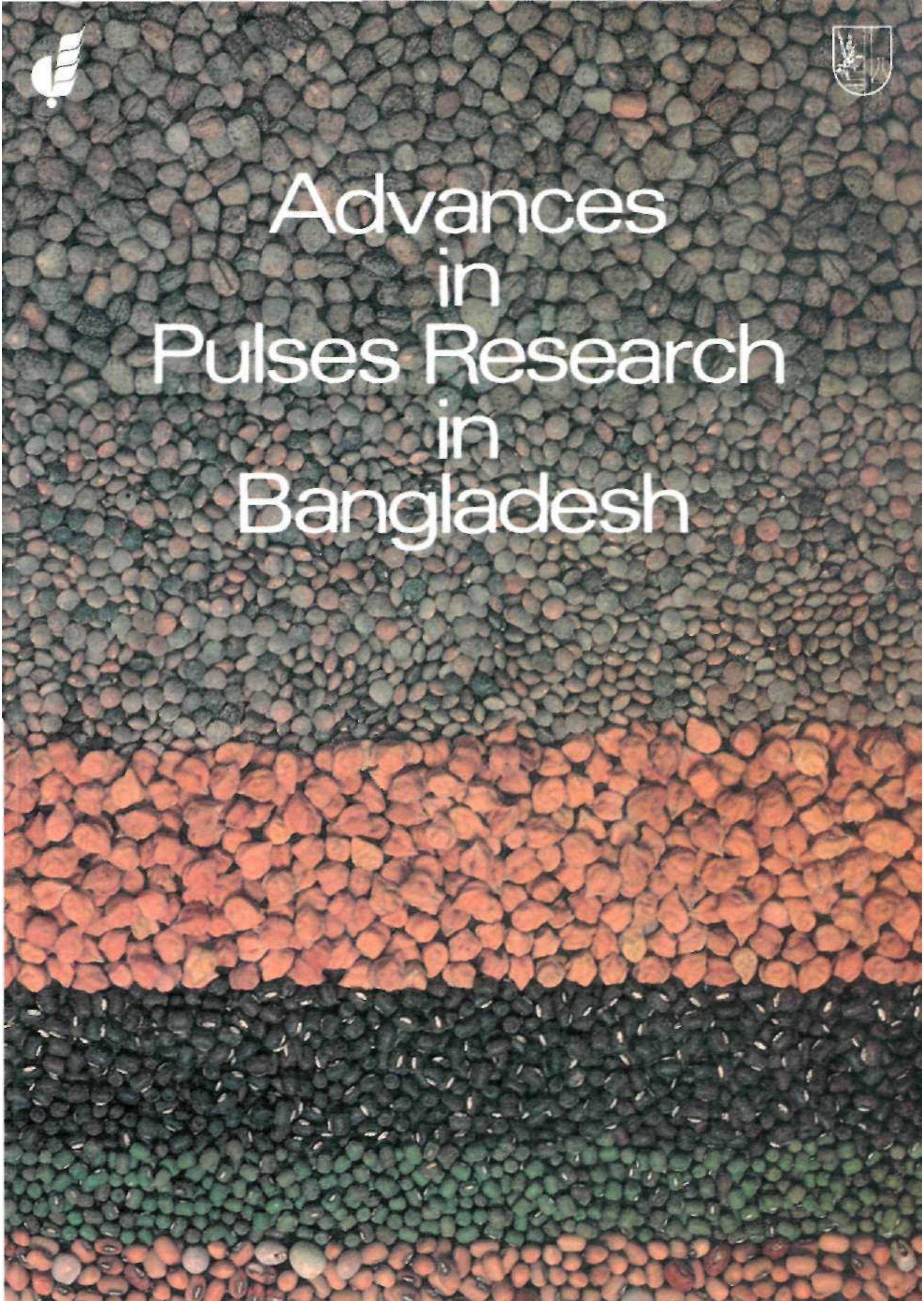
Advances in Pulses Research in Bangladesh



Abstract

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in pulses research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Fifty scientists actively engaged in pulses improvement in Bangladesh participated in the second National Workshop on Pulses which was held at the completion of the BARI-IDRC Pulses Project. The representatives of the Pulses Programs from India, Nepal, and Myanmar and scientists from ICRISAT Center (India) also participated. Papers reviewed pulses research done in the eighties on breeding, crop management, crop protection, seed prodution and consumer quality, and regional pulses research links. The workshop recommended expansion of the Pulses Improvement Program In Bangladesh. It was agreed that more genetic variability should be obtained for making rapid progress. The workshop suggested that increased efforts be made to breed for early maturing, disease and pest resistant cultivars and for development of cultural practices for obtaining high stable yields of pulses. The recommendations form a valuable guideline for future research and development of these crops in Bangladesh and other similar regions.

Résumé

Référence : BARI (Bangladesh Agricultural Research Institute). 1991. Progrès effectués dans la recherche sur les légumineuses au Bangladesh : comptes rendus du Deuxième colloque national sur les légumineuses, 6-8 juin 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, Inde : International Crops Research Institute for the Semi-Arid Tropics.

Le Deuxième colloque national sur les légumineuses, qui s'est tenu lors de l'achèvement du Projet légumineuses BARI-CRDI, a réuni cinquante chercheurs travaillant activement en matière d'amélioration des légumineuses au Bangladesh. Les représentants des programmes de légumineuses de l'Inde, du Népal, du Myanmar, ainsi que des chercheurs du Centre ICRISAT en Inde ont également participé à ce colloque. Les communications ont fait le point des travaux de recherche sur les légumineuses réalisés pendant les années 80, et plus particulièrement sur la sélection, l'aménagement des cultures, la protection des cultures, la production des semences et la qualité à la consommation. Elles ont aussi examiné les liens de recherche régionaux sur les légumineuses. Le colloque a recommandé l'expansion du Programme d'amélioration des légumineuses au Bangladesh. Il a été convenu que plus de variabilité génétique doit être obtenue afin de réaliser des progrès rapides. Le colloque a suggéré que des efforts plus intenses doivent être mis en place pour la sélection de cultivars à maturation précoce et résistants aux maladies et aux ravageurs, ainsi que pour la mise au point de pratiques culturales permettant l'obtention de rendements élevés et stables des légumineuses. Les recommendations constituent des indications utiles pour la recherche et le développement futurs de ces cultures au Bangladesh et dans d'autres régions semblables.

Resumen

Citación : BARI (Bangladesh Agricultural Research Institute) 1991. Avances en Investigación sobre Legumbres en Bangladesh: Actas del Segundo Taller Nacional sobre Legumbres, 6-8 de Junio de 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Cincuenta científicos, investigando actualmente sobre el mejoramiento de legumbres en Bangladesh, participaron en el Segundo Taller Nacional sobre Legumbres que se celebró a la clausura del Proyecto de Legumbres BARI-IDRC. El Taller contó con la participación de los representantes de los Programas de Legumbres procedientes de India, Nepal y Myanmar asi como los científicos del Centro ICRISAT (India). Las ponencias examinaron las investigaciones sobre legumbres que se realizaron durante los años 80 en el campo de la crianza, el manejo y la protección de cosecha, la producción de semillas y la cualidad del producto de consumo, asi como los vínculos regionales en la investigación sobre legumbres. El Taller recomendó la expansión del Programa de Mejoramiento de Legumbres en Bangladesh. Se acordó que debe adquirirse más variabilidad genética para poder alcanzar progreso más rápido. El Taller sugerió dirigir más esfuerzos hacia la crianza que permitirá la maduración temprana y cualidades resistentes a enfermedades e insectos nocivos asi como hacia el desarrollo de prácticas de cultivo a fin de obtener altas y más estables cosechas de legumbres. Las recomendaciones del dicho Taller presentan pautas importantes para investigación y desarrollo futuros en este campo en Bangladesh y en regiones semejantes.

Advances in Pulses Research in Bangladesh

Proceedings of the Second National Workshop on Pulses

6-8 Jun 1989

Joydebpur, Bangladesh

Sponsors

	Bangladesh Agricultural Research Institute, (BARI) Joydebpur, 1701, Bangladesh.
CANADA IDRC	International Development Research Centre, (IDRC), P.O. Box 8500, Ottawa, KIG 3H9, Canada.
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Published for
Bangladesh Agricultural Research Institute (BARI)
by

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1991

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ISBN 92-9066-199-1

The International Crops Research Institute for the Semi-Arid Tropics is a nonprofit, scientific, research and training institute receiving support from donors through the Consultative Group on International Agricultural Research. Donors to ICR1SAT include governments and agencies of Australia, Belgium, Canada, People's Republic of China, Federal Republic of Germany, Finland, France, India, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, United Kingdom, United States of America, and the following international and private organizations: African Development Bank, Asian Development Bank, Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), International Board for Plant Genetic Resources, International Development Research Centre, International Fertilizer Development Center, International Fund for Agricultural Development, The European Economic Community, The Opec Fund for International Development, The Rockefeller Foundation, The World Bank, United Nations Development Programme, University of Georgia, and University of Hohenheim. Information and conclusions in this publication do not necessarily reflect the position of the aforementioned governments, agencies, and international and private organizations.

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Message from IDRC

It has been particularly rewarding for IDRC to be part of the evolution and achievements of the BARI pulses project since 1976. The culmination of this effort has been the second national workshop on pulses, which provided an opportunity to reflect on the knowledge gained, and to discuss the directions and research needs for the near future.

Crop improvement is a never-ending activity and this is well recognized by researchers in Bangladesh. These achievements need to be supplemented by new traits and variability. Several of the major pulse crops have adequate international backup, others (lathyrus is perhaps one example) will provide great challenges to the ingenuity and resources of the national research system.

We wish BARI every success in its important endeavor to enhance and improve pulses production in Bangladesh.

Foreword

Mohammad H. Mondal,

Director General, Bangladesh Agricultural Research Institute (BARI),
Joydebpur, 1701, Bangladesh

Pulses play an important role in the agriculture and in the diet of the people of Bangladesh. A program was set up to conduct research on pulses at the Bangladesh Agricultural Research Institute (BARI) in 1979. The Institute hosted the First National Pulses Workshop in August 1981 to bring together scientists working in pulses in Bangladesh to focus on the status of improvement of these crops. Important aspects of production —agronomy, physiological adaptation, breeding, diseases and pests, and quality characteristics-were considered and the scientists proposed a program to improve the genetic potential for yield and quality in pulses.

The Second National Workshop on pulses was held in 1989 with similar objectives. In the intervening 8 years, many contacts had been made with international programs. Efforts were made to collect and evaluate more germplasm of these crops. Improved cultivars for some pulses were released during this period. Multilocational testing of advanced genetic materials was initiated in different agroecological zones of the country. The program was supported by IDRC of Canada up to February 1989. The aim of the 1989 workshop was to provide a forum for summarizing the overall development of pulses research undertaken in the previous 8 years and stress increased productivity and stability, which call for strengthening cooperation among national and international research institutions. Basic information is needed to understand various biotic and abiotic constraints limiting increased productivity of pulses.

The workshop was held at an opportune time, as a major scheme for pulses development was initiated with the support of the Canadian International Development Agency (CIDA). Thus the goals set in this workshop may form a guideline for pulses research and development in Bangladesh for the next 10 years. Participation in this workshop of scientists from ICRISAT and neighbouring countries was a very encouraging development. We must take advantage of their valuable suggestions and foster closer cooperation among the Asian Grain Legumes Network (AGLN) member countries to solve our common problems. In total, there were 78 participants and 33 presentations were made. The participants discussed various problems of pulses and made useful suggestions. It was agreed that more genetic variability should be obtained for the five major pulses and increased efforts be made to develop early maturing cultivars with resistance to important diseases and pests. Increased emphasis on cultural practices, use of inocula, and improved storage of seeds was also suggested. To achieve these goals, it was recommended that the pulses improvement program be expanded and strengthened at various institutions in Bangladesh.

BARI sincerely acknowledges IDRC's support for undertaking research on pulses and holding this important workshop. ICRISAT's assistance in publishing the proceedings of this workshop is also gratefully acknowledged.

I congratulate the organizers of the pulses workshop for publishing the proceedings and believe that the volume will be valuable reference material for pulse scientists, administrators, and development and donor agencies working in Bangladesh.

Address by Special Guest

M. Motlubor Rahman,

Executive Vice Chairman, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka -15, Bangladesh

Pulses are important, both as human and animal food. They also improve soil health. As yet, there has been no major breakthrough in the productivity of these crops. As these are difficult crops to handle, we plan to work very closely with ICRISAT, ICARDA, and other international centers. This will require dedicated team work. This national workshop which is being held after a gap of 9 years, should develop a definite plan for the improvement of these crops.

A Crop Diversification Project (CDP) is likely to be implemented soon. However, there is little technology that can be directly taken to the farmers. With improvement in management, good quality seed, and timely sowing it is possible to increase yields by 40 - 50%. With ICRISAT's help, we have achieved some success with chickpeas. We should continue with this and make similar efforts with other pulse crops so that the CDP is successful. It is necessary to assess and suitably package the technology and to suggest a strategy for quick multiplication of seed to BADC. Simultaneously, massive demonstration of the developed technology at block levels and a more intense program of extension needs to be undertaken by the Department of Agricultural Extension. I would urge the scientists gathered here to consider that the population of this country may increase to 150 million by 2000 A.D. They should come up with a package of recommendations so that the production of pulses can keep pace with the increasing population. If we fail in our efforts, there will be a great setback. We also want to move away from rice-wheat rotation to sustain soil health. You have a challenging task. I wish the workshop great success!

Inaugural Address

Kazi M. Badruddoza,

Former Executive Vice Chairman, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka -15, Bangladesh

I am very pleased to have been invited to inaugurate this important workshop on pulses. Let me begin by mentioning that we, in Bangladesh, consume only 5.5 g (12.5 g according to the new statistics) of pulses capita^{-1}day^{-1}. This is a far too low quantity to protect the nutritional status of the population, most of which is very poor. We should aim to make available at least 20 g. There is thus an urgent need to increase the production of these crops. But the task is not so easy.

The people of Bangladesh are generally rice eaters and they prefer rice to any other crop. With the phased expansion of irrigation facilities, more areas have come under rice; and pulses and other crops have been pushed to marginal land. The area under pulses has shrunk over the years. The strategic approach to improve the present situation should be to increase the area under pulses by developing short-duration high-yielding cultivars which would grow between two rice crops or by developing appropriate cropping systems which will allow pulses to be grown without affecting the interests of farmers for rice. The *Barind* tract of Bangladesh, which remains generally fallow after rice provides opportunities for pulses to be grown there, if the technology for the production of pulses in this tract could be developed.

The pulses improvement program has been under implementation for some years. Good progress has been made. IDRC helped the program in its initial phases. A large number of pulses scientists have been trained. There is now a good team with the program. In addition to the support from IDRC, the IARCs have also been very active in giving their inputs to strengthen the program.

Of late, the idea of a Crop Diversification Project (CDP) was initiated by the Government. This will provide adequate support to the development of crops which could be grown in rotation with rice and wheat. This project is being implemented with assistance from CIDA. I hope emphasis will be given to the development of suitable cultivars and improved seed production programs. I am very hopeful that with the administrative, financial, and scientific support which is available from various sources-now, the production and productivity of these crops will improve in the near future. Pulses, amongst them, will play a major role in the crop diversification project. I am confident that this important workshop will provide guidelines in the development of technology for pulses improvement in Bangladesh.

I wish this workshop all success!

A Word from ICRISAT

D.G. Faris

Coordinator, AGLN, ICRISAT, Patancheru, AP 502 324, India.

There is much enthusiasm among pulses researchers in Bangladesh. This can be seen in many activities such as the promised beginning of the Crop Diversification Project that is expected to give good financial support to pulses improvement; the tackling of seed certification problems that will ensure a good supply of quality seed; and the recent release of the chickpea variety Nabin which has shown good yields of around 4 t ha^{-1} on farmers' fields. Such technology now needs to be effectively demonstrated to farmers. ICRISAT's cooperation is available to Bangladesh for chickpea and pigeonpea development. We will do everything possible to effectively help pulses development in Bangladesh. I hope this workshop will focus attention on the important issues, so that it will suggest ways to overcome the major biotic and abiotic constraints to pulses productivity identified by the participants. We are happy to have supported the participation of the pulses coordinators of the neighboring countries in this workshop and also in publishing the proceedings.

Editor's Note

The Bangladesh Bureau of Statistics (BBS) revised pulses production figures in the country in 1989, as a result of readjustment with the areas enumerated under the Agricultural Census 1983/84 (BBS 1989). These indicate that the area and production of pulses 1983/84 onwards, were about two times more than those for 1981/82 and 1982/83 (Table 1). There is much increase for lentil (*Lens culinaris* Medic), chickpea *(Cicer arietinum* L.), mung bean *(Vigna radiata* (L.) Wilczek), black gram (*Vigna mungo* (L.) Hepper), and pigeonpea (*Cajanus cajan* (L.) Millsp.). The production figures for other pulses, which now include khesari (*Lathyrus sativus* L.) show much reduction. Two papers on "Status of pulses marketing in Bangladesh" (A.K.M. Bazlur Rahman) and "Socioeconomic constraints limiting pulses production" (S.M. Elias) in these workshop proceedings briefly mention the revision in the production statistics. All other papers have used the old statistics. In view of the revised production statistics the future plans and projections for pulses improvement and utilization in the country need modification.

Table 1. Revised statistics of Area ('000 ha) and Production ('000 t) of pulses in Bangladesh, 1981/82-1987/88.

	Lentil		Chickpea		Black gram		Mung bean		Other Pulses[1]		Total	
Year	A[2]	P	A	P	A	P	A	P	A	P	A	P
1981/82	74.9	49	57.5	37	42.9	29	15.4	7	119.8	83	310.1	205
1982/83	73.3	45	53.8	41	40.1	28	15.0	8 11	8.2	90	300.4	212
1983/84	240.5	161	113.4	87	84.2	60	59.9	34	28.7	19	526.7	361
1984/85	233.6	164	108.9	81	74.9	54	60.3	35	30.8	20	508.5	354
1985/86	222.7	160	103.6	78	69.2	45	59.5	33	28.3	19	483.4	290
1986/87	213.0	149	103.6	82	65.6	43	57.5	35	27.1	18	466.8	327
1987/88	216.6	159	103.2	75	70.5	52	57.9	33	31.2	20	479.4	339

1. Includes khesari
2. A = area, P = production.
Source: BBS (1989).

We would like to thank the following for reviewing the conference papers: J. Arihara, A. Bakr, Y.S. Chauhan, T. Dasgupta, D.G. Fans, M.P. Haware, T.G. Kelley, V.K. Mehan, P.T.C. Nambiar, C.S. Pawar, M. Pimbert, M.M. Rahman, A. Ramakrishna, K.L. Sahrawat, S.C. Sethi, R.P. Singh, U. Singh, and J.A. Wightman.

I also thank the administrations at Bangladesh Agricultural Research Institute, International Development Research Centre, and International Crops Research Institute for the Semi-Arid Tropics, particularly Drs M.H. Mondal, M.A. Islam, M. Matiur Rahman, N. Mateo, K.W. Riley, D. McDonald, D.G. Fans, and H.A. van Rheenen for asking me to help organize the workshop and edit the proceedings. Ms. S. Prasannalaxmi of ICRISAT Library assisted with the references.

Additional Note: Because the decision to publish the proceedings at ICRISAT Center was taken at a late stage in the editorial process, not all papers conform to ICRISAT's style.

Keynote Address

M.A. Islam and M. Matiur Rahman
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

*Multidisciplinary coordinated research on six pulses: lentil (*Lens culinaris *Medic), chickpea (*Cicer arictinum *L.), khesari* (Lathyras sativus *L.), black gram (*Vigna mungo *(L.) Hepper), mung bean* (Vigna radiata *(L.) Wilczek), and pigeonpea (*Cajanus cajan *(L.) Millsp.), was initiated in 1979 at the Bangladesh Agricultural Research Institute (BARI), with financial support from the International Development Research Centre (IDRC), Canada. Problems were identified and research priorities were fixed, and the research work was started. Progress has already been made in manpower development as well as in the generation of technology in different disciplines of the Pulses Improvement Program. Two cultivars of mung bean, Mubarik and Kanti, and one of chickpea, Nabin, were released for general cultivation. One line each of lentil and black gram were proposed for release to the National Seed Board. Several promising wilt-resistant lines of chickpea, low-neurotoxin lines of khesari, and one line of pigeonpea were identified, some of which may be proposed for release. The germplasm of these crops has been collected and maintained. Major diseases and insect pests prevalent in farmers' fields and in their stores have been identified. New cropping patterns involving mung bean cultivars appear more promising than those existing in the northern parts of the country. These new patterns, if adopted, would substantially increase the area under these crops. We plan to undertake extensive, area-specific surveys to understand the problems of pulses cultivation and the reasons for low productivity in farmers' fields. Efforts will also be made to extend the cultivation of pulses as postrainy crops after rice in the *Barind *tract and in other nontraditional areas for these crops. In addition, facilities will be strengthened for basic research in all disciplines to back up the applied research.*

Introduction

Pulses are important food crops in Bangladesh. They occupy an area of about 0.3 million ha (2.34% of the total cropped area) and contribute about 1.07% of the total grain production of the country (Ahmed 1985). The major pulses grown in Bangladesh are: khesari *(Lathyrus sativus* L.), lentil *(Lens culinaris* Medic), chickpea *(Cicer arietinum* L.), black gram *(Vigna mungo* (L.) Hepper), mung bean *(Vigna radiata* (L.) Wilczek), and field pea *(Pisum sativum* subsp *arvense)* (Table 1). Among these, khesari, lentil, chickpea, and field pea are grown during winter (November-March) and contribute about 82% of the total pulses. Black gram is grown in late summer (August-December). Mung bean is grown both in early summer (February-April) and late summer.

Though pulses play a vital role in the national economy and in the diet, they have been neglected by most pulse-growing countries including Bangladesh. They are generally considered minor crops, so the national programs receive little funding for research and development. After achieving considerable success in rice and wheat production, most governments of this region have taken some measures to improve the production of pulses. New technologies have also been developed in some countries and are being adopted by farmers, but the mean yields of most of these crops have remained very low. There is still a wide gap between the growing demand and the production of

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Table 1. Area and production of pulses in Bangladesh, 1984/85.

Name of Pulse	Area (ha)	Production (t)	Yield (kg ha^{-1})	% of Total	
				Area	Production
Khesari	81 000	60000	735	31	32
Lentil	71 000	48 500	680	27	26
Chickpea	50 000	37 500	750	19	20
Black gram	33 600	25 000	714	13	13
Mung bean	15 338	5 052	590	6	5
Fieldpea	9900	6600	666	3	3
Total[1]	261 591	185 652			

1. includes minor pulses as well. Source: BBS (1986).

these crops in Bangladesh. The present per capita consumption of 5.5g day^{-1} is rather low, as compared to 45g in neighboring India (Ahmed 1984).

In order to increase food production, irrigation facilities are being expanded. Currently, these are mostly used in winter rice cultivation with pulses being continuously pushed to marginal and submarginal lands, resulting in low productivity. As a result cereal production has increased significantly over the last few years but the area and production of pulses has gradually declined. The technology required to improve the productivity of pulses include: promising crop varieties and rhizobial strains; improved cultivation practices and cropping patterns; improved integrated pest management; and improved seed production, processing, storage, and distribution systems.

Since pulses generally do not respond to high management in respect of irrigation and fertilizer use, it has not been possible to develop improved standard cultural practices for these crops. Moreover, factors such as the inherently low yield potential of pulses cultivars, high susceptibility to various diseases and insect pests, and sensitivity to microclimatic changes contribute to large variations in their output from year to year, and to their low productivity. The problem is therefore highly complex, making it difficult to halt the present declining trend of pulses in terms of area and production, unless disease-resistant, high-yielding pulses varieties, improved cultural practices ensuring sustainable high yields, and proper economical plant-protection measures are developed. To solve all these problems a coordinated pulses improvement program was initiated in The Bangladesh Agricultural Research Institute (BARI) in 1979. In the context of the problems mentioned above, the future research priorities are briefly discussed in this paper.

Research Progress

Research on pulses was initiated during the early fifties but very little progress was made. The work was confined to the collection and evaluation of local germplasm. In 1979 a multidisciplinary coordinated approach was initiated with financial support from the International Development Research Centre (IDRC) of Canada and technical support from the Food and Agricultural Organization (FAO) of the United Nations. A consultant of the International Agricultural Development Service (IADS) suggested shifting the pulses program to a suitable location such as Ishurdi (Kumar 1984). Later, he (as IADS/Winrock International Consultant) helped develop this program at Ishurdi in 1984/85 (Kumar 1985). The progress made in manpower development and in research is briefly described here.

Varietal Development

Lentil

Variation in local germplasm in respect of yield potential, disease resistance, seed size, and growing period is very small. About 1000 exotic germplasms and advanced lines were introduced from India, Pakistan, and Syria (ICARDA), but these were all longer-duration varieties which did not produce high yields. Moreover, the macrosperma (large seeded) types are late maturing and they set fewer pods but some of them are resistant to rust. Among the local germplasm L5 was found to be better with respect to yield and maturity period (105-110 days). It has been placed before the National Seed Board (NSB) for release. This cultivar resembles other local cultivars in resistance to rust and stemphylium-blight diseases. Our present effort is directed at making this line disease free, and improving its yield, by increasing seed size. The crossing program was initiated in 1984 and the segregating populations are now in the F_4 generation.

Chickpea

About 200 local and 800 exotic germplasm lines have been collected and evaluated at BARI. The Bangladesh Institute of Nuclear Agriculture (BINA) released the chickpea cultivar Hyprosola in 1982, and BARI released chickpea cultivar Nabin in 1987. Their agronomic characters are given in Table 2.

Strong links have been established with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India. We have been regularly receiving segregating populations and advanced lines from ICRISAT, and are screening these in our wilt-sick plots. Some wilt-resistant lines have already been identified. We initiated a crossing program involving the local chickpea cultivars Sabur 4 and Hyprosola in 1984 (Kumar 1985). The segregating material is being screened in the wilt- and root rot-sick plots; these are now in the F_5 generation. Materials are also being screened for their late-sowing potential.

Khesari

Khesari ranks first in terms of hectarage and production. About 167 local germplasm lines have been collected and their seeds have been analyzed for ß-N-oxalylaminoalanine (BOAA) content. Some lines were found to have low toxic substance, but they are low yielding. Khesari lines Jamalpur, Charbadna, and Pahartoli were found to be high yielding and early maturing. A crossing program was initiated involving low-toxin lines and the materials are in F_6 and F_7 generations. The lines with low toxin content are being tested for their potential in different locations.

Black gram

About 750 local and exotic germplasm lines have been collected and evaluated for high-yield potential. One daylength-insensitive line is awaiting release as a variety. The germplasm is also being screened for resistance to powdery mildew, which is a major disease affecting this crop.

Mung bean

About 1200 exotic germplasm lines have been screened against the major disease, yellow mosaic virus (YMV), but none has been found resistant. However, one tolerant mung bean cultivar Mubarik, was released in 1981 for March/April sowing (Ahmed 1984). It is also suitable to the mung bean-aman (rainy season) rice/postrainy season cropping pattern. Another moderately resistant mung bean cultivar Kanti, was released in 1987 for August/September sowing in the *aus* (rainfed) rice/jute-mung bean/postrainy season cropping pattern. Both these lines are daylength-insensitive and

Table 2. The mean performance of Nabin and two local cultivars in Bangladesh, 1984/85.

Variety	Days to flowering	Days to maturity	Plant height (cm)	100 seed mass(g)	Seed yield (t ha^{-1})
Nabin	60	122	67	11.8	2.95
Sabur	4	128	58	8.8	2.21
Hyprosola	72	127	52	7.6	2.18

Source: BARI (1985).

mature early (65-70 days). Golden-seeded mung bean, which is preferred by consumers, is day length sensitive. Efforts are being made to develop day length-insensitive golden-seeded mung bean through hybridization.

Pigeonpea

Long-duration pigeonpea is cultivated on small pieces of land in Kushtia and on the roadside in Rajshahi, Pabna, and Jessore. Some short-duration introductions from the USA and ICRISAT, India were evaluated. Two pigeonpea lines 76012 and 76013 were identified as promising.

Plant Protection

The major and minor diseases of pulses have been recorded (Ahmed et al. 1982; Fakir 1983). Wilt-sick plots for screening of chickpea against fusarium wilt disease have been developed at Joydebpur and Ishurdi. Similarly, the entomology division of BARI has studied the reactions of different pulses to insect pests and identified the major pests for each of these crops. They are also trying to develop effective and economical control measures for the major insect pests. The farmers' methods of seed storage and the extent of damage by grain pests and diseases in storage have also been studied. Two species of pulse beetle, *Callosobruchus chinensis* and *C. maculatus* are the main insect pests (Rahman et al. 1982). About 15-17 species of storage fungi found associated with different pulses have also been identified. Among these, *Alternaria* sp., *Aspergillus curvuleria, Cladosporium* sp, and *Penicillium* sp were predominant (BARI 1984). The scientists are now trying to develop suitable cultural measures for these diseases to help minimize their incidence.

Cultural Management

The soil science division of BARI has conducted fertilizer trials all over the country and has recommended fertilizer doses on the basis of the soil-fertility level. These are: N-30, P-85, K-35, S-20, Zn- 10kg ha^{-1} for low-fertility soil; N-20, P-50, S-10, Zn-5 kg ha^{-1} for medium-fertility soil; and N-10 and P-30 kg ha^{-1} for high-fertility soil (BARC 1985).

The agronomy division has developed improved cultural practices for the released cultivars. They have also conducted experiments to determine the optimum time of sowing and the effect of different sowing times on yield. It was found that the yield and yield-contributing characters of an early chickpea declined if sowing was delayed beyond mid-November (Rahman and Mallick 1986). They also found that mung bean fits well in the aus/jute-fallow-postrainy season cropping pattern and it is possible to grow postrainy crops like wheat, lentil, mustard, etc. after mung bean. The agronomy division of BARI also found that mung bean and black gram can be grown under minimum-tillage conditions in the above patterns (BARI 1986).

It was further observed that 100% lentil + 30% mustard was the most appropriate seed rate in the commonly followed mixed-cropping pattern. Currently the division is conducting mixed-cropping experiments with black gram and short-duration pigeonpea, chickpea, or barley. They have now initiated work to maximize the plant stands by different methods of sowing and to maximize yield by different cultural manipulations.

Future Research

Varietal Improvement

The breeding program should be strengthened to develop high-yielding disease-resistant cultivars on a priority basis. To achieve the common goal for each of these crops, an integrated approach needs to be taken by breeders, pathologists, agronomists, entomologists, and social scientists.

Lentil

Very little success has been achieved so far in lentil. Rust and stemphylium blight still cause much damage to this crop. Priority should be given to developing rust- and stemphylium-resistant cultivars. All the germplasm should be screened under artificially inoculated conditions to identify better parents for hybridization. The crossing program with previously identified germplasms should be continued.

Chickpea

Collar rot, wilt, root rot, and botrytis gray mold are the major diseases affecting chickpea. A few wilt-resistant lines have been identified and are being used for crossing with the locally adapted cultivars and may also be released as cultivars. This effort should continue. Screening of the existing germplasm against collar and root rot should immediately be initiated to find out the resistant/tolerant lines. Steps should immediately be taken to develop disease-resistant varieties. Help may be sought from ICRISAT in this regard. The effort to develop late-sown cultivars should continue. Of late, kabuli-type chickpea has become popular. High-yielding, disease-resistant, medium/bold-seeded kabuli cultivars may be developed through direct introduction from ICRISAT. Efforts should be made to release the promising lines already in trials (BARI 1987).

Khesari

Efforts should continue to develop low-toxin, high-yielding, early maturing cultivars resistant to downy and powdery mildew diseases.

Black gram

Early maturing, high-yielding, powdery mildew-resistant cultivars should be developed. The variability in the existing germplasm for yield is very low. Efforts should be made to create variability through extensive crossing, mutation, and introduction. There are some lines which are tall and are of the creeping type, grown in the grasses under zero-tillage conditions. A crossing program should be taken up involving these to see if this character can be transferred to the common cultivars.

Mung bean

Early maturing, YMV-resistant/tolerant, and cercospora-resistant cultivars should be developed for early rainy-season planting in the southern part of the country, where about 60% of the total mung bean is produced. These cultivars should fit into the *aus* rice-*aman* rice-mung bean cropping pattern. The same should also be developed for August planting in the northern parts of the country so as to fit into the *aus* rice-mung bean-postrainy season cropping patterns. During this time there is a risk of waterlogging, therefore tolerant cultivars are needed.

Cultural Management

A vast area in Rangpur and Dinajpur districts remains fallow after the harvest of *aman* rice in December/January. These soils favor the vegetative growth of chickpea, but without pod setting. Initial investigations show that this is due to boron deficiency (BARI 1987). This investigation should be extended to other locations to determine the actual cause, and to arrive at an effective remedy to the problem. It may help to bring a larger area under chickpea cultivation. A survey needs to be carried out in the pulse-growing areas to analyze the soils of the best pulses plots for soil type, nutrients, moisture, and *Rhizobium* status. On the basis of this ideal soil type, the necessary nutrient requirement should be ascertained. The soil physicists should monitor the levels of soil moisture of the best pulses plots during sowing, plant establishment, flowering, podding, etc. to develop appropriate irrigation experiments for particular soil types. They should also extensively monitor the soil-moisture status of the farmers* fields during sowing and design an appropriate experiment to help screen the germplasm for germination capability under minimum soil-moisture regime.

Agronomists should continue experiments on the *aus* rice-mung bean/black gram-postrainy season cropping pattern to see how any depressing effect of mung bean or black gram on subsequent crops can be overcome. Experiments should continue to develop standard cultural practices which will ensure good plant stand and higher and stable yields. Large-scale production of inoculum should be undertaken for distribution among the farmers.

BARI agronomists recommended the appropriate seed rate for newly developed cultivars on the basis of an experiment conducted at their research stations under ideal conditions but this is not sufficient under farmers' field conditions. As a result farmers do not want to follow these recommendations. A large-scale survey should be conducted during sowing on the seed size, viability, and seed rate used by the farmers to determine a rate that can be followed directly for the new cultivars.

On-Farm Research Division

Scientists are at present conducting farmers' field trials with the newly developed cultivars and any new technologies generated by other research divisions. They should include *aus* rice-mung bean-postrainy season cropping patterns in their farmers* field trials in suitable areas.

Plant Protection

The present screening of crop cultivars against major diseases and pests under natural conditions is not enough. This should be supplemented with screening under artiftcally augmented conditions. Hence facilities should be developed for artificial screening against diseases and insects, to help breeders screen their germplasm and segregating populations. Efforts should be made to develop pod borer-resistant/tolerant cultivars in chickpea, mung bean and pigeonpea. ICRISATs help in supplying *Helicoverpa-resistant* nurseries of chickpea and pigeonpea should continue.

Entomologists should continue their effort to develop integrated pest-management schedules and also an economical chemical spray schedule for the control of pod borer on chickpea, mung bean, pigeonpea, etc. They should also study the feasibility of biological control of major insect-pests by using effective insect pathogens.

Socioeconomics

The socioeconomic reasons contributing to the decline in the area under pulses and the low level of production should be correctly determined and remedies suggested by agricultural economists so that the present problems in pulses production can be effectively resolved.

Discussion

R. N. Mallick: Higher biomass legumes are essential for livestock feeds. Have you plans for a future thrust on khesari and black gram for higher biomass for dairy-development areas such as Bagabari?

M. M. Rahman: We have already identified some higher biomass lines in khesari. The livestock people are welcome to take up collaborative research on this aspect.

M. A. Khaleque: Storability is an important subject of pulses, but this has been omitted. Will you kindly give me some idea about these?

M. A. Islam: A detailed presentation on storage of pulses has been made in the plant-protection session.

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Session I:
Breeding

Status and Future Breeding Strategies for Chickpea

M.O. Islam, M. Matiur Rahman, A. Rahman, A. Sarker, and W. Zaman
Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh

Abstract

*Chickpea (*Cicer arietinum *L.) is the third most important pulse crop in Bangladesh. Low and highly unstable productivity has limited the expansion of the area under this crop. Local and exotic germplasm has been collected, evaluated, and characterized. Linkages have been established with international institutes. A chickpea cultivar Nabin was released in 1987. It is earlier in maturity and has a larger seed size than local cultivars. Constraints to higher productivity have been identified. Crosses among sources of resistance to root diseases and local cultivars are being made since 1984/85 and segregating populations are being screened in wilt-sick plots. International trials and nurseries and elite breeding lines received from ICRISAT have been tested and selections made. Multinational trials of several of these selections over 3 years have identified ICCL 83007 and 83008 (kabuli) and ICCL 83228, 83107, 83105, and 83103 (desi) as promising. There is a need to expand the program and develop screening facilities for botrytis gray mold, collar rot, and* Helicoverpa *pod borer. Introduction of extra short-duration cultivars may help fit this crop into different crop sequences and in late sowing. Screening facilities for emergence under limited moisture, for drought tolerance and for high-input conditions are required. There is a need to breed for relatively larger seed size and consumer preference, and to produce larger quantities of breeders' seed.*

Introduction

Among the pulses grown in Bangladesh, chickpea (*Cicer arietinum* L.) ranks third in area (47 000 ha) and production (37 0001) and contributes about 20% of the total pulses (BBS 1987). About 85% of the chickpea crop is grown in the five greater districts of Faridpur, Jessore, Kushtia, Rajshahi, and Pabna (23°-25°N latitude). Here, the soils are loam and clay loam with moderate moisture-retention capacity. The pH ranges from 6.5 to 7.5.

About 5% to 8% of the chickpea is grown in the Tista floodplains area of eastern Bogra, Joypurhat, Serajganj, and parts of Rangpur and Dinajpur districts. Here, the soils are silty clay loam, with pH ranging from 5.5 to 6.5. In this area the plants sometimes suffer from overgrowth due to excess soil moisture (160 mm -450mmat 100cmdepth). Chickpea is also sporadically grown in a few other small pockets, i.e., Dhaka, Mymensingh, Barisal, etc. In other parts of the country this crop does not grow well due to unfavorable agroclimatic conditions.

In the traditional chickpea-growing areas about 60-65% of the crop is grown under the *aus* (rainfed) rice/jute-fallow-chickpea cropping pattern. In this pattern chickpea sowing starts at the beginning of November, and is harvested by early March, in the southern parts of the country. In the northern districts, it is sown in mid-November and harvested in late March or early April. The remaining 35-40% is grown under the *aman* (rainy-season) rice-chickpea-fallow cropping pattern under late-sown conditions.

The mean yield of chickpea is 765 kg ha^{-1} (BBS 1987). The main reasons for this low productivity are discussed below.

1. Lack of standard cultural practices: Standard agronomic practices which can ensure high yields have

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

not been developed yet. As this crop is extremely sensitive to soil moisture, and its response to irrigation is inconsistent (in some cases negative), it may put up excessive vegetative growth and lodge in high-moisture conditions (Smithson et al. 1985). As a consequence, farmers do not use any inputs (fertilizer/irrigation) for chickpea cultivation.

2. Late sowing: About 35-40% of the chickpea is sown as late as the end of December. However, the crop maturity date is almost fixed by early rains. The effective crop period is reduced from 140 days (20 Nov sowing) to 100 days (1st Jan sowing) according to Rahman and Mallick (1986). The late-sown crop generally has a shorter period for vegetative growth, which, coupled with moisture stress, and a rise in end-season temperature, results in poor yields.

3. Cultivars: Like other pulses, farmers also give the lowest priority and care to chickpea cultivation. Existing cultivars are small-seeded desi types. These give unstable yields because they are susceptible to diseases and insects (Kumar 1984). However, under good management there is a potential to obtain high yields of 4.5 t ha^{-1}.

Ail these factors, coupled with the expansion of wheat and *boro* (winter) rice, have led to a decline in the area under chickpea, at the rate of 700 ha $year^{-1}$ (BBS 1987). To halt this decline, a multidiscipiinary coordinated research program on pulses was initiated at the Bangladesh Agricultural Research Institute (BARI) in 1979 with financial support from International Development Research Centre (IDRC). Since then, some progress has been made in chickpea breeding, some problems have been identified, and breeding efforts have been concentrated on the major constraints. The objective of the present paper is to review past activities and suggest future breeding strategies.

Research Progress in Chickpea Breeding

Research on pulses, though initiated in the early 1950s, focused mainly on germplasm collection and evaluation. The chickpea cultivars Sabur 4, Bhangura 45, and Faridpur 1 were identified for commercial cultivation during 1955-1962. Linkage was established with ICRISAT in 1978, and since then BARI has been receiving germplasm, advanced lines, and segregating populations from there. During 1979-81,208 desi-type and 149 kabuli-type germplasm, 149 F_2, 24 F_4 progenies, and 37 late-sown genotypes were evaluated (Islam et al. 1982). However, no genotypes were selected subsequently.

Germplasm collection and evaluation, and handling of segregating materials and trials conducted have been summarized in Table 1. During 1982-89, 540 germplasm lines were collected from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). BARI and ICRISAT jointly collected 200 local germplasm lines in 1985. Testing of advanced materials from ICRISAT trials, i.e., ICCT-DSJCSN-DS, and ICSN-DM continues. One chickpea cultivar Nabin (S_1) was released in 1987. This cultivar evolved through selection derived from ICCL 81248 of ICSN-DS, which was introduced at Regional Agricultural Research Station (RARS), Ishurdi in 1981/82. Nabin has a larger seed size, and yielded 14% more than the chickpea cultivar Pabna Local and 36% higher than chickpea cultivar Hyprosola. Nabin also flowers earlier than both Pabna Local and Hyprosola.

Chickpea suffers from a range of diseases of which wilt (*Fusarium oxysporum),* dry root rot *(Rhizoctoniabataticola),* collar *rol(Sclerotium rolfsii), and* botrytis gray mold *{Botrytis cinerea)* are important (Ahmed et al. 1982; Smithson et al. 1985). Eleven species of insect-pests have been recorded. Pod borer *(Helicoverpa armigera)* is the only damaging pest of chickpea (Rahman et al. 1982). Considering the above factors, BARI changed the breeding approach in 1984. The pulses program was shifted to RARS, Ishurdi in 1984 (Kumar 1984). The research effort is concentrated on the following fields (Kumar 1985).

Breeding for disease resistance (wilt)

BARI has been trying to develop wilt-resistant cultivars since 1984. A number of exotic and local germplasm lines have been screened in the wilt-sick plots at Joydebpur and Ishurdi and some resistant genotypes have been identified from both sources. BARI has also been introducing International Chickpea Root Rot and Wilt Nursery (ICRRWN) from ICRISAT and screening this nursery in wilt-sick plots. A few lines have been identified resistant to wilt (Table 2). Their yield potential is being tested over locations and years. Some of them may be released as commercial cultivars even though they are not resistant to the root-rot pathogen prevalent in this region. As yet, resistance to collar rot and botrytis gray mold has not been found (Smithson et al. 1985). A suitable field-screening technique against botrytis gray mold is not available. In addition to our own efforts we look forward to ICRISATs success in

Table 1. Chickpea trials and materials evaluated in Bangladesh, 1982-89.

	Sources of germplasm		Source of trial material		No. of promising lines studied							
Year	BARI	ICRISAT	BARI	ICRISAT	F_1	F_2	F_3	F_4	F_5	F_6	Promising entries selected	Remarks
1981/82	-	528	2	7	-	-	16	10	-	-	K 850, L 550, K 850/27, ICC 7968, -7942, -7969, ICCL 81248 (S1)	Less affected by botrytis
1982/83	-	528	2	6	-	-	50	15	-	-	HMS 6, ICCE 5, ICCL 80031, -81248 (S1),-73111,-74304, Pule G-4, -G-7,	S1 found promising
1983/84	-	-	6	3	-	-	7	13	-	-	ICCL 83001, -83002, -83008, -83150, -83251, -83228, -83223, E 2, E 9, E 9, E 20, E 24, ICC 4951	
1984/85	-	211	3	5	-	23	12	-	-	-	L 6-2, E 2, E 24, E 9, ICC 4920, -8585, -9323.	
1985/86	281	-	12	3	8	-	9	5	-	-	ICCL 83228, -86210, -84205, -82230, -82127,-83103,-83105,-83107, -83007, -83008, -85222, ICC 11320 RPSP 336.	
1986/87		-	12	1	10	38	-	335	139	-	43(F_4), 15(F_5), ICCL 85204, -85222, -84204, -85226, -85324, -84201, -83107,-82127,-83105,-83150, -83228, -86210, -86237, -86236. ICC 11320	S1 released as Nabin
1987/88	741	-	6	1	14	-	25	-	6	-	ICCL 11320, ICCL 86237, -86236, -86210, -85204, -84212, -85103. -83105, -83107, -S3228, -82127, -83007, -83008, -85102, RBH 243(b), -127(a),-109(a), -220(a), -333, ICC-11320	Found tolerant to botrytis and suitable for advanced trials
1988/89	7 4 1	-	9	2	21	102	-	38	19	10	ICCL 83103, -83007, -83105, -83228, ICC 11320.	WR[1]
											ICCL 84212, -85151, -83153, -86237, ICC 11320	Suitable for late sowing.

1. WR = Wilt resistant

identifying varieties resistant to these important diseases (Kumar 1990).

A crossing program involving local cultivars and exotic wilt-resistant germplasm was initiated in 1984 and the segregating materials are being screened in successive generations in wilt-sick plots (Kumar 1985). A good number of resistant F_6 families have been selected. This program is continuing, with more local and wilt-resistant germplasm being included. The pedigree method of selection has been followed with emphasis on higher number of pods and branches per plant, large seed size and wilt resistance.

Table 2. Mean yield of best-performing wilt-resistant entries, Bangladesh, 1985/86, 86/87, 88/89.

Entry/Cultivar	Yield (t ha^{-1})				100 seed mass (g)	Disease reaction		Observation
	85/86	86/87	88/89	Mean		Wilt	Botrytis	
ICCL 83107	2.7	1.4	1.7	1.9	19.2	R[1]	S	
ICCL 83228	2.5	1.8	2.0	2.1	11.9	R	S	
ICCL 83103	3.1	1.7	2.3	2.4	20.8	R	S	
ICCL 83007	1.2	1.3	1.5	1.4	28.7	R	S	
ICCL 86237	NT	NT	1.6	-	14.3	R	MR	Botrytis tolerant/LSP
ICCL 84232	NT	NT	1.6	-	8.4	R	S	
ICCX 840114 (F_5)	NT	NT	1.7	-	10.1	R	S	
S1 x JG 74(F_5)	NT	NT	2.4	-	14.0	R	S	
JG 74 x Sabur 4(F_5)	NT	NT	1.8	-	11.4	R	S	
Nabin	1.8	1.5	1.9	1.7	13.5	S	S	

1. S = Susceptible, R = Resistant, MR = Moderately resistant, NT = Not tested, LSP = Late sowing potential.

Breeding for late-sowing potential

BARI has been trying to develop cultivars for late-sown conditions since 1986. Six wilt-resistance lines, ICC 11320, ICCL 83151, 86237, 83107, 85222, and 83103 have been identified on the basis of their fast growing habit and large number of fertile pods. Their yield potential will be tested in different locations from next year. Besides these, a modest effort to develop suitable kabuli-type cultivars continues. Two lines, ICCL 83007 and 83008, have been identified to be high yielding and wilt resistant.

Future Breeding Needs and Strategies

Chickpea yields can be increased substantially in traditional growing areas, provided the high yield is stabilized by incorporating disease resistance. Chickpea should be extended to non-traditional zones like *Barind* to increase the total production. For this, we must develop the following:

1. Multiple disease-resistant (wilt, root rot, and botrytis)cultivars, with ICRISAT's help. Moreover, germplasm screening should be initiated against collar rot to identify resistance sources.

2. Cultivars suitable for traditional and non-traditional zones in the rice-fallow systems. Improvement of chickpea under late-sown conditions could be facilitated by combining tolerance to cold and drought, and fast growing habit and short duration.

3. A chickpea cultivation package for the *Barind* tract of greater Rajshahi district where only one rice crop, i.e., local *aman* (rainy-season) rice, is grown traditionally due to lack of sufficient moisture. A cropping pattern trial conducted by the On Farm Research Division, (OFRD) in 1988/89, indicated that green manure-aman rice (BR- 14)-chickpea has wide scope in this region. A large area (about 0.75 m ha) which otherwise remains fallow could be sown to chickpea. For this purpose thermoneutral, drought-tolerant and fast growing cultivars are necessary. ICRISAT has already identified a drought-tolerant genotype, ICC 4958, which possesses a prolific root system (ICRISAT 1989). Islam et al. (1987) have reported genetic variability and significant contribution of root characters to shoot growth in chickpea.

4. Cultivars with restricted growth. Some parts of Bogra and Dinajpur remain fallow after harvest of *aman* rice. The soils are silty clay loam to silty loam, and soil moisture is quite high. Therefore,

Table 3. Biotic and abiotic stresses for chickpea and priorities for research in Bangladesh.

	Traditional zone	Nontraditional Zone		
Stresses	Gangetic floodplains	Tista and Brahmaputra floodplains	*Barind* tract	Observation
Biotic				
Wilt, rot root collar rot	1[1]	1	2	Severe crop damage in epidemic years.
Botrytis gray mold	1	1	0	Same as above (Epidemics in 1981/82 and 1987/88).
Helicoverpa pod borer	2	2	3	
Abiotic				
Drought	1-2	0	1	
Excessive soil moisture	1	0	0	
Micronutrient deficiency	2	1	3	

1. 0 = no problem, 1 = first priority, 2 = second priority, 3 = third priority.

chickpea plants in these regions grow vigorously and produce sparse pods. A preliminary soil test response study at Rangpur indicated that it may be due to a deficiency of boron and other micronutrients (BARI 1985). However, the local cultivars set more pods and yield better than the exotic lines under these light soil conditions. Screening of local and exotic germplasm should be initiated immediately in the light-textured soils to identify desirable genotypes for these conditions, so that the potential fallow areas can be made use of.

5. Cultivars which can emerge in limiting soil moisture. Crops in farmers' fields in rice fallows or elsewhere show suboptimal plant stands, primarily caused by poor germination/seedling establishment under the low soil-moisture regime (Kumar 1984). The existing moisture conditions have already been recorded by ICRISAT (Saxena 1987). Possibilities for developing cultivars capable of fast germination under minimum soil-moisture conditions should be explored.

6. Cultivars tolerant to *Helicoverpa armigera.*

7. A more efficient ideotype of chickpea. Plant architecture has played a significant role in crop improvement for high-yielding genotypes in various crops. Soybean provides one of the best examples of the potential of plant architecture in augmenting yield (Islam 1986). In relation to chickpea, Singh and Auckland (1975), proposed a plant type concept with high pod-formation potential, a greater number of seeds per pod and larger *seed size.* A plant canopy designed for maximum light interception, and growth of structural attributes should favor high harvest index. Bahl (1988) suggested that plants should be medium-tall or tall with upright and compact habit, optimum number of primary and secondary branches, and fewer tertiary and late-order branches. Islam et al. (1987) observed a predominant positive effect of active nodules on grain yield, provided the crop was grown in a suitable environment. While considering the character associations, pods plant^{-1} and seeds pod^{-1} were found to be significantly and positively correlated with seed yield, but this is of little utility in selection. Seed size is highly heritable and variation is predominantly additive, and also correlates positively with seed yield. However, increase in seed size is usually accompanied by decrease in the number of pods per plant and seeds per pod.

There is clearly a delicate source-sink balance (Smithson et al. 1985). Notwithstanding this, increased seed size may be achievable without affecting pod and seed numbers. Finally, it has been recommended that large seed size and more pods per plant should be used as selection criteria in conventional breeding following the pedigree method of selection. Besides, disruptive selection may be a suitable procedure for such desirable trait recombinations. Lal and Tomer (1980), using this method, developed lines (HMS-6) having 2 to 3 seeds per pod, without adversely affecting the size. Furthermore, recurrent selection may serve to simultaneously improve seed size and pods per plant or seeds per pod, maximizing heterozygosity, crossing over, and recombination among alleles at linked loci. This method also incorporates multiple genotypes into a central population, leading to a broader use of germplasm, breaking of linkage blocks, and release of desirable genetic recombinations (Jensen 1970).

8. Cultivars responding to high inputs.

9. Zone-specific cultivars with standard packages.

10. Further linkage with ICRISAT for obtaining crosses with local cultivars and sources of resistance.

Discussion

M. O. Hyder: It is observed in mustard that polyploids have the ability to produce more seeds. Polyploids of some of our pulses might have the potential for higher productivity.

M. O. Islam: Polyploidy (tetraploidy) has been tried at 1CRISAT but was not found to be useful.

M. S. Hoque: You have included in your studies, breeding for disease resistance and breeding for late sowing, besides high yield. But you have not included breeding for high nitrogen fixation, since the crop is a legume, and our soils are very deficient in nitrogen content. Do you not think that this is an important aspect for this crop ?

M. O. Islam: I have included disease resistance and late sowing potential as these two are the major constraints to high yield. I have also given priority to high yield. In our observation chickpea yield is directly and positively correlated with a high nodulated condition, provided the crop is grown under suitable conditions (optimum soil moisture and nutrient status). It is also our observation that highly nodulated genotypes produce profuse vegetative growth and finally give poor yields.

P. N. Bahl: It has been reported that there is no pod setting in chickpea in a couple of districts which represent flood-prone areas. Possibly, it is due to the excessive moisture. From our experience in India we may suggest that late sowing should be tried in such areas. This practice will cut short the vegetative phase of the crop. However, as a crop lentil is more amenable to late sowing than chickpea.

M. O. Islam: Thank you for your comment, but our observation is that in these districts the addition of a small amount of boron produces good results. Moreover our local genotypes are capable of producing pods in this condition. I have also observed that in flood-prone areas chickpea can grow well. However, I also agree with you that there is a failure of pod formation in conditions of excessive soil moisture.

S. K. Roy: Is there any material that will give more than one pod per node? If so, can't it be used in a breeding program to increase the number of pods per unit area?

M. O. Islam: Genotypes producing 2 pods per peduncle are available at ICRISAT. Our objective is to increase yield as well as disease resistance. It may come through single pod per node or double pod per node, as the genotypes have certain limits to pod formation capacity. So, double pod per node cannot ensure an increased number of pods per unit area.

C.L.L. Gowda: This character (2 pods per node) had been used extensively in the breeding program at ICRISAT, India, and we have been able to increase the pod number, and thereby, the harvest index.

M. H. Mondal: You have considered larger seed size as your selection criterion for yield. What will the proposed seed size be? And there is the question of seed viability - generally larger seeds are less viable than smaller seeds.

M.O. Islam: Thank you for your comments. We have to make a compromise for this trait, in order to keep yield as our first priority. Yes, generally smaller seeds have better viability than larger seeds.

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Status of Lentil Breeding and Future Strategy

A. Sarker, M. Matiur Rahman, W. Zaman, M.O. Islam, and A. Rahman
Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh

Abstract

Lentil (Lens culinaris *Medic.) is the most preferred and second most important pulse crop in Bangladesh. Low productivity has progressively reduced the area under this crop. Over 1518 local and exotic germplasm lines were collected (1979-84) and evaluated (1982-87). None of these lines were superior to BLL 79694 (L5) with respect to yield, maturity, and resistance to the prevalent diseases. However, some of these had larger seed size and were resistant to rust and stemphylium blight. Variability among the local germplasm is very low. L 5 was purified and has been proposed to the National Seed Board for recommendation. Hybridization between L 5 and large-seeded, disease-resistant accessions was initiated in 1984/85. These crosses are in the F_3 and F_4 generations. Introductions from 1CARDA are day length sensitive and so far no useful selection has been made from these. At our request ICARDA made crosses of L 5 with rust-resistant parents and sent us the F_3 generation in 1988. We propose to obtain more germplasm and attempt crosses to incorporate resistances, improve seed size, and earliness.*

Introduction

Lentil (*Lens culinaris* Medic.) is the second most important pulse crop in terms of both area and production, and rates the highest consumer preference. During 1985/86, it was grown on about 67 000 ha and produced 47 000 t of grain with an average yield of 700 kg ha^{-1}. It contributed 25% of the total pulse production (BBS 1987). This crop is generally grown in the traditional *aus* (rainfed) rice/jute/fallow-lentil cropping pattern and can also be grown in the proposed aus/jute-black gram (*Vigna mungo* (L.) Hepper/mung bean (*Vigna radiata* (L.) Wilczek) - lentil pattern. It is cultivated as a sole or mixed crop with mustard (*Brassica campestris* L.), and to a very small extent, as a relay crop with *aman* (rainy season) rice. The existing local varieties are small seeded, have low yields and are susceptible to diseases like collar rot, wilt, rust and stemphylium blight. Moreover, the crop faced tough competition in the recent past from cereals, particularly wheat and *boro* (winter) rice, due to the expansion of irrigation facilities and the availability of high-yielding varieties. There has been a tremendous diversion of land from winter pulses to these cereals. Therefore, there is a need to increase the productivity of lentil, so that it becomes remunerative to farmers. The various constraints to productivity and the efforts made to alleviate these constraints have been discussed in this paper. Factors responsible for low productivity are both genetic and cultural. The main genetic reasons are given below.

1. **Low yield potential of the existing varieties:** Cultivated lentil varieties are inherently low yielding, owing to factors such as less branching, low podding intensity, and small seed size.

2. **Susceptibility to diseases:** The major diseases affecting lentil are rust (*Vromyces fabae*) and stemphylium blight (*Stemphylium* sp). The incidence of stemphylium blight in Bangladesh was first reported during 1980/81. It has caused considerable losses to crops in the last few years.

3. **Poor response to high inputs:** The cultivars used at present do not respond to fertilizers and irrigation. It is well known that genetic erosion

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

has occured in most of the pulses due to continuous cultivation in marginal and poor soils, but enough potential still exists and the crop may respond well to better management.

4. **Low level of sowing by farmers:** Instability of yield is one of the main factors that discourages farmers from sowing lentil. Therefore, total production in the country is reduced. It is essential to develop varieties that give consistently high yields over different locations and years under varying soil and climatic conditions.

5. **Delay in sowing by farmers:** Winter in Bangladesh lasts only 100-110 days. Farmers do not sow in time. Therefore, the crops have an even shorter period for vegetative growth, and are severely affected by rust and stemphylium blight, resulting in poor yields.

6. There is a lack of standard cultural practices to ensure high and stable yields for this crop. Therefore farmers do not give enough importance and inputs to lentil cultivation.

Bangladesh Agricultural Research Institute, (BARI) has attempted to overcome these genetic limitations through conventional breeding approaches. Some progress has been made.

Table 1. Lentil germplasm collected and utilized at BARI, Joydebpur, and Ishurdi, Bangladesh, 1979-1984.

Year	Local germplasm	Exotic germplasm[1]
1979	78	550 (ICARDA + 400)
1980	139	(None)
1981	101	50 (India)
1984	0	200 (ICARDA)
Total	318	1200
Present position	318	692

1. Many exotic lines did not flower at all and most of them were of the macrosperma type.

Achievements

Although research on lentil was initiated during the early 1950s, the main effort was directed at the collection and evaluation of local germplasm. A few lines were tested over locations during the early 1960s but no progress could be made (Gowda and Kaul 1982). With the inception of the Pulses Improvement Program at BARI in 1979, lentil breeding work was restarted, with the objective of developing short-duration high-yielding varieties. For this purpose, a vigorous effort was initiated to collect local and exotic germplasm. These were evaluated under local conditions (at BARI) to select the desirable types. So far 318 local and 1200 exotic germplasm lines have been collected from the International Center for Agricultural Research in Dry Areas (ICARDA), Syria and Plant Introduction Center (PIC), Washington, USA and India (Table 1). All the lines were evaluated and preliminary selections were made for yield and other specific characters. It was observed that none of the exotic materials performed better than the local types with respect to yield, duration, disease response or any other character except seed size. The macrosperma type, which originated in the Mediterranean region, does not perform well under Bangladesh climatic conditions, although some cultures were found to be resistant to rust and stemphylium blight. However, these are extremely late and sometimes set few or no pods. The local collections exhibited very narrow genetic variability in respect of maturity, yield, and other characters. However, podding intensity was good in a few cases (Sarwar et al. 1981). Among the local stocks, a landrace (accession no. BLL 79694) collected from the Pabna district was found to be the highest yielder. This line, along with other selections from local and exotic sources, was tested during 1982-87 in different locations (Tables 2 and 3). It was observed that BLL 79694 performed well, and produced stable yields over years and across locations. This was proposed for recommendation as a commercial variety in 1989. This variety is early maturing (100-110 days), and has medium plant height (35-40 cm) with non-tendrillar growth habit but smaller seed size (1.4-1.6g 100 seeds^{-1}).

Very little success has been achieved in the selection and adaptation of exotic germplasm in our environment through direct introduction. Therefore, the breeding strategy was recast in 1984 and short-and long-term approaches are now being followed (Kumar 1984, 1985). The short-term approach was to collect more exotic germplasm, evaluate them, and select better genotypes for immediate release as cultivars. Some of the selections from exotic sources are in

Table 2. Seed yield (t ha^{-1}) of BLL 79694 (L 5) and other test lines at various locations, 1981/82 to 1983/84.

Entries	1981/82 (2 Locations)	1982/83 (4 Locations)	1983/84 Different locations[1] Isd.	Jam.	Jes.	Joy.	Raj.	Mean	Overall mean
BLL 79592	0.96	0.88	2.99	1.50	2.32	1.18	1.85	1.97	1.27
BLL 79554	0.61	0.85	2.83	1.40	2.62	1.40	1.83	2.02	1.16
BLL 79504	0.93	0.90	3.23	1.30	2.54	1.08	1.93	2.02	1.28
BLL 79546	0.65	0.79	3.04	1.20	2.43	1.07	1.85	1.92	1.12
BLL 79543	0.93	0.84	3.14	1.40	2.54	1.27	1.79	2.03	1.27
BLL 79513	0.97	0.97	2.89	1.50	2.44	0.48	2.10	1.88	1.27
BLL 79694 (L 5)	1.03	0.85	3.47	1.70	2.61	1.10	2.04	2.18	1.30

1. Isd: Ishurdi; Jam: Jamalpur; Jes: Jcssore; Joy: Joydcbpur; Raj: Rajashahi.

advanced generations and under multilocational yield tests (Tables 3 and 4). The long-term program is to develop short-duration, high-yielding rust- and stemphylium blight-resistant varieties with relatively larger seed size. The hybridization program was initiated in 1934/85 with the objective of incorporating rust resistance and large seed size into the widely adapted line BLL 79694 (L 5).

In addition to L 5, the following parents are being used in this program:

1. Rust resistance : 84233, 84228, E 1
2. Stemphylium resistance : V 81103
3. Bold seed : 79666,84248,84228, 84233,84143
4. High podding intensity : 79542,79437

Different cross combinations were made among these parents in 1984/85 and their progenies are in different generations. The segregating populations are being screened against rust and stemphylium blight using lines highly susceptible to rust (BLL 81149) and stemphylium blight (BLL 81124) as spreader rows after every 5 rows of segregating materials. The pedigree method of selection is being followed and individual plants/families with resistance to both diseases, high podding intensity, and earliness are selected for the next generation. At present a total of 7 F_4 and 106 F_3 families are being advanced.

In 1985, ICARDA was requested to make some crosses using L-5 and their rust-resistant lines, and to supply us with the segregating populations (Kumar 1985). This program has received F_3 generations of 8

Table 3. Seed yield (t ha^{-1}) of BLL 79694 (L 5) and other test lines at various locations 1984/85 - 1986/87.

Entries	1984/85 2 Locations	1985/86[1] Isd.	Jes.	Joy.	Raj.	Jam.	Mean	1986/87[1] Isd.	Joy.	Dinj.	Mean	Over-all Mean
BLL 81114	1.34	2.04	1.05	1.04	1.11	1.30	1.31	1.34	0.99	1.07	1.13	1.26
BLL 81122	1.15	2.14	1.08	1.26	1.19	1.31	1.40	1.53	0.89	1.02	1.15	1.23
BLL 81124	0.94	1.61	0.93	1.24	1.19	0.63	1.12	0.95	0.79	0.33	0.69	0.92
BLL 81143	1.39	2.11	0.85	1.20	1.13	0.97	1.25	1.77	0.83	0.67	1.09	1.24
BLL 81150	1.48	2.22	0.78	0.88	1.11	1.17	1.25	1.75	0.98	0.81	1.18	1.31
BLL 79694 (L 5)	1.56	2.32	0.94	1.13	1.08	1.31	1.35	1.69	0.89	0.99	1.19	1.37

1. Isd: Ishurdi; Jes: Jessore; Joy: Joydebpur, Raj: Rajshahi; Jam: Jamalpur, Dinj: Dinajpur.

Table 4. Seed yield and other characters of promising lentil lines at Regional Agricultural Research Station, Ishurdi, Bangladesh, 1989/89.

Entries	Days to maturity	Plant height (cm)	100-seed mass (g)	Yield ($t\ ha^{-1}$)
BIX 81122	113	38	1.6	1.8
BLL 84135	121	42	2.6	1.29
BLL 84143	117	40	2.9	1.08
BLL 84248	124	44	3.8	1.92
BLL 85049	120	47	2.3	1.81
BLL 80010	118	39	1.7	1.75
BLL 80038	117	37	1.7	1.50
BLL 80018	117	40	1.6	1.75
S 113-55	112	36	1.6	1.95
BLL 79694 (L 5)	112	36	1.6	1.70
CD. (0.05)	2.43	4.3	0.61	0.319

crosses this year. These will be screened under Bangladesh conditions following the above procedures. Besides these, we received 29 F_3 bulks (LIF$_3$ T-E) from ICARDA in 1984/85 of which 7 F_6 lines have been developed for single as well as multiple characters. These lines and their characters are as follows:

1. Rust resistance : 103-16,125-5,110-78
2. Highpodding : 125-5,113-55,110-117,113-51
3. Maturity : All 7 selections are at par with L 5 (110 days)
4. High yield : 113-55, 113-51, 125-5

From these selections, the line 113-55 is now undergoing multilocation yield trials and others have been included in the hybridization program for specific characters.

We also received and evaluated 224 lines under the Lentil International Yield Trial (LIYT) and Lentil International Screening Nursery (LISN). Most of the lines were late and did not flower, or flowered late, and produced only a few pods developed at the top branches of the plant. Moreover, in some cases the plants died due to diseases like collar rot and wilt. We also observed restricted growth of the root system in these lines. Only three lines (ILL 5405, ILL 5486, and ILL 6037) were selected from the LIYT-E 88 trial for higher yield, more podding, rust resistance, and early maturity. These lines are under observation.

Future Breeding Needs

Muehlbaur et al. (1985) indicated that for a narrow range of environments the breeding objectives should be clearly defined, including specific characters of locally grown cultivars that are to be improved, and that the pedigree method may be advantageous in selection. In Bangladesh the winter lasts only around 110 days. So the new varieties must be of about 110-120 days' duration. Moreoever, they should be resistant to rust and stemphylium-blight diseases and must produce stable and high yields.

Breeding varieties for high-management conditions is also essential to make lentil competitive with cereals. Development of varieties that could give higher yields under better management such as fertilizers and irrigation is important. Although it is well known that genetic erosion has occurred in most of the pulses due to their cultivation on marginal and poor soils, there is enough potential for a favorable response to better management.

Lentil can be grown in the flat *Barind* areas of Godagari and Dinajpur regions but the lack of soil moisture is a limiting factor during the cropping season. It is therefore necessary to develop varieties that can thrive well in these conditions.

Strategies

Lentil is specifically adapted and therefore gives small yields when introduced in new environments (Muehlbaur et al. 1985). More germplasm especially from the Indian subcontinent, should be introduced. The National Bureau of Plant Genetic Resources (NBPGR), India, and ICARDA, Syria are potential sources of germpiasm. At present ICARDA maintains about 4700 germpiasm lines from 47 different countries and we may request them to supply us materials according to our needs.

The ongoing hybridization program needs to be further intensified, involving local cultivars. Muehlbaur et al. (1985) reviewed the yield component studies. They concluded that branching pattern and number of fruits reaching maturity are the most important characters which contribute positively to yield, although these characters are also influenced by environments and agronomy (spacing, time of sowing, fertilizers). Singh and Singh (1969) reported high heritability estimates and genetic advances for pod number, seed size and grain yield. They observed that pod number had the strongest association with seed yield and seed size had a negative association with seed yield. Several other workers have reported the important contribution of pod number and primary and secondary branches to grain yield. Smithson et al. (1985) reported that seed size is a heritable character and larger seed size (within a certain limit) contributes positively to yield in chickpea (*Cicer arietinum* L.). Therefore, during selection, emphasis should be given to the production of a larger number of branches and pods,and relatively larger seed size.

Screening against rust and stemphylium blight should continue with the spreader-row technique. However the disease incidence under natural conditions varies, and sometimes is not sufficient to create a disease pressure on the population. Therefore, a proper selection of the resistant plants or families is difficult. Sufficient disease pressure must be ensured by artificial inoculation of the fungal culture in the laboratory. The pathologists should also study whether spraying of leaves and plant parts of the susceptible lines would be an effective technique to create disease pressure, particularly for rust and stemphylium blight.

ICARDA's help in crossing L 5 with early, rust-resistant lines with larger seed size should continue. In fact, this linkage should be strengthened further. Co-operation of other institutions working on lentils, such as the Crop Development Centre, Saskatoon, Canada; USDA-ARS, Washington State University, USA and the Directorate of Pulses Research, Kanpur, India may be sought for seed materials and scientific information regarding crop improvement.

Therefore, to increase lentil productivity in Bangladesh, varieties of 110-120 days' duration, resistant to rust, stemphylium blight, with 100-seed mass around 2.0 g, and yield potential of 2.0-2.5 t ha^{-1} are required.

Discussion

M. A. Islam: You want to include one legume crop, namely mung bean, in the existing cropping pattern i.e., broadcast (B.) aus/jute - fallow - lentil. Yes, this is possible. But did you observe the effect of the late monsoon season (kharif II) mung bean on lentil, as both are legume crops?

A. Sarker: Of all the existing and proposed patterns, B. aus/jute-black gram/mung bean-lentil is the most profitable one. For data and nutrient status you may refer to Aziz and Rahman (1990).

S. K. Roy: There is a problem of low harvest index (HI) for legumes. Is there any research program to improve the HI of lentils? Did you measure the leaf area index (LAI) of lentil? If so what was the range?

A. Sarker: Yes, in our long-term strategy we have included breeding for higher HI. In our multidisciplinary approach for pulses improvement we have physiology as a component part. Such information has already been recommended by physiologists.

ML H. Rahman It has been mentioned in the paper that under local collection, accession no. BLL 79694 (L 5) from Pabna district produced stable yields over years and locations. We have been hearing about this for many years. In view of good performances L 5 deserves to be released as a variety. Why has it not yet been released?

A. Sarker: The accession no. BLL 79694 was collected and evaluated for some time. After its evaluation over years and across locations, we have submitted the documents for release of this line to the National Seed Board this year.

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Status of Khesari Breeding and Future Strategy

M. Matiur Rahman[1], M. Quader[1], and Jagdish Kumar[2]

1. Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh;
2. ICRISAT, Patancheru, A.P. 502 324, India.

Abstract

Khesari (Lathyrus sativus *L.) occupies the first position in terms of area and production among pulses in Bangladesh. Two hundred and sixty seven local and exotic lines have been evaluated for their performance and neurotoxin content since 1980. Three of these khesari lines Jamalpur, Pahartali, and Charbadna, were found to be high yielding. Line 3968 was relatively low in neurotoxin content, early in maturity and low in seed yield. Hybridization among high-yielding and low-neurotoxin lines has been attempted since 1984/85. These and some other populations from the Indian Agricultural Research Institute (IARI), New Delhi, are in F_2 to F_6 generations. A three-location test for the ß-N-oxalyl aminoalanine (BOAA) content of 13 lines showed significant effects for cultivars, environments, and their interaction. The mean toxin content for the lines grown at Ishurdi was tower than that at either Joydebpur or at Jessore. Attempts to establish association of various characters with low toxin content showed low or no correlation. Since no faster and reliable method has been developed so far, it may not be possible to screen large populations. It is suggested that the single-seed descent (SSD) method of breeding may be followed. Screening for BOAA content may be done at F_5 - F_7 generations only to select individual progenies. In future attempts will be made to collect more germplasm, to make more crosses, to screen breeding populations for major diseases of this crop, and to develop cultivars suitable for seed and fodder production.*

Introduction

Lathyrus sativus L., locally known as khesari, is the most important pulse crop in Bangladesh. In 1984/85, it was grown on 82 000 ha, with a production of 60 000 t. The mean productivity of 735 kg ha^{-1} is low, as in other pulse crops. When it constitutes a major portion of the diet it is known to cause a disease called lathyrism. A neurotoxic compound, ß-N-oxalyl aminoalanine (BOAA), found in this species, has been associated with the disease (Spencer et al. 1986). Despite this, the crop is cultivated widely in most parts of Bangladesh and elsewhere because of its tolerance to drought and excessive moisture and because it requires low inputs. It has much wider adaptability than any other pulse crop. Moreover, it produces quality fodder for milch cattle. It is not possible to replace its cultivation in the foreseeable future as it is an important source of protein in some areas of Bangladesh. Research has indicated that it is possible to breed cultivars which are relatively safe for consumption. In this paper we describe recent developments in this direction.

Germplasm Collection, Evaluation, and Utilization

Since 1981, a total of 267 local and exotic germplasm lines were collected. These were tested at Joydebpur, Ishurdi, and other places. The lines Jamalpur local, Pahartali, and Charbadna showed high yields, but were relatively late maturing. Strain 3968 which was relatively early maturing had low neurotoxin content but also had lower yields (Tables 1 and 2).

Hybridization

Since the 1984/85 postrainy season 30 crosses have

Citatum: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Basngladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502324, India: International Crops Research Institute for the Semi-Arid Tropics.

khesari, RARS, Ishurdi, Bangladesh since 1984/85.

Parent	Character
3968	Low neurotoxin, early maturity
3604	High yield
LSD 6	Low neurotoxin, bold seed
Jamalpur	High yield
P2	High yield
8603	Low neurotoxin
8609	Low neurotoxin
8608	Low neurotoxin
P4	High yield

been made between high-yielding local cultivars and those having early maturity, large seed size, and relatively lower-neurotoxin content (Kumar 1985) (Table 1). These populations and some others received from the Indian Agricultural Research Institute (IARI), New Delhi (Quader et al. 1986) are in F_2 to F_6 generations and will be tested for yield and other agronomic traits. The promising segregants will be further evaluated for their neurotoxin content and tested for their adaptability.

Screening for Low BOAA Content

A number of germplasm lines and segregants have been tested for their BOAA content using the spectrophotometer at Joydebpur (Quader et al. 1986; Kaul et al. 1986; Hussain and Khatun 1987), from which some low-toxin lines were identified. However, different environments and storage periods appeared to influence the toxin content. Unfortunately the large-scale screening required in a major breeding program is not possible with the present facilities. We are now working with other laboratories so as to adopt faster procedures (Briggs 1988) and to expand this activity.

Association of BOAA Content with Morphological Traits

Attempts have been made to associate neurotoxin content with morphological traits and seed characters. Dahiya (1976) observed that light cream-colored seeds had the lowest BOAA content. Quader et al. (1986) reported that blue- flowered lines had relatively lower BOAA content. Quader et al. (1988) observed that lines having low neurotoxin content were of short-duration maturity and low yielding, and that high-yielding lines had high toxin content. However, Kaul et al. (1986) did not find any consistent association between BOAA content and morphological traits. A wider array of germplasm needs to be studied to establish any such relationship.

Evaluation of Segregating Materials

In the BARI breeding program selection is presently made starting with the F_2 generation (BARI 1986).

Table 2. Mean yield (t ha^{-1}) of the entries in advanced yield trials of khesari, at various locations in Bangladesh, 1979-1984[1].

Line	1979/80 (Jamalpur)	1981/82 (4 loc.)	1982/83 (4 loc.)	1983/84 (7 loc.)	Mean
6118	1.54	1.38	1.53	1.87	1.58
Charbadna	1.80	1.48	1.77	1.83	1.72(3)[2]
Barisal	1.22	1.44	1.60	1.87	1.53
3970	1.11	1.40	1.63	1.82	1.49
3968	0.93	1.23	1.49	1.59	1.31
Pahartali	1.83	1.45	1.77	1.91	1.74(2)
6130	1.35	1.22	1.62	1.78	1.54
Jamalpur (Control)	1.94	1.36	1.78	1.99	1.76(1)

1. No data were available for 1980/81.
2. Figures in parentheses are ranks for seed yield.

However, in the absence of faster screening procedures for determining BOAA content, early generation selection for this trait is not possible. We propose that the single-seed descent (SSD) method be followed in the breeding program. This ensures a large variability advancing to the F_6 generation. After visual selection for agronomic traits the homozygous progenies can be evaluated for their BOAA content. The low-neurotoxin lines thus selected can be tested multilocationally for their yield and adaptability.

Seed Production

We have observed substantial bee activity on the khesari flowers, as also reported by Kumar (1985) and Kaul et al. (1986). There is 4-16% outcrossing in this crop (BARI 1986). This is substantiated by the presence of different flower and seed colors in local cultivars, even after they are purified. While this finding can be used in the breeding process, special care should be taken in producing breeders' and foundation seed.

Utilization

While the search for low-neurotoxin lines continues, efforts should be made to detoxify the khesari *dhal* through processing at the mill level and/or the consumer level. Parboiling of the *dhal* or soaking overnight and decanting, and soaking in lime water have been suggested to detoxify the *dhal* (Hussain 1990).

Future Strategy

Priorities in the future include:

- Collection of more germplasm and its utilization in breeding superior cultivars;
- Us ing the SSD method to achieve large variability for homozygosity, and testing these lines for their BOAA content;
- Breeding for resistance to stemphylium blight and downy mildew;
- Breeding for relatively short-duration cultivars which suit the various cropping patterns and rotations practised in Bangladesh;
- Breeding for better consumer acceptance;
- Breeding dual-purpose cultivars for food and fodder; and
- Strengthening linkages with other countries and international agencies working on khesari.

Discussion

M. A. Islam: Are you trying to develop any cultivars of khesari for relay cropping?

M. M. Rahman: As a strategy our advanced materials will be tested in relay cropping as the farmers' do and the best ones will be released.

M. A. Wahhab: When does BOAA accumulation occur in the developing seed?

Table 3. Characteristics of six lines of khesari in trials over locations, Bangladesh, 1984-1986.

Line	Days to flowering	Days to maturity	Plant height (cm)	Pods plant^{-1}	100 seed mass (g)	Yield (t ha^{-1}) 1984/85 (4 Locations)	Yield (t ha^{-1}) 1985/86 (5 Locations)
3600/2	57	111	60	43	4.5	1.61	1.58(2)
3604	58	114	53	55	4.8	1.63(3)[1]	1.45
3906	63	120	54	46	5.1	1.77(2)	1.57(3)
3968	49	104	45	39	4.9	1.61	1.35
LSD 3	59	118	59	56	6.0	1.21	1.32
LSD 6	57	117	63	60	6.2	1.23	1.46
Jamalpur (Control)	60	114	53	41	4.5	1.99(1)	1.78(1)

1. Figures in parentheses are ranks for seed yield.

M. M. Rahman: I have not come across any literature on this aspect.

P. N. Bahl: Some of the recent publications suggest that there is a strong positive correlation between protein content and BOAA content in *Lathyrus sativus* L. I wonder if this information can be used to scan the breeding populations in this crop?

M.M.Rahman: We may try this in future. However, the results of association of low toxin content with other characters are inconsistent.

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Factors Limiting the Expansion of Summer Pulses

M. Matiur Rahman
Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh

Abstract

*The Bangladesh Agricultural Research Institute released a mung bean (*Vigna radiata *(L.) Wilczek) cultivar Mubarik, in 1982 and identified several black gram (*Vigna mungo *(L.) Hepper) lines for cultivation in the early-monsoon (kharif-I) season, and in the postrainy crop-mung bean-t.* aman *(rainy season) rice/fallow cropping pattern, to replace* aus *(rainfed) rice. This has not found favor with farmers in the targeted areas mainly due to the uncertain weather during this season. The crop must be sown before March, otherwise it is badly damaged by excessive rain and humidity at maturity. Excessive moisture may delay maturity and result in the seed rotting within the pods. About 60-65% of mature pods of Mubarik can be harvested at 65-70 days, but a complete harvest may take up to 3 months and hand picking is uneconomical. Yellow mosaic virus (YMV) damage reduces yields substantially. A large area remains fallow between the early monsoon and postrainy seasons. This period is designated as late monsoon (kharif II). Kanti, another cultivar of mung bean was released in 1987 for cultivation in this season. We propose to lay relatively more emphasis on the development of short-duration YMV, and Cercospora leaf spot-resistant cultivars which can tolerate some waterlogging. These will fit the* aus *(rainfed) riceljute-mung bean-postrainy season crop in the northern and the t. aman-mung bean-aus rice cropping pattern in the southern parts of the country. The pulses program is now developing more such cultivars.*

Introduction

Among the pulse crops in Bangladesh, mung bean *(Vigna radiata* (L.) Wilczek), ranks fifth in terms of area and production. It was grown on about 15 338 ha producing 9 052 t of grain with a mean yield of 590 kg ha^{-1} (BBS 1986). It is traditionally grown in two cropping patterns. About 60-65% of the total mung bean is grown under the *boro* (winter) rice mung bean-*aus* (rainfed) rice cropping system in five southern districts: Patuakhali, Barisal, Madaripur, Noakhali, and Cox's Bazar from mid January to April (Table 1). In these areas the local green-seeded mung bean is cultivated. Under the *aus* rice/jute-mung bean cropping pattern (August/September), mainly golden-seeded daylength-sensitive cultivars are cultivated.

An effort was made at the Bangladesh Agricultural Research Institute (BARI) to introduce short-duration, daylength-insensitive mung bean cultivars for March-April sowing to replace the uncertain rainfed *aus* rice, particularly in the northern districts of the country (Sarker et al. 1982). Since the winter pulse area is gradually decreasing, the idea of growing pulses in summer was accepted as a major step towards increased production. BARI released a mung bean cultivar, Mubarik, in 1982. It was assumed that a large area would be planted to this crop. However, only a few hectares of land has been occupied by this crop in the planned area. The objective of this paper is to analyze the agroecological factors limiting the expansion of summer pulse cultivation in Bangladesh, and the future course of research on these crops.

Major Limitations

Limited Sowing Time and Lack of Moisture at Sowing

A mung bean crop grown in summer must be harvested before the onset of the monsoon to avoid early rains.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Area, production, productivity, and cropping patterns of mung bean in different districts of Bangladesh, 1984/85.

District	Area (ha)	Production (t)	Yield (kg ha^{-1})	Total area(%)	Cropping pattern
Patuakhali	2901	1383	477	19.0	Pattern -1
Barisal	2632	1663	632	17.0	*Aman* rice-mung-*aus* rice/jute
Faridpur	2103	1176	559	14.0	(Jul-Dec)(Jan-Mar)(Apr-Jul)
Noakhali	1514	640	423	10.0	Mung bean cultivar Faridpur (green seeded)
Coxes Bazar	318	246	774	2.0	
Comiila	397	226	569	2.6	
Sub total	9865	5334	541	64.6	
Jessore	1005	625	576	7.0	
Rangpur	905	635	702	2.9	Pattern-ll
Dhaka	773	482	623	5.0	Aus/jute-mung-fallow/wheat
Jamalpur	421	271	644	2.7	(Apr-Jul)(Aug-Dec)(Dec-Apr)
Kishoregonj	403	167	414	2.6	Mung bean Sonamoong (golden seeded)
Pabna	318	246	774	2.1	
Dinajpur	326	231	709	2.1	
Sub total	4231	2657	627	27.4	
8 other districts	1196	817	883	8.0	
Total	15 292	8808	576	100.0	

Source: BBS (1986).

Therefore, if the last date of harvest is assumed to be 20 June and if the crop duration is about 70 days then the last date of sowing would be 10 April. A date-of-sowing experiment showed that sowing in late March gives better results (Fig. 1). Traditionally farmers grow pulses under rainfed conditions and if they have irrigation facilities they will not grow mung bean. The probability of receiving 10 mm rainfall in the second week of April ranges from 40-60% in the northern districts, based on which no production plan could be successful (Manalo 1978). Sufficient rain for sowing occurs at the end of April or early May. If mung bean is sown at that time the crop will mature in July making harvest difficult. The farmers will then have no choice but to plough down the crop (BARI 1984; OFRD 1987).

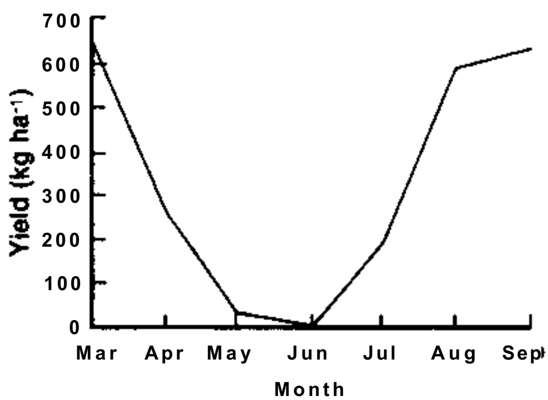

Figure 1. Yield of mung bean at different dates of sowing at Ishurdi.

Moisture Variation at Planting and Maturity

Climatic factors primarily responsible for adaptation of mung bean and black gram *(Vigna mungo* (L.) Hepper) are daylength, temperature, humidity, and rainfall. Although mung bean and black gram are reported to be drought-tolerant crops (Morton et al. 1982; Rachie and Roberts 1974), they are susceptible to moisture stress during the establishment period and flowering stage (Rosario and Faustino 1985) The optimum temperature for mung bean and black gram ranges from 28-30°C (Lawn and Ahn 1985). It may be possible to sow these crops in Bangladesh during March in some years but they may suffer from prolonged drought during April/May, due to high temperature (34-36°C), low humidity (46-60%), high potential evapotranspiration rate (5-6 mm day^{-1}), and a negative water balance (139-165 mm). The aridity index is reported to range from 0.11 at Dinajpur to 0.24 at Pabna (Manalo 1978). These factors result in poor plant growth, wilting and abscission of flowers, leading ultimately to poor yields. If excess rains occur during this period, wet and humid conditions stimulate vining, luxuriant growth, and favor incidence and spread of foliar diseases (Lawn and Ahn 1985), again resulting in low yields.

Problems During Harvest

Farmers of the targeted area are not accustomed to hand picking as a means of harvesting the pods. But this practice cannot be avoided during the summer. Rains generally occur by the end of May when the crop is at the pod-filling stage, thus increasing soil moisture and humidity. Long days coupled with favorable soil moisture stimulate successive flushes of flowers. Thus individual racemes may simultaneously bear flower buds, flowers, green, and ripe pods. In black gram the growth *of* new leaves and fruiting continues and the ripening period extends over many weeks. It has been found that only about 65% pods can be harvested in the first picking at 72 days, 18% in the second at 82 days and 17% in the third at 97 days (Table 2). So at least 90-95 days are required for a complete harvest. If it rains continuously over 2-3 days during the maturity period, seeds in mature pods will sprout, or may get discolored and shrivelled, lose viability, and spoil or become infested with fungi. Thus harvesting, drying, and threshing become more difficult.

Biotic Stress Factors

The yield potential of mung bean is not realized because of disease and pest damage. So far, eight diseases have been identified, of which yellow mosaic virus (YMV), Cercospora leaf spot (CLS), and powdery mildew (PM) are the most serious (Ahmed et al. 1982; Fakir 1983). Sources of resistance have been identified for all the major diseases except for YMV, for which only moderate resistance is available (AVRDC1983; Sandhu 1978).

Fourteen species of insect pests of mung bean have

Table 2. Mean performance of 10 mung bean lines at different dates of sowing at RARS, Ishurdi, 1983/84.

	Dates of Sowing[1]						
Character	March	April	May	June	July	August	September
Days to flower	40	41	45	41	41	40	37
Plant height (cm)	37	53	64	52	41	40	55
YMV(%)	11	69	65	52	42	4	57
Pod borer (%)	19	17	10	8	4	17	28
Yield (kg ha^{-1})	638	266	31	0	192	592	634
% yield at 1st harvest	65(72 days)[2]						
% yield at 2nd harvest	18(82 days)						
% yield at 3rd harvest	17(97 days)						

1. Sowinging done on 15th of every month indicated.
2. Figures in parentheses Indicate the number of days taken to a particular harvest.
Source: BARI (1994).

also been identified of which leaf beetle *(Madurasis obscurella and Monolepta singnata)* skeletonizes leaves at an early stage, while pod borer *(Maruca testulalis)* and leaf webber *(Laprosoma indicate)* are most damaging at podding stage. Green bug *(Nazera viridula)* and thrips (*Caliothrips indicus)* cause substantial flower shedding and result in poor pod setting and yield (Rahman et al. 1982). *Whitefly (Bemisiatahaci) and aphids (Aphis craccivora)* are major vectors for YMV. A study indicated that 25-30% yield loss may occur due to pod borer (BARI 1986). In black gram the insect problem is less acute. The most damaging are leaf beetle at the early stage, and later hairy caterpillar (*Diacrisia obliqua).* Farmers usually do not adoptplant-protection measures and generally realize poor yields.

Abiotic Stresses

Among the abiotic stresses, soil type and fertility play a major role. Both mung bean and black gram perform best on deep, well-drained loams and sandy loams (Mehta 1970; Rachie and Roberts 1974) and neither are well suited to the shallow or unfertile sandy soils on which they are often grown. It was reported that a crop producing 1 t yield removes 40-45 kg N, 3-5 kg P_2O_5, 12-14kg K, 1.5-2kg each of Sand Mg, and 1-1.5 kg Ca from the soil (Lawn and Ahn 1985). However, farmers do not use any fertilizer or perform intercultural operations.

Conclusions and Future Work Plan

It is clear from the above discussion that it may not be possible to replace the rainfed *aus* rice with mung bean or black gram even if YMV-resistant cultivars are developed because of the major limitations, i.e., lack of moisture and sowing time.

However, cultivation is possible with presowing irrigation if it does not rain in time. On the other hand a large area remains fallow from August to October, after the harvest of *aus* rice or jute till the beginning of the postrainy season. In spite of the heavy monsoon rains during August-September, it is possible to grow mung bean and black gram during this period. Postrainy-season crops like wheat, lentil, mustard (*Brassica campestris* L.), or tobacco can follow these (BARI 1986). BARI is already working in this line and has released a mung bean cultivar Kanti, for this period. Mung bean is better suited to this pattern than black gram but the latter gives more stable yields. The crop with synchronous pods matures at the end of October and whole plants could be harvested, thus reducing the labor requirement. The existing cropping patterns in the northern districts are *aus* rice/jute (April-July/August) - fallow (August-October) - *rabi* (November-April) or *aus* rice-jute-black gram (August-September-December) - fallow. With the new pattern involving mung bean, a large area may be brought under pulse cultivation which otherwise remains fallow. Two things are important, i.e., suitable soil (sandy loam, silty, or silty loam) with adequate drainage facility and timely sowing (in August).

Short-duration mung cultivars (60-65 days) are required for this season. These should be resistant/tolerant to YMV and CLS and to waterlogging. In black gram, short-duration (65-70 days), YMV- and powdery mildew-resistant/tolerant cultivars capable of growing under zero-tillage conditions should be developed, for which purpose landraces should be used in the hybridization program. For the southern part of the country short-duration, high-yielding cultivars with resistance/tolerance to YMV and CLS, suitable for the existing *aman* rice-mung bean-aus rice cropping pattern may be developed.

Discussion

A.A. Miah: You have mentioned some problems for early-monsoon (kharif-I) mung bean such as number of pickings and germination within the pods. Why don't you try to develop cultivars with determinate growth habit and seed dormancy to avoid those problems?

M.M. Rahman: Our present strategy is to develop suitable varieties for the late monsoon (kharif-II) season where these problems do not arise. I think we should not spend much time and effort on these characters for the uncertain early monsoon mung bean, because there is no certainty of rainfall in March when this crop is to be sown.

P.N. Bahl: I would like to share our experience with mung bean cultivation as a spring/summer crop in contrast to your experience in Bangladesh. This is an area with great potential for us in India. The incidence of yellow mosaic virus is low and quality of seed is better in this season as compared to the kharif-grown crop. Of course we need short-duration varieties (65-days' maturity) to exploit this crop in the northern parts of the country where intgation is not a limiting factor in the summer months.

J. Kumar: Monsoon sets earlier in Bangladesh than in northwestern India.

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Pulses Improvement Through Nuclear and Conventional Techniques

M.A.Q. Shaikh
Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

Abstract

*Gamma-irradiation of a chickpea cultivar (*Cicer arietinum *cv Faridpur-l) resulted in the release of a high-yielding and high-protein chickpea cultivar Hyprosola. Its yield is 20% more and it contains 4% more protein than the mother cultivar. It has a fortuitous combination of a few more improved characters. A mung bean (*Vigna radiata *(L.) Wilczek) strain, MB 55, was identified which has resistance to cercospora leaf spot and 20% more yield than the recommended cultivar, Kishoregonj. It has been developed through single-plant selections from a local collection. Two black gram (*Vigna mungo *(L.) Hepper) mutants M 23 and M 25, were developed through gamma-irradiation of a local collection. M 23 is an erect, synchronous dwarf with bold, glabrous and upright pods. More plants of this cultivar can be accommodated per unit area, thereby increasing the yield. Mutant M 25 is synchronous and determinate and its pods are considerably less hairy than its parent B 10. The mutant yields about 15% more than the mother cultivar. Both mutants are tolerant of cercospora leaf spot and yellow mosaic virus. These are in advanced stages of testing. Treatments with physical and chemical mutagens have yielded chickpea, lentil (*Lens culinaris *Medic), and mung bean mutants with various improved characters. These are under intensive screening and evaluation. Future breeding strategies are: for chickpea, bold seed, resistance to root-rot complex, botrytis gray mold and pod borer, and potential for late sowing and early harvesting; in lentil, earliness, bold seed, resistance to root-rot, wilt and stemphylium; in mung bean and black gram, resistance to or tolerance of yellow mosaic virus and abiotic stresses; and in khesari (*Lathyrus sativus *L.), the isolation of low-neurotoxin varieties. Attempts will be made to improve these crops through mutations and use of mutants in hybridization.*

Introduction

The total area, annual production, and even the per hectare productivity of the major pulses in Bangladesh have been on the decline for quite a long time (Shaikh 1977). The national nutritional crisis foretold by Shaikh et al. (1978) has been aggravated during recent years. The food grain biased policy i.e., increase of rice and wheat production at the expense of other crops (Jabbar 1987) has brought this nation to the brink of total nutritional disaster (Elias 1988).

It was, however, realized by the small groups of pulse researchers at Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Institute of Nuclear Agriculture (BINA) from the mid-1970s that productivity must be improved since increase of hectarage was not possible under the prevalent socioeconomic conditions. A few more years elapsed before a modest pulse-research program encompassing all aspects of production was underway at both the Institutes. The main emphasis was, of course, on varietal improvement. The achievements were reported and analyzed in the First National Workshop on Pulses (Kaul 1982). Progress in the genetic improvement of major pulses at BINA since then will be reviewed and some future strategies will be discussed.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics

Achievements and Present Status

The crops on which research is being done at BINA are: chickpea (*Cicer arietinum* L.), mung bean (*Vigna radiata* (L.) Wilczek), black gram (*Vigna mungo* (L.) Hepper). lentil (*Lens culinaris* Medic), and khesari (*Lathyrus sativus* L.). The achievements in the breeding efforts of these crops during the last 8 years have been summarized by Shaikh (1988) and are mentioned below.

1. Identification of yield components with high contribution.
2. Determination of coefficient of variability for these characters and the scope for their improvement.
3. Establishment of correlation among the components.
4. Collection, screening, and evaluation of germplasm of local and exotic origin, and selection of superior genotypes.
5. Induction of mutations through treatment with physical and chemical mutagens, and selection and development of superior genotypes.
6. Utilization of mutants in hybridization with other mutants and with adapted cultivars.

Chickpea

The number of pods and branches plant^{-1} were found to have positive correlation with seed yield (Ahmed et al. 1986). Partial and multiple correlation studies also revealed a positive correlation between number of pods and seed yield. These studies suggested that number of pods should be considered the best selection criterion.

Treatment of the chickpea cultivar Faridpur 1 seeds with 20 kR gamma rays (60 Co) and subsequent selection of a mutant, M 669, superior in yield and protein content led to the identification of cultivar Hyprosola (Shaikh et al. 1982). It has more pods and seeds plant^{-1} and higher harvest index. The slightly (10%) smaller seed size of the mutant compared to Faridpur 1 is more than offset by the increased number of seeds thereby increasing the total seed yield. Protein content in M 669 was 22.5% compared to 18.5% in the parental cultivar (Tables 1 and 2). The mutant has relatively more field tolerance to pod borer (Shaikh et al. 1982), and Altemaria leaf spot and also improved nodulation and better symbiosis with *Rhizobium* local strain No. TLS (Poddar et al. 1980). The mutant was released in 1982 and named Hyprosola (High-yielding-high protein chickpea).

Oram et al. (1987) studied the isozyme similarity and genetic differences in morphology between Hyprosola and Faridpur 1 and indicated the presence of

Table 1. Mean protein content, protein yield per unit area of land and important amino add content in Hyprosola and Faridpur-1.

Character	Hyprosola (Mean)	Faridpur-1 (Mean)
Protein content (%)	22.5±0.5	18.5 ± 0.4
Seed yield (t ha^{-1})	2.29	1.92
Protein yield (kg ha^{-1})	5153	355.6
Increase in protein yield		
Absolute (kg ha-^{1})	159.7	-
Percentage	45	-
Amino acids (g 16 g^{-1} N)		
Lysine	7.44 ±0.01	8.05 ± 0.40
Methionine	1.56 ±0.04	1.60 ± 0.04
Cystine	1.61 ±0.13	1.61 ± 0.04

Source: Shaikh et al. (1982) and Shaikh (1988).

Table-2. Comparison of various agronomic characters of Hyprosola with the mother cultivar, Faridpur-^{1}.

Character	Faridpur^{1}	Hyprosola
Height (cm)	50-55	45-50
No. of branches plant^{-1}	9	7
Maturity (days)	155	145
No. of pods plant^{-1}	80	92
No. of seeds plant^{-1}	125	155
1000 seed mass (g)	85	75
Harvest index (%)	33	40
Color of mature fruit	Dull	Shiny
Possible population (plants ha^{-1})	70 000 ± 5 000	80 000±500

Source: Shaikh et al. (1982).

a few recessive mutant alleles in Hyprosola. These were alleles for small seeds (ssd), long and narrow leaflets (lnl), and early flowering (efl). The reduced plant height in Hyprosola apparently results from recessive mutation at two loci, rht-1 and rht-2, one of which is linked to ssd with 16 + 6% recombination.

Desirable mutants for earliness, disease tolerance, higher number of pods, and erect plant architecture were isolated from a second batch of irradiated Faridpur 1 seeds (Shaikh 1983). One mutant, G 299 proved its superiority over other mutants and Faridpur 1 (Shaikh et al. 1983).

Sodium azide treatment of Hyprosola seeds resulted in isolation of 15 true-breeding chickpea lines, 9 of which have more pods plant^{-1} and higher yield (Shaikh et al. 1985). These are undergoing further tests.

Mung Bean

Simple correlation coefficients of some agronomic characters of 70 strains revealed significant positive association of number of pods and number of branches with yield plant^{-1} (Ahmed et al. 1981) Seed size, plant height, days to flowering, and maturity were negatively correlated with yield plant^{-1}. Partial and multiple correlation coefficients also revealed a strong association of pods plant^{-1} with yield. It was concluded that pods plant^{-1} should serve as the best selection criterion for improving the yield potential of mung bean. Another study (Shamsuzzaman et al. 1983) showed that in addition to pods plant^{-1}, number of branches also was an important character for selecting high-yielding genotypes.

Two cycles of single plant selections of germplasm collected from Sitakundu (Ahmed et al. 1982) resulted in the isolation of a line, Accession no. MB 55, resistant to cercospora leaf spot and tolerant of mung bean yellow mosaic virus (MYMV). Its yield is 20% more than the recommended cultivar, Kishoregonj (MB 63) (Tables 3 and 4) (Shaikh et al. 1988). Its seeds are about 25% larger than those of Kishoregonj (Ahmed et al. 1978).

Time-of-sowing experiments with 60 local and exotic germplasm lines through fortnightly sowings placed the accessions in groups like "real summer", "modified summer", and winter types. Some of these are of the short-duration type and fit well between two major crops (Begum et al. 1983).

In multilocational trials MB 146, a hybrid derivative from the cross of a mutant x V 5197 yielded more (Shaikh et al. 1988) (Table 5). An Asian Vegetable

Table 3. Mean seed yield (t ha^{-1}) of three selected mung bean lines in different sites and years.

Sites	Year	Seed yield of lines				Trial Mean
		Sitakundu (MB 55)	Golden	Mutant 36	Kishore-gonj[2]	
Kishoregonj	1978/79	1.56a[1]	1.32b	1.18b	1.20b	1.30
Ishurdi	1978/79	0.65a	0.56b	0.48b	0.49b	0.54
Kishoregonj	1979/80	0.83a	0.68bc	0.61c	0.71b	0.56
Ishurdi	1979/80	0.43a	0.28d	0.34bc	0.36b	0.35
Jamalpur	1979/80	0.60b	0.77a	0.52bc	0.41c	0.46
Kishoregonj	1981/82	1.29a	0.95bc	1.08ab	0.75c	1.02
Mymensingh	1981/82	0.99a	0.88b	0.85b	0.74c	0.86
Line mean		0.90	0.78	0.72	0.67	
Regression coefficient		1.1	0.89	0.91	0.77	
Correlation coefficient		0.98**	0.93**	0.98**	0.94**[3]	

1. Means within each row followed by common letters are not significantly different at the 0.05 level.
2. Control.
3. **Significant at the 0.01 level.

Table 4. Combined analysis of variance in mung bean yield trials.

Source of variation	Degree of freedom	Mean square	F-test
Year	2	2167966	300.58**[1]
Year x sites	4	1274761	176.74**
Residual	23	7213	1.06
Cultivars	3	236788	34.68
Year x cultivars	6	38668	5.66
Year x site x cultivar	12	41733	6.11
Residual	69	6828	

1. ** Significant at the 0.01 level.

Research and Development Center (AVRDC) entry V 2272 was comparatively free from YMV, and had more pods and more yield.

Evaluation of gamma-ray induced mutants and germplasm for disease incidence was carried out. Some of these breeding materials showed altered plant architecture and synchrony in maturity (Shaikh et al. 1985).

Dwarf-erect, bold-seeded, synchronous, and high-yielding mutants were selected from gamma-ray treatment of MB 55 and MB 56 (Shaikh et al. 1982). NaN_3 treatment of MB 55 seeds yielded erect and synchronous mutants (Sheikh et al. 1983).

Black Gram

Number of pods and inflorescences plant^{-1} showed a high positive correlation with seed yield. Similarly the former two characters were positively correlated with each other.

Erect, disease-resistant, synchronous, early, and bold-seeded mutants were isolated following gamma-ray treatments (Shaikh and Majid 1982). Mutant M 23 is erect, synchronous, and determinate in growth habit. Its pods are hairless, bolder, clustered, and upright compared to horizontal/downward borne pods of the parental cultivars (Shaikh et al. 1982). Mutant M 25 is synchronous, determinate, slightly more dwarf and its pods are considerably less hairy than the parent B 10. In addition, M 25 is moderately resistant to CLS and YMV and is also higher yielding than both B 10 and B 23 (Shaikh 1988).

Lentil

Number of pods and branches plant^{-1} and plant height were found to be the main contributors to yield (Islam and Shaikh 1978). Promising high-yielding mutants

Table 5. Mean seed yield (t ha^{-1}) of selected mung bean lines in different sites and years.

		Lines							
Site	Year	MB 246	MB 1	MB 1	VC 1000	VC2272	Mubarik (Control)	MB 87 (Control)	Trial mean
Kishorcgonj	1984	0.50a[1]	0.40ab	0.31bc	0.20cd	N.T[2]	0.39ab	0.16d	0.33
Ishurdi	1984	1.63a	1.14b	0.92cd	0.79d	N.T	1.04bc	0.55e	1.01
Kishorcgonj	1985	0.57a	0.48ab	0.23c	0.33bc	N.T	0.45ab	0.27c	0.39
Ishurdi	1985	1.66a	1.23ab	0.73c	0.86bc	N.T	1.25ab	0.61c	1.06
Kishorcgonj	1986	0.74a	0.46b	N.T	N.T	0.69a	0.34b	0.37b	0.43
Ishurdi	1986	1.62a	0.98bc	N.T	N.T	1.40ab	0.96bc	0.91c	0.98
Faridpur	1986	1.24a	0.96ab	N.T	N.T	1.19a	0.84b	0.87b	0.85
Barisal	1986	0.91a	0.39b	N.T	N.T	0.59ab	0.40b	0.58ab	0.48
Line mean		1.11	0.76	0.55	0.55	0.97	0.71	0.54	

1. Figures in a row with common letters do not differ significantly at the 0.01 level.
2. NT = Not tested.

have been selected from the segregating population following acombined treatment of NaN_3+gamma-rays (Shaikhetal. 1985). Advanced tests are being conducted for these.

Khesari

Narrow ranges for days to maturity and number of seeds plant^{-1} were found by Shaikh et al. (1985). Variations for number of pods plant^{-1}, seed size, and yield plant^{-1} were quite high.

NaN_3 treatment of Accession no. GP 1 resulted in isolation of 32 mutants and 6 mutant families (Ali et al. 1986). Mutants had different plant type, earliness, and flower colors.

Number of pods plant^{-1} had the highest coefficient of variation and this character along with plant height were the main yield determinants.

A negative corn-elation was found between seed size and neurotoxin p-(N)-oxalylamino-L-alanine (BOAA) content (Islam et al. 1986). Mutants and local germplasm lines were of the small-seeded type but had higher BOAA content. Exotic ones have a bigger seed size and lower BOAA content. Hybridization between the two groups was started with the objective of combining high yield and low neurotoxin content. Some lines with lower BOAA content and reasonably higher yields are under intensive yield testing.

Future Breeding Strategies

The future breeding strategy for pulses in general will be to achieve:

- larger seed size,
- increased branching, allowing increased fruiting nodes,
- resistance to diseases and pests,
- tolerance of physical stress factors,
- suitability for new cropping patterns, and
- stability of yield over locations and years.

Breeding strategy for specific crops will be as follows:

Chickpea: Bold seed; resistance to root-rot complex, botrytis gray mold and pod borer; potential for late sowing and early harvesting,

Lentil: Bold seed; resistance to root rot, wilt and stemphylium blight; potential for late sowing and early harvesting.

Mung bean and black gram: Resistance to YMV and tolerance to high humidity and rain damage (only for summer mung bean); incorporation of yellow seed coat color in summer mung bean.

Khesari: Development of low-neurotoxin variety.

To achieve the above mentioned objectives, the approaches will be:

- to screen existing germplasm further.
- to create variability through inducting mutation, and
- to develop mutants into varieties or to use mutants as donor parents in hybridization.

Discussion

S.K. Roy: In the case of lentil, how do plant height and number of branches plant^{-1} become yield-contributing characters? Please explain.

M.A.Q. Shaikh: Simple multiple correlation studies and path-coefficient analysis revealed that these two characters had the highest positive influence on yield. This might be due to the fact that lentil plants are very small and have only a few primary branches under Bangladesh conditions. A taller plant with increased branching would have increased sites for pod bearing, thereby increasing the yield. The two characters were indirect contributors to yield.

M.O. Islam: 1. Would you please explain your proposed improved plant architecture of chickpea?
2. So far we know that BINA followed radiation breeding as well as conventional breeding for pulses improvement. Are these your present breeding strategies?

M.A.Q. Shaikh: 1. Less branching, compact plant with semi-erect growth habit will be the future plant architecture.
2. Yes, we also followed conventional breeding in the past along with mutation breeding. Our present mandate is to induce mutations and develop varieties directly from the mutants or to use the mutants as donor parents in hybridization programs.

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Progress and Prospects of Minor Pulses in Bangladesh

M. Matiur Rahman
Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh

Abstract

*Research on six pulse crops was initiated in 1979 but the major effort was concentrated on chickpea (*Cicer arietinum *L.), lentil* (Lens culinaris *Medic), khesari* (Lathyrus sativus *L.*), *andmung bean (*Vigna radiata *(L.) Wilczek). Very little attention has been paid to black gram* (Vigna mungo *(L.) Hepper), pigeonpea* (Cajanus cajan *(L.) Millsp.), and cowpea* (Vigna unguiculata *(L.) Walp.). Fieldpea* (Pisum sativum *subsp* arvense) *has not been included for research so far due to resource constraints. One black gram line was proposed to the National Seed Board for release. Short-duration pigeonpea has been studied in different locations and one promising line, 76012, was identified. Some local and exotic germplasm lines of black gram and cowpea have been collected and evaluated. These may fit into new cropping patterns and specific situations. Black gram can be grown as a relay crop with flood-affected* aman *(rainy-season) rice. Short- and medium-duration pigeonpea may be grown as a mixed crop with black gram or on field bunds, and in the Chittagong hill tracts. Apart from the traditional areas, cowpea has the potential to be grown in the southern parts of the country in the* aman *rice-cowpea-aus (rainfed) rice cropping pattern. Thus these minor pulse crops can play a significant role in halting the declining pulses area and production provided high -yielding cultivars are developed. These possibilities along with the need for specific types of cultivars have been discussed in this paper.*

Introduction

A multidisciplinary coordinated research effort on six pulse crops, lentil *(Lens culinaris* Medic), chickpea *(Cicer arietinum* L.), khesari *(Lathyrus sativus* L.), mung bean *(Vigna radiata* (L.) Wilczek), black gram *(Vigna mungo* (L.) Hepper), and pigeonpea *(Cajanus cajan* (L.) Millsp.) was initiated at the Bangladesh Agricultural Research Institute (BARI) in 1979. Later cowpea *(Vigna unguiculata* (L.) Walp.) was included in the program. Lentil, chickpea, and khesari are grown in winter and account for about 80% of the total pulses (Islam and Rahman 1990). Mung bean contributes 5%, and has the special advantage of being a short-duration crop, and so can be used as a catch crop. Hence a major emphasis was given to these four crops. Little attention has been paid to black gram, pigeonpea, and cowpea due to resource constraints. Fieldpea *(Pisum sativum* subsp *arvense)* has not yet been included in the program. Some progress has been made in germplasm collection and evaluation, identification of biotic and abiotic constraints, and in developing potential cropping patterns for these crops. These pulses can play a significant role in increasing production if suitable high-yielding cultivars are developed with specific characters for particular situations. The objective of this paper is to describe the present position, and prospects for future research on these crops.

Black Gram

Black gram is the fourth most important pulse crop of Bangladesh, grown on 33 600 ha, producing 24 000 t of grain with a mean yield of 714 kg ha^{-1}, and contributing about 13% of the total pulses (Islam and Rahman 1990). It is generally sown in August/September in well-drained high or medium highlands after harvest-

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

ing upland *aus* (rainfed) rice or jute in the *aus* rice/jute-black gram-fallow/wheat cropping pattern. Some farmers grow this crop in October/November in the *char* (sandy) land after the flood water recedes or sometimes as a relay crop with flood-affected *aman* (rainy-season) rice. It is also grown under zero-tillage conditions, on the roadside or by dams, mostly for fodder purposes.

Most of the late-sown crop is affected by powdery-mildew (PM) disease which may cause a yield loss of about 32% (BARI 1987). Local cultivars suffer damage by yellow mosaic virus (YMV).

There is variation among local cultivars for growth pattern, duration, disease reaction, etc. Short-duration cultivars (70-75 days) are grown in the *aus* ricc/jute-black gram-postrainy-season (*rabi)* cropping pattern. Long-duration cultivars (85-95 days) are grown in the *aus* rice-black gram-fallow cropping pattern. The latter pattern is being replaced by the *aus* rice-fallow-postrainy-season cropping pattern, and consequently the area under black gram is shrinking.

Current status

About 300 local and 450 exotic germplasm lines have been collected from India and Pakistan and evaluated for earliness and high yield potential. The variation for yield and yield-contributing characters is very low although there is some variation in seed size (100 seed mass varies from 3.0-5.3 g), crop duration (65-85 days), pods plant^{-1}, and pod pubescence (BARI 1986). The local collections are daylength sensitive and exotic ones are mostly photoinsensitive. One day length-insensitive line (MAK 1) has been placed before the National Seed Board (NSB) for release. Currently these germplasm lines are being screened against PM and YMV diseases to identify resistance sources. Some sources of resistance have been identified against YMV but none has been found against PM so far.

Prospects

Black gram is a more hardy crop, more tolerant to waterlogging, and has fewer disease and insect problems compared to other pulses. It also produces more stable yields and can be grown with minimum care. If a high-yielding variety is used, the total production can be increased with the existing cropping pattern. A cropping pattern trial has been conducted with the black gram line MAK 1 and it was found that it can be grown under minimum tillage. It was found to fit well into the *aus* rice-black gram-lentil wheat/mustard cropping pattern (BARI 1986). This pattern is suitable for light-textured soils in high or medium highlands with adequate drainage facility. If this pattern could be extended, a large area would come under pulses without disturbing the existing cropping pattern. Damage by floods has become a regular phenomenon in Bangladesh, and a search is on for suitable alternate agricultural technology. Black gram can play an important role in this respect. High-yielding varieties with late-sowing potential (October-November), resistance to PM, and with potential to be sown as a relay crop with partially damaged *aman* rice are required.

Future research

Future breeding efforts should focus on developing short-duration (65-70 days), high-yielding, YMV-resistant varieties suitable for the *aus* rice-black gram-postrainy season cropping pattern, and high-yielding, powdery mildew-resistant varieties for the postflood situation. In both situations varieties capable of growing under minimum-tillage conditions are desirable. Therefore, hybridization programs and selection involving the normal cultivated type and the fodder types (which are grown with minimum tillage) should be made under those conditions.

As a general strategy additional exotic germplasm should be collected, and an extensive crossing program initiated to create variability. The podding potential in black gram is greater (Lawn and Ahn 1985) hence the number of pods per plant may be used as a selection criterion. For pulses in general, emphasis should be laid on slightly larger seed size during selection. In addition, an effort should be initiated to select pure lines from the landraces. Simultaneously further agronomic studies should continue on the cropping pattern involving black gram. It has been observed that black gram has a depressing effect on the subsequent postrainy-season crops. A similar result has been reported from Australia (Lawn and Ahn 1985). Detailed studies should be undertaken to overcome this problem.

Pigeonpea

Pigeonpea is one of the minor pulses grown in Meherpur, Kushtia, Jessore, parts of Pabna and Rajshahi districts, and also along the roadsides almost throughout the country. It was grown on 3238 ha, producing 2072 of grain with a mean yield of 640 kg ha^{-1} in 1985/86 (BBS

1986). The long-duration (about 300 days), tall pigeonpea is grown in this country mainly for fuel purposes. It is sown as a mixed crop with *aus* rice, finger millets, etc., in April/May and harvested during February/March. Its area is also declining due to competition with the postrainy-season crops, and is now relegated mainly to the roadsides and backyards.

Current status

BARI has introduced some short-duration pigeonpea from ICRISAT and United States Department of Agriculture (USDA). Of these, four lines have been evaluated over locations for several years and one promising line, 76012, has been identified (Table 1). On an average they produced a yield of 1300 kg ha^{-1} within 125-135 days. The lines showed a yield potential of 2300 kg ha^{-1} at Ishurdi in 1985/86 and about 4000 kg ha^{-1} at Bogra in 1987/88. It was shown that the optimum time of sowing for these pigeonpea lines is September, a difficult time to find land for this crop. Alternatively it has been found growing as a mixed crop with black gram in the *aus* rice-black gram-fallow cropping pattern. The pigeonpea line 76012 will be placed before NSB for release.

Prospects

Though pigeonea is a minor crop, it has the potential to fit into the diversified cropping systems practised in this country. One of the cropping patterns in the northern part of this country is *aus* rice-black gram-fallow. In this pattern farmers cannot grow postrainy-season crops after black gram due to lack of moisture at sowing time. In this pattern short-duration pigeonpea can be grown as a mixed crop with black gram. Pigeonpea is sown in lines 60 cm apart along with broadcasted black gram. Black gram is harvested in December when pigeonpea attains a height of about 60 cm and begins to flower. Thus it does not affect the black gram yield. If this cropping system is extended, a large area can be brought under pigeonpea which otherwise remains fallow. Another possibility would be to grow pigeonpea as an "aisle" crop around the bunds of rice fields throughout the northern parts of the country where it should be sown by the dibbling method. This is a very common practice in eastern Nepal. For this practice probably high-yielding medium- and long-duration pigeonpea may be good. High-yielding, long-duration varieties may also be tried as sole crops or bund crops in the traditional areas as well as in hill farming.

Future research

There are variations among the fanners' cultivars in respect of disease reaction (to sterility mosaic), growth habit, and yield. Therefore local germplasm should be collected and evaluated so as to select the best lines. Fortunately ICRISAT is working on this crop arid a huge genetic diversity is available. We should take this opportunity to develop short-, medium- and long-duration, high-yielding varieties suitable for our cropping system, through introduction and selection.

Mixed-cropping experiments to determine population density, spacing, and fertilizer placement should continue. Large-scale demonstration of bund cropping in *Barind* and other highland areas should be emphasized.

Cowpea

Cowpea, locally called *Falon* is the most important pulse crop in the Chittagong Division. It is mostly grown in Chittagong, the Chittagong hill tracts, and the southern part of Noakhali. It is also grown sparsely in Barisal and Patuakhali and the coastal islands. In Chittagong and Noakhali it is sown from the end of November till mid-January in the transplanted *aman* rice-cowpea cropping pattern. The local cultivars are of the long-duration type, which take about 130 days to mature, and are indeterminate in habit.

Current status

Some research was initiated on cowpea in 1984 at Regional Agricultural Research Station (RARS) Hathazari, Chittagong, and since then it has been serving as the only station for cowpea research (BARI 1985). There is a tremendous shortage of manpower but despite this they have made some progress in germplasm collection and evaluation. About 50 germplasm lines were collected from Australia and two local (black- and pink-seeded) lines were evaluated over several years. The two local collections were found better for yield and other characters (Table 1).

The insect-pest complex has been surveyed in the Chittagong area. Six insect pests have been identified (BARI 1986): stem and pod flies (*Ophiomyiaphaseolh Melanoagromyza obtusa).* Aphid *(Aphis craccivora),* Gaierucid *(Madurasia obscurella),* hairy caterpillar *(Diacrisia obliqua),* *(Amsacta moorei),* spotted pod borer *(Maruca testulalis),* and hairy-streak blue-butterfly pod borer *(Echrysias cnejus).* Pod borer and

Table 1. Mean performance of the advanced promising lines or cultivars of different crops over locations, 1984/85 and 1985/86.

Crop	Variety/ line	Days to flowering	Days to maturity	Plant height (cm)	Pods $plant^{-1}$	100-seed mass (g)	Yield ($t\ ha^{-1}$)	Remarks
Black gram	MAK-1	36	80	47	33	4.1	1.70	Daylength-insensitive type
Pigeonpea	76012	56	124	84	96	6.2	1.31	Highest yield of 2.35 $t\ ha^{-1}$ at Ishurdi and 3.98 $t\ ha^{-1}$ at Bogra
Cowpea	(a) Local pink	93	131	63	12	9.9	1.83	More Common
	(b) Local black	103	137	98	17	12.9	2.19	

Source: BARI (1985), (1986).

galerucid are the more serious pests. Pod borer causes damage to the pods to an extent of 47% (BARI 1987).

Prospects

Cowpea is more stable and has higher yield potential compared to other pulses in Chittagong area. With high-yielding varieties the present production can be increased substantially in the traditional areas of cultivation. Its cultivation may also be extended in the southern districts like Barisal, Patuakhali, Bhola, etc. in the t. *aman* rice-cowpea-aus rice cropping pattern. Cowpea also responds well to high management compared to other pulses, so the present production can be increased.

Future research

Cowpea research has received strong international support. The International Institute for Tropical Agriculture (IITA) has a strong program for cowpea research. Many national programs like those in India, Philippines, USA, and Australia, have also placed much importance on its research. Therefore, this has good prospects of development, provided we assign sufficient manpower and resources are assured. Therefore, in the future, the following steps may be taken.

1. Cowpea research should be strengthened at RARS, Hathazari by increasing the manpower resources. Another substation for cowpea research can be developed at Rahmatpur, Barisal.
2. Local germplasm should be collected from the traditional areas.
3. More germplasm should be collected from different international sources.
4. A disease survey should be done and yield losses due to major diseases determined.
5. Economic control measures against major insects should be developed.
6. Links with IITA should be strengthened and international nurseries like the Bruchid-resistant nursery, short-duration determinate type nursery, etc., should be introduced, and tested in our environment to select the better lines.
7. If suitable genotypes for specific characters are identified, hybridization programs may be taken up and the segregating materials be handled through the modified bulk method (Navarro 1985).
8. Research on cultural management should be strengthened over locations to improve yield through cultural manipulation.

Discussion

A. Hamid: In your paper "Progress and prospects of minor pulses in Bangladesh" you mentioned that RARS, Hathazari has been serving as the only station for cowpea research. This is not true. In IPSA we have been working on agronomic and physiological aspects of cowpea production for the past several years. Some of our findings have been published in national and international journals. The BAI Agronomy group is also working on cowpea.

M.M. Rahman: I mentioned that BARI's cowpea research is only concentrated at Hathazari. Thank you for the other information.

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Session II:
Crop Management

Soil Nutrient Status Affecting Productivity of Pulses in the Major and Potential Pulse-Growing Areas

M.S.Islam
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

A brief description of the general soil types of the major and potential pulse-growing areas of Bangladesh is given. Seven general soil types have been identified as being suitable for these crops. The soil pH of the majority of such soils are near neutral to alkaline. Organic-matter content is low to medium in most cases. The mean field capacity of these soils is 30 - 40%. Supplemental irrigation is necessary in the postrainy season. The Ca and Mg supplying capacity of the soils is generally adequate except in a few soil series where external Mg supply would be beneficial. Exchangeable-potassium content ranged from medium to high. Available phosphate supplies are generally low. Nitrogen is critically deficient in all soils. Sulphur supplies vary from critically low to adequate. Among micronutrients only boron and zinc have been found deficient in almost all soil series. The availability of Cu, Fe, and Mn is generally considered adequate. Nutrient requirements of various pulse crops based on yield goals have been given.

Introduction

Well-drained friable soils with good moisture-holding capacity such as deep silt loam and silty clay loam are most suitable for growing pulses. In Bangladesh pulse crops are mainly cultivated in the districts of Pabna: khesari (*Lathyrus sativus* L.), black gram *(Vignamungo* (L.) Hepper), chickpea *(Cicerarietinum* L.), lentil *(Lens culinaris* Medic), and fieldpea *(Pisum sativum* subsp *arvense);* Jessore: chickpea and lentil; Faridpur: chickpea, lentil, pea, mung bean *(Vigna radiata* (L.) Wilczek), black gram, and khesari; and Kushtia: chickpea and lentil (BBS 1987). Cowpea *(Vigna unguiculata* (L.) Walp.), is mainly grown in Chittagong and Bhola districts.

General Soil Types

The general soil types of the pulse-growing areas include mainly noncalcareous gray floodplain soils, noncalcareous dark gray floodplain soils, calcareous dark gray floodplain soils, calcareous gray floodplain soils, and gray piedmont soils. A brief description of these general soil types follows.

Noncalcareous alluvium

This general soil type consists of recent deposits carried by Tista, Brahmaputra, Jamuna, Middle Meghna, and some smaller rivers that usually occupy active floodplains. The soils are gray in color and stratified from the surface. These are mainly sandy loam to silty loam in texture and are deeply flooded during the monsoon. Lentil and khesari are among the pulses currently grown in a scattered manner on these soils.

Calcareous alluvium

These soils occur on the active floodplain of the Ganges and extensively in the Meghna Estuary. These soils show stratification either from the surface or from within 25 cm of the surface. They are generally olive-gray to olive-brown. The soils are sandy loam to silty loam in texture and the seasonal flooding is generally

Citation: BAR1 (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

deep. Some soils in the southern parts of Noakhali and Patuakhali are also affected periodically due to salt water flooding and most become saline in the top layers during the dry season. Chickpea, lentil, khesari, cowpea, and mung bean are widely grown on these soils.

Noncalcareous gray floodplain soils (nonsaline phase)

These soils occupy most of the Tista, Jamuna, eastern Surma-K Kushiyara, middle Meghna and the Gangetic floodplains. They also occupy some parts of the old Brahmaputra and old Meghna estuarine floodplains. The soils are gray or olive-gray when dry but become darker when wet and reduced in the monsoon season. The soils are mainly loam to clay loam in texture. They are seasonally flooded and characterized by the presence of gray flood coatings along subsoil cracks and pores. Chickpea, lentil, and khesari are grown on these soils.

Noncalcareous dark gray floodplain soils

These soils occur widely on the old Brahmaputra and old Meghna floodplains. They are seasonally flooded and characterized by the presence of dark gray to black flood coatings along the subsoil cracks and pores. They are loam to clay loam in texture. Chickpea, lentil, and khesari are grown in a scattered manner on these soils.

Calcareous dark gray floodplain soils

This general soil type includes a wide range of soils varying from friable, oxidized, and calcareous ridge soils. They are mainly characterized by the presence of dark gray flood coatings and occupy most of the Ganges river floodplains of Rajshahi, Pabna, Manikganj, Kushtia, Faridpur, and Jessore districts. These soils are generally deeply flooded in the monsoon season. They are dark gray but sometimes brown on ridges, and loamy in texture. These soils are suitable for the cultivation of all kinds of pulses.

Calcareous brown floodplain soils

These soils occur extensively on the highest parts of floodplain ridges on the Ganges river floodplains. They also occur to a lesser extent on the lower Meghna estuarine floodplain and on the narrow ridges in the Ganges tidal floodplain. The brown-colored soils are loam to clay loam in texture. Some of the soils lie above normal flood level and others are mainly flooded to shallow depth for a short period during the monsoon season. All pulses can be grown on these soils.

Gray piedmont soils

These soils are developed from the alluvial outwash materials which accumulate at the feet of the northern and eastern hills. Seasonal flooding is mainly shallow but occasional flash floods from the hills occur. The soils are gray to pale brown in color when dry and become reduced in the monsoon season. These are mainly loamy in texture, sandy near the hills and along stream channels, silty and clayey further away where they merge into gray or dark gray floodplain soils or into acid-basin clays. Of the pulses, cowpeas are extensively cultivated in these soils.

Nutrient and Moisture Status

Noncalcareous alluvium

These soils are slightly acidic to near neutral. Their pH ranges from 5.9 in Shaghatta soil series to 6.5 in Bonarpara and Kanuia series. Organic matter content of these soils is around 1.0%. However, levels as low as 0.57% are present in Sarikandi soil series. The calcium and magnesium content of these soils is satisfactory. Ca values range from 3.0 to 7.1 meq 100 g^{-1} of soil while Mg values range from 1.41 to 1.73 meq 100 g^{-1} soil. The potassium status is variable. K values may be considered low, and a liberal dressing of potash is necessary to obtain optimum yields. Nitrogen is deficient in all soil series with NH_4-N values ranging from 8-17 µg g^{-1} soil. Phosphorus content is quite variable. Bonarpara and Sariakandi soil series contain phosphate values below critical level. Other soil series may be classed as medium with respect to phosphate content.

Among the micronutrients copper, iron, and manganese contents are satisfactory. Boron content is variable and ranges from trace to 0.40 µg g^{-1} soil. Poor pod formation and sterile grains in some soil series may be associated with boron deficiency. Zinc content is low and external supply will be beneficial.

These soils contain a good amount of moisture (32-

45%) at field capacity. Supplemental irrigation would ensure better crop production in the postrainy season.

Calcareous alluvium

The soils are mainly calcareous but the top soil on the lower Meghna estuarine is often noncalcareous. The pH values of these soils range from 6.9 to 8.0. Organic matter content is variable, ranging from 1.12 to 2.50%. It is low in Darshana series and high in Ramgati series. Calcium and magnesium contents are high in almost all series except Ramgati where 3.7 meq 100 g^{-1} and 1.12 meq 100 g^{-1} soils are present. In other series Ca values vary between 17.6 and 22.8 meq 100 g^{-1} soils while Mg values vary between 3.97 to 5.56 meq 100 g^{-1}. Exchangeable potassium contents are satisfactory in almost all soil series except Darshana and Ramgati. However, a maintenance dose of potassium would be beneficial. Nitrogen is highly deficient. NH_4 - N content ranges from 5 to 16 µg g^{-1} soil. Phosphorus supply of these soils is low and results in poor seed yield of pulses. All calcareous soils may be classified as low in phosphorus and an adequate amount must be added to raise its content to the optimum level. Sulphur content is satisfactory in almost all series except Darshana which contains only 9 µg SO_4 -S g^{-1} soil. However, a basal dressing would be beneficial.

All calcareous soils are rich in micronutrient contents except those with high pH where zinc deficiency is prevalent. It is necessary to apply zinc in these high pH soils otherwise the productivity of pulses will be reduced.

These soils have higher field capacity (33-39%). Even this soil moisture is not sufficient for postrainy-season crops. Supplemental irrigation or rainfall is necessary for good production of postrainy crops.

Noncalcareous gray floodplain soils (nonsaline phase)

These soils usually have low to medium acid content with pH values ranging from 6.0 to 6.5. Except in two series organic matter content is below 1 %. Polashbari series has the lowest organic matter content (0.34%).

Among the five series reported here Ca values are satisfactory. Magnesium is deficient in most of these. The values range from as low as 0.51 to 0.97 meq. Mg 100 g^{-1} soil. Exchangeable potassium is satisfactory in four of the five series. The Gangachari series has as low as 0.15 meq K 100 g^{-1} soil. Nitrogen is critically deficient with NH_4-N values ranging from trace to 37 µg g^{-1} soil. Among the five series Gangachari has available phosphate below critical level. In other series the status is satisfactory. Sulphur is deficient in most of these soil series. The values range from 12 to 28 µg SO_4-S g^{-1} soil.

Among the micronutrients boron is deficient only in the Pirganj series, and zinc in nearly all. Copper, iron, and manganese contents appear to be adequate. The mean field capacity of these soils is about 34-39% which indicates better moisture storage capacity for crop production.

Noncalcareous dark gray floodplain soils

The pH of these soils is slightly acidic to neutral. The pH ranges from 6.2 in the Naraibag series to 7.0 the in Chandina series. Organic matter content is low. Chandina series has the lowest value of 0.57%. In other series the values range from 1.30% in the Tippera series to 2.0% in the Buricheng series. These soils contain good amount of moisture (34%) at field capacity. Supplemental irrigation is necessary in the postrainy season.

Calcium and magnesium contents of these soils are satisfactory with Ca values ranging from 2.9 meq 100 g^{-1} soil in the Tippera series to 11.3 meq 100 g^{-1} in the Ghatail series and Mg values from 0.95 meq 100 g^{-1} soil in Tippera to 3.60 meq 100 g^{-1} soil in Chandina series. Potassium status is fairly good and varies from 0.32 meq 100 g^{-1} soil in the Tippera series to 0.54 meq 100 g^{-1} in Shilmondi series. Only a maintenance dose is needed to obtain maximum economic yield. Nitrogen is critically deficient in all soil series. Of the 7 soil series 4 have available phosphate values above critical level. In the other 3 soil series phosphate values are critically low.

Among the micronutrients only boron and zinc are severely deficient in most of the soil series. In Buric hang, Chandina, and Sonatola series only trace amounts of boron are detectable. Copper, iron, and manganese contents are satisfactory.

Calcareous dark gray floodplain soils

The topsoil is calcareous having pH values ranging from 7.2 to 8.1. Organic matter content is quite variable (0.95-2.00%). Organic matter is lowest in Ishurdi and highest in Gopalpur series. The mean field capacity of the soils lies between 31 and 40%. Supplemental irrigation is necessary in the postrainy season.

Since these soils are calcareous it is expected that calcium and magnesium contents would be high. Values as high as 24.9 meq Ca and 5.12 meq Mg 100 g^{-1} soil occur in the Mehendigen series. The comparatively low value of 7.8 meq Ca 100 g^{-1} soil in Ghior indicates that some decalcification might have taken place.

Potassium contents are quite high. This is due to the presence of a large amount of potash-bearing minerals in these soils. Nitrogen is deficient in all series. Phosphate is deficient in some. The available phosphate contents range from 7 µg g^{-1} soil in Sara and Mehendiganj series to 27 µg g^{-1} soil in Gopalpur series. Sulphur is critically deficient only in Sara series. In other soil series its content is adequate.

Among the micronutrients only a trace of boron is detectable in the Sara series. In other series boron content is sufficient. Copper, iron, and manganese contents are quite satisfactory. Zinc deficiency is prevalent in all soil series because of their high pH values.

Calcareous brown floodplain soils

These soils are calcareous having pH values ranging from 6.8 in Rupper series to 8.0 in Darshana series. Organic matter contents are generally low. Ruppur series has the lowest values (0.40% while Gangetic Alluvium contains the highest amount of organic matter (1.80%). These soils have a higher field capacity (37-42%). Supplemental irrigation would ensure better crop production in the postrainy season.

Calcium and magnesium supplies are high in almost all series except Mirpur and Ruppur. Comparatively lower contents of calcium in these series indicate that some decalcification has taken place. Except Mirpur and Ruppur, all other series have sufficient supplies of exchangeable potassium. Nitrogen is critically deficient in all the soil series. In Mirpur and Ruppur series only trace amounts are detectable. Phosphorus is generally low. Except Jhenaidah and Ruppur all other series have available P contents below critical level. Sulphur is highly deficient in all series of these soils. Sulphate values are much below critical level. In Ruppur series only trace amount is detectable.

Among micronutrients boron content is highly variable. It varies from trace amounts in Mirpur and Ruppur to 1.14 µg g^{-1} soil in Jhenaidah series which could be toxic. Copper is sufficient except in the Ruppur series. Iron content is high. In Ruppur and Nachole series manganese is comparatively low. All the soil series have exchangeable zinc below critical level.

Gray piedmont soils

These soils are acidic. The soil reaction is mildly to strongly acid. The pH ranges from 5.4 to 6.0. Organic matter contents are generally low. Except Sitakundu and Pahartali all other series have organic matter content of around 1.5%.

Calcium and magnesium contents are adequate. Calcium contents range from 4.6 to 7.1 meq 100 g^{-1} soil while magnesium contents range from 2.00 to 3.67 meq 100 g^{-1} soil. Nitrogen contents are below the critical level in all soil series. Phosphorus deficiency is common in almost all series. Other than Sitakunda and Roozan series, all the soil series have available phosphate values much below critical level. Sulphur supplies are medium. Only Sitakundu and Miresharai soil series have available sulphate below critical level.

Among micronutrients boron content is quite variable. It ranges from trace amounts in Sitakundu to 0.66 µg g^{-1} soil in Noapara series. Copper, iron and manganese supplies are adequate. Zinc content is also adequate except in Barkal where it is much below critical level. These soils have 31-35% mean soil-moisture content at field capacity.

Nutrient Requirements

Nutrient requirements of different pulse crops depend on initial fertility status as well as yield goals. In Bangladesh pulse crops are generally grown without any fertilizers and manures. Information on nutrient requirements of various pulse crops is scanty. However, a short review on current information is furnished below.

Chickpea

This crop can meet its nitrogen requirement by symbiotic fixation of atmospheric nitrogen. Since Bangladesh soils are critically deficient in nitrogen, a basal application of 20 - 30 kg N ha^{-1} has been found to increase the seed yield of chickpea (BARC 1981 to 1984).

Response of chickpea to phosphate fertilization is high (Table 1). Khanom and Islam (1984) obtained yield increases (31%) by application of 30 kg P_2O_5 ha^{-1}. A further increase of about 15% was reported by the additional application of 30 kg P_2O_5 ha^{-1}. Islam et al. (1985) observed the beneficial effect of potash fertilization on grain yield of chickpea in calcareous brown floodplain soils. The sulphur progressively increased the pod and straw yields of chickpea (Table 2)

Table 1. Response of chickpea to phosphate fertilization at Jessore, Jamalpur, and Faridpur, Bangladesh, 1961-84.

	Yield (t ha^{-1})				
	Jessore			Jamalpur	Faridpur
P_2O_5 (kg ha^{-1})	1980/81	1981/82	1982/83	1983/84	1983/84
0	0.57	0.62	1.37	0.82	1.03
30	0.68	0.66	1.78	1.04	1.39
60	0.89	0.99	1.96	1.20	1.66
90		0.90	1.91	1.64	1.75
CD. (0.05)	0.06	0.07	0.31	0.13	0.20

with increasing rates approaching 25 kg S ha^{-1} (Talukder et al. 1984).

In the case of micronutrients, responses to boron and zinc were observed in noncalcareous gray floodplain and calcareous brown floodplain soils. Boron addition helped in forming nodules and thereby increased yield. Further investigations are in progress. Zinc application at the rate of 5 kg ha^{-1} increased grain yield from 0.81 t ha^{-1} in the control plot to 1.02 t ha^{-1} in a treated plot (Table 2).

Lentil

Very little work has been done on this crop under Bangladesh soil conditions. Khanom and Islam (1983) observed that application of phosphate (up to 60 kg P_2O_5 ha^{-1}) increased the grain yield of lentil in the gray floodplain soil of Jamalpur (Table 3). Phosphate fertilization had no effect on per cent N and P content. In calcareous brown floodplain soils, Islam et al (1985) obtained beneficial effects of 90 kg K_2O ha^{-1} along with N30 P60 in increasing the grain yield. In other trials in gray floodplain and calcareous brown floodplain soils phosphate and potash application significantly increased grain yields at both locations. Sulphur and zinc application had little effect. In another missing nutrient trial conducted in calcareous brown floodplain soils of Rajshahi the significant combined influence of N,P,K,S,Zn, Cu, B, and Mo, was noted over the control plot.

Table 2. Effect of sulphur or zinc application on seed and straw yield of chickpea at Jessore, Bangladesh, 1964/85.

	Yield (t ha^{-1})			Yield (t ha^{-1})	
Sulphur (kg ha^{-1})	Seed	Straw	Zinc (kg ha^{-1})	Seed	Straw
0	0.18	2.42	0	0.81	2.43
25	1.07	3.15	5	1.02	3.20
50	0.88	2.64	10	0.93	2.78
CD. (0.01)	0.06	0.35		0.06	0.35

Table 3. Seed ami stalk yield and nutrient uptake by lentil at different levels of phosphate fertilization at Jamalpur, Bangladesh, 1981/82.

P_2O_5 (kg ha^{-1})	Seed yield (t ha^{-1})	N content (%)	N-uptake (kg ha^{-1})	P-content (%)	P-uptake (kg ha^{-1})
0	0.68	3.97	27.0	0.53	3.6
30	0.86	4.34	37.3	0.60	5.2
60	0.93	4.36	40.7	0.67	6.3
90	0.73	4.08	29.4	0.59	4.3
CD. (0.05)	0.09	-	NS	-	NS

Mung bean and black gram

Information on nutrient requirement of mung bean and black gram under Bangladesh soil conditions is meagre. Islam et al. (1986) found that 20 kg S ha^{-1} significantly influenced the grain yield of mung bean, and 30 kg S ha^{-1}, that of black gram (Table 4). In another trial Ahmed et al. (1984) observed that grain and straw yields of mung bean increased significantly with increasing addition of phosphorus up to 60 kg P_2O_5 ha^{-1} (Table 5). Application of sulphur up to 40 kg ha^{-1} progressively increased yield and protein content of mung bean. There is little information available on

Table 4. The response of mung bean and black gram to sulphur ferilizatlon at Joydebpur, Bangladesh, 1983/84.

Sulphur (kg ha^{-1})	Mung bean Seed yield (t ha^{-1})	Sulphur (kg ha^{-1})	Black gram Seed yield (t ha^{-1})
0	1.08	0	0.90
20	1.29	15	1.04
40	1.06	30	1.10
		45	0.79
CD. (0.05)	0.15		0.07

Table 5. Effect of phosphorus and sulphur on seed yield and protein content of mung bean at Joydebpur, Bangladesh, 1983/84.

			Protein content (%)	
(kg ha^{-1})	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Seed	Straw
0	0.54	0.91	21.1	4.27
30	0.55	0.99	22.1	4.93
60	0.57	1.09	24.1	5.31
90	0.56	1.04	24.9	5.75
CD. (0.01)	0.070	0.06	0.90	0.28
S(kg ha^{-1})				
0	0.54	0.32	21.1	4.53
20	0.55	1.00	23.1	4.89
40	0.58	1.11	25.0	5.78
CD. (0.05)	0.032	0.08	0.11	0.54

the nutrient requirement of these pulses under Bangladesh conditions.

Fertilizer Recommendations

On the basis of available information Islam and Amin (1988) suggested fertilizer doses for various pulse crops in Bangladesh (Table 6). Soil fertility and yield goals were the main criteria in formulating such recommendations.

Table 6. Recommended doses of nutrients for obtaining given yield levels for various pulse crops.

	Kg ha^{-1}				
Fertility status	N	P_2O_5	K_2O	S	Zn
Low	10-15[2]	30-40	25-30	8-10	3
Medium	5-10	25-30	20	0-7	0
High	0	15-20	0-15	0	0

1. Yield levels (t ha^{-1}): chickpea and lentil: 1.0-1.5; mung bean and black gram: 0.6-0.8; khesari: 0.8-1.0.
2. Lower ranges are usually for khesari.

Conclusion and Future Research Needs

Due to competition with cereal crops, pulses are being pushed to marginal lands where nutrient limitations are severe. As a result pulses area and productivity are decreasing. Poor nodulation and pod setting in many soils are associated with nutrients that are not commonly used by the farmers. Furthermore, new problems are appearing in many pulse-growing areas. Limited research conducted in the country has indicated that it is possible to increase yields of pulses substantially through proper soil-fertility and water-management practices. Therefore, research on nutrient and water requirement of pulses under varied soil conditions of Bangladesh should be undertaken on a priority basis.

Discussion

M.S. Hoque: All soils may not contain effective rhizobia in sufficient numbers for adequate nitrogen fixation to meet the requirement of a pulse crop. Added nitrogen will increase crop growth and yield in soils where suitable rhizobia are absent or sparse. But if inoculation is used added urea-N may not be needed.

M.S. Islam: Yes. I fully agree.

D.G. Faris: Can you give us an idea of the percentage the various soil types occupy in Bangladesh?

M.S. Islam: It is very difficult to give the percentage of each general soil type. Alluvial soils comprise about 80%, hill soils 12%, and terrace soils 8%. About 50% of alluvial soils are suitable for growing pulses.

M.R. Ali: In one of your slides, in the Gangachari series the plants grown in optimum soil also show deficiency symptoms like that of Mg, why?

M.S. Islam: Mg deficiency was not observed in the predicted optimum treatment.

S.K. Roy: Were the fertilizer doses calculated under irrigated or nonirrigated conditions?

M.S. Islam: Fertilizer doses have been calculated on the basis of yield goal and initial soil fertility. We recommend supplemental irrigation (wherever possible) if the winter rainfall is not enough.

D.G. Faris: You have given many results and have indicated the need for further studies. However, (1) Do you feel you have enough information for providing appropriate fertilizer and cropping packages for farmers? (2) If so, do you have these packages already put together and given to the Extension Service for trial by farmers ? (3) Do you have a feedback mechanism from the farmer as to the effectiveness of the packages and need for adjustment of packages ?

M.S. Islam: (1) For the Ishurdi area (calcareous brown floodplain soils) we have information for two cropping patterns for the farmers. (2) We think we can give fertilizer information for the patterns we have tested, to extension service for trial by the farmers. (3) We have a feedback mechanism but it needs to be strengthened.

M.A. Karim: In your trials on plant nutrients you found very good response of some added nutrients on the crop yield. Did you repeat the above experiments for 2-3 years and get the same results ?

M.S. Islam: Yes. We repeated the field trials at least for two years. Sometimes we noted variations between 2 years' results. But the responses to added nutrients in deficient soils were significant.

A. Ahad Mian: What cultivars of chickpea, lentil, black gram, mung bean, etc. have you used in your micronutrient trials? In spite of application of micronutrients the yield levels of those pulses recorded by you seems to be lower compared to yields obtained in our experiments without the application of micronutrients. Can you kindly explain?

M.S. Islam: The cultivars we have used were chickpea cultivar Sabur 4; lentil cultivar L 5; black gram cultivar Baromashi; and mung bean cultivar Mubarik. Yields obtained with different fertilizer treatments have been reported. The other yield function was maintained constant for fertilizer treatment. It is very difficult to understand how you obtained higher yields without application of any fertilizer since Bangladesh soils are generally deficient in 3 to 5 nutrient elements.

C.L.L. Gowda: In your fertilizer recommendation, why have you kept a yield target of 1.5 t ha^{-1} when the potential is 3.5 t ha^{-1} ?

M.S. Islam: Only medium- or moderate-yield goals have been considered. We can also suggest fertilizer inputs for low or high yield goals.

A. Islam: Since fertilizer is a costly input, your trial should be accompanied by a partial budget analysis.

M.S. Islam: Yes. I fully agree.

A. Razzaque: What are the critical levels of B, Zn, and S for pulse crops? What should the fertilizer dose be for different pulses?

MLS. Islam: Critical levels for B, Zn, and S are 0.2, 2, and 14 μg g^{-1} soil. Fertilizer, suggestions for different pulses have been given in my paper.

H. Rahman: Soil is a dynamic system changing its nutrient status with time. Once a fertilizer recommendation of a pulse crop is made, how long may it remain valid? Would you kindly give your opinion?

M.S. Islam: Fertilizer recommendations need updating every 2 or 3 years.

A.R.M. Sayedur Rahman: We know that the addition of N increases yield or that yield increase depends on addition of N to a certain limit. But in the case of pulses, addition of N leads to the increase of biomass, not yield. Please explain the reason behind this.

M.S. Islam: For pulses we only recommend 15-20 kg N ha^{-1} as a basal or starter dose since Bangladesh soils are critically deficient in N. I think this small amount cannot encourage vigorous vegetative growth.

O. Islam: We have observed in Thakurgaon soil, that our local genotypes were significantly podded but the exotic genotypes failed to produce any pods. Please explain this.

M.S. Islam: The reason could be nutritional/physiological. Soil-fertility investigations need to be made in detail. Then it would be possible to give a proper explanation.

M.A. Wahhab: You have shown only the deficiency symptoms of different fertilizers on pulses. Don't you find any toxicity effect of any fertilizer on pulses?

M.S. Islam: Yes, sometimes we get toxicity symptoms due to addition of high amounts of Cu, Zn, B, and Mo.

R.N. Mallick: Your results indicate substantial increase of grain yield by the use of different nutrient elements. The fertilizer doses have been recommended but fanners seldom use any fertilizer on pulse crops. Do you recommend extension result demonstrations on a large scale to create awareness as this was proved effective in case of cereals (rice and wheat)?

M.S. Islam: Yes, you should conduct extension result demonstrations on a large scale to create awareness among farmers.

A. Sarker: We have seen in the Thakurgaon farm of BARI that our chickpea experiments suffered badly from sterility. But a patch of the experimental area showed good podding. The scientists found that in the area where they applied Zn in the previous crop, intensive podding occurred. Is Zn or boron responsible for the sterility problem in chickpea?

M.S. Islam: Boron deficiency is mainly responsible for causing sterility in grain crops. I think it is boron which caused sterility in the Thakurgaon chickpea plot.

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Fertilizer Management on Pulses-Based Cropping Patterns

A.F. Mahbubur Rahman, M.S. Islam, and M.A. Rouf
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

*Two field experiments have been conducted at the Regional Agricultural Research Station, Ishurdi, since 1983, to determine the effects of pulses on soil fertility within different cropping patterns. These were: wheat-mung bean-t.aman (rainy-season) rice and mustard-mung bean-t. aman. In both the mung bean (*Vigna radiata *(L.) Wilczek) cultivar Mubarik was introduced between two cereal crops during the early monsoon (kharifl) (March-May) season. In pattern I, using N-0 and 15, P-0,30 and 60 and K-0, 15 and 30 kg ha^{-1}, a selected set of 12 treatments was tested on Mubarik and the largest grain yield of 1.84 t ha^{-1} was obtained by the treatment N-15, P-60 and K-15 in 1984/85. In pattern 2, Mubarik was tested against 10 treatment combinations using N-0 and 15, P-0,30 and 60 kg ha^{-1} and the highest grain yield of 1.8 t ha^{-1} was recorded from the treatment N-15, P-30 in 1984/85. In both the patterns a huge amount of biomass was added to the soil. This ranged from 9.3 to 12.7 t ha^{-1} in pattern 1 and 3.7 to 5.1 t ha^{-1} in pattern 2. The biomass was useful in maintaining soil fertility. Inclusion of pulses in the cropping pattern reduced the use of fertilizers for the next crop. Farmers can produce enough pulses in their fallow lands for their own consumption and marketing. Similar studies will be carried out with other cultivars of mung bean and other pulses.*

Introduction

It has been observed that cultivation of pulses is currently undergoing a slight decline. This is the result of the availability of irrigation for the cultivation of *bora* (winter)-rice. Therefore, the main task of pulse scientists is to motivate farmers to grow pulse crops by making them aware of the advantages of pulses over cereals. If the farmers grow *boro-rice* in their fields they will have three cereal crops in one year, thereby reducing the fertility of the soil. On the other hand, by growing pulses between two cereal crops, the soil is enriched due to the nitrogen-fixing ability of pulses. Pulses may fix 110-115 kg nitrogen ha^{-1} from the air. A large amount of biomass is also added to the soil which ultimately increases its organic matter. The addition of nitrogen and organic matter helps to maintain the fertility of the soil and consequently reduces the requirement for chemical fertilizers for the next crop. This study was undertaken to determine the effect of mung bean *(Vigna radiata* (L.) Wilczek) on two cropping patterns involving wheat *(Triticum aestivum* L.) and *t.aman* (rainy-season) rice and mustard (*Brassica campesths* L.) and t.*aman.*

Methods and Materials

Both experiments were planned in a randomized complete block design replicated three times. The unit plot size was 6m x 5m. In pattern 1 there were 12 treatment combinations while in pattern 2 there were 10. The spacing was 30 cm between rows in both cases. In pattern 1 there were 2 doses of nitrogen (O and 15 kg ha^{-1}), 3 doses of phosphorus (O, 30, and 60 kg ha^{-1}), and 3 doses of potassium (0,15, and 30 kg ha^{-1}). In pattern 2 there were 2 doses of nitrogen (O and 15 kg ha^{-1}) and 3 doses of phosphorus (0, 30 and 60 kg ha^{-1}). All fer-

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

tilizers were applied at the time of final land preparation. The experiments were sown on 9 March 1988 and 6 April 1988 and the area of 20 m^2 was harvested at maturity on 27 March 1988 for pattern 1 and 9 June 1988 for pattern 2. Biomass yield and grain yield were recorded along with other necessary data.

Results and Discussion

The effect of fertilizers on the yield of mung bean is presented in Table 1. The highest yields recorded were 1.43 t ha^{-1} in pattern 1 and 0.87 t ha^{-1} in pattern 2. The yield of mung bean was low. In 5 years' yield data highest yield of 1.84 t ha^{-1} was recorded in pattern 1 in 1984/85 and 1.80 t ha^{-1} in pattern 2 in the same year. Biomass yields of these two cropping patterns were recorded in 1986/87 and 1987/88. A large amount of biomass was added to the soil. In pattern 1 up to 14.3 t ha^{-1} of biomass was added to the soil in 1986/87 and 12.7 t ha^{-1} in 1987/88. In cropping pattern 2 the addition of biomass was up to 7.2 t ha^{-1} in 1986/87 and 5.1 t ha^{-1} in 1987/88.

Table 1. Mung bean yield (t ha^{-1}) with different doses of fertilizers in two different cropping patterns, RARS, Ishurdi, Bangladesh, 1987/88.

Pattern -1 (Wheat - mung bean - t.*aman*)		Pattern - 2 (Mustard - mung bean - t. *aman*)	
Treatment N-P-K	Yield (t ha^{-1})	Treatment N-P	Yield (t ha^{-1})
0-0-0	0.83	0-0	0.63
15-0-0	1.30	15-30	0.73
15-30-0	1.36	15-30	0.70
15-30-0	1.43	15-30	0.68
15-60-0	1.40	15-30	0.70
15-60-0	1.18	15-60	0.87
15-60-15	1.41	15-0	0.53
15-60-15	1.33	15-0	0.68
15-0-15	1.20	15-0	0.68
15-0-30	1.30	15-0	0.70
15-60-30	1.38		
0-25-0	1.33		
F.Test	**[1]		NS[2]
C.D.). (0.01)	0.42		-
C.V.(%)	7.1		21

1. Significant at the 0.01 level.

2. NS = Non-significant.

Economic studies of these two cropping patterns were performed for the last 3 years. For this, we considered only the prices of the fertilizers, all other factors being constant. An economic study of these cropping patterns indicated that in pattern 1 a high cost-benefit ratio of 1:9.34 was achieved. In cropping pattern 2 the ratio was 1:6.35.

Beside these experiments, the On-Farm Research Division has carried out a large number of cropping-pattern experiments at different Farming Systems Research (FSR) Sites. The results of the cropping patterns over a 3-year period indicated significant differences among treatments. The returns from these patterns are very encouraging and fanners are accepting the patterns. Although the patterns under consideration are becoming popular among the farmers still there is a possibility that they may change their decision. Once irrigation becomes available, farmers usually will grow rice for their own family use. Hopefully the success of these patterns will reverse this trend.

Discussion

S.K. Roy: Do you suggest fertilizer application to individual crops within a pattern or to the pattern as a whole? If yes, why?

A.F.M. Rahman: Yes. The fertilizer needs of different crops vary. But as mung bean has been introduced between two crops the addition of fertilizer in the next crop will definitely be less.

M.O. Islam: When did you plant mung bean in your proposed cropping pattern? Is it possible to grow or fit this crop into a traditional cropping pattern economically?

A.F.M. Rahman: The mung bean was sown in the later part of March. Yes, I have tested the crop for the last 6 years and successfully fitted it in the pattern. I think you have marked the economic study in the paper and that is profitable.

M.S. Hoque: The inclusion of a legume like mung bean in a cropping pattern may show more spectacular benefit over a longer period of time and not within 2-3 years.

A.F.M. Rahman: I do agree with you. I have studied the patterns for the last 5 years and it is still continuing. The result is self explanatory. I think getting something from nothing is even more encouraging.

Prospects of Increasing Pulses Production Through Improved Cropping Systems

M.Z. Abedin and Md. Akram Hossain
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

Pulses occupy a position of pride in Bangladesh agriculture for various reasons. However, due to continued emphasis on cereals, these are being replaced by rice or wheat crops, especially in irrigated areas. Increasing yield per hectare is the main way to augment pulses production, though opportunities to grow pulses in current fallows exist. Experiments conducted both on-station and on-farm suggest that these crops could befitted into existing cropping patterns in nontraditional areas and in times of the year when they are not usually grown. Further, proper seed rates in the existing intercropping practices can boost yields. Pulses could be grown successfully as mixed crops with wheat. This paper discusses the research results of trials on intercropping with pulses and on pulse-based cropping systems conducted during 1981-88 in Bangladesh. Suggestions for future areas of concern have been made.

Introduction

The major reasons for reduction in area and production of pulses are replacement of these crops by cereals, and stagnant and poor yields. Farmers produce more cereals, especially rice, to minimize the risk of household food shortage. Wheat is cultivated by expanding irrigation facilities and under rainfed conditions. Moreover, *boro* (winter) rice under irrigation has replaced pulse crops. Lentil *(Lens culinaris* Medic), and chickpea (*Cicer arietinum* L.), have also been replaced mostly by wheat and to a certain extent by *boro* rice. Poor productivity of pulses has also made them less attractive than other crops.

At a minimum per capita consumption rate of 15 g day^{-1} the total requirement of pulses in 1989/90 was estimated to be around 600 000 t for a population of 110 million. In other words the production needs to be trebled in the coming years if we want to provide a cheap source of protein to our people.

Constraints to Pulses Production

A critical analysis of the problem identifies the following constraints to increased yield and production of pulses in Bangladesh.

1. Cultivars
2. Seed
3. Weather
4. Agronomy
   a. Delayed sowing time
   b. Low seed rate
   c. Inadequate land preparation
   d. Inadequate interculture
   e. Inadequate irrigation
5. Crop nutrition
6. Plant protection
7. Consumer preference

These have been described elsewhere in this proceedings and will not be discussed here (Islam and Rahman 1990; Ahad et al. 1990).

Opportunities for Increasing Production

Though improved cultivars of the pulses are not as high yielding as those of cereals and potatoes, they can give

Citation: BAR! (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

relatively good yields if proper production technology is followed. Similarly the crop-production technologies for these crops are not as advanced as those for other crops. However, their adoption does lead to increased production. The strategies described here may be utilized to increase the production of pulses.

The present-day national productivity of pulses is around 600 kg ha^{-1}. It can easily be increased, possibly doubled, provided proper management practices are followed by the farmers. Some of the available technologies are described below.

Introduction of Improved Cultivars

Cultivars play a key role in increasing yield as responses to management practices are mainly decided by the genetic potential. Recent advances are:

- Mung bean *(Vigna radiata* (L.) Wilczek): cultivar Mubarik released in 1982. Yields about 0.8 - 1.0 t ha^{-1}.
  Cultivar Kami released in 1987. Adapted to September sowing. Matures within 60-65 days. Synchronous in podding. Mean yield is about 1.0-1.2 t ha^{-1}.
- Chickpea cultivar Nabin: released in 1987. Flowers and matures about 15 days earlier than the local check, seed size about 25% larger than the local check (cultivar Sabur 4) and yield is 30-35% more than local varieties under farmers' management conditions.
- Black gram (*Vigna mungo* (L.) Hepper) line MAK 1 awaiting release (Rahman 1990). Maintains more or less stable yield across locations. Produces 20-30% higher yield than local check varieties. Mean yield is around 1.0 t ha^{1}. Suitable for rainy-season sowing.

Besides these, the Bangladesh Institute of Nuclear Agriculture (BINA) has developed a black gram mutant 'M 25' and a mung bean strain 'MB 55'. M 25 outyielded (1.25 t ha^{-1}) the local variety at the Boda Multilocation Trials (MLT) site in the postrainy season, 1987/88. The mutant also proved to be more tolerant to yellow mosaic virus (YMV). Mung bean strain MB 55 produced about 1 t ha^{-1} but infestation at the later vegetative stage was more than the check cultivars.

Fertilization

Though the fertilizer requirements of pulses are not as high as that of cereals, they certainly respond to small doses of nitrogen, phosphorus, and potassium. Islam (1990) recommended fertilizer doses for pulse crops after a series of experiments conducted by the Soil Science Division of Bangladesh Agricultural Research Institute (BARI) in different parts of the country.

Inoculation with *Rhizobium* sp Culture

Khanam and Hossain (1988) reported that different strains of the *Rhizobium* sp culture significantly increased the yield of chickpea. The grain yield of chickpea may be increased by as much as 58% if seeds are inoculated (Table 1). Khanam and Hossain (1988) also reported that the yield of lentil was higher when plants

Table 1. Effect of *Rhizobium* inoculation on cultivars of chickpea nodule, grain and byproduct mass, high Ganges floodplain soils, Bangladesh, 1987.

Chickpea cultivars	Nod.mass (kg ha^{-1})	Byproduct mass (t ha^{-1})	Grain yield (t ha^{-1})	Increase in grain yield (%)
Sabur 4 (N)[1]	16.8	1.55	1.64	0
Sabur 4 (1)	31.8	1.30	1.79	9.2
Nabin (S1) (N)	15.9	1.75	1.66	0
Nabin (S1) (1)	30.9	1.77	1.69	1.8
JG 74 (N)	11.5	1.51	1.50	0
JG 74(1)	42.9	1.64	1.70	13.2
E2 (N)	22.8	1.29	1.02	0
E2 (1)	33.4	1.76	1.43	57.9

1. N=Nominocultask, I=Inoculated.

were fertilized with proper doses of nitrogen, phosphate and potash along with application of inoculum (Table 2).

Though efficient strains of *Rhizobium* sp have been identified, the production of culture has not been undertaken on a large scale.

Dates of Sowing

Studies by the Agronomy Division, BARI (BARI 1982a) revealed that among the five mung bean stains tested, BM 7706 produced the highest grain yield (1.61 t ha^{-1}) followed by BM 7704 (1.57 t ha^{-1}), when sown on 15 April at the BARI Farm, Joydebpur.

Studies at Jessore, Ishurdi, and Joydebpur by the Agronomy Division of BARI (BARI 1985) showed that optimal time of sowing chickpea would be middle of Nov but it can be sown till middle of Dec with higher seed rates. Seeding of lentil till 25 Nov had similar effect on yield and other characters. But 5 Dec sowing showed some decline in yield and yield-contributing characters.

Karim et al. (1988) reported that yield and yield components of the mung bean line 'MK 72' were influenced by time of sowing. Higher grain yield was obtained from the crop sown on 15 March.

Additional Area Approach

Introduction of pulses in new areas

When irrigation facilities expanded, the area under pulses cultivation was reduced and a search for new places for the cultivation of pulse crops began. Cultivation of pulse crops in current fallows incorporating these in the existing cropping systems may open up new possibilities for area expansion. Researchers started finding out the exact possibilities through the on-farm farming systems research.

Training in application of new cropping patterns on farmers' fields by BARI, Bangladesh Jute Research Institute, (BJRI), and Bangladesh Agricultural University (BAU) during 1980/81 has also shown good prospects for incorporating pulses in the traditional cropping patterns. A review of the National Coordinated Cropping Systems Research Project in Bangladesh (BARC 1985) identified the following pulse-based cropping patterns as biologically feasible and economically viable.

Agroecological zone (AEZ)	**Recommended cropping pattern**
High Ganges floodplain F	Rice (b.aus)-fallow-mustard
Highland F1	Maize - mung bean - mustand
Brahmaputra floodplain F	Rice *(aus)* - rice (t. *arnan-* Khesari
Medium highland F1 :	(Lathyrus sativus L.) Rice (D. S. Aus)-rice (*t.aman* lentil)
F	Jute -*t.aman* rice -khesari
F1	Jute -*t.aman* rice cultivar 'BR-4' khesari.

Multinational testing of the following cropping patterns that were found to be biologically stable and economically viable at different Farming Systems Research (FSR) sites was started by the On Farm Research Division (OFRD), BARI in different

Table 2. Lentil grain, byproduct, and nodule mass as affected by *Rhizobium* inoculation and chemical fertilizer, old Brahmaputra floodplain soil, Bangladesh, 1987.

Input	Nod.mass (kg ha^{-1})	Byproduct mass (t ha^{-1})	Grain yield (t ha^{-1})	Increase in grain yield (%)
No fertilizer	1.9	0.84	0.79	0
N[1]	1.4	0.97	0.93	18.3
PK[2]	1.3	0.94	0.91	16.0
NPK	1.5	0.89	0.92	16.8
Control + Inoculum	2.2	1.04	0.94	19.1
PK + Inoculum	2.4	1.07	1.06	35.1

1. N = nitrogen;
2. P= phosphorus, K = potassium.

agroecoiogical zones from the postrainy season of 1988/89.

AEZ	Cropping Pattern	Moisture Pattern
High Ganges Floodplain	Maize-mung bean	Rainfed highland
Tista Flood-plain	Jute-mung bean-tobacco	Partially irrigated highland
	Aus (rainfed) *rice-t.aman* (rainy season) rice/khesari	Rainfed, medium to medium-high lowland

The results of agroeconomic studies at the FSR sites are presented in Tables 3,4, and 5.

The cropping intensity in the *Barind* area is low. Farmers grow single t.aman crop in most areas (82%). Rahman and Kar (1988) reported that mung bean can be grown in *Barind* with yield around 450 kg ha^{-1} after *t.aman* rice (cv 'BR 11'*)*. In 3 out of 5 years, chickpea in the green manure (GM)-t.aman-chickpea cropping pattern produced very good yields, and an acceptable yield in one year. The crop could not be established in one year due to depletion of soil moisture at sowing time.

Table 3. Summary of agroeconomic performance of maize + mung bean-t.aman-wheat pattern on Gopalpur soil series under partially irrigated, medium highland at Kalikapur site, Bangladesh, 1986-88.

		(F)[1] *B.aus-t.aman-wheat*				(FA)[2] maize+mung.bean-t.aman-wheat			
Variable	Pattern	1985/86	1986/87	1987/88	Mean	1985/86	1986/87	1987/88	Mean
Variety	C1[3]	-	Kalabakri	Kalabakri	-	-	Sadaf+Mubarik	Sadaf+Mubarik	
	C2	-	BR 11	BR 11	-	BR 11	BR 11		
	C3	Sonalika	Sonalika	Kanchan		Kanchan	Kanchan	Kanchan	
Field duration (days)	C1	-	108	105	106	-	92(M)	96(M)	94(M)
	C2	-	126	118	122	-	125	120	122
	C3	103	103	105	104	113	113	108	111
Yield (t ha^{-1})	C1	-	1.47	1.16	1.31	-	5.41+0.318	3.25+0.186	4.33+0.25
	C2	-	3.99	3.29	3.64	-	4.50	4.16	4.33
	C3	1.83	2.20	1.03	1.68	2.51	2.40	1.42	2.11
Gross benefit (Tk ha^{-1})	C1	-	11 003	7 096	9 049	-	29 276	25 433	27 354
	C2	-	23 354	19 084	212 119	-	26 726	24 316	25 521
	C3	9 555	11 450	5 962	8 989	13 367	12 452	8 216	11 345
Total variable cost (Tk ha^{-1})	C1	-	3 418	3 525	3 471 -	5 542		5 212	5 377
	C2	-	8 015	7 595	7 805	-	8510	9 514	9 012
	C3	5 140	5 372	5 382	5 298	6 979	7 031	6 076	6 695
Gross margin	C1	-	7 585	3 571	5 578	-	23 734	20 221	2 190
	C2	-	15 339	11 489	13 414	-	18 216	14 802	16 509
	C3	4415	6078	580	3 689	6 388	5 421	2 140	4 649
Cost-benefit ratio (Tk^{-1})	C1	-	3.22	2.01	2.61	-	5.28	4.88	5.08
	C2	-	2.91	2.54	2.72	-	3.14	2.56	2.85
	C3	-	2.13	1.11	1.70	1.92	1.77	1.35	1.68

1. F = Existing cropping pattern;
2. FA a Alternative cropping pattern;
3. C1-C3= Crops.

Table 4. Economic performance of farmers'alternative cropping pattern[1] (FA) as compared to farmers' existing cropping patterns (F1 and F2) under Pirgacha-Polashbari highland soil at FSR, Janokinathpur, Rangpur, Bangladesh, 1987/88.

Crop	Jute	Mung bean	Tobacco	Total	Jute	Fallow	Tobacco	Total	Jute	Fallow	Potato	Total
Yield increase (%)	1(F1)	1(F2)	-	33	-	-	-	-	-	-	-	-
Gross benefit (t ha^{-1})	15 597	5640	44 225	65 462	14 109	-	33 150	47 150	15 178	-	18846	34 024
Total variable cost (t ha^{-1})	7 184	3009	10 526	20 719	7 829	-	10 623	18 452	7 923	-	17 306	25 229
Gross margin (t ha^{-1})	8 413	2 631	33 699	44743	6 280	-	22 525	28 807	7 255	-	1 540	8 795
Cost-benefit ratio	2.17	1.87	4.20	3.16	1.80	-	3.12	2.56	1.92	-	1.09	1.35

1. FA = jute-mung bean-tobacco; F1 - jute-fallow-tobacco; F2 = jute-fallow-potato.

The on-farm research division of BARI in collaboration with the Department of Agricultural Extension has also undertaken pilot production programs of the following pulse-based cropping patterns since they were found to be better at FSR and Multilocation Trials (MLT) sites.

AEZ	**Cropping pattern**	**Condition**
Low Ganges Floodplain	B.aus-lentil+mustard	Rainfed highland
Brahmaputra floodplain	Maize-mung bean-mustard	Rainfed highland
Tista Rood-plain	Mung *bean-t.aman-* wheat	Rainfed, medium highland

Introduction of lentil in mixed cropping in cropping pattern 1 yielded about 700 kg ha^{-1} lentil; yield of sole mung bean was about 800 kg ha^{-1} in the other patterns.

Results show that with proper adjustment of other crop cultivars, sowing date, and seeding technique, it is possible to incorporate pulses in patterns and areas where these are not traditionally grown. Studies in the Tista floodplain also showed that the mung bean - t.*aman* - wheat pattern could be best fitted in a 2-year rotation with another cropping pattern of *jute-Laman-*wheat.

Mixed cropping of pulses and other crops

Karim et al. (1988) reported from a 2-year field trial conducted at BARI, Joydebpur during 1986/87 that mustard when grown with lentil in different planting geometry (strip cropping, intercropping, and mixed cropping) produced the highest yield of 1.24 t ha^{-1} from the sole treatment. From the same experiment 784 kg ha^{-1} of lentil was obtained from sole treatment. The combination 100% lentil broadcasted between mustard rows 60 cm apart gave highest land equivalent ratio (LER) (1.31)net return (Tk. 10 358 ha^{-1}), and cost-benefit ratio (3.12). They also reported from 2 years' results that lentil grown between widely spaced rows of mustard (60 cm) gave higher lentil/mustard LER and net return than that of monoculture of either lentil or mustard or other forms of mixed cropping.

From studies in Jessore (OFRD 1988) it was found that an LER higher than 1.0 could be obtained if mustard is mixed with lentil or chickpea. The highest yield and LER were observed when mustard and chickpea were mixed cropped in a 50-50% seed rate (6 kg ha^{-1} mustard, 20 kg ha^{-1} chickpea). The seed rates of the sole crops were 12 kg ha^{-1} for mustard and 40 kg ha^{-1} for chickpea and lentil.

A trial on the seeding ratio of mixed cropping of lentil with mustard, lentil with linseed, chickpea with

Table 5. Economic performance of the farmer's alternative pattern (FA:B.aus-t.aman(MV)[1] khesari as compared to farmers' existing patterns under Bonapara - Imadpur medium-highland rainfed soil at FSR Site, Janokinathpur Rangpur, Bangladesh, 1986/87.

	Fanners' alternative pattern (FA)			Mean	Farmers' pattern (F)				Farmers* pattern			
Information	*Aus*	*t.aman* (MV)	Relayed khesari		Jute	*t.aman* (MV)	Fallow	Total	Fallow	*t.aman* (MV)	Fallow	Total
Value of main product (Tk ha^{-1})	11 385	21 430	4 109	36 924	7 000	16 185	-	23 185	-	16 620	-	16620
Value of by product (Tk ha^{-1})	1 431	3 025	426	4 882	3 786	2 241	-	2402	-	2 402	-	2 402
Gross return (Tk ha^{-1})	12 816	24 455	4 535	41 806	10 786	18 426	-	29 212	-	19022	-	19 022
Material cost (Tk ha^{-1})	2 446	2 468	400	5 314	1 395	1 165	-	2 560	-	1 168	-	1 168
Animal power cost (Tk ha^{-1})	1 704	1 704	-	3 462	2 394	1 980	-	4 374	-	1 836	-	1 836
Total variable cost (Tk ha^{-1})	7 513	7 310	1 120	15 943	9 984	6 433	-	16417	-	6 256	-	6 256
Gross margin (Tk ha^{-1})	5 303	17 145	3 415	25 863	802	11 993	-	12 795	·	12 766	-	12 766

1. Modern variety.

mustard, and chickpea with linseed was conducted at the OFRD site, Bagherpara, Jessore on the Darshana soil series highland phase (OFRD 1988). Trials on lentil with mustard, and chickpea with linseed were conducted on Amjhupi soils also during the postrainy season, 1988/89. The seeding ratios were 100:50, 100:25, 75:25, 75:50, and 80:40 of the recommended seed rates of the respective crops. The results are given below.

Lentil + mustard. In Darshana soil series of High Ganges Floodplain, the gross returns from mixed cropping at all the seeding ratios were higher (Tk. 9086 to Tk. 13273 ha^{-1}) than that of their sole crop. A seeding ratioof 75:25 produced the highest LER of 1.77 followed by the seeding ratio 100:25(1.64), 80:40(1.52), 100:50 (1.48), and 75:50 (1.43). With the increase in the mustard population the yield of lentil was suppressed and thereby the seed yield was also suppressed.

Chickpea + mustard. The yield of chickpea was lower under all the mixed-crop treatments than as a sole crop. Chickpea yield of 572 kg ha^{-1} was obtained from 100:50 seeding ratio. The highest LER (1.68) was obtained from 75:50 seeding ratio. The highest gross return (Tk. 6368 kg ha^{-1}) was obtained from 100:50 seeding ratio followed by 100:25 (Tk. 6300 kg ha^{-1}), and 75:25 (Tk. 6105 kg ha^{-1}). The highest monetary advantage (Tk. 2461 kg ha^{-1}) was obtained from the 100:50 seeding ratio.

Lentil + linseed. The gross return in all the seeding ratios were higher (Tk. 5400 to Tk. 7100 ha^{-1}) than that of their sole crops. The 100:50 seeding ratio produced the highest LER (1.59) and gross return (Tk. 7160 ha^{-1}), and monetary advantage was highest (Tk. 2657 ha^{-1}). Lentil yield did not change proportionately with change in population of linseed.

Chickpea + linseed. In Darshana soil series the gross returns in all the seeding ratios were higher (Tk. 3170 to Tk. 4655 ha^{-1}) than that of sole croppings. In Amjhupi soil series all the seeding ratios gave lower gross returns than sole chickpea except the seeding ratio 100:25. In Darshana soil series 60:40 seeding ratio produced highest LER of 1.57 followed by the seeding ratios 75:50 (1.52). In Amjhupi soil series highest LER of 1.20 was obtained from the seeding ratio 100:25.

Wheat + lentil. Studies on the mixed cropping of wheat with lentil at Palima and Kanaipur sites of Tangail and Faridpur during the postrainy season 1987/88 showed that the seeding ratio 100:33 gave the highest LER value, cost-benefit ratio and gross margin (OFRD 1988).

Relay cropping

Studies at Jamalpur by the Agronomy Division, BARI indicated that the khesari cultivar Jamalpur with 45 kg seeds ha^{-1} was suitable for relaying in t. *aman* rice (BARI 1985).

Alam and Costa (1988) reported that improved management of khesari + maize intercrop used for fodder and green cob, respectively, when relayed in t.*aman* rice gave higher gross margin (Tk. 26 300 ha^{-1}) and cost-benefit ratio (4.00). The yield of intercropped khesari + maize was reported to be 1.48 and 3.88 t ha^{-1}. Khesari was utilized as fodder because there is an acute shortage of fodder in Tangail during January-February.

Intercropping

In a study conducted by the Agronomy Division, BARI it was found that the highest net return (Tk. 8840 ha^{-1}) was obtained from maize + wheat intercropping followed by maize + chickpea intercropping (Tk. 7 720 ha^{-1}) (BARI 1982b). It was also found that during the early rainy season intercropped mung bean produced 0.73 t ha^{-1} and *lalsak* (leafy amaranthus) 1.89 t ha^{-1} with an LER of 1.45 in the pattern cabbage + *lalsak* - mung bean + *lalsak*-Indian spinach + *kangkong* *(Ipomoea* sp).

Again intercropped mung bean produced 0.65 t ha^{-1} and radish 1.31 t ha^{-1} (69% of monoculture) with an LER of 1.46 in the pattern cabbage +spinach - mung bean + radish -lady's ringer + *kangkong.*

An intercropping experiment of maize, mustard and wheat with khesari under zero-tillage conditions in the farmers' fields in the flood-affected area of Keshabpur, Jessore during the postrainy season, 1987/88 was conducted after recession of flood water. Maize and khesari were found to be suitable for sowing on the mud after the flood receded. Khesari could be harvested without affecting the timely transplantation of *boro* rice.

Conclusions and Recommendations

In spite of the possibility of an increase in the area under *horo* rice after the introduction of irrigation there remains enough scope to increase the production of pulses in Bangladesh. Keeping this in view, and considering the various limitations, future research should include the following issues:

- Search for better cultivars to suit varying agroclimatic situations and different cropping systems. Yields could be increased from the existing area if high-yielding cultivars are introduced.
- Short-duration cultivars to fit into systems involving *boro* rice. This will need varieties maturing in about 80/90 days. Such varieties will to a great extent regain the pulse area lost to *boro* rice.
- Improved management practices for sole and mixed cropping. Increased production through higher yields of existing pulses could be obtained through better seed rate, weeding, and better land preparation.
- Development of new cropping systems involving pulses. This will allow introduction of pulses in new areas and in different seasons.
- Adjustment of existing cropping patterns. Existing cropping patterns often delay seeding thereby reducing yield, due to poor soil-moisture conditions. Seeding during optimum moisture conditions and time can greatly increase yield. Short-duration rice varieties can help to achieve this.
- Fodder crop production. Traditionally green pulses crop and hay are used as fodder. Reduction of the pulses area has reduced the fodder availability, thereby affecting animal health. Cultivars producing higher biomass may com-

pensate for lower fodder production due to the reduced area.

- Improved pest-management practices. Disease and insects are important factors for reduced yield. Economically sound practices should be developed so that farmers are motivated to use pest-management practices.
- Better seed storage conditions. Better seeds would mean good plant stands and higher yields. Insects cause a lot of damage to pulse seeds in storage, therefore improved storage methods are a matter of urgent necessity.
- Emphasis on khesari, lentil and chickpea. Because of their share in national pulses production the emphasis of research should be on khesari, lentil, and chickpea.
- Regional emphasis. The area on which mung bean and cowpea (*Vigna unguiculata* (L.) Walp. are cultivated is comparatively less than the other pulses, yet in some areas, their importance is not negligible. Therefore, research on these two crops should be intensified, especially mung bean for the southern area (Barisal and Patuakhali), and cowpea for the Chittagong area.

Apart from the abovementioned areas for research there exists scope to increase the pulses production using currently available technologies. A dedicated, well-organized and well-coordinated program can achieve this. It is expected that if the suggested strategies are adopted pulses production could be increased by about 107 000 t within the next 5 years, despite the invasion of pulses area by irrigation technology suitable for cereals.

Strategy	Expected additional production (t)
Adoption of improved cultivars (20% area i.e., 50 000 ha) of chickpea, lentil and mung bean	20 000
Adoption of newly developed cropping patterns (70,000 ha)	70 000
Use of fertilizer and biofertilizer (10% area)	2 000
Sowing under proper moisture conditions and at the proper time	5 000
Use of quality seed	4 000
Improved mixed cropping including new patterns	3 000
Plant-protection measures	3 000
Total	107 000

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Progress in Agronomic Research on Pulses

A.F.M. Maniruzzaman and A. Ahad Miah
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

Agronomic research carried out during 1981-1988 indicated that timely sowing was a key factor in realizing the yield potential of postrainy-season pulses. For rainy-season pulses, maintenance of adequate plant stand and appropriate management practices were critical in raising productivity. Research work covered several areas including the development of cultural practices to increase yields of newly released cultivars and those in the pipeline; determination of the benefits of low vs high management practices; incorporation of specific pulses (for grain and green manure) into existing cropping patterns; inter, mixed and relay cropping of pulses with crops like cotton, barley, wheat, linseed, maize, etc; and crop physiological investigations to provide a basis for management practices. These findings and their implications are described and discussed. Constraints to obtaining high yields and research needs for the future are suggested.

Introduction

Rice-pulse combinations have always predominated the traditional diets of the people of Bangladesh. However, emphasis on cereal production in official food policies has led to the neglect of the production of pulses in recent years (Khan and Khan 1985). This has resulted in a reduced per capita availability of protein (Ahad et al. 1990). Traditionally, pulses are grown in Bangladesh during the postrainy season and the rainy season. Khesari *(Lathyrus sativus* L.), lentil *(Lens culinaris* Medic), chickpea *(Cicerarietinum* L.), black gram (*Vigna mungo* (L.) Hepper), and mung bean (*Vigna radiata* (L.) Wilczek) account for nearly 95% of the total area under pulses. Presently pulses occupy less than 5% of the total cultivated area and contribute about 2.4% of the total food-grain production. Yields of these crops are low as they are generally grown without irrigation or other inputs. The crops are mainly confined to marginal lands, with poor fertility conditions and low moisture status. Rice and wheat are grown on the more productive lands. These crops are grown in the postrainy season after the cessation of the monsoon rains, utilizing residual soil moisture. The rainy-season pulses, on the other hand, are grown with the first premonsoon shower or along with the monsoon rains. In both cases the crops are raised under poor management conditions. Consequently there has been a decline in the area and production of pulses. Considering the importance of pulses in the diet of the people of Bangladesh and their beneficial effect on soil fertility, there is a need for concerted efforts to enhance pulses production. It is necessary to bring together all the available information on pulses production, to enable planners, policy makers to formulate policy measures, researchers to determine future research needs, and farmers to benefit from the results.

Climatic Requirements of Pulses

Postrainy-season Pulses

The major postrainy-season pulses are khesah, lentil, and chickpea. The temperature optima for the growth of postrainy-season pulses lie between 10°C and 30°C (Saxena 1979). On this consideration, 110-115 days are available for growing postrainy-season pulses. For

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

the short and mild winter conditions of Bangladesh, cultural management should be designed to fully exploit the available growing period.

Rainy-season Pulses

These pulses include black gram, mung bean, and pigeonpea *(Cajanus cajan* (L.) Millsp.) The optimal temperature for growth and development of most summer pulses is between 25°C and 35°C. They can tolerate high temperatures up to 40°C, but are sensitive to low temperatures (below 18°C). These crops are normally drought tolerant but sensitive to waterlogging. Mung bean and black gram, grown during the summer, are daylength insensitive. However, a daylength-sensitive mung bean cultivar locally known as Sonamoong is grown in certain specific locations during the postrainy season. Summer pulses can be grown almost throughout the year except during the short winter season.

The Role of Pulses in Cropping Systems

All the major cropping patterns are rice-based. Therefore, postrainy-season pulses have to compete with *boro* (winter) rice and wheat, particularly in regions where irrigation facilities are available. In areas where lentil and chickpea are sown after the harvest of *aman* (rainy-season) rice (August-December) growth and yield are affected adversely. In the early monsoon (Kharif I) season (March-May) uncertain and erratic rainfall restricts the cultivation of summer pulses. In the late monsoon season (Kharif II) (August-October), mung bean and black gram have the potential to follow *aus* (rainfed) rice or jute (April-July), particularly in the northern districts. In the southern districts, mung bean may follow *aman* rice and precede *aus* rice. Temperatures during the late monsoon are sufficiently high to support the growth of summer mung bean.

Research Studies

Effect of Date of Sowing and Seeding Rate on Chickpea and Lentil

Pulses like lentil and chickpea are grown in the dry winter months under rainfed conditions. As the climate imposes a restriction on the duration of growth of lentil and chickpea (approximately 110 days), timely sowing is important in order to exploit the residual soil moisture and to bring the crop to maturity. Experiments conducted on combined time of sowing and seeding-rate with lentil cultivar Pabna local and chickpea cultivars Nabin and Sabur 4 over the vears at various locations in Bangladesh underline the importance of timely sowing. Irrespective of the seeding rates used (20-40 kg ha^{-1}), the optimum date of sowing for lentil at Ishurdi and Jessore, appeared to be between the third week of October and the third week of November (Table 1). At Joydebpur, where late October sowing was not possible due to excess soil moisture, the optimum date was between the first and third week of November. For chickpea the optimum time of sowing appeared to be between the third week of October and middle of November (Table 2). Late sowings (December) significantly reduced grain yields as high temperatures during the pod setting and grain filling stages reduced the grain-filling period and days to maturity (BARI 1985). A survey carried out in farmers' fields in Natore and Faridpur districts (results not presented here), also corroborated the experiment station results. Irrespective of seeding rates used by the farmers, significantly higher chickpea yields were obtained from the crop sown in November (compared to the later-sown crop).

Yield Response of Lentil and Chickpea Under Different Management Practices

Experiments were conducted to determine whether lentil and chickpea yields could be improved through better management practices. The effect of different levels of management on lentil was evaluated at

Table 1. Performance of lentil (Pabna local) at different dates of sowing at three locations (mean of three different seeding rates), 1985/86.

	Yield (t ha^{-1})		
Date of sowing	Joydebpur	Ishurdi	Jessore
23 Oct		1.60a[1]	1.70a
5 Nov	1.67a	1.70a	2.00a
25 Nov	1.20b	1.50a	1.70a
15 Dec	0.57c	0.40b	1.20b

1. Values within a column followed by the same letter do not differ significantly at the 0.05 level.

Table 2. Performance of chickpea (Nabin) at different dates of sowing at three locations (mean of three seeding rates), 1985/86.

Date of sowing	Yield (t ha^{-1}) Joydebpur	Ishurdi	Jessore
23 Oct		3.20ab[1]	1.30ab
1 Nov	2.80a	3.30a	1.70a
16 Nov	2.50ab	2.50ab	1.50a
1 Dec	1.90b	1.70c	1.70a
16 Dec	1.10c	1.40cd	0.70c
1 Jan	0.50d	0.70d	0.30d

1. Values within a column, followed by the same letter do not differ significantly at the 0.05 level.

Jamalpur during 1984/85 (Table 3). Conventional tillage (as practised by the farmers) coupled with one hand weeding at 3 weeks produced higher yield (1000 kg ha^{-1}) than that produced by minimum tillage. Additional benefits from hand weeding are possible only with conventional tilling. With minimum tillage, hand weeding and fertilizer use produced higher yields only when combined.

In chickpea Nabin irrigation and fertilizer application failed to elicit any response in terms of yield at Ishurdi and Jessore (Table 4). Moreover, fertilizer application and drilling seed in the moist zone had no effect on chickpea yields (Table 5). These results show that presently available cultivars of chickpea and lentil do not respond to better management practices.

Table 3. Effect of low and high management levels on grain yield of lentil at Jamalpur, 1984/85.

Levels of management	Yield (t ha^{-1})
Minimum tillage (MT)	0.56bc[2]
MT + Hand weeding (HW)	0.47bc
MT + Fertilizer (F)[1]	0.38bc
MT + HW + F	0.81abc
Conventional tillage (CT)	0.86ab
CT + HW	1.03ab
CT + F	0.86ab
CT + HW + F	0.98ab
CT + Insect Control (IC)	0.80abc
CT + HW + F + IC	1.09a

1. Fertilizer (20-40-20 N,P_2O_5 and K_2O)
2. Values followed by the same letter do not differ significantly at the 0.05 level

Table 4. Effect of irrigation and fertilizer application in chickpea (Nabin), Ishurdi and Jessore, 1985/86.

Treatment	Yield (t ha^{-1}) Ishurdi	Jessore
A. Effect of Irrigation		
No Irrigation	3.13	1.96
Irrigation at 35 DAE	3.03	2.09
Irrigation at 45 DAE	3.45	1.71
	NS[1]	NS
B. Effect of Fertilizer N-P_2O_5 - K_2O		
0 - 0 - 0	3.09	1.84
0 -40 -20	3.38	1.93
20 -40 -20	3.14	1.96
	NS	NS

1. NS = Non significant.

Crop Management in Mung Bean

Experiments on the effect of plant population and weed-control measures (Table 6) reveal the importance of sufficient plant stand on the yield of mung bean (Hamid et al. 1988). One hand weeding carried out between 10 and 20 DAE (days after emergence) under the highest population density (500 000 plants ha^{-1}) gave the best individual crop yield. An experiment conducted to determine the response of mung bean to different cultural practices revealed the importance of fertilizer application (20-40-30 N-P_2O_5 - K_2O) and hand weeding in minimum-tilled plots. The highest cost-benefit ratio (CBR) and marginal rate of return (MRR) was also obtained from this treatment (Table 7). Results showed that fanners unable to invest in other inputs may suitably opt for minimum tillage instead of conventional tillage. Possibilities of growing mung bean and black gram under minimum-tillage conditions during the late monsoon have been discussed by Aziz and Rahman (1990).

Table 5. Effect of method of sowing and fertilizer placement on the yield of chickpea (Nabin), Joydebpur and Barind, 1987/88 and 1988/89.

Treatment	Joydebpur Yield (t ha^{-1})		Barind Yield (t ha^{-1})
	1987/88	1988/89	1988/89
Broadcast sowing (BS) without fertilizer (F)	1.90	1.94	1.54
Drill sowing (DS) without fertilizer (F)	2.17	2.16	1.45
BS + FB[1]	1.83	2.33	1.62
DS + FB	2.06	1.83	1.36
BS + F placed 30 cm apart	1.86	2.36	1.51
DS + F drilled	1.61	1.75	1.67
BS + FB + TSP placed 30 cm apart	1.85	2.17	1.60
DS + FB + TSP drilled in rows.	1.88	2.53	1.53
	NS[2]	NS	NS

1. FB = Fertilizer broadcast.
2. NS = Non significant.

Table 6. Effect of time of weeding and plant density on the yield of mung bean cultivar (Mubarik) under rainfed conditions, Joydebpur, 1985.

Weeding	Plant density	Grain yield (t ha^{-1})
No weeding		0.30f[2]
	S_2	0.35ef
	S_3	0.83bc
Hand weeding at 10 DAE[3]	S_1	0.69bcde
	S_2	0.85bc
	S_3	1.29a
Hand weeding at20DAE	S_1	0.60cdef
	S_2	0.96ab
	S_3	0.74bcd
Hand weeding at 30 DAE	S_1	0.43def
	S_2	0.57cdef
	S_3	0.69bcde
Hand weeding at 40 DAE	S_1	0.40def
	S_2	0.44def
	S_3	0.74bcd

1. S_1: 333 x 10^3 plants ha^{-1}
   S_2: 400 x10^3 plants ha^{-1}
   S_3 : 500 x 10^3 plants ha^{-1}
2. Values followed by the same letter do not differ significantly at the 0.05 level
3. Days after emergence.

Mixed Cropping and Intercropping of Pulses

Since pulses have to compete with a number of crops, mixed cropping and intercropping are widely prevalent in Bangladesh. Experiments have established the feasibility of growing chickpea, lentil, mung bean, and black gram mixed cropped or intercropped with maize, wheat, cotton, or linseed. However, experiments at many locations have revealed the importance of establishing proper seeding ratios for the component crops. The highest land equivalent ratios (LERs) were obtained from 100 : 50 wheat-legume (chickpea or lentil) and 50 : 100 wheat-legume combinations. In other experiments, two rows of mung bean between paired rows of maize or cotton proved to be the best combination. It was also possible to reduce the dose of nitrogen from 45 to 30 kg N under intercropping without affecting yields. In lentil/linseed intercropping, the highest LER was obtained when 4 rows of lentil were intercropped with 1 row of linseed.

Future Research Needs

1. Time of sowing is important for postrainy season pulses. Therefore, existing cropping patterns may have to be adjusted, or alternative cropping patterns developed.
2. Improved plant establishment techniques need

Table 7. Effect of tillage and cultural practices on the yield and return of mung bean, Joydebpur, rainy-season, 1984.

Management levels	Grain yield (t ha^{-1})	Total[1] variable cost (\$ ha^{-1})	Gross return (\$ ha^{-1})	Gross margin (\$ ha^{-1})	Cost-benefit ratio (\$$^{-1}$)	Marginal rate of return (%)
Minimum tillage MT	0.68	38	163	125	4.29	-
MT + Hand weeding (HW)	0.93	92	223	131	2.42	15
MT + Fertilizer (F)	0.72	62	173	111	2.79	-
MT + F + HW	1.32	116	317	201	2.73	292
Conventional tillage (CT)	0.80	65	192	127	2.95	7
CT + HW	0.96	119	230	111	1.93	-
CT + F	0.84	89	202	113	2.27	-
CT + F + HW	1.40	143	336	193	2.35	-
CD (0.05)	0.50					

1. 1 US \$ = 32.85 Tk in 1989.

to be developed for different agroecological zones.

3. Low-cost implements should be developed to make the best use of residual soil moisture.
4. Rhizobial inoculation techniques should be incorporated in management practices. A total management package for pulse-based cropping patterns should be developed.
5. Improved management practices are required for mixed and intercropping situations. Basic research should continue to obtain a better understanding of mixed and intercropping situations.
6. Potential areas should be identified for growing pulses in nontraditional regions.

Discussion

D.G. Faris: Do you have agronomic package(s) of practices for pulses ready for trial (testing) or use by farmers?

A.F.M. Maniruzzaman: We are now only ready for testing by the farmers in different pulse-growing regions.

M.V. Reddy: Yields of chickpea could not be increased by high seed rate, irrigation, and fertilizers. These practices of increasing crop biomass and canopy also increase incidence of diseases like botrytis gray mold. Do you have any observations on disease incidence? The advantages of agronomic practices are often negated by diseases. Hence, further studies are needed.

A.F.M. Maniruzzaman: We did not observe disease incidence (botrytis) to any great extent in our experiments. I agree, these should be more closely observed in experiments with high management inputs.

R.N. Mallick: (Comment) You have presented thesis results too. The quality of research is high, if it is for thesis purpose. This type of research should be encouraged to address some of the potential problems needing immediate attention.

A.F.M. Maniruzzaman: Yes, I agree.

A. Rahman: What is the optimum growing degree days to exploit the full yield potential of some of the postrainy season pulses viz., khesari, lentil?

A.F.M. Maniruzzaman: We have not yet tackled these problems. However, these will be addressed later on.

A.H. Talukder: You have mentioned that the optimum time of sowing chickpea should be between Nov 15 - Nov 25 but chickpea generally is grown after harvesting *t.aman.* During the above period, *\.aman* is just being harvested and although wheat optimum sowing is earmarked for Nov 15 - Nov 20, the area achieved was still found to be only 5-10%. So with the experience in wheat, how much area under pulses do you think we can achieve, if you stick to optimum time of sowing?

A.F.M. Maniruzzaman: If acceptable yield levels are to be achieved in chickpea, then it is very important that it should be sown at the optimum time. Hence, the previous *aman* rice crop should be of shorter duration, so that it is harvested by the middle of November.

M.A. Karim: You reported the effect of dates of sowing on the crop yield of some pulses. I am interested in knowing (i) the number of years you continued your experiments at each site, and (ii) sowing on the same date in different years may give significantly different crop yields. What would you do to avoid discrepancies in your experimental results?

A.F.M. Maniruzzaman: The results described were evaluated from experiments carried out for at least 3 years. We also relate our results with climatic data. We have not noticed much year-to-year variability in climatic elements.

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Possibilities of Growing Mung Bean and Black Gram under Minimum-Tillage Conditions

M. Abdul Aziz and M. Matiur Rahman
Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh

Abstract

To determine the productivity of mung bean (Vigna radiata *(L.) Wilczek) and black gram (*Vigna mungo *(L.)Hepper) under minimum tillage, experiments were conducted at the Regional Agricultural Research Station, Ishurdi on: (i) effect of different levels of tillage and weeding on mung bean after wheat, (ii) seed rate and relay cropping of mung bean in broadcast* aus *rice under zero-tillage conditions, (iii) performance of mung bean and black gram in* aus *(rainfed) rice-fallow-postrainy season cropping pattern under different methods of sowing, and (iv) effect of different levels of tillage on the yield of mung bean and black gram after broadcast* aus *rice in the* aus *rice-fallow-postrainy season cropping pattern. No significant differences were found in yield for different levels of tillage as well as different methods of sowing. Therefore, mung bean and black gram can be grown under minimum-tillage conditions with the first onset of rain in the early monsoon season (kharif I) where the land is kept fallow up to June/July for upland transplanted* aman *(rainy-season) rice. In the late monsoon season (kharif II) it could be grown in the* aus *rice-fallow-postrainy season cropping pattern in the northwestern region of Bangladesh, using the fallow period without disturbing the existing postrainy season crops mustard, lentil* (Lens culinaris *Medic), and wheat, provided the soil is light textured (sandy loam-silty loam) and the sowing is completed in August.*

Introduction

The area under pulses and their production are declining due to crop competition in the postrainy *(rabi)* season. These crops in general do not respond to high management. Therefore, the option is to cultivate these between the two main cropping seasons, rainy and postrainy. Minimum tillage has the potential to reduce the turnaround time between cropping seasons. This may facilitate the sowing of the crop at the optimum time. One of the major upland cropping patterns of the northern districts is *aus* (rainfed) rice (April-mid August)-fallow (August-October)-postrainy season (November-March). This pattern is followed in well-drained highlands with light-textured soils. If this fallow period of 80-90 days could be utilized for growing short-duration pulse crops like mung bean *(Vigna radiata* (L.) Wilczek) or black gram *(Vigna mungo* (L.) Hepper), a large area would become available for cultivation without disturbing the existing cropping pattern. However, one should be cautious because August is the peak of the rainy season and there is a high risk of crop failure. During this period, land preparation is very difficult by conventional tillage, though some farmers still practice it in parts of Rajshahi, Pabna, Kushtia, and Jessore. Since the fallow period is very short the crop must be sown by mid August and if the conventional method is followed, this may not be possible in some years due to heavy rains. Establishment of optimum plant population is also difficult. Therefore, there is a need for alternative technologies. Some of the options available are:

1. to grow pulses as relay crops in *aus* rice, or
2. to sow under zero tillage on the same day after *aus*-rice harvest.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Experiments were conducted during 1985/88 at RARS, Ishurdi, The results are discussed below:

1. Seed rate and potential of mung bean as a relay crop with *aus* rice: This trial was conducted to study the feasibility of growing mung bean as a relay crop with *aus* rice and to determine the appropriate method and seed rate. A factorial experiment was conducted during 1985 and 1987 with 3 replications with 3 seed rates (20, 40, and 60 kg ha^{-1}) and 3 sowing conditions, i.e., sowing as a relay crop 15 days before *aus-rice* harvest (M_1), sowing after harvest of *aus* rice leaving 20-cm stubbles above the ground level (M_2), and sowing after harvest of *aus* rice to the ground level (M_3).

The results indicate that there were no significant differences in yield and its components with different seed rates or methods of sowing in either year (BARI 1987).

2. Effect of different levels of tillage on the yield of mung bean and black gram after *B. aus* rice: The experiment was conducted to evaluate the profitability/ acceptability of minimum tillage compared to conventional tillage. A randomized complete block design with four replications was used to test no tillage *(aus* rice harvested to the ground level), reduced tillage 1 (1 ploughing +1 laddering), reduced tillage (2 ploughings + 2 ladderings), and conventional tillage (3 ploughings + 2 ladderings) during the late monsoon season (kharif II) of 1985 and 1987.

The results showed no significant differences in yield and yield-contributing characters for different levels of tillage in either year in both crops (BARI 1987). The maximum cost-benefit ratio was obtained from no tillage in both crops during both years and the lowest from conventional tillage. It was found that increasing the number of ploughings added to the total variable cost and decreased the net return as well as the cost-benefit ratio. No tillage gave medium returns but poses the problem of free grazing of cattle, therefore one ploughing is recommended under minimum-tillage conditions to overcome the problem.

3. Growing mung bean and black gram in the *aus* rice-mung bean/black gram-postrainy season cropping pattern against the existing cropping pattern of *aus*-fallow-postrainy season crop: One of the major cropping patterns in the northern districts is *aus* rice-fallow-postrainy season crop. Farmers usually keep the land fallow for about 80 to 90 days after harvest of *aus* rice, till the end of October. Mung bean and black gram may be introduced as catch crops in this pattern during the late monsoon season to utilize the non-crop period.

Six cropping patterns (F1) were tested at Ishurdi during 1987 and 1988 against the existing cropping patterns (F) (BARI 1988, 1989). *Aus* rice was cultivated using farmers' practice; after harvest of *aus* rice to the ground level mung bean and black gram were sown under minimum-tillage conditions and three postrainy-season crops viz., wheat *(Triticum aestivum* L.), mustard *(Brassica campestris* L.), and lentil *{Lens culinaris* Medic), were grown after mung bean and black gram. Recommended management practices were adopted for postrainy-season crops and the cost-benefit analysis was done on the basis of the whole pattern.

Cropping pattern 7. aus *rice-mung bean-wheat*

The results showed that the total yield under the farmers' pattern (F) was 4098 kg ha^{-1} in 1987 and 3802 kg ha^{-1} in 1988 and that under the improved pattern (F1) was 4727 kg ha^{-1} and 4438 kg ha^{-1} which was 15% and 17% higher than the farmers' pattern (Table 1) (BARI 1988, 1989). The annual net return increased by 62% and 131% in FI over F. The cost-benefit ratio was positive in FI whereas it was negative in F.

Cropping pattern 2: aus *rice-mung bean-mustard*

The results (Table 1) indicated that the total yield in FI increased by 36% in 1987 and 34% in 1988 over F, resulting in net returns higher by 101% and 139% (BARI 1988, 1989). The cost-benefit ratio was 1.15 and 1.16 under FI compared to 0.66 and 0.55 under F in both the years.

Cropping pattern 3: aus *rice-mung bean-lentil*

The inclusion of lentil increased the total yield by 32% and 30% (Table 1) over F in 1987 and 1988, respectively, resulting in 63% and 78% higher net returns over the farmers' pattern (BARI, 1988, 1989). The cost-benefit ratio was 1.64 in 1987 and 1.91 in 1988 under F1 against 1.19 in 1987 and 1.29 in 1988 under F.

Cropping pattern 4: aus *rice-black gram-wheat*

The results indicated that the total yield was 4780 kg ha^{-1} and 4525 kg ha^{-1} in F1 resulting in 19% higher yield over F in both years (Table 1) (BARI 1988, 1989).

Table 1. Per cent yield increase, net return, and cost-benefit ratio of the *aus* rice-mung bean/black gram-postrainy season crops compared to the existing *aus* rice-fallow-postrainy season crops, 1987 and 1988.

Cropping patterns	% yield increase		% net return increase		Cost-benefit ratio		Increase/decrease yield of last crop (kg ha^{-1})	
	1987	1988	1987	1988	1987	1988	1987	1988
Aus rice-mung bean-wheat	15	17	62	131	1.04	1.05	-354	-77
Aus rice-mung bean-mustard	36	34	101	139	1.15	1.16	+52	+50
Aus rice-mung bean-lentil	32	30	63	78	1.64	1.91	-6	-39
Aus rice-black gram-wheat	19	19	90	123	1.16	1.01	-312	-110
Aus rice-black gram-mustard	46	44	133	146	1.33	1.19	+115	+132
Aus rice-black gram-lentil	37	29	74	53	1.79	1.90	-49	-166

Source: BARI (1988,1989).

Compared to F the annual net return increased by 90% in 1987 and 123% in 1988. The cost-benefit ratio was found to be positive in F1 whereas it was negative in F.

Croppping pattern 5: aus *rice-black gram-mustard*

The total yield increased by 46% and 44% under FI during the 1987 and 1988 cropping years over the farmers' pattern (Table 1) (BARI 1988, 1989). The net return was increased by 133% and 146% over F. The cost-benefit ratio was 1.33 in 1987 and 1.19 in 1988 under the improved cropping pattern, against 0.65 and 0.55 in the farmers' pattern.

Cropping pattern 6: aus *rice-black gram-lentil*

In this pattern (Table 1) the total yield in FI as compared to F increased by 37% in 1987 and 29% in 1988 (BARI1988,1989). The net return under F1 was 74% and 53% higher than the farmers' pattern. The cost-benefit ratio was 1.79 in 1987 and 1.90 in 1988 under FI compared to 1.21 and 1.49 under F.

The gains in total yield and net return of the six patterns over the existing farmers' pattern have shown that mung bean and black gram can easily be fitted into the common practice of *aus* rice-fallow-postrainy season cropping pattern for increased total yield, net returns, and an improved cost-benefit ratio. Among the farmers* cropping patterns *aus* rice-fallow-lentil was and to be better (positive cost-benefit ratio) compared to the *aus* rice-fallow-wheat/mustard patterns (negative cost-benefit ratio). This resulted in higher increase percent net return in the *aus* rice-mung bean/black gram-wheat/mustard pattern compared to *aus* rice-mung bean/black gram-lentil pattern. However, the latter is still considered the best pattern as it is supported by the highest cost-benefit ratio. It is interesting to note that the yield of mung bean and black gram was reduced to some extent when they were grown as sequential crops as compared to control plots in both the years. Lentil recorded a small yield reduction when grown after mung bean when compared to black gram. This may have been due to depletion of nitrogen from top soils (Lawn and Ahn 1985). But surprisingly the yield of mustard increased when it followed both the pulse crops and in fact improvement in yield was greater after black gram. The reasons for this difference are unknown.

The conclusions drawn from these experiments are that in general mung bean and black gram can be grown in the fallow period of the *aus* rice-fallow-postrainy-season cropping pattern, and among the postrainy-season crops preference should be given to lentil followed by mustard and wheat.

4. The effect of mung bean/black gram residues on certain postrainy-season crops: It was observed that mung bean and black gram had a depressing effect on the following wheat and lentil crops. An experiment was conducted to study: (i) the effect of ploughing of mung bean plants after harvesting the pods under dry conditions before sowing postrainy-season crops; and

(ii) which of the postrainy-season crops performed better under the above conditions. A split-plot design with three replications was followed for this experiment The main plots were: (i) control (fallow after *aus* rice), (ii) harvesting of mung bean plants to ground level, and (iii) ploughing down of mung bean plants after harvest of pods. The sub-plots were sown with postrainy-season crops viz., lentil cultivar L 5, mustard cv cultivar Tori 7, and wheat cultivar Kanchan. The crops were sown 12 days after the mung bean was ploughed down. Plot size was 5m x 4m, and recommended doses of fertilizers were added during final land preparation. Data on yield and yield components were recorded.

It appears from Table 2 that ploughing down the mung bean increased the grain yield and seed size of all the postrainy-season crops probably due to the added

Table 2. Effect of mung bean residues on the following postrainy season crops in the aus rice-mung bean-postrainy season cropping pattern, Ishurdi, Bangladesh,1986787.

Lentil

Treatment	Plant population (m^2)	Plant population (cm)	No.of pods plant^{-1}	No.of seeds pod^{-1}	1000 seed mass(g)	Yield (t ha^{-1})
Fallow (control)	70a[1]	41	72b	1.9	12.2	0.76b
Harvesting of mung plants	55b	43	64c	1.8	11.5	0.75b
Plough down of mung plants	54b	47	88a	1.9	12.8	0.91a
F -test	*2	NS[3]	*	NS	NS	*

Mustard

Treatment	Plant population (m^{-2})	Plant height (cm)	No.of siliqua plant^{1}	No.of seeds siliqua^{-1}	1000 seed mass (g)	Yield (t ha^{-1})
Fallow (control)	124	72	75b	14b	1.2	1.01b
Harvesting of mung plants	114	74	78b	16b	1.1	0.89b
Plough down of mung plants	127	72	84a	19a	1.3	1.26a
F-test	NS	NS	*	*	*	NS

Wheat

Treatment	No.of spikes (m-^{2})	Plant height (cm)	Length of spike (cm)	No.of grains spike^{-1}	1000 seed mass (g)	Yield (t ha^{-1})
Fallow (control)	160	79	8.1b	30	47.3b	1.36ab
Harvesting of mung plants	146	77	8.0b	29	46.3b	1.22b
Plough down of mung plants	155	80	8.8a	33	50.3a	1.49a
F-test	NS	NS	*	**	*	**

1. Values followed by same letters within a column are not significantly different at the 0.05 level.
2. *Significant at 0.05;** at 0.01 levels.
3. NS = Nonsignificant

Source: BARI (1987).

green manure. Lower yields were obtained in all the postrainy-season crops where mung bean plants were harvested. This might be due to loss of soil fertility and moisture as was also reported by Lawn and Ahn (1985). However, in this case mustard and lentil produced yields similar to those obtained in the fallow treatment.

Conclusions

The general conclusions are:

1. Mung bean and black gram can be grown as catch crops after harvest of *aus* rice in the *aus* rice-fallow-postrainy season cropping pattern provided the land is well drained and light textured (sandy loam-silty loam).
2. *Aus* rice should be harvested to the ground level and mung bean (40 kg seed ha^{-1}) and black gram (50 kg seed ha^{-1}) should be used for planting under minimum-tillage conditions.
3. To avoid the social problem of free grazing of cattle one ploughing is recommended in the case of minimum tillage.
4. To maximize the net return, *aus* rice-mung bean/black gram-lentil followed by *aus* rice-mung bean/black gram-mustard cropping patterns may be recommended.
5. It is possible to grow almost all the postrainy-season crops following mung bean in the *aus-mung* bean-postrainy season cropping pattern. However wheat or lentil appear to be more profitable.
6. Mung bean and black gram may have a slightly depressing effect on the subsequent postrainy-season crops which could be overcome by ploughing down the residues of mung bean as green manure under dry conditions, provided sowing of the following postrainy crop is not delayed.
7. If these patterns are extended in the northern parts of the country a large area which otherwise remains fallow may become available for pulses cultivation. This extended area will not disturb the existing cropping patterns, and can lead to increased total pulses production.

The future research thrust should be directed toward the following areas:

1. Optimization of cultural practices such as plant density, planting geometry, weed control, etc. for mung bean and black gram in the *aus* rice-mung bean/black gram-postrainy season cropping pattern.
2. Monitoring of soil-moisture depletion and water-use efficiency from the whole pattern (*aus* rice-mung bean/black gram-postrainy season crops).
3. Study of the reasons for reduction in yield of subsequent postrainy-season crops after harvest of the whole mung bean or black gram plant and suggestions for appropriate measures to maintain the soil fertility and yield of the postrainy-season crops.
4. Quantification of added green manure from the residues of mung bean and study of soil fertility status after ploughing down to determine the fertilizer dose for the following crops.
5. Development of management practices for insect-pest control.
6. Feasibility of replacing the local *aus* rice by HYVs and its effect on the whole pattern to increase the annual net return.

Discussion

D.G. Faris: For clarification, if a farmer has a negative cost-benefit ratio using his own cropping pattern, does that mean that he is losing money? If so, how does he continue?

A. Aziz: Yes, because he does not account for his own resources like labor, draft power, etc. He is minimizing the cost-benefit ratio by growing other crops. Moreover he does not have any other alternative.

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Problems and Prospects of Pulses Production

A. Ahad Miah, A.F.M. Maniruzzaman and M. Motior Rahman

Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

There has been a continuous decline in production of pulses in Bangladesh during the last decade. The daily capita^{-1} availability of pulses has declined from about 7 g in J 976/77 to about 5 g in 1985/86. Wheat and boro *(winter) rice have replaced to a considerable extent the area under pulses. Major problems with pulses include, low yield potential, unstable production levels due to biotic and abiotic stresses, lower responses to environmental manipulation and high inputs, lack of research input, defective storage systems, and absence of proper marketing facilities. However, their high nutritive value, higher cost-benefit ratio, beneficial effects on soil structure and health, and adaptation to limiting environmental and soil conditions will sustain their place in the existing cropping patterns of this country. Efforts to increase research inputs in terms of high-yielding stable cultivars, improved management practices, modern seed-production technology, suitable storage structures, and proper marketing facilities will go a long way in improving and increasing pulses production in the country.*

Introduction

In Bangladesh, pulses are traditionally grown during the dry winter months under rainfed conditions. Some like black gram *(Vigna mungo* (L.) Hepper), mung bean *(Vigna radiata* (L.) Wilczek), and pigeonpea (*Cajanus cajan* (L.) Millsp.) are grown during summer. However, the area under cultivation is small. Most of the pulse crops are concentrated in the districts of Faridpur, Pabna, Jessore, Rajshahi, Kushtia, Dhaka, Barisal, and Noakhali. They occupy an area of about 0.3 million ha (less than 3% of the total cultivated area) and produce about 0.2 million t of grain (less than 2% of total grain production) in the country (BBS 1987).

Khesari *(Lathyrus sativus* L.) tops the list in respect of area and production. The predominance of this crop is due to its wider agroclimatic adaptability, and its capability to withstand droughts and waterlogging. It can grow well under temperatures ranging between 10° and 30°C. Khesari is usually raised under minimum or zero tillage and management. Lentil (*Lens culinaris* Medic.) is the second most important pulse crop but is more popular among the consumers. It is the most preferred pulse and is one of the main items in the daily diet of a vast majority of the people. The present cultivars cannot tolerate extreme cold or hot climates. This crop has some level of drought tolerance but it is highly susceptible to waterlogging. Chickpea *(Cicer ahetinum* L.) is the third important pulse crop. It is one of the best legumes for human and animal consumption. It is commonly used as '*dhal*' and in the preparation of a variety of snacks and sweets. It is drought tolerant but highly sensitive to excess moisture. High humidity and cloudy weather affect its flowering and pod setting and it is very susceptible to foliar diseases. Therefore, it is difficult to raise this crop in poorly-drained lowlands. Black gram is the fourth pulse crop. As a tropical crop, it tolerates high temperatures, and can be cultivated both in the rainy season and in late monsoon (kharif II) season. Its growth is affected by temperatures below 10°C. It is a short-day plant, but day-neutral cultivars are available for summer cultivation. It is a drought-resistant crop and can tolerate waterlogging for short periods. However, waterlogging for long periods is detrimental. Although the area and production of mung bean is small as compared to the other major

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulse, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

pulses it is considered as a quality pulse in this country. Being a tropical and a subtropical crop it requires warm temperature regimes for its growth and can tolerate high temperatures. It can be grown both in the rainy season and in the late monsoon season. But, it is normally sensitive to low temperatures and cannot withstand waterlogging. Fieldpea *(Pisum sativum* subsp *arvense)* and pigeonpea are not important because their use is limited to a small section of the population.

Constraints to Production

Low Research Input

Due to lack of sufficient manpower, there has been no systematic research directed toward the improvement of various pulse crops. As a result, no significant achievements could be made for the development of improved cultivars and proper management practices to achieve higher yields. Thus the mean national yields of pulses are very poor. Research on modern seed production and postharvest technology has also not received serious attention.

Competition With Other Crops

Release and cultivation of a wide array of high-yielding cereal cultivars has pushed pulse crops to marginal and submarginal lands of low productivity leading to poor yields. As a result, there has been a continuous decrease in area and production of pulses during the last decade (Fig. 1). Wheat and *bora* (winter) rice have replaced a considerable amount of the area under pulses, particularly where irrigation facilities are available. Hence the area and production of wheat and *boro* (winter) rice have increased during the last decade (Fig. 2). Besides, cotton, tobacco, mustard, potato, etc. have also taken over some area of

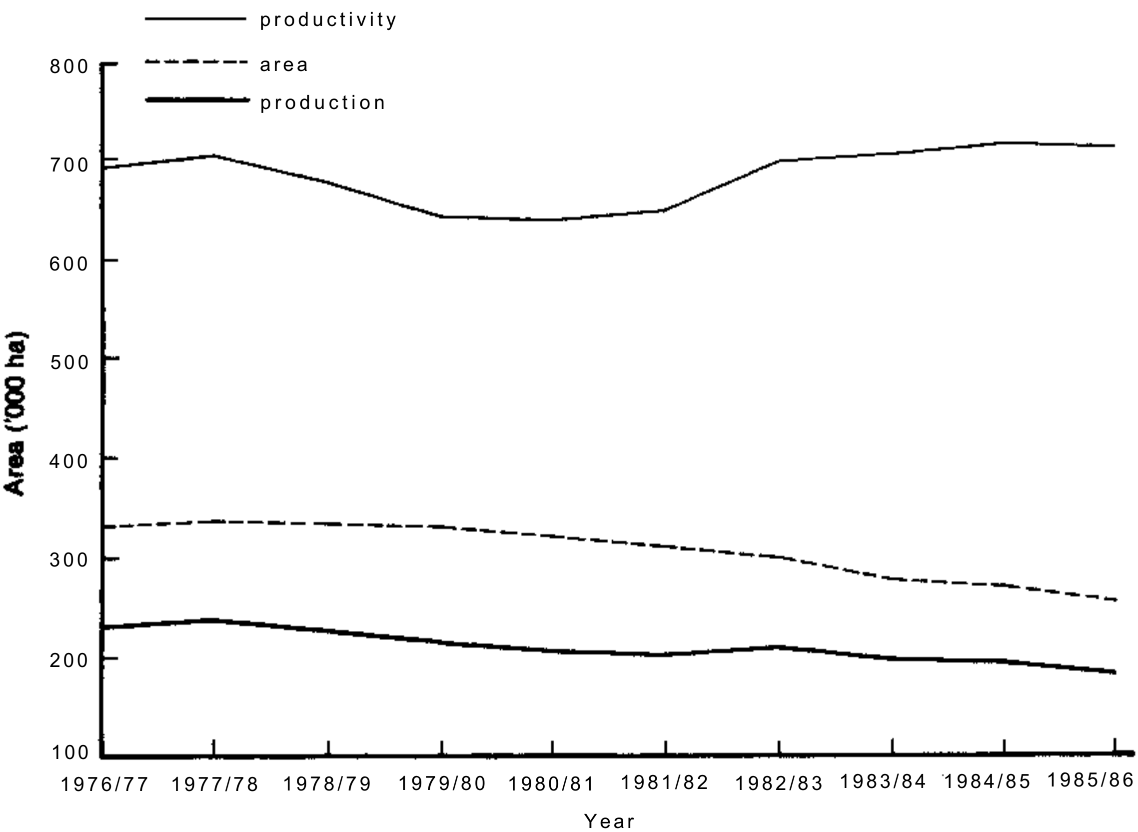

Figure 1. Area ('000 ha), production ('000 t), and productivity (kg ha-[1]) of pulses in Bangladesh 1076-1985/86.

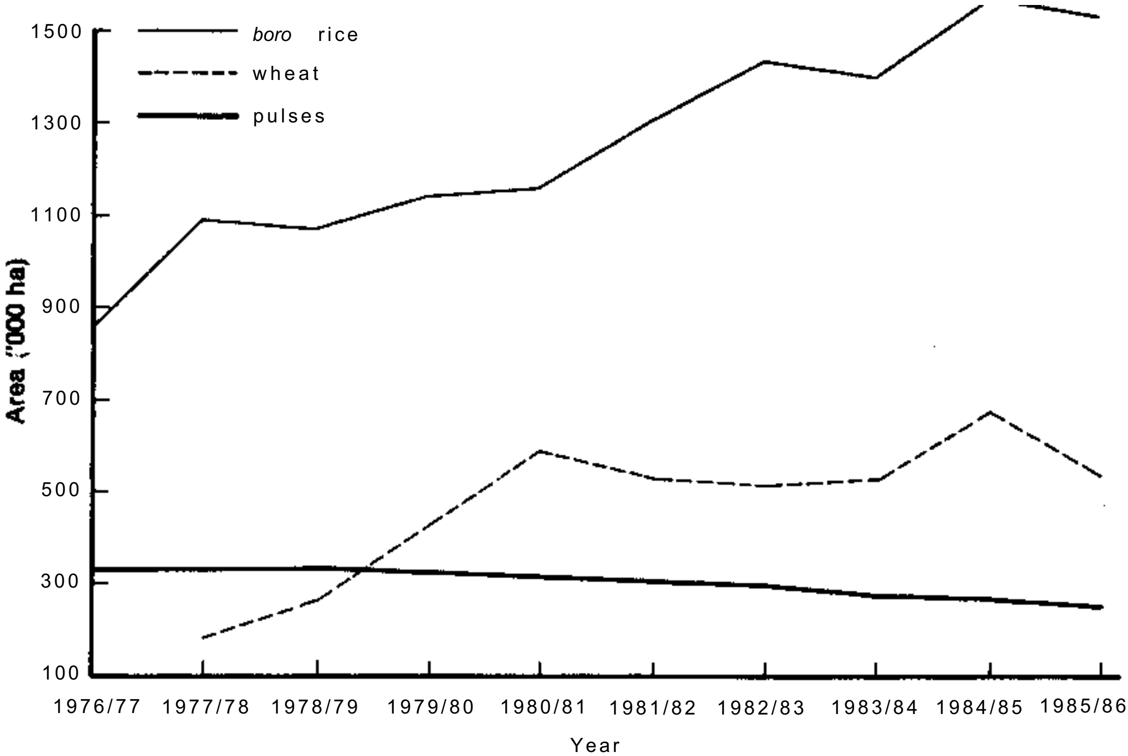

Figure 2. Area of *boro* (winter) rice, wheat, and pulses in Bangladesh 1976/77 -1985/86.

pulses due to their high yield potential and better economic returns.

Low Response to High Inputs

Because of the inherent low yield potential of the local cultivars, pulses are not usually responsive to high inputs compared to other crops. These crops are therefore grown under low levels of management in areas where there is little or no scope for the cultivation of other profitable crops.

Lack of Proper Management

1. Pulse crops in Bangladesh are grown with minimum care and under low levels of management. Seeds are sown without proper land preparation, optimum time of sowing is usually not maintained, and weeding, application of fertilizers, irrigation, etc. are not practiced. Moreover, these crops are susceptible to various insect pests and diseases which cause enormous damage, but no plant-protection measures are taken. All these factors are responsible for poor yields.
2. Most pulse crops are grown during the dry postrainy season under rainfed conditions on residual soil moisture with minimum tillage. Due to uncertain and low rainfall during the growing period adequate soil moisture cannot be assured. This hampers proper germination and emergence (Manalo 1978). Consequently optimum plant stands are not established, and as a result higher yields cannot be achieved.
3. Proper time of sowing is a key factor for maximum yield realization in all pulses. In the existing cropping pattern, chickpea and lentil are sown after the harvest of transplanted *aman* (rainy-season rice), broadcast *aman* or a deep-water *aman* rice. These crops are also raised under the pattern of *aus* (rainfed)rice/juie-fallow-chickpea/lentil in some parts of the country. In order to achieve higher yields, chickpea must be sown between the first and last week of November, while the optimum time of sowing for lentil is mid-October to first week of November. When these crops are sown after the harvest of *aman* rice, sometimes sowing is delayed and the late-sown crops are subjected to a high

temperature regime during the pod setting and grain filling stages, thereby shortening the grain-filling period and the maturity of the crops, and affecting their yield adversely (BARI 1985).

4. Grain-legume crops are capable of fixing atmospheric nitrogen in association with the bacteria in their root nodules. Proper nodulation is very useful for improving crop growth and increasing yields. In many countries effective strains of rhizobia are being used for different grain-legume crops to ensure profuse nodulation and increased yields (Burton 1979). Considerable increase in yield is also obtained in different pulse crops in India by the use of microbial inoculants popularly known as biofertilizers (Subba Rao and Tilak 1977). But until recently, this technology was not made available to the farmers of Bangladesh.

Unstable Production Levels

Pulses are affected more than other crops by the vagaries of climate. Photoperiod, air temperature, humidity, soil-moisture status, and their interactions, are the major environmental conditions that regulate the various physiological factors like germination, growth and development, leaf area index, leaf area duration, rate of photosynthesis, crop growth rate, net assimilation rate, "source-sink*' relationship, harvest index, etc. and realization of yield potential. Due to climatic hazards and biotic factors the production levels of pulses vary substantially from year to year.

Problems of Rainy-season Pulses

Cultivation of pulse crops like black gram and mung bean during early monsoon (April-July) and late inonsoon (August-November) in some areas showed some promise. Lack of high-yielding, short-duration, daylength-insensitive cultivars having synchronous maturity, seed dormancy, and resistance to insect pests and diseases along with adverse climatic conditions have hindered the extension of area and production of these crops in the rainy season.

For summer cultivation of black gram and mung bean, seeds must be sown within the second week of April for economic yield realization. Due to inadequate soil moisture coupled with the probability of minimum rainfall during that period, it becomes difficult to sow the seeds in time (Manalo 1978). Delayed sowing causes the crops to mature by the end of June. The heavy rainfall and high humidity at this time makes harvesting, threshing, and drying difficult. Sometimes, the seeds may germinate within the pods due to lack of dormancy, reducing yields drastically. On the other hand, for crops sown in August, land preparation and proper tillage become difficult due to heavy rainfall, and crops may be damaged seriously due to waterlogging, severe infestation by weeds, and insect pests, leading to poor yield.

Lack of Seed Production Technology

1. There is no modern seed production, processing and preservation technology for pulses in Bangladesh. Therefore farmers use their own seeds, which are often of low quality, preserved under traditional defective storage structures, less viable, and contaminated with various seedborne diseases. Use of low-quality seeds results in poor plant stand, damage to crops at the initial stages of growth, and poor yields.
2. The existing local cultivars of different pulses are not very responsive to high inputs but a few high-yielding cultivars, like Nabin of chickpea showed very high yield potential (more than 2 t ha^{-1}) with the adaptation of better management practices in farmers' fields. In the absence of a modern seed-production technology and distribution system, quality seeds of high-yielding cultivars cannot be made available to farmers and the benefits are not utilized to increase production.

Lack of Adequate Postharvest Technology

There is no scientific and suitable storage structure for pulses in Bangladesh. Seeds are usually stored in gunny bags, earthen pots, tin containers, bamboo baskets, cemented store houses, or in godowns. Storage in gunny bags is risky, although it is widely used in this country. Insect-pests, particularly bruchids (*Callosobruches* sp) cause serious damage to pulse grains. A considerable quantity of the total produce is lost every year due to defective storage. Insect-pest infestation causes poor grain quality, loss in seed viability, reduction in nutritive value, and in extreme cases the grains may become unfit for human consumption.

Lack of a Marketing System

Production of pulses is concentrated in a few districts, and as a result there is a slump soon after harvest in the markets in these areas. Due to lack of a proper marketing system and price policy for pulses, the margin between the price paid by the consumers and that received by the farmers is very high. Although prices of all pulses have increased at the consumers' level, their low price at the growers' level and poor yield potential have made their cultivation nonrenumerative (Elias et al. 1986).

Prospects for Improvement

Varietal Improvement

1. Development of high-yielding cultivars of different pulses, resistant to biotic and abiotic factors, suitable for different agroclimatic conditions and responsive to high input and management will go a long way in bringing about a major breakthrough in the pulses production of the country. Multidisciplinary research is being carried out at the Bangladesh Agricultural Research Institute (BARI) since 1979 to improve pulses production in the country. Two high-yielding cultivars of mung bean, Mubarik and Kanti, and one of chickpea, Nabin, have already been released for commercial cultivation. One high-yielding cultivar of black gram is awaiting release. A number of lines of different pulses, having high yield potential have been identified and are expected to be released in the near future.
2. Development of chickpea and lentil cultivars with late-sowing potential and higher yields, and cultivars of black gram and mung bean suitable for the rainy season, will bring about a significant increase in area and production of these pulses. Efforts are being made to achieve these goals.

Improvement of Management Practices

1. Proper management is important for maximum yield realization of any crop. Improved management practices have been developed to achieve higher yields for some of the pulse varieties already released. Development, dissemination, and adoption of improved management practices like proper time of sowing, seed rate, maintenance of optimum plant stand, seeding, application of manure and fertilizers including micronutrients, and irrigation and plant-protection measures for the cultivation of different pulses, can lead to a significant increase in the total pulses production of the country.
2. Use of biofertilizer may help to substantially increase the pulses production in Bangladesh. Collection, isolation, and identification of effective strains of rhizobia for different species of pulse crops are essential prerequisites for the preparation of rhizobial inoculum with suitable carrier materials. Generation and adoption of this technology will play a vital role towards increasing the production levels of pulses.
3. The yield potential of all grain crops is largely determined by their efficient utilization of available solar radiation for dry-matter production and favorable partitioning of dry matter to the seeds. Studies on the physiological basis of yield variation under different management conditions (in relation to growth habit, stature, height, branching behavior, nodulation pattern, leaf orientation, crop-growth rate, net assimilation rate, leaf-area indices, leaf-area duration, canopy architecture, light interception by the crop canopy, and source-sink relationship) are being carried out for the development of improved management practices through agronomic manipulation.

   These investigations may also help breeders determine suitable ideotypes having higher photosynthetic efficiency and capable of supplying more assimilates during the pod setting and grain development stages, an important factor in achieving high yields.
4. The cost-benefit ratio of pulses is high (1.97) compared to wheat (1.44) and *bow* (winter) rice (1.39), although the yield potential of pulse crops is very low (Fig. 3). Therefore pulses are generally cultivated by poor farmers who cannot afford the high investment required for the cultivation of other crops (Karim and Elias 1986). Availability and adoption of modern technology will increase the productivity of pulses. As a result, farmers will be motivated to cultivate pulses in a wider area, which would considerably increase pulses production.
5. Pulses are important components under different cropping patterns in some regions of the country (Table 1). Improved management practices with high-yielding varieties will increase the productivity of all component crops with higher monetary returns (Islam 1989). Thus, there is an ample scope to increase the area and production of pulses, using modern technology.
6. Mixed cropping and intercropping of pulses with other crops such as mustard, linseed, sesame, wheat, barley, cotton, maize, and sugarcane are being practiced in different regions of the country with success. However, experimental evidence shows that use of optimum seed ratios of the component crops for mixed cropping and maintenance of proper sowing geometry of the companion crops in the case of intercropping would be very effective for higher economic returns.
7. The necessary arrangements must be made to

produce and supply quality seeds and other inputs like fertilizers, insecticides, etc., to farmers at the proper time, as this will help to increase the productivity of pulses through improved management practices.

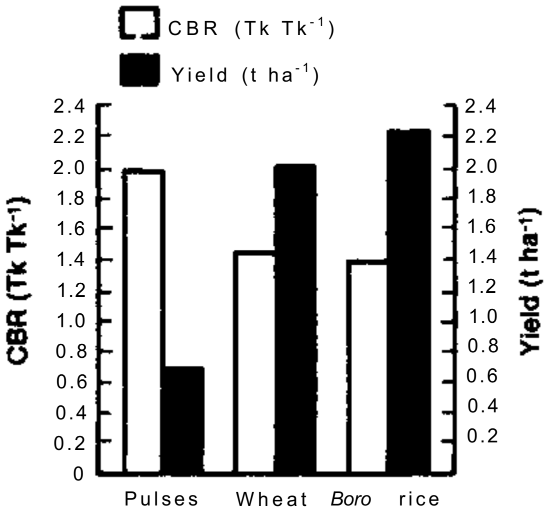

Figure 3. Cost-benefit ratio and mean yields of pulses, wheat and *boro* rice in Bangladesh 1985/86.

Expansion of the Area under Rainy-season Pulses

Vast areas of medium and high lands in the northern parts of the country are left fallow after the harvest of *aus* rice or jute during the end of October until the sowing of winter crops like wheat, chickpea, lentil, etc. between the end of October and the first week of November. This gap can be utilized to raise mung bean or black gram. Besides, there is some possibility for the cultivation of mung bean during summer (March/April), replacing the low-yielding *aus* rice. Appropriate management practices with the availability of high yielding, short-duration, daylength-insensitive, and synchronous cultivars of mung bean and black gram having seed dormancy and resistance to biotic and abiotic stresses will be very effective in increasing the area and production of pulses.

Improvement of Postharvest Technology

Development of postharvest technologies for mechanical threshing, drying, winnowing, and suitable storage structures will significantly reduce losses of pulse grains due to defective storage systems. With such technology, pulse grains can be stored at safe moisture levels (8-10%) after the removal of inert

Table 1. Productivity and total monetary returns of different cropping patterns under rainfed conditions.

Cropping patterns	Crop yield ($t\ ha^{-1}$) I	II	III	Total	Monetary returns ($Tk\ ha^{-1}$)
(F)[1] B. aus-black gram wheat	0.99	0.70	1.03	2.72	18 896
(F) B. aus-black gram chickpea+linseed	1.03	0.63	0.54 (0.31+0.23)	2.20	19 602
(F) B. *aus-block* gram lentil+mustard	1.01	0.65	0.61 (0.22+0.39)	2.27	21 744
(F) B. aus-mung bean mustard	1.03	0.62	0.68	2.33	25 062
(I)[2] B. aus-mung bean mustard	1.82	0.80	0.95	3.57	36 078

1. (F) = Fanners pattern (Local cultivars without improved management).
2. (I) = Improved pattern (High-yielding cultivars with improved management).

Source: Islam (1989).

materials, seed appendages, and application of chemical protectants. Research work in this area has been carried out. Containers like fabricated kerosene tin, earthen pitcher with polythene lining or coating with coal tar have been found to be advantageous compared to traditional storage structures (BARI 1985).

Development of the Marketing System

Presently the Government has no definite price policy or marketing system for pulses. The market price drops sharply during harvest and the poor farmers are deprived of a proper price for their produce. A rational price policy and an effective marketing system with the necessary infrastructure must be developed to ensure remunerative prices to the farmers. This will to a great extent encourage farmers to cultivate pulses.

It may therefore be concluded that despite several constraints, there is a wide scope to explore and exploit the production potential of pulses leading to a substantial improvement in the production of these important crops.

Discussion

A.K.M.B. Rahman: Marketing research conducted by the Department of Agricultural Marketing indicates that marketing margins/cost is not very high. The farmer's share in the consumer Taka is about 80%.

A. A. Miah: A survey report published by the Agricultural Economics Division of Bangladesh Agricultural Research Institute (BARI) indicated that, at present the Government does not have any price policy and marketing system for pulses. As a result, there is a wide gap between the price paid by the consumers and that received by the growers.

S.K. Roy: Do you think that leaf area index (LAI) is the limiting factor of grain legume yield in all cases? Because light penetration down into the canopy is negatively correlated with LAI. I think plant architecture and leaf orientation are matters to be considered.

A.A. Miah: I don't think so, and I have not mentioned it in our paper. The yield potential of legumes is largely determined by the efficient utilization of available solar radiation for dry-matter production and favorable partitioning of dry matter to the seeds. Besides, other factors like canopy architecture and light interception by the crop canopy, are of course important.

G.A. Fakir: From your paper it appears that seedborne pathogens affect the seed health quality of pulses. Do you advocate routine seed-health tests in the country to ensure production and distribution of high quality seeds?

A.A. Miah: Yes. I suggest development of modern seed production technology including proper seed-health tests. This is very important for the production and supply of quality seeds to the farmers.

M.A. Sattar: Biofertilizers are now being produced in the country by the Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh Agricultural University (BAU), and BARI, but not on a large scale. These fertilizers were found very useful in increasing yield and nitrogen fixation of lentil, chickpea, khesari, and mung bean at different places of the country. This technology needs to be popularized.

A.A. Miah: In my paper I have already suggested the use of biofertilizer to increase the yield potential of pulses. This technology should be made available to farmers, and they should be motivated to adopt it.

M.S. Islam: Pulse crops meet their nitrogen requirement through biological nitrogen fixation. In your paper, you have emphasized only biofertilizer. What do you think about the other deficient nutrients? Is it not necessary to provide an adequate supply so as to increase yield of pulses?

A.A. Miah: Judicious application of different fertilizers depending on soil-nutrient status is very important to increase the productivity of any crop and this is true for pulses as well. I have emphasized biofertilizer, because it is a potential area and very little work has been done on this aspect.

M.A. Bakr: You have mentioned that the production of black gram can be increased by growing it *inaus* rice-black gram-wheat cropping pattern. Would you please let us know what percentage of cultivated area at present is under this pattern?

A.A. Miah: I do not have the exact percentage of total cultivated area available for black gram cultivation under this pattern. However, a vast area of medium and high lands, particularly in the northern parts of the country, are left fallow after the harvest of *aus* rice or jute during August to October until the sowing of winter crops like wheat, chickpea, and lentil. This gap can be utilized for the cultivation of black gram or mung bean.

M.S. Chowdhary: 1. Does low response of pulse crops to high inputs indicate low-yield potential? If so, is the high-yield potential of Nabin chickpea cultivar due to its response to high inputs?
2. Is flower or pod drop due to low nitrogen fixation during pod development or due to source limitation? If there is an increase in rhizobial activity during pod development, there may be more pod drop because more assimilates will be diverted to nodules for nitrogen fixation by the microbes. Please comment.

A.A. Mian: 1. Yes, low response of pulses to high inputs is mainly due to inherent low-yield potential of local cultivars. Nabin is a high-yielding improved cultivar and responds to high inputs.
2. Flower drop in pulses occurs due to source limitation, particularly not due to low nitrogen fixation by their root nodules. Yes, I agree with you. Increase in rhizobial activity during pod setting and development may lead to higher pod drop. Suitable ideotypes having prolonged leaf area duration can increase photosynthetic efficiency during pod setting and prevent flower and pod drop.

M.A.Q. Shaikh: What are the reasons for the little or no cultivation of mung bean or black gram after *aus* rice or jute until sowing of the winter crop, though there is a gap which you have mentioned in your paper?

A.A. Mian: Lack of high-yielding, short-duration, daylength-insensitive varieties with synchronous maturity, seed dormancy, and resistance to biotic and abiotic stresses, are the limiting factors for the cultivation of mung bean and black gram during late monsoon season.

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Physiological Aspects of Yield Improvement in Mung bean

A. Hamid[1], W. Agata[2], A.F.M. Maniruzzaman[3], and A. Ahad Miah[3]

1.Institute of Post Graduate Studies in Agriculture, Salna, Bangladesh; 2.Crop Husbandry Laboratory, Faculty of Agriculture, Kyushu University, Hakozaki, Fukuoka, 812, Japan; 3 .Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

The reasons for low yield potential in mung bean (Vigna radiata *(L.) Wilczek) are discussed, using some physiological parameters that regulate crop growth and developmental processes. A slow rate of early vegetative growth contributes, at least indirectly, towards lower yield. However, there is potential for improvement. Light and temperature optima for maximal photosynthetic rates have been evaluated. Greater demand for N and low uptake from soil accentuates N remobilization from leaves resulting in rapid decline in leaf photosynthetic activities. It has been suggested that improvement of source strength through adequate N fertilization would stop or reduce remobilization of photosynthates from leaves and abscission of reproductive organs. An equation for the yield-density relationship in mung bean has also been worked out.*

Introduction

The yield of mung bean *(Vigna radiata* (L.) Wilczek) is comparatively lower than other grain legumes (Rachie and Roberts 1974). Unlike cereals, research on grain legumes, except soybean, has been inadequate and hence the understanding of the basis of yield is limited. Over the past three decades there has been a dramatic improvement in the yield of cereal grains. This was achieved by manipulation of the genetic make up and physiological characteristics of these crops. Such a breakthrough in the seed yield of grain legumes by genetic means or cultural manipulation has not been possible so far. Some sporadic studies carried out in national and international research centers indicate that the lower yield of mung bean is due to short growth duration, particularly the slow rate of dry-matter accumulation prior to flowering, unfavorable canopy structure, non-responsiveness to fertilizer application, etc. This paper discusses some physiological features of mung bean with a view to determining the characters which control yield and to ascertain whether any of those characters could either be used as indices for selection and breeding for high yield or as a basis for improving cultural practices.

Plant Growth and Leaf-area Development

Leaf area is an important component that is closely related to the physiological processes controlling yield and dry-matter production. Seed yield in a broader sense depends on the size, duration, and activity of the source and the sink capacity. Source size and its activity regulate the rate of dry-matter accumulation. An efficient plant tends to attain optimum leaf-area index (LAI) to maximize light interception immediately after germination (Kuo et al. 1978). Studies conducted in Bangladesh (Biswas 1988; Matsunaga et al. 1989) and elsewhere (Kuo et al. 1978; Trung and Yoshida 1985) showed that the canopy development of mung bean prior to flowering is very slow. It was observed that mung bean plants developed less than 50% of canopy prior to flowering (Biswas 1988). Total dry-matter produced prior to flowering was around 20% of total dry-matter attained at maturity. Maximum crop growth rate (CGR) synchronized with the attainment of maximum leaf mass immediately after flowering which was also for a very brief period (Fig. 1). Dry-matter accumulation after flowering greatly influences seed yield, for most of the photosynthate produced at this stage is used for pod and seed development. It

Citation. BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

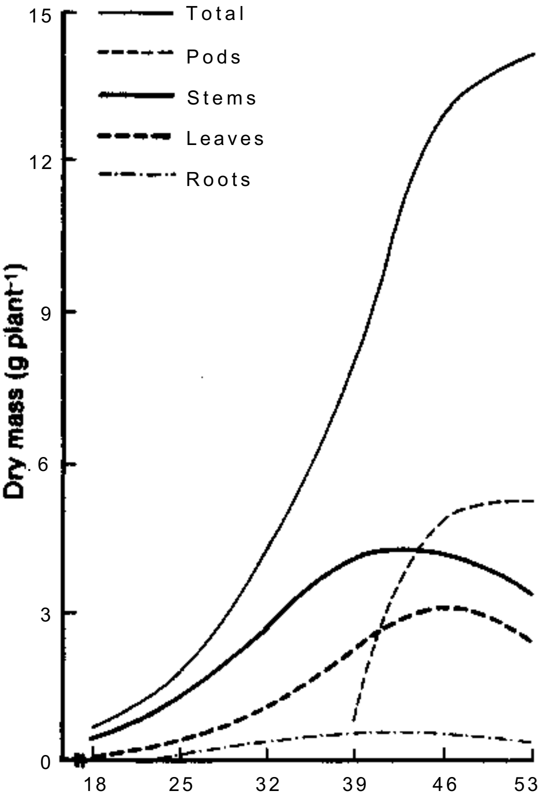

Figure 1. Time course of dry-matter accumulation in leaves, stems, roots, and pods of mung bean (Biswas 1988).

follows that higher initial CGR having greater portion of photosynthates partitioned towards grain during the post-flowering period would be a desirable trait for efficient genotypes.

Seed Size and Crop Growth

Nakaseko (1984) analyzed the differences in the early vegetative growth of azuki bean, kidney bean, and soybean in relation to their seed size. All the genotypes of the three species showed a strong association between seed size and dry-matter accumulation, or leaf area attained 10 days after emergence. Depth of planting has a marked effect on the stand establishment of mung bean (Hamid et al. 1988), as emergence rates of seedlings of bolder seeds were better compared with small-seeded ones (Sangakkara and Bieler 1988). It seems that potential exists to improve the early vegetative growth in grain legumes by planting bolder seeds.

Seasonal Effects On Growth

Apart from genetic make up, environmental conditions like temperature regulate leaf growth and dry-matter accumulation to a great extent (Fig. 2). Although the climate in Bangladesh favors growing mung bean almost throughout the year, a great deal of seasonal variations in leaf area development, crop growth and yield performance have been observed (Matsunaga et al. 1989). Such a difference is mainly attributed to the growth temperature. Our observations on plants grown in phytotron also suggest that the growth and development of mung bean is adversely affected when growth temperature falls below 20°C and completely checked at or below 15°C.

Canopy Architecture and Crop Productivity

Crop productivity in general depends on the photosynthetic rate and canopy architecture of the crop. A productive system should operate most efficiently when the size and structure of the canopy is such that light interception and CO_2 assimilation are maximal while the sinks are active and capable of accepting photosynthates supplied from leaves, and when the respiratory loss is minimal. Productivity of such an efficient structure depends on how much of the light falling on the crop is intercepted by the leaves. Distribution of intercepted light across all the leaves of the canopy is one of the most important determinants of canopy photosynthesis. The interception of light and its distribution within the canopy is governed by the orientation of the leaves. The arrangement of long petioles with wide leaflets in mung bean makes the plant less efficient in light interception (Trung and Yoshida 1985). Our preliminary observation of mung bean canopy structure reveals that at closed canopy more than 80% of the light is intercepted by less than 40% of the total leaves arranged vertically from the top. Around 20% of the leaves arranged in the bottom layers are affected by mutual shading or receive mostly diffused light. This might be improved by developing genotypes with better orientation of leaves within the canopy. Working with field beans Wien (1973) reported that orientation of bean leaflets depended on the pulvinule, a small round portion of the leaflet petiole that acts both as the hinges on which the leaflet turns, and also as the photoreceptor that undergoes positive

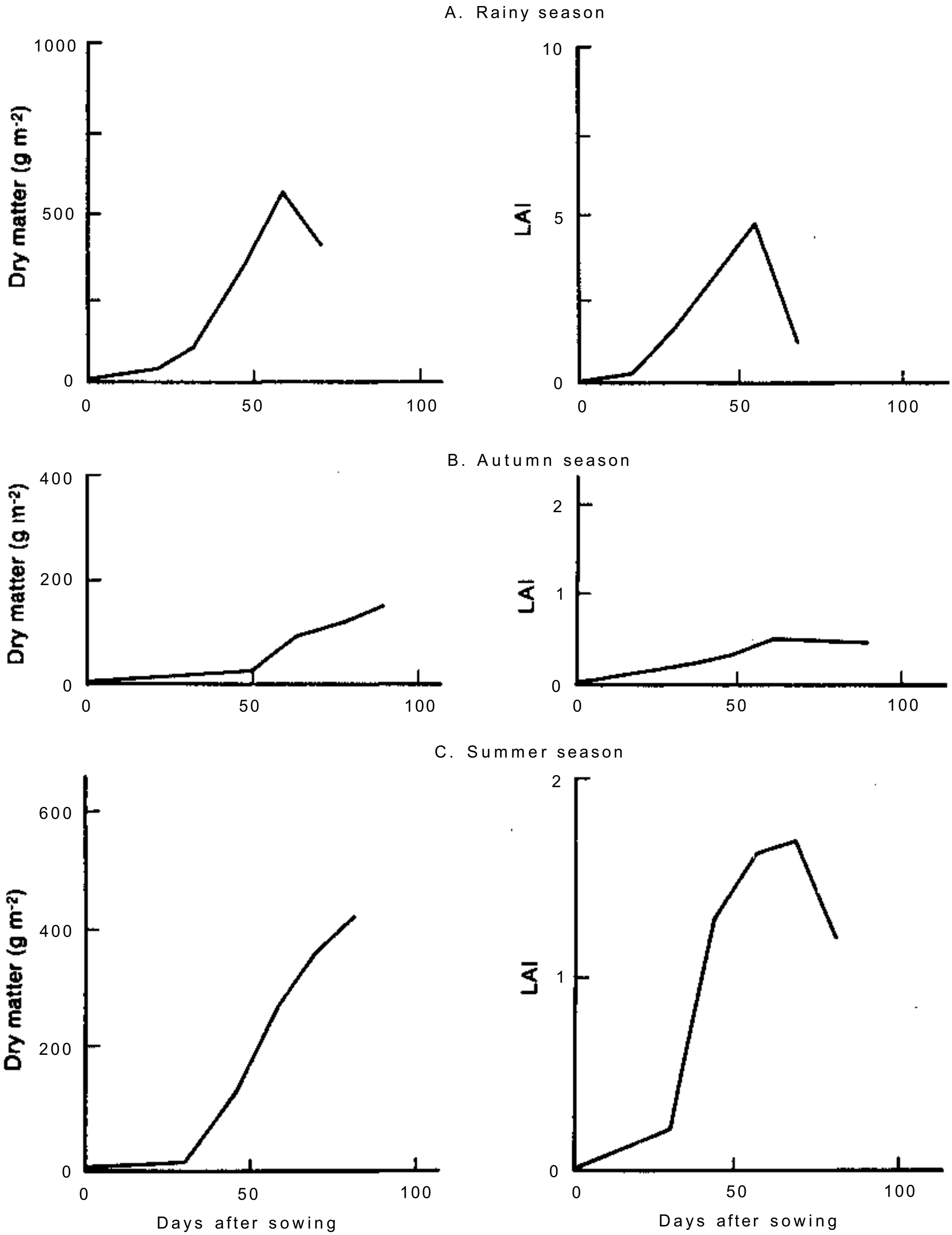

Figure 2. Seasonal change in dry-matter weight and leaf area index (LAI) of mung bean (Matsunaga et al. 1989).

curvature when illuminated by light from a unidirectional source. Application of etherel during the early vegetative phase of soybean and azuki bean is reported to have improved canopy structure and light interception.

Photosynthetic Characteristics

Production of biomass and yield in crop plants largely depends on the function of leaf-area development and consequential photosynthetic activity. High photosynthetic rates generally are capable of producing high levels of biomass (Planchon 1979), but a direct relationship between economic yield and photosynthetic rate is hardly ever achieved (Lambers 1987). Variations in photosynthetic rates among species (Hesketh 1983) and within species (Dornhoff and Shibles 1970) have been reported. Mung bean is a C_3 plant. Srinivasan et al. (1985) reported maximum values of net photosynthesis rate, 13.2 - 30.9 mg dm^{-2} h^{-1} which is much lower than C_3 cereals like rice (Tanaka et al. 1966) and wheat (Planchon 1979). The leaf-photosynthetic rate is low at the beginning and increases progressively, reaching a peak at around the first flowering after which it starts declining (Srinivasan et al. 1985; Mitra and Ghildyal 1988). As the crop approaches maturity the photosynthetic rate drops to about 25% of its maximum.

Photosynthetic carbon assimilation in a crop community is influenced by numerous biophysical factors and therefore studies on the fluctuations in gas exchange in response to environmental variations may contribute substantially to the understanding of factors which influence the rate of dry-matter accumulation and yield formation. Our studies with mung bean under a controlled environment suggest that the light requirement of mung bean for achieving high photosynthetic rates is quite high when compared with other C_3 plants (Leverenz 1987). As shown in Figure 3 the net photosynthesis (Pn) increases with increasing light intensity, attaining a plateau at around 1400 µmol m^{-2} s^{-1} beyond which any further increase in light intensity does not cause any improvement in Pn, indicating light saturation of photosynthesis (Hamid et al. 1990).

A quadratic relationship of the temperature response of mung bean photosynthesis is shown in Figure 4. Maximum photosynthetic rate was obtained at a leaf temperature of around 25°C with a general declining trend on further increase of leaf temperature. However, a separate study conducted under a controlled environment revealed that the photosynthetic response of mung bean varies greatly depending on the temperature regime under which the plants are grown. Table 1 shows that the maximum photosynthetic rate of mung bean grown at 20°C was 22.6 µmol m^{-2} s^{-1}, which dropped sharply to 11.3 umol m^{2} s^{-1} for plants grown at 30°C. The conspicuous varietal difference in Pn due to variation in growth temperature is also apparent. It appears that although mung bean is adaptable under hot, humid environments, its yield performance cannot be expected to be high in the hotter months when mean temperature rises beyond 25°C unless temperature-tolerant varieties are developed.

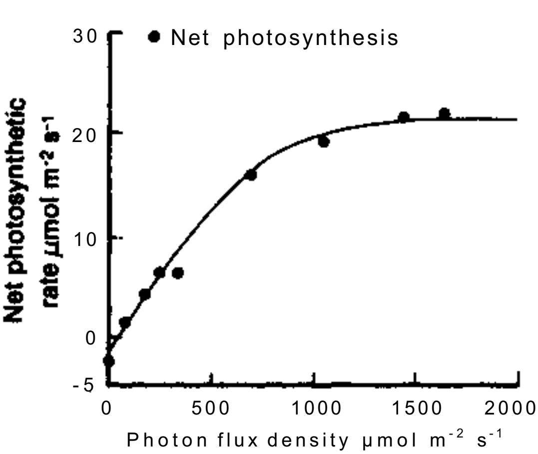

Figure 3. Response of leaf photosynthesis of mung bean to light Intensity (Hamid et al. 1990).

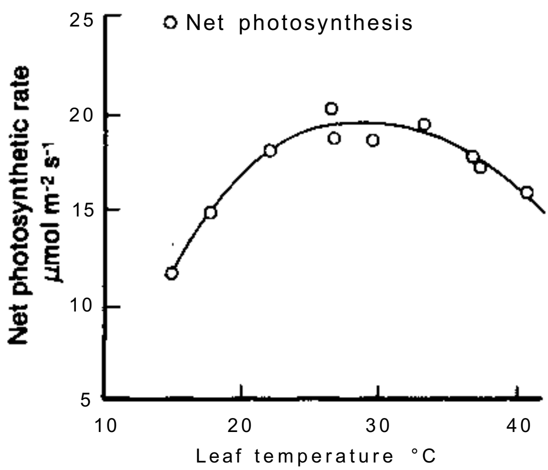

Figure 4. Response to leaf photosynthesis of mung bean to temperature (Hamid et al. 1990).

Table 1. Effect of growth temperature on the maximum photosynthetic rate (P_{max}) of two cultivars of mung bean.

Temperature regime (°C)	Cultivars	
	MB 7706	BSL Local
	P_{max} ($\mu mol\ m^{-2} sec^{-1}$)	
20	22.6	18.5
25	15.5	12.0
30	11.3	7.8

Nitrogen Nutrition

One of the probable reasons for low yield of grain legumes in general is high requirement of nitrogen for the formation and development of prominent grains stands (Alberda and Bower 1983). To produce one unit of seeds, mung bean needs as much as three times more nitrogen than that needed by cereals like rice (Sinclair and de Wit 1975). Mung bean requires a large amount of nutrients in 2-3 periods (Trung and Yoshida 1985). The former peak in the vegetative period is for the development of vegetative structures and the latter peak in the reproductive phase is mainly for the production and development of seeds. Mung bean needs much more N at the reproductive stage than it does in the vegetative stage. In a recent study Mitra et al. (1988) showed that a moderate-yielding mung bean crop requires 27.86 mg N g^{-1} photosynthate during the first 20 days of pod and seed development. Conversely, nutrient uptake after flowering either slows down or stops because of root inactivation during the reproductive phase. During this period less than 40% of N required for sustaining growth and development is obtained from the soil supply (Mitra et al. 1988) while most of the N demand for grain development is met through the remobilization of N and assimilates from the leaves or other organs. This transportation of N to seed is an essential feature in the reproductive phase. Such remobilization enhances early senescence and reduces grain growth duration; the phenomenon which Sinclair and de Wit (1975) referred to as "self destruction" of plants.

It is now clear that the source rather than the sink limits higher yield in mung bean (Chowdhury et al. 1982; Rao and Ghildyal 1985). Much of the source limitations, particularly in the reproductive phase, can be attributed to the N remobilization from photosynthesizing organs. Development of pods and seeds relies almost wholly on current photosynthesis during the post-flowering period. Photosynthetic activity is closely related to leaf-N concentration (Lugg and Sinclair 1981). Biswas (1988) showed that during the 21 days following first flowering, leaf N was reduced to almost 43% of its maximum concentration. Remobilization of N from leaves to grains and developing tissues might be the reason for such a drastic reduction in leaf N concentration. It is probable that high rates of leaf activity are maintained by checking N remobilization through supplying N during or immediately prior to the peak requirement period. Several reports (Hamid 1988; Mitra et al. 1988) indicate a substantial increase in seed yield through foliar application of urea at the reproductive stage.

Flowering and Abscission of Reproductive Organs

Mung bean produces a large number of flowers but the greater portion of them abscise without forming pods. Abscission of reproductive organs might be one of the possible reasons for the lower yield. Several reports (Kaul et al. 1976; Savitri et al. 1978) indicated alarmingly high rates of flower abscission in mung bean. The extent of flower abscission, however, varies depending on the growing season (Matsunaga et al. 1989). In summer the rate of pod set was less than 30%. It was about 85% in autumn and 41 % in the rainy season. But in absolute value the highest number of pod set was found in the plants grown in summer. In an earlier report (Hamid 1989) it was shown that retention of flowers and pod set is somewhat source-limited. It might be possible to increase seed yield if the flower abscission were controlled or reduced through increasing source capacity.

Yield Analysis

Grain yield per unit area is a function of yield of individual plants and population density. Plant yield is governed by number of pods $plant^{-1}$, number of seeds pod^{-1} and unit seed weight. Both yield and yield attributes are markedly influenced by population density. At wider spacing the plant develops more branches but the contribution of secondary and tertiary branches towards grain yield is negligible (Hamid, unpublished). Variation in grain yield was mainly due

Table 2. Plant density effects on plant characters and grain yield of mung bean cultivar MB 7706.

Plant density (no. m^{2})	Seed weight (g $plant^{-1}$)		
	Main stem	Primary branch	Total
3.7	5.21	2.06	7.27
10	3.61	0.67	4.26
23	2.90	0.46	3.36
35	2.50	0.24	2.74
51	2.30	0.18	2.48
156	0.09	0.00	0.09

to an increase in the number of pods $plant^{-1}$ which was accentuated by the increasing pod-bearing branches at lower density (Table 2). If the grain yield per unit area is plotted against density, a parabolic curve is obtained (Fig. 5). It appears that optimum density for higher yield should be somewhere between 50 and 60 plants m^{*2}. When Table 2 and Figure 5 are viewed in conjuction it will be apparent that for maximizing yield the plant should have few branches and most of the pods should be in the main stem.

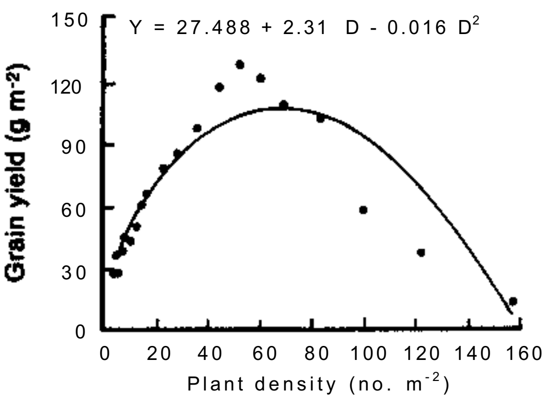

Figure 5. Plant density effect on the grain yield of mung bean (Hamid 1989).

Conclusion

Our understanding of the growth processes and physiological mechanism of yield formation or the reasons for low productivity in mung bean is still not adequate. The research results discussed in the preceeding paragraphs are based mostly on some fundamental studies conducted under controlled environmental conditions. However, it is assumed that the information so generated will give some direction of future research. In the pursuit of higher seed yield some basic issues like slow vegetative growth and relatively inefficient canopy structure demand greater attention. Selection of mung bean genotypes based on high leaf-photosynthetic rates has not been successful so far. While leaf-photosynthetic rate at a particular growth stage may shed light on the biophysical factors regulating carbon assimilation, in a selection process growth analysis still seems to be a better and convenient tool from the practical standpoint. Growth hormones might be involved in abscission of reproductive organs or remobilization of photosynthates, but this has not been studied as yet. Studies aiming at improvement of source capacity and increasing the duration of the reproductive phase may be worth attempting.

Acknowledgement: We thank Mr M. Tajul Islam for his technical assistance.

Discussion

A. Sarker: Is there any way to synchronize the photosynthesis and nitrogen fixation time, in order to achieve the development of more efficient plants?

A. Hamid: Our studies with existing mung bean varieties show that the highest rate of Pn and nitrogenase activities are at the first flowering. Pn rate does not drop very rapidly but nitrogen fixation does not keep pace with the Pn rates. Our breeding strategies would be to develop varieties capable of retaining high nitrogenase activity at the end of the pod development stage which is 20-30 days after flowering.

M.S. Hoque: There is no doubt that the requirement of N for pulse crops is higher than many other crops. But the important point is that if we apply more urea N, then the biological system of atmospheric nitrogen fixation and utilization will be hampered. So we should be careful in adding nitrogenous fertilizers for growing legume crops.

A. Hamid: If the addition of N fertilizer can be synchronized with the demand of the mung bean plant, the photosynthetic activity as well as the dry-matter production can be improved. In our studies we noticed that foliar application of urea at around flower initiation increases leaf nitrogen content and total seed yield. Foliar application of urea 7 days after first flowering helps reduce flower and pod abscission to some extent. On the other hand, N fixation by mung bean perhaps is the lowest among the grain legumes. However, if the required N during post-anthesis period is supplied through biological nitrogen fixation that will help reduce the nitrogen fertilization cost.

M.S.I. Chowdhury: What is the reason for the drop in photosynthetic rate at saturation condition? Was it due to leaf wilting from root damage caused by saturation?

A. Hamid: Leaf conductance or the reciprocals of resistances in plants subjected to soil saturation was close to zero. Plant water potential did not limit transportation. The drop in photosynthetic rate was therefore caused by the closure of stomata which resulted in the drop in conductance.

S.K. Roy: It seems strange to me that the LAI of mung bean was 71.0 in autumn. Can't we increase LAI singly by increasing the seed rate in autumn?

A. Hamid: Perhaps not. At low temperatures plant growth is retarded and when temperature falls to 15^0C or lower, the growth stops totally. Autumn-grown plants might have encountered low temperature before or at flowering, which retarded leaf area development and flowering. Increasing the seed rate will definitely help increase leaf area at the vegetative stage at flowering or after that would follow enhanced senescence.

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Status of Microbiological Research on Pulses

M.S. Hoque and M.A. Sattar

Bangladesh Agricultural University and Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh

Abstract

*Collection, isolation, authentication, selection, and production of effective strains of rhizobia of mung bean (*Vigna radiata *(L.) Wilczek), black gram* (Vigna mungo *(L.) Hepper), lentil* (Lens culinaris *Medic), khesari* (Lathyrus sativus *L.), and chickpea (*Cicer arietinum *L.) have been carried out at the Bangladesh Agricultural University (BA U) and the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, since 1977. In pot and field experiments yield increases of 25 to 70% were obtained with these pulses. The most effective strains were BAU 604 and TAL 441 on mung bean; BAU 502 and 510 on black gram; BAU 416,421, and 439 on khesari; BAU 303,* L_1, L_5, *and TAL 638 on lentil; and BAU 16 and 24, and CP 2200, and Y 29 on chickpea. Among the four strains for chickpea, BAU 16 showed higher viability than any of the other three in different inoculants prepared with peat, sawdust, and soil materials as the carriers. Field trials with khesari and black gram indicated that 20-40 g of inoculant with 109 viable rhizobia* g^{-1} *were sufficient to produce the desired dry matter and yield. Strains BAU 439 and BAU 444 maintained relatively higher viability up to 11 weeks of storage at room temperature. Combined inoculation with* Rhizobium *sp, phosphate dissolving microorganisms, and Vesicular-Arbuscular Mycorrhizae (VAM) at different levels of urea, triple superphosphate (TSP), and pesticides at seven locations produced better crop growth, nodulation, dry matter, seed and hay yields, and increased fixation of atmospheric nitrogen. In future we plan to study the effects of specific strains of rhizobia on individual pulses and assist in producing inoculants for use by the farmers.*

Introduction

Nitrogen is the most limiting element in the soils of Bangladesh. Legumes fix atmospheric nitrogen for their growth if inoculated with proper strains of *Rhizobium.* Through microbiological research, the most suitable *Rhizobium* bacteria can be isolated, screened, and mass-cultured for use as bacterial inoculants. This can reduce the requirement of nitrogen for cultivating legume crops. In Bangladesh, biological nitrogen-fixation studies with pulse crops are being carried out mainly at the Bangladesh Agricultural University (BAU), Bangladesh Agricultural Research Institute (BARI), and Bangladesh Institute of Nuclear Agriculture (BINA). In this paper, the microbiological research studies on pulses carried out at BAU and BINA have been reviewed since the First National Workshop on pulses, held at BARI, Joydebpur, in August 1981.

Results and Discussion

Collection, Authentication, and Maintenance of *Rhizobium* Culture

After collecting nodules from fields in different regions of the country many rhizobia strains have been isolated in the laboratories at BAU and BINA. A number of strains have also been obtained from the Nitrogen Fixation by Tropical Agricultural Legumes (NifTAL) project, Hawaii, USA; the Rothamsted Experimental Station, United Kingdom; the Biological Nitrogen Fixation Resource Centre (BNFRC), Bangkok, Thailand; the Indian Agricultural Research Institute (IARI); the International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT), India; International Center for Agricultural Research in the Dry Areas (ICARDA), Syria; and from other sources. The local isolates and the exotic strains were then

Citation: BAR! (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

authenticated by nodulation tests and stored in test tube slants. At present more than 100 strains of rhizobia effective on different pulse crops are being maintained at BAU and BINA. Every year new additions are made.

Response to *Rhizobium* Inoculation

Many pot and field experiments were carried out to study the response of khesari *(Lathyrus sativus* L.), lentil *(Lens culinaris* Medic), mung bean (*Vigna radiata* (L.) Wilczek), chickpea *(Cicer arietinum* L.), and black gram *(Vigna mungo* (L.) Hepper) to rhizobia inoculation, and to evaluate the effectiveness of different strains of rhizobia on these pulses. Distinct beneficial effects of *Rhizobium* inoculation have been observed in respect of nodule formation, nodule mass, shoot dry matter, and grain yield of khesari, lentil and mung bean (Tables 1,2,3). Data in Table 1 show that there were significant increases in nodule number and nodule mass per plant, shoot dry matter, and grain yield of three khesari cultivars due to *Rhizobium* inoculation (Alam et al. 1988). The effect was more pronounced in the cultivar V-3968 than the local and Pahartali cultivars used in the study. Table 2 shows the influence of *Rhizobium* inoculation on nodule formation and grain yield of lentil (Hoque 1988a). There was a significant increase in shoot dry matter and grain yield of lentil due to application of urea-N and the effect was more pronounced in the presence of P and K application. *Rhizobium* inoculation gave 70% more grain yield than noninoculated control. Yield was 96% more when inoculation was used along with P and K application. In another field trial, it was observed that inoculation with different strains of rhizobia gave 12 to 47% increase in the grain yield of mung bean over noninoculated control in 1984/85 while application of 50 kg urea-N failed to produce marked increase in mung bean yield (Bhuiya et al. 1985). The strain BAU 604 appeared best and strains BAU 606 and TAL 441 were equally effective (Table 3).

The results also show that inoculation with different strains of rhizobia produced higher number of nodules and shoot dry matter per plant compared to control treatments. Strains of rhizobia responded differently with lentil in different soils (Sattar and Podder 1988). The strain L_1 recorded the highest number of nodules, dry matter, and grain and hay yields with Comilla, Mymensingh, Bogra, and Rajshahi soils, while the strain L_7 did best with Jessore and Pabna soils. The strain L_{Din} performed better in Dinajpur soil. The maximum shoot mass in Faridpur soil and grain yield

Table 1. Response of 3 khesari cultivars to *Rhizobium* inoculation at BAU, Mymensingh, Bangladesh, 1986787.

Treatment	Nodule no. plant^{-1} Main root	Nodule no. plant^{-1} Branch root	Nodule mass (g plant^{-1})	Shoot mass (g plant^{-1})	Grain yield (kg ha^{-1})	% Yield increase
Var. local						
Noninoculated	7.2d[1]	6.2c	0.008b	0.203ab	802b	-
Inoculated	9.1ab	7.8abc	0.011a	0.233a	952ab	19
Var. 3968						
Noninoculated	7.7bc	7.5bc	0.09b	0.173b	845b	5
Inoculated	10.0a	9.6a	0.011a	0.217a	997a	24
Var. Pahartali						
Noninoculated	7.5cd	6.7bc	0.008b	0.168b	815b	2
Inoculated	9.4ab	9.3ab	O.OlOab	0.207ab	972a	21
SE	±0.41	±0.61	±0.0005	±0.012	±47	

1. Values followed by the same letters within a column do not differ significantly from each other at the 0.05 level.

Table 2. Response of lentil to *Rhizobium* inoculation at BAU, Mymensingh, Bangladesh, 1987/88.

Treatment	Nodule no. plant^{-1}	Nodule mass (g plant^{-1})	Shoot mass (g plant^{-1})	Pod no. plant^{-1}	Grain yield (kg ha^{-1})	% yield increase
Control (Noninoculated)	1.0c	0.7b	0.09ab	10.1	235e	-
N[1]	1.0c	0.8b	0.11a	10.8	348cd	48
K	1.1c	0.7b	0.08b	11.1	283de	20
NPK	1.7c	1.6b	0.11a	14.4	411 abc	75
Inoculated	5.7b	3.6ab	0.10a	11.5	400bc	70
PK+Inoculated	9.3a	6.5a	0.11a	12.6	461 ab	96
NPK+Inoculated	8.5a	6.3a	0.12a	14.5	484a	106
SE	±0.8	±1.2	±0.07	±NS	±24.8	

1. N = nitrogen, P = phosphorus, K = potassium.
2. Values followed by the same letters within a column do not differ significantly from each other at the 0.05 level.

in Khulna soil were recorded by strain L_5. The application of small doses of urea at 20-30 kg N ha^{-1} with inoculants gave high yield in lentil. Higher doses of N drastically reduced nodulation and yield. TSP application up to 60 kg P_2O_5 ha^{-1} favored inoculation response in recording higher nodulation and yield of lentil and chickpea (Sattar et al. 1987; Sattar and Podder, 1988). Nitrogen application with inoculants showed negative results in some studies.

Better performance of rhizobial mixed-culture inoculations over single culture on chickpea were observed in several field experiments (Sattar et al. 1988). Local inoculants were better than the exotic inoculants in nearly all the cases.

Screening and Selection of Effective Rhizbobia Strains

Many trials have been conducted in greenhouse and in fields on the effectiveness of different strains of rhizobia collected locally and from abroad. Some results are reported below.

Results of pot-culture trials with sterilized sand

Table 3. Response of mung bean to *Rhizobium* inoculation at BAU, Mymensingh, Bangladesh, 1986/87.

Treatment	Nodule no. plant^{-1}	Nodule mass (g plant^{-1})	Shoot mass (g plant^{-1})	Grain yield (kg ha^{-1})	% yield increase
Control (Noninoculated)	1.6bc[1]	0.002b	1.69c	660d	-
BAU 502	NT[2]	NT	NT	NT	NT
BAU 604	4.1a	0.004ab	3.17a	972a	47
BAU 606	3.2ab	0.003ab	3.85ab	818bc	24
TAL 441	3.9a	0.004ab	2.30b	740cd	12
Mixed culture	3.0ab	0.005a	2.15b	920ab	39
Urea-N (50 kg ha^{-1})	1.0c	0.001b	1.69c	705cd	7
SE	±0.6	-	±0.20	±42.3	-

1. Values followed by the same letters within a column do not differ significantly from each other at the 0.05 level.
2. NT = Not tested.

showed that of 6 isolates of khesari rhizobia, BAU 488 and BAU 449 produced higher nodule number than others (Bhuiya et al. 1983). These two isolates and BAU 450 gave identical but higher shoot dry matter and shoot N content than others. Data of a similar trial with lentil indicate that from among 7 local and 2 exotic strains studied, BAU 303, BAU 344, and BAU 346 (local) and TAL 638 (exotic) were found equally promising and better than others in producing shoot dry matter (Hoque 1988b). Pot-culture studies with black gram rhizobia have shown that out of 9 isolates tested, BAU 516, BAU 517, BAU 518, and BAU 519 were most promising in terms of nodule formation and producing shoot growth of the crop. The highest shoot N content of 3.39% was noted in BAU 516 and BAU 519 compared to 2.25% in the control pot (Bhuiya et al. 1983).

Performance of different strains of khesari rhizobia was studied by laying out field trials at various locations of the country (Bhuiya et al 1982, 1983). In a 1981/82 field trial, during the winter season BAU 416 appeared to be the best strain in producing nodule number and grain yield in all the locations at BAU, Mymensingh, at Ishurdi and at Jessore farms (Table 4). BAU 421 gave the next best results at the BAU farm. In a 1983/84 winter trial BAU 416 and BAU 444 performed better at the BAU farm. In the case of lentil, BAU 303 and TAL 638 were found to be more effective than any other strain in a 1987/88 winter trial (Hoque 1988b). The black gram isolate BAU 501 was more promising in 1981/82 winter trial (Bhuiya et al. 1982) and BAU 502 and BAU 504 performed better in 1982/83 winter trial (Bhuiya et al. 1983). Five strains of lentil (L_1, L_5, L_7, L_{Din}, and L_{Nil}) were found promising in extensive field experiments conducted at seven different locations in Bangladesh (Sattar et al. 1987).

Table 4. Effect of different strains of rhizobia on khesari, various locations, 1981/82.

	Nodule no.	Dry matter (g plant^{-1})	Grain yield (t ha^{-1})	% yield increase
BAU				
Control (Noninoculated)	2.5a[1]	0.57b	0.80a	-
BAU 416	4.2b	0.82a	1.37b	71
BAU 421	3.5ab	0.74a	1.30a	62
BAU 424	3.2ab	0.70ab	1.23a	54
Ishurdi				
Control (Noninoculated)	4.5b	1.95b	1.96	-
BAU 416	7.5a	2.88a	2.45	25
BAU 421	6.3ab	3.00a	1.96	0
BAU 424	6.5ab	2.98a	2.05	4
Jessore				
Control (Noninoculated)	5.1b	0.26b	1.61	-
BAU 416	7.8a	0.34a	1.94	20
BAU 421	7.4a	0.31a	2.05	27
BAU 424	6.9a	0.29ab	1.69	5

1. Values followed by the same letters within a column do not differ significantly from each other at the 0.05 level.

Crop Cultivar x *Rhizobium* Strain Interaction

Several field trials conducted during 1983-85 to study the interaction between crop variety and *Rhizobium* strain did not show any preference of any *Rhizobium* strain to any crop cultivar. Strains BAU 439 and BAU 444 as well as their mixed culture were more promising on local and charbadna cultivars of khesari in farmers' fields at Fulbaria upazila, Mymensingh (Bhuiya et al. 1984). These strains also performed similarly in another trial in Jamalpur farm (Bhuiya et al. 1984). Strain BAU 421 was more effective on local and Jamalpur cultivars in another trial conducted at BAU farm during winter, 1984/85. In black gram BAU 502 and BAU 510 were found more effective than others on the local variety and 2038 cultivar (Bhuiya et al. 1986). On the black gram cultivar T 9, the strains BAU 510 and 511 were more effective (Bhuiya et al 1984). Significant variations of different host-rhizobia combinations in plant mass, nodulation, dry matter, grain yield, and nitrogen uptake were observed in chickpea (Podder and Habibullah 1982). Different germplasm lines/ mutants of chickpea responded differently to *Rhizobium* inoculation in augmenting yield and yield-contributing characters. The increase in the nitrogen fixation rate of chickpea lines due to inoculations was 34-126%, the highest fixation being with the germplasm G 97 (73 kg N ha^{-1}) followed by G 296 (70 kg N ha^{-1}), and ICCT 5 (65 kg N ha^{-1}) (Sattar et al. 1988). The percentage increase over noninoculated control for G 97 was 106, for G 296, 126, and for ICCT 5, 69.

Survival of Rhizobia in Inoculants During Storage

Survival of khesari rhizobia in the inoculants prepared with BAU 439 and BAU 444 using peat, sawdust, and charcoal as carrier materials was studied up to 75 days of storage at room temperature (Bhuiya et al. 1983). The survival rate of both BAU 439 and BAU 444 was much higher in the peat carrier than in either of the other two materials. Storage up to 75 days showed as high as 1.1 x 10^9 viable cells (g inoculant)$^{-1}$ prepared with either of these strains of rhizobia. In another survival study with chickpea rhizobia by Khanam et al. (1984), it was observed that the strain BAU 16 in peat-based inoculant showed very high survival of 2.2 x 10^9 (g inoculant)'^{1} after 75 days of storage at room temperature while under similar storage condition the same strain showed only 0.46 x 10^9 viable cells (g inoculant)$^{-1}$ in soil and 0.30 x 10^9 viable cells (g inoculant)$^{-1}$ in sawdust-based inoculants. Several field trials during winter 1982/83 (Bhuiya et al. 1983) showed that 20 or 40 g of peat-based inoculants having approximately 10^9 viable rhizobia g^{-1} would be sufficient for inoculating 1 kg seeds to produce desired-dry matter and grain yield of khesari and black gram.

Studies with Vasicular-Arbuscular Mycorrhizae (VAM) and Phosphate-Dissolving Microorganisms

Response of chickpea to VAM culture was evaluated in a pot-culture experiment. Significant response due to VAM inoculation was recorded in respect of growth, nodulation, and yield of the crop. The benefit was more pronounced when phosphate was incorporated at 30 kg P_2O_5 ha^{-1} (Sattar and Roy 1989). Nodulation, dry matter, and yield of lentil were improved by the inoculation of phosphate-dissolving cultures *(Aspergillus awamori F_{18} , Bacillus polymyxa H_5,* and *B.megaterium* TSR III). Effective nodules, nodule mass dry matter, and grain yield were maximum when inoculated with local isolate *(B. megaterium* TSR III) in presence of TSP at 30 kg $P_2O_5ha^{-1}$ (Sattar et al 1986). Among the single-and composite-culture treatments, *Glomus,* and *Rhizobium* and *Glomus* gave the highest yield in chickpea (Sattar and Roy 1989). Beneficial effects of combined inoculation of *Rhizobium,* phosphate-dissolving microorganisms and VAM have also been obtained over individual strains.

Production of Inoculants

Small-scale production of bacterial inoculants and distribution among the farmers were initiated at the Department of Soil Science about a decade ago (Hoque 1988a). At present the inoculant is being produced on a small scale at BAU and BINA for use in the cultivation of mung bean, black gram, chickpea, and khesari.

Recommendations

Microbial inoculants could be a cheaper alternative when compared with the costly synthetic fertilizers.

Greater emphasis should be laid on systematic microbiological research with pulse crops, in close cooperation between breeders and microbiologists.

The establishment of adequate physical facilities and manpower development should be given priority.

Pulse crops which are the main source of protein in Bangladesh should be included in the rice-based cropping systems. Effective measures should be taken for utilization of already developed promising microbial strains by the farmers through establishing biofertilizer production centres.

Discussion

A. Ahad Miah: In your experiments on the effect of *Rhizobium* inoculation on the yield of different pulses, in most cases you have counted nodules and measured their dry mass only once. May I request you to study the nodulation pattern at different stages of growth? This will enable you to interpret results properly and help in screening and selection of effective strains of rhizobia. When did you count nodules?

M.S. Hoque: In most of our studies, we have recorded nodule count and mass of nodules at two growth stages of the different pulses. But for mung bean, lentil, and black gram, a one-time observation at 40 - 55 days has been found satisfactory for these short-duration crops.

S.K. Roy: Inoculum bacteria die in many cases if they come in contact with direct sunlight. What is your suggestion to the farmers who want to sow seed in the middle of the dry season? How can farmers store inoculum for a longer period, say from one season to another?

M.S. Hoque: It is suggested that the inoculated seeds should be sown in the field either in the morning or late afternoon. But, if the farmers have no other choice but to sow the seeds in the midday sun they should cover the land immediately after sowing so that the inoculated seeds are not exposed to the scorching sun for a long time. However, it is not advisable to sow the inoculated seeds in the hot sun.

M. O. Islam: In our observation [Islam et al. 1987, Annals of Agriculture Vol.8 (2)] we found that there exists clear variability among the genotypes for nodulation under normal field conditions. It has also been established that specific host genotypic x *Rhizobium* interactions exist. So, could we recommend biofertilizer in general instead of a specific *Rhizobium* inoculum for specific cultivars in chickpea?

M.S. Hoque: We do not have many studies on the interaction of host genotype x *Rhizobium* interaction with chickpea. Some studies with khesari, mung bean and black gram cultivars x *Rhizobium* strain interaction have shown very little interaction effect among different cultivars of a crop with different rhizobia strains.

M.A. Bakr: From your paper it is clear that the application of bio-fertilizer has distinct merit in increasing yield of pulses. Why are efforts not made to make it available to the end users?

M.S.Haque: I think this workshop can suggest appropriate measures for making the biofertilizers available to the end users.

M.A. Newaz: 1. There is genetic variation of symbiotic efficacy among both pulse genotyes and rhizobia strains. Under this situation how would you propose to rationalize biofertilizer recommendation for different landcaces used by the farmers?
2. If you suggest "mixed culture", then how many strains should be combined for commercial use?

M.S. Hoque: 1. In our studies with crops like mung bean, black gram, and khesari on crop cultivar x *Rhizobium* strain interaction we have seen little such interaction effect.
2. At the moment, we do not suggest the the use of any mixed culture.

D.G. Faris: Are there plans to produce rhizobia strains commercially by a private company or a government enterprise?

M.S. Hoque: There has not been any initiative from the government as yet for the commercial production of rhizobia inoculants.

Until now the Department of Soil Science of Bangladesh Agricultural University has been producing some amount of inoculants for use in mung bean and khesari and distributing it to the farmers through Bangladesh Agricultural Development Corporation (BADC), Mennonite Central Committee (MCC), and the BAU Agriculture Extension Project.

D.G. Faris: You show some very high increase due to rhizobia inoculation. 1. Could you please give the soil condition of the "control" in your various trials?
2. Were they rice fallows only?
3. What was the nutrient status of the soils (Outside N)?
4. What was the earlier history of cropping with legumes (All without previous legumes)?
5. What was the soil type usually?

M.S. Hoque: 1. and 2. Neither nitrogenous fertilizer nor rhizobia inoculant was applied in the control plots. We did not analyze the soils of our field trials for the status of different nutrients except for available N and organic matter content and for some soils, analysis was done also for available P and S contents. The organic matter content of the experimental soils varied from 1.0-1.3%; soil pH from 6.5 -7.8; available P from soils, 10-18 ppm; and available S, from 10-20 ppm.
3. Generally rice follows pulses, but sometimes jute follows.
4. In the inoculation response studies, the trials were mostly carried out in fields not cultivated with a particular pulse during the last 2-3 years.
5. The soil types were in general noncalcareous dark gray, floodplain, and calcareous brown floodplain or calcareous dark gray floodplain. The soil texture varied from sandy loam to clay loam.

C.L.L. Gowda: 1. Is there a survey to assess the native population level of different rhizobia in different crops in Bangladesh?
2. What is the survival ability of *Rhizobium* in paddy (puddled soil) areas, compared to upland areas?

M.S. Hoque: 1. No systematic survey has been done to assess the native population level of different rhizobia effective on different crops in Bangladesh soils. Only some sporadic studies have been made.
2. No such studies have been made as yet with pulses. In a 4-year study of soybean it has been observed that 2-3 inoculations in subsequent years could result in the survival of sufficient rhizobia to cause effective nodulation in a t.*aman* (rainy season) rice-soybean cropping system at the BAU farm.

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Session III:
Crop Protection

Progress and Prospects of Disease-Management Research on Pulses

H.U. Ahmed
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

Many diseases of chickpea (Cicer arietinum *L.), lentil* (Lens culinaris *Medic), mung bean (*Vigna radiata *(L.) Wilczek), black gram* (Vigna mungo *(L.) Hepper),and khesari* (Lathyrus sativus *L.) have been recorded in Bangladesh. Wilt, collar rot, and botrytis gray mold of chickpea; rust, collar rot, wilt, and stemphylium blight of lentil; yellow mosaic, leaf spot, and powdery mildew of mung bean and black gram; and collar rot and downy mildew of khesari were found to be the most important. Yellow mosaic and powdery mildew caused 16.0% and 26.0% yield loss on mung bean and 10.0% and 255% yield loss on black gram. Collar rot of chickpea caused 84.4% loss under inoculated conditions. Fusarium wilt-sick' plots were developed at Joydebpur and Ishurdi and a large number of chickpea lines Have been screened over the years. Susceptible check lines for wilt of chickpea (ICC 4951); rust (L 81149) and stemphylium blight (L 81124) of lentil; yellow mosaic of black gram (B 31); and yellow mosaic of mung bean (IMN 86) were identified. Many lines of different pulses were identified resistant to various diseases. Fourteen genera of fungi were identified as seedborne pathogens of different pulses. Solarization with a polythene sheet for 3 months in summer controlled fusarium wilt and other soilborne pathogens. Many effective seed dressings and foliar fungicides were identified. Development of laboratory-screening procedures for diseases of lentil, and downy mildew of khesari to supplement field results will be undertaken. Research on integrated disease-management procedures will be intensified.*

Introduction

Among the various factors responsible for low yield of pulses, disease plays an important role. The rainy season with its hot and humid weather as well as the soil conditions of Bangladesh are favorable for the growth and reproduction of plant-disease inciting agents like fungi, bacteria, viruses, and nematodes.

Diseases of Pulses

Seventy-nine diseases have been recorded on chickpea (*Cicer arietinum* L.), lentil *(Lens culinaris* Medic), black gram *(Vigna mungo* (L.) Hepper), mung bean *(Vigna radiata* (L.) Wilczek), and khesari *(Lathyrus sativus* L.) in Bangladesh up to 1988. Of these, 54 are caused by fungi, 9 by nematodes, 1 by a bacterium, 11 by viruses, and 4 by mycoplasma (Ahmed et al. 1982; BARI 1982, 1983, 1984; Bakr and Zahid 1986; Fakir 1983). There are some diseases which are greatly influenced by environmental conditions. It appears from various records available in. the country that chickpea suffers from 11 diseases, lentil from 17, mung bean from 16, black gram from 21, and khesari from 14 (Table 1). Among the 11 diseases of chickpea, the most important are wilt *(Fusarium oxysporum),* collar rot *(Sclerotium rolfsii),* and gray mold *(Botrytis cinerea).* As many as 17 different diseases affect lentil. Of these, *rust (Uromyces vici-fabae),* foot rot *(Sclerotium rolfsii),* wilt *(Fusarium oxysporum)* and stemphylium blight *(Stemphylium* sp) are the most destructive. Of the 16

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. The number of diseases affecting the five pulse crops and their causal organisms recorded in Bangladesh up to 1987/88.

	Causal agent					
Crop	Fungi	Nematodes	Bacteria	Virus	Mycoplasma	Total
Khesari	10	2	0	2	0	14
Lentil	12	2	0	2	1	17
Chickpea	8	1	0	2	0	11
Black gram	15	2	0	3	1	21
Mung bean	9	2	1	2	2	16
Total	54	9	1	11	4	79

diseases of mung bean, the most important are: yellow mosaic (virus), powdery mildew (*Odium* sp), and leaf spot (*Cercospora cruenta*). Black gram is affected by 21 different diseases: yellow mosaic, leaf spot, and powdery mildew are the most important. Recently root-knot nematode *(Meloidogyne* sp) occurrence in the field has also become quite common. In khesari, 14 diseases were recorded. Of these, downy mildew *(Peronospora viciae)* and collar rot occur more often.

Yield Reduction due to Disease

Yield losses in pulses caused by different diseases in the country have not been investigated. The plant pathology divisions at Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Agricultural University (BAU) have estimated yield losses by a few diseases like collar rot, and wilt of chickpea, powdery mildew, and yellow mosaic of mung bean and black gram (BARI 1987,1988; Bakr and Ahmed 1988; Fakir 1983). Collar rot caused 84.4% yield loss, while wilt caused 60% loss in chickpea. Powdery mildew caused 26% yield loss in mung bean and 26.5% yield loss in black gram. Yellow mosaic caused 16% yield loss in mung bean and 10% yield loss in black gram.

Disease Control through Host Resistance

Management of crop diseases through host resistance is economical and practical. To develop resistant cultivars, many cultivars and germplasm lines of chickpea, lentil, mung bean, black gram, and khesari were evaluated during 1983-1987 (BARI 1988; Rahman and Ahmed 1985; Dey et al. 1988). Efforts were made to locate resistant sources through artificial inoculation. A screening experiment was conducted against chickpea wilt with many exotic and local entries in wilt nurseries both at Joydebpur and Ishurdi. A highly susceptible check entry (ICC 4951) was sown after every two test entries and so far, we have obtained 41 resistant lines. In lentil 13 entries resistant to foot rot; 19 entries resistant to rust; 17 entries resistant to stemphylium blight; and 4 entries resistant to root rot were found. Several screening experiments against yellow mosaic of mung bean and black gram were conducted at BARI and Bangladesh Institute of Nuclear Agriculture (BINA). In mung bean only 2 entries (BM 84-2-7-5, BM 84-2-18-6) were found resistant, while only 2 mutants M 25 and M 26 were resistant to yellow mosaic in black gram (BINA 1988). In case of root-knot *(Meloidogyne* sp), 1 entry was found resistant in mung bean, and 4 entries in black gram, (BARI 1984). Regarding the diseases of khesari, 1 entry was resistant to root knot, 49 to foot rot, and 4 to downy mildew (BARI 1984, 1986, 1988).

Seedborne Diseases

Field fungi associated with seeds cause deterioration of quality, affect viability and reduce germination of seeds. Many studies were done at the Plant Pathology Divisions of BARI and BAU to investigate the prevalence of fungi in seeds. Ten fungi were detected in chickpea, 5 in lentil, 17 in black gram, and 9 in khesari. Eleven seedborne diseases were reported in four pulses. They are: blight, wilt, and seed rot of chickpea, rust of lentil, leaf spot and seed rot of mung bean, and seedling blight, anthracnose, foot rot, leaf spot, and seed rot of black gram.

Storage Pathogens

Most storage pathogens are species of *Aspergillus, Penicillium,* and *Rhizopus.* The storage fungi may cause decrease in germination, discoloration of seed, various biochemical changes that may make grains unfit for food, and toxins that are a health hazard for humans and animals. The factors that mainly determine infection by storage molds are moisture content of seed and type of storage containers. Effect of moisture content on the prevalence of fungi in stored chickpea seeds was studied by maintaining 3 levels of moisture: 8%, 12% and 16%. Relatively lower levels of mold incidence and higher germination were recorded at the lowest level of moisture content. Of the storage containers, kerosene tin, plastic bag, and bamboo *'dole'* were found promising (BARI 1984).

Control of Seedborne Pathogens

Seedborne diseases cause enormous loss to pulse crops. The seedborne disease infection can be effectively reduced if the seeds are treated before sowing. Research done by the Plant Pathology Division, BARI, indicates that seed treatment with Benlate T-20® and Captan can eradicate the seedborne infection of *Fusarium oxysporum* causing wilt of chickpea, while Vitavax-200®, and captan significantly controlled collar rot of chickpea (Bakr and Ahmed 1987; Bakr 1988). It was also found that about 74% reduction of foot rot occurred in lentil when seeds were treated with Baytan 10DS® and when treated with Vitavax-200® the reduction was 40% (BARI 1987). The Department of Plant Pathology, BAU reported that Homai 80 WP reduced seedborne infection of *Macrophomina phaseolina* resulting in less pre- and post-emergence mortality of seedlings and increased germination by 48%, and Vitavax-200® reduced infection by 46% (BAU 1985).

Studies on polythene mulch

In recent years, soil solarization has become an effective means of controlling soilborne plant pathogens on a limited scale. It was found that polythene mulch was effective in lowering the fusarium population in the soil by 71% resulting in 82% lower incidence of wilt (Table 2) (BARI 1987).

Disease Control through Plant Treatment

Several fungicial trials were conducted at BAU and BARI to determine effective treatments against different foliar diseases of black gram, mung bean, lentil, and khesari. Results showed that powdery mildew of mung bean and black gram can effectively be controlled by spraying either Thiovit® -(0.2%) or Karathane® (0.1 %) or Tilt 250® EC (0.1%) (Goswamietal. 1988). Similarly cercospora leaf spot of mung bean and black gram can be controlled by Bavistin (0.1 %) or Bayleton® (0.2%) (BARI 1988). Rovral® 50 WP (0.2%) was effective in controlling stemphylium blight of lentil. Leptosphaerulina leaf blight of khesari can be controlled by spraying either Dithane M-45® (0.2%) or Trimiltox forte® (0.2%) or Topsin M® (0.1%) or Copperoxychloride (0.3%) (BAU 1986).

Future Research Needs

Further studies on disease development under specific climatic conditions, screening of breeding materials against major diseases, identifying effective chemicals,

Table 2. Effect of polythene mulch on *Fusarium* sp control at BAR1, Joydebpur and at RARS, Ishurdi, Bangladesh, 1984/85.

	Fusarium population		Wilted plants		Yield	
Treatment	Actual 10^3 dilution	Decrease over control (%)	Actual (%)	Decrease over control (%)	Actual (t ha^{-1})	Increase over control (%)
Polythene mulch	2.25	71.26	1.07	81.6	1.58	5.61
Control	7.83		5.82		1.50	

developing integrated control approaches are future areas of research in disease management of pulses.

Discussion

A. Sarker: 1. You have identified 53 lines resistant to different diseases. Have you got any lines which are resistant to more than one disease? 2. Two papers on plant pathology carry more or less the same title and many things are duplicated. You could have put the crops into two separate papers. 3. How is the stemphylium blight transmitted?

H.U. Ahmed: 1. Records are to be consulted to see whether the same line is resistant to two or more diseases. Now I cannot say the exact position. 2. My paper is a review paper while Bakr's paper deals with management of major diseases of various pulses. 3. Stemphylium disease is transmitted by airborne spores.

E.D. Magallona: In Table 3, the damage to chickpea by collar rot is 84% while that from wilt is 60%. This is greater than 100% (144%). Could you offer an explanation for this?

H.U. Ahmed: Loss estimation for collar rot and wilt was done in two separate experiments and the findings are for each disease. Therefore, the loss cannot be added together.

M.P. Bharati: In your paper you have included gray mold as one of the major diseases on chickpea. However, you have no data on yield loss from the disease and no other follow-up statistics. Why?

H.U. Ahmed: In our country gray mold incidence is irregular. In some years the incidence is very high while in other years it is low. We could not do any study on yield loss under controlled conditions. At present we are monitoring the disease under different agroecological situations.

M.M. Rahman: Incidence of rust and stemphylium of lentil under natural conditions is uncertain and unreliable for identification of resistant lines. What artificial measures are you going to take to ensure enough disease pressure on this crop to screen for resistance?

H.U. Ahmed: Wherever possible artificial inoculation will be done.

S.K. Roy: Is there any remedy to *Sclerotium rolfsii* in lentil and cowpea once it is established in the crop? We have this problem at Hathazari.

H.U. Ahmed: No, At this moment we do not have any control measure for *Sclerotium rolfsii,* if it is established on the crop.

R.N. Mallick: The extent of loss due to diseases is very high according to your report, but farmers seldom use any plant-protection measures. Are these losses below the economic threshold?

H.U. Ahmed: Under normal field conditions so far observed, the disease incidence is irregular. The loss estimation as shown is under high epiphytotic conditions.

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Management of Important Diseases of Major Pulses

M.A. Bakr
Regional Agricultural Research Station, Ishurdi, Pabna, Bangladesh

Abstract

Seventy-nine diseases of five pulse crops were recorded in Bangladesh. Forty-one lines of chickpea (Cicer arietinum *L.) were identified resistant to fusarium wilt. Since 1986,174 chickpea breeding lines were screened in the wilt-sick plot at Ishurdi and 50 were selected for further evaluation. In lentil* (Lens culinaris *Medic), 19 lines were found resistant to rust and 17 to stemphylium blight. No stable resistant source was found to mung bean* (Vigna radiata *(L.) Wilczek) yellow mosaic virus. Damage by rust can be avoided by sowing the crop before the first week of November in northern parts of Bangladesh and before the last week of October in the southern parts of Bangladesh. Powdery mildew of black gram* (Vignamungo *(L.)Hepper) and mung bean was found to cause less damage when crops were sown before the end of September. Seed treatments against inoculum* of Fusarium oxysporum *and* Sclerotium rolfsii *were found effective. Foliar sprays against stemphylium blight, powdery mildew, and cercospora leaf spot were determined. Future work plans are discussed.*

Introduction

Among different approaches for disease management, use of resistant cultivars, cultural management, polythene mulching, avoidance by manipulation of sowing dates, seed treatment as dry dressing and plant treatment as foliar sprays were explored. So far 79 diseases of pulse crops have been reported in Bangladesh. Only 12 are economically important (Ahmed 1985) (Table 1). In this paper the technologies developed for management of important diseases of five pulses; chickpea *(Cicer arietinum* L.), lentil *(Lens culinaris* Medic), khesari *(Lathyrus sativus* L.), black gram *(Vigna mungo* (L.) Hepper), and mung bean *(Vigna radiata* (L.) Wilczek.) are discussed. Mention has been made of the methods and practices available elsewhere.

Chickpea

Of the 50 pathogens reported on chickpea from different parts of the world, 14 have been reported in Bangladesh (Ahmed 1985; Fakir 1983). The important diseases are wilt *(Fusarium oxysporum* f. *sp. ciceri),* collar rot *(Sclerotium rolfsii),* dry root rot *(Rhizoctonia bataticola),* and botrytis gray mold *(Botrytis cinerea).*

Wilt

Wilt is widespread in the chickpea-growing areas of Bangladesh. Although no precise information is available on the extent of damage by the disease a rough estimate of 10% loss has been considered to be a regular feature in the chickpea-growing states of India (Singh and Dahiya 1973). In Bangladesh, seasonal observations have shown much higher incidence of the disease. The pathogen causes total or partial wilting. When split open lengthwise the xylem portion of the tap root shows dark brown to black discoloration. The disease development is rapid at soil and air temperatures of 24 to 27°C while the infection remains restricted at ambient temperatures below 17°C (Grewal 1988). The causal fungus is soil as well as seedbome. It can survive by forming chlamydospores in dead-plant debris for more than 5 years (Haware, personal communication).

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Important diseases of major pulses.

Crop	Disease	Pathogen
Chickpea	Wilt Collar rot Botrytis gray mold Dry root rot	*Fusarium oxysporum f. sp Ciceri* *Sclerotium rolfsii* *Botrytis cinerea* *Rhizoctonia bataticola*
Lentil	Rust Stemphylium blight Foot rot Wilt	*Uromyces fabae* *Stemphylium sp* *Sclerotium rolfsii* *Fusarium oxysporum*
Mung bean	Yellow mosaic	Mung bean Yellow Mosaic Virus
Black gram	Cercospora leaf spot Powdery mildew	*Cercospora cruenta* *Erysiphe polygoni/Oidium sp*
Khesari	Downy mildew	*Pernospora viciae*

Lentil, pigeonpea (*Cajanus cajan* (L.) Millsp.), and fieldpea (*Pisum sativum* subsp *arvense*) were identified as symptomless carriers of this pathogen (Haware and Nene 1982). Forty one entries from local and exotic sources have been identified as resistant to this disease (Table 2). Mulching soil with polythene sheet during the height of summer reduces the pathogen population by 71% and wilt incidence by 81% (BARI 1987) but the use of resistant cultivars is the only suitable answer.

Haware et al. (1978) reported that the seedborne inoculum could be eradicated by dressing seed with

Table 2. Germplasm entries found resistant to diseases at BARI, 1989.

Crop	Resistant to	Place	Germplasm Entries
Chickpea	Fusarium wilt RARS, Ishurdi	BARI, Joydebpur	CC 2484, -1405,-594, -11320,-3274, -9035, -11322, 3208, -3595, -1437,-11329,-454, -422, -598,-312,-589, ICCL-82104, -85109, -85108, -85107,-85102, -85111, -84215, -83142, RBH 135(b),-228(a), -196(a),-174b),-87(a), -90(a), -109(a), E 498, -317,-243, -506, -114, -395-244, 336, -426, and 443.
Lentil	Rust	RARS, Ishurdi	112-19, 107-37,119-88, 119-107, 104-5, 111-71, 107-41,117-10,119-117,110-22, 122-29, 111-58, 107-11, 125-14,110-78, B 62, 85005,80670, and ILL-2501.
	Stemphylium	RARS, Ishurdi	U 3136,-2993, ILL-2501,-1868,-blight 2149,-4406,-3904,-3765,-3814,-3823,-3554,-3230,-2997,-2876,-2874,-2784, and 2754.

Benlate®-T. Further studies at BARI with Benlate® T-20 showed that the fungicide also provided some protection against early wilting under field conditions (Bakr and Ahmed 1987).

Collar Rot

Collar rot is prevalent throughout the chickpea-growing areas of Bangladesh. Outside Bangladesh the disease has been reported from several countries including India (Nene et al. 1984). It is, however, assumed that the disease exists in almost all tropical and subtropical countries where chickpea is grown. The disease can cause 4-84% loss in seed yield (Bakr and Ahmed 1988). It usually appears at the seedling stage although incidence is not rare in older plants. The fungus attacks the plant at the collar region at soil level. No discoloration of the root occurs. White mycelial strands along with mustard seed-like sclerotia are observed on the infected portion. The initial high soil moisture and the high soil temperatures (28° - 30°C) favor infection. Excess soil moisture after crop establishment suppresses the growth of the fungus. The nondecomposed organic matter near the soil surface provides the substratum for rapid growth of the pathogen.

Disease incidence can be reduced considerably by removing residues of the previous crop (Table 3) (Bakr and Ahmed 1988). The early incidence of the disease was reduced significantly by presowing seed dressing with Vitavax-200® at 2.5g (kg of dry seed)$^{-1}$ (Bakr 1988). There are no reports of resistance to this disease.

Table 3. Extent of mortality of chickpea plants and seed yield loss at different inoculum levels at RARS, Ishurdi, 1987.

Treatment	Initial	Total mortality (%)	Mean seed yields (t ha^{-1})	Seed yield loss (%)
1. Soil inoculation without cleaning residues of previous crop	162b[1]	69.51ab (87.64)[2]	0.31c	78.7
2. Soil inoculation after adding chopped paddy straw	122b	75.07a (93.15)	0.23c	.84.4
3. Soil inoculation after cleaning all residues	139b	64.02b (80.63)	0.66b	53.3
4. Soil inoculation after cleaning residues and treating soil with terrachlor	221a	43.02d (46.73)	1.41a	4.2
5. Control (residues cleaned untreated and uninoculated)	226a	51.85c (61.61)	1.47a	0

1. Values followed by the same letters within a column do not differ significantly at the 0.05 level.
2. Values in parentheses are original values of per cent mortality.

Source: Bakr and Ahmed (1988).

Table 4. Effect of presowing seed dressing with fungicides for the control collar rot disease of chickpea, RARS, Ishurdi, 1987.

Treatment	Seed germinated pot^{-1}	Pre em.[1] death	Post em.[2] death	Total death
Bavistin	0.4c[3]	19.6a	0.0c	19.6a
Benlate T-20	0.0c	20.0a	0.0c	20.0a
Captan	9.0b	11.0b	3.6a	14.6b
Ridomil	0.8c	19.2a	0.8bc	20.0c
Thiride-75	9.8b	10.2b	2.4ab	12.0c
Vitavax-200	18.0a	2.0c	1.8b	4,4d
Control	0.0c	20.0a	0.0c	20.0a

1. Pre em. = Preemergence.
2. Post em. = Postemergence.
3. Values followed by the same letters within a column do not differ significantly at the 0.05 level.

Source: Bakr (1988).

Botrytis Gray Mold

Botrytis gray mold is caused by *Botrytis cinerea.* It was first recorded in 1981. Outside Bangladesh the disease is present in Nepal, India, Pakistan, Spain, Australia, Canada, Colombia, and Argentina (Nene and Reddy 1987). During 1988 the disease appeared in Bangladesh, devastating the chickpea crop throughout the country. The fungus forms gray or brown to light-brown lesions on leaflets, branches, and pods. The infected portion is covered with erect hairy sporophores giving a moldy appearance. Young growing twigs and flowers are particularly susceptible to the infection. The plants at dense canopy turn grayish. Later the crop has a blighted appearance.

A dense crop canopy, formed due to excess soil moisture and the abundant use of nitrogenous fertilizers, aids development of the pathogen. The disease develops fast in soils with high nutrient status and organic-matter content. The pathogen has a wide host range and the inocula exist almost always in the environment. In appropriate weather conditions the pathogen sporulates profusely. The pathogen is seedbome. Storage of seed at room temperature reduced the pathogen viability appreciably (Laha and Grewal 1983). The fungus remained viable on infected plant parts present as an admixture in seed lots and was found to be externally seedborne to the extent of 8.2% and internally seedborne to the extent of 2.5% in naturally infected seeds at 18°C for 5 years (Grewal 1988).

The seedborne inoculum can be eradicated by seed dressing with Bavistin 50 WP® as well as Bavistin + thiram at the rate of 2.5g (kg of dry seed)$^{-1}$ (Grewal and Laha 1983). These fungicides were also found effective in controlling aerial infection by *Botrytis cinerea* up to 8 weeks after sowing. Two lines, ICC 1069 and ICC 5055, were found resistant (Grewal 1988).

Selecting land with soils with heavy texture and moderate to substantial nutrient status reduces the severity of the disease.

Dry Root Rot

This disease was not common in farmers' fields but in recent years its incidence has increased considerably. Infection is scattered in the field. Affected plants dry up suddenly with a straw-colored appearance. The tap root is brittle and devoid of lateral and finer roots. The dead roots show shredding of the bark. Very minute dark-brown sclerotia can be observed with the aided eye below the bark and in the pith. The pathogen is reported to perpetuate on diseased plant debris and persists in the soil as a facultative parasite. The best solution is to use resistant cultivars.

Lentil

Fifteen pathogens causing 17 diseases have so far been recorded in Bangladesh (Ahmed 1985; Bakr and Zahid 1986) but only few are severe causing severe losses in yield. These are rust *(Uromyces fabae),* stemphylium blight *(Stemphylium* sp), Wilt *(Fusarium oxysporum),* and foot rot *(Sclerotium rolfsii).*

Rust

The disease was first recorded by Talukder (1974). It causes severe damage to the crop almost all over the country. Losses depend upon the stage of the crop at the time of infection. The incidence of the disease varies considerably from year to year depending upon environmental conditions. High humidity, cloudy weather, and temperatures of 20-22°C favor disease development. The disease appears in areas with dense canopy. Aecial cups are formed on stems, leaves, and pods followed by uredo and teleutopustules. Black or dark-brown telia are formed on the stem late in the season. In severe cases, the leaves are shed and plants dry up prematurely.

The fungus is autoacious and completes its aecial, uredial, and telial stages on the lentil plant. The primary infection source seems to be admixtured teleutospores on infected plant parts mixed with seed lots. The disease was observed to occur generally before mid-February in northwestern districts and before the end of January in the south. Lentil cultivar L 5 matures in 100 to 110 days. So the disease can be avoided by sowing such early maturing cultivars by the first week of November in the north and by the last week of October in the southern parts of the country. The primary source of infection can be avoided by properly cleaning the seed lots and plant parts that possess teleutospores.

Resistant sources from local and exotic germplasm have been identified (Table 2). These are being utilized in hybridization. Protective sprays with Dithane M®-45 (250 ppm) at 10-12 days interval were reported to be effective (Khare et al. 1979). These results could not be reproduced at BARI.

Stemphylium Blight

Stemphylium blight is a new disease of lentil which was recorded during 1986 in Bangladesh (Bakr and Zahid 1986). The disease is widespread almost throughout the country but severity is highest in the greater districts of Jessore, Kushtia, Faridpur, Dhaka, and Pabna. Due to its increasing severity the disease has already gained much importance. Symptoms of the disease start as pinheaded light brown or colored spots on leaflets in plants in thick populations. The spots enlarge rapidly and within 2-3 days cover the entire leaflet resulting in the defoliation and death of young twigs. In severe cases, the crop fields exhibit a blighted appearance. However, the pods are still green. The pathogen seems to be airborne. No reports exist on its

Table 5. Effect of some foliar fungicides on the incidence of stemphylium blight and yield parameters of lentil, RARS, Ishurdi, 1986.

Fungicides	Diseases score	Twig infection (%)	No. of pods $plant^{-1}$	Seed mass $plant^{-1}$ (g)	Seed yield ($t\ ha^{-1}$)
Rovral (0.2%)	1.0d[1]	29.0c	1263a	2.5a	1.54a
Uniflow sulfur (0.4%)	2.3c	57.0bc	966b	2.2ab	1.18c
Antracol (0.2%)	3.3b	46.5bc	954b	1.9ab	1.38b
Dithane M-45® (0.2%)	2.5c	46.8bc	816bc	1.7b	1.39ab
Control	4.0a	72.3a	623	1.2b	1.21c

1. Values followed by the same letters within a column do not differ significantly at the 0.05 level.

seedbome nature (externally or internally). The detailed etiology is yet to be studied. Seventeen lines have been identified as resistant to the disease and should be exploited in the crossing program (Table 2). Foliar sprays with Rovral 50 WP® at 0.2% were found effective when applied three to four times at 7-day intervals (Table 5).

Foot Rot and Wilt

Foot rot is mainly a seedling disease attacking the crop usually up to 30 days of germination and is caused by *Sclerotium rolfsii.* The fungal strands along with mustard seed-like sclerotia are generally observed associated with the infected portions at soil level. The disease can also be caused by *Fusarium oxysporum* at the seedling stage and it is called wilt when the fungus attacks the older plants. The tap roots are infected and normal growth is arrested initially giving a stunted appearance and finally causing wilting and drying of the plants. When split open lengthwise, brown discoloration involving pith and xylem is observed.

Disease incidence has been observed to be higher in soil with initial high moisture content. Therefore, sowing should be done at optimum moisture level. Presowing seed dressing with fungicides Baytan 10 DS® 0.25% dry seed was found very effective in reducing the disease incidence. The avoidable loss was reduced up to 74% with Baytan and with Vitavax-200® the avoidable loss was reduced up to 39.8%, (Table 6) (Mortuza and Bhuiya 1988).

Mung Bean and Black Gram

Sixteen pathogens have so far been recorded on mung bean and 21 on black gram in Bangladesh (Fakir 1983; Ahmed 1985) of which three diseases attacking both the pulses are considered major depending upon the extent of damage they cause. These diseases are: yellow mosaic caused by YMV, cercospora leaf spot *(Cercospora cruenta),* and powdery mildew *(Erysiphe polygoni / Oidium* sp).

Yellow Mosaic

Yellow mosaic is the most serious limiting factor in mung bean and black gram cultivation. The disease can attack the crop at any stage of growth but losses are severe when it attacks at an early stage. Total loss has been reported when the crop was infected at 1-2 weeks, 63% at 3 weeks, and around 20-30% at 4-7 weeks (BARI 1984). Symptoms of the disease appear on

Table 6. Effect of fungicides in controlling foot and root rot disease of lentii.

Treatment	Infection/dead plants (%) Seedling stage	Growing stage	Mature stage	Total	Reduction of disease (%)	Seed yield ($t\ ha^{-1}$)
Calixin	31.64b[1]	6.12b	0.98	48.74c	7.51	0.25c
Vitavax-200	15.92a	14.46b	1.34	31.72b	39.81	1.04a
Dithane M-45	28.45b	16.52b	0.59	49.56c	13.55	0.92b
Baytan 10DS	7.98a	5.48a	0.22	13.68a	74.04	1.22a
Bavistin	30.90b	16.52b	0.91	48.33c	8.29	0.90b
Captan	31.05b	14.64b	1.20	46.89c	11.02	0.91b
Control	30.42b	21.48c	0.80	52.70c	0	0.81b

1. Values followed by the same letters within a column do not differ significantly at the 0.05 level.
Source: Mortuza and Bhuiya (1988).

leaves as minute yellow specks that expand and may cover the entire leaf area. Mixture of irregular yellow and green patches can be observed on the leaves. Pods are reduced in size and bear small shrivelled seeds. The aecia are transmitted by whitefly (*Bemisia tabaci*) and has a wide host range. Weeds have been reported to harbor the virus and act as a primary source of inoculum (Verma and Subramanyam 1986).

Management of the disease seems to be very difficult. Many attempts at BARI and elsewhere to screen resistant sources were made but no stable resistant source has been identified so far. Spraying systemic insecticides like aldicarb (Sharma and Verma 1982) and Formothion® (Chenulu et al. 1979) were reported most effective in checking the spread of the disease by controlling the vector.

Cercospora Leaf Spot

Cercospora leaf spot (CLS) attacks both mung bean and black gram. The disease causes spots of variable sizes and shapes that are purplish at the beginning and later the centre becomes grayish in color. The disease also causes premature defoliation. The pathogen was reported to perpetuate on infected plant debris (Grewal 1988). A few lines were identified as resistant and can be utilized in crossing program (Dey et al. 1987; Grewal 1988). Foliar sprays with Bavistin 50 WP® at 0.1 % were found effective in controlling the disease (BARI 1986).

Powdery Mildew

The disease is serious mostly during late summer. It has been estimated to cause about 42% yield loss in late summer (BARI 1987) and around 17% loss in early summer crop of mung bean (BARI 1986). Disease incidence has been observed to be severe when the crops are sown late, i.e., early October onwards. Powdery masses are formed on the leaves which later turn dirty white, leading to defoliation in some cases.

Table 7. Effect of fungicides on the incidence of powdery mildew of black gram.

Fungicide	Disease severity (0-5) scale	Yield ($kg\ ha^{-1}$)	1000-grain mass (g)
Antracol	2.2bc[1]	140	39.5
Karathane	1.5b	157	39.9
Bayleton	1.7bc	144	40.7
Thiovit	1.5b	177	40.8
Tilt 250 Ec	1.0a	201	41.0
Calixin	2.5b	164	40.0
Control	3.8c	135	38.7

1. Values followed by the same letters within a column do not differ significantly at the 0.05 level.
Source: Goswami et al. (1988).

The disease can be avoided or damage reduced to noneconomic level by sowing early, i.e., from mid-August to first week of September. It was effectively controlled by 2-3 foliar sprays of Tilt 250 EC® (0.1 %); Thiovit 80 WP® (0.2%) or Karathene (0.1%) applied at 12-15 day intervals (Table 7) (Goswami et al. 1988; BARI 1986). Tilt was more effective than Bavistin 50 WP®.

Khesari

Downy Mildew

Fourteen pathogens of khesari have so far been reported from Bangladesh (Ahmed 1985). Among the diseases downy mildew (*Pernospora viciae)* is considered to be the most important, and was estimated to cause about 17% loss in yield (BARI 1986). Symptoms of the disease are the downy growth of mycelium and sporophores on the dorsal side of the leaves which look like yellow lesions from the ventral side. At later stages the infected leaves turn grayish to light brown.

Resistant sources have been identified against the disease. No precise study on chemical control by sprays was undertaken. It was observed in related studies that Thiovit 80 WP was effective in controlling the disease to a significant level.

Future Strategy

The crop loss due to diseases needs to be prevented. On a more restricted scale, economic losses for the diseases require management effort by individual growers. But to decide correctly whether or not to attempt management practices, growers need accurate details about disease severity and its destructive potential. Although successful disease management frequently requires several integrated approaches and techniques, in this paper these have been considered singly for simplicity. Many management practices developed against important diseases of major pulses have been discussed. It is necessary that the package of practices be used by the growers and seed producers. In this regard great responsibility lies with the extension personnel and on-farm research scientists to create a general awareness about the availability of the practices and to demonstrate their effectiveness. If this is ensured, it can then be expected that the huge loss due to diseases be minimized and the national production level raised considerably.

Discussion

M.O. Hyder: There are some vaccines against some diseases prevalent among both human beings and livestock. Would you please comment on the possibility of developing methods of vaccination for such diseases caused by bacteria and viruses? If the answer is positive, what is our contribution in that field ?

M.A. Bakr: Our main thrust is to develop low-cost, easily usable remedial measures against pulse diseases. Cross-protection measures may be practised in some fruit and vegetable diseases but in the case of pulse diseases nowhere in the world are these in practice, nor are we doing any work.

R.N. Mallick: Your recommendation for disease prevention and control seems to be quite practical. Have you illustrated these measures in the extension bulletins you have distributed this morning in Bangla?

M.A. Bakr: Thank you for this suggestion. We will try to do the needful.

M.V Reddy: Can you please elaborate on future research strategies for control of pulse diseases ?

M.A. Bakr: This will be discussed at the plenary session.

M.S. Hoque: You have mentioned that the incidence of collar-rot disease of chickpea can be reduced greatly by removing residues of the previous crop. But from the soil-fertility management point of view farmers are advised to incorporate the crop residues for better yields of subsequent crops, keeping in mind the alarmingly low organic matter content of our soils. Under such an antagonistic situation, what is your opinion with regard to management of this disease?

M.A. Bakr: Only undecomposed residues are to be removed if the crop is to be sown immediately after the harvest of the previous crop. But if sufficient time has lapsed before sowing of the next crop and the crop residues are fully decomposed then these do not do any harm.

M.P. Bharati: How does not sowing chickpea in light-textured soil reduce botrytis gray mold incidence ? Please explain.

M.A. Bakr: It is our observation that chickpea when sown in light soils produces profuse vegetative growth. Whenever a light shower occurs it favors the incidence of botrytis gray mold.

M.A. Wahhab: Seed treatment was done and chemicals were used to control the diseases of pulses. Don't you think that burning of crop-residues in the field may help control them to some-extent?

M.A. Bakr: Yes, this is a general recommended sanitary measure for many diseases.

M.O. **Islam:** You have mentioned in your paper that botrytis gray mold can be avoided by:

1. avoiding use of nitrogen fertilizer,
2. avoiding light-textured soil,
3. nipping the twigs, and
4. grazing by sheep

In our experience at RARS, Ishurdi we do not use any fertilizers, grow the pulses in heavy soils, and even put it in 1m. line-to-line distance, but why does botrytis appear in severe form ?

M.A. Bakr: The Ishurdi RARS soil is rich in organic matter, which encourages profuse vegetative growth. In the presence of sufficient moisture particularly in the growing season when early showers occur, these conditions help development of the disease.

A. Rahman: 1. In your paper you mentioned 100-seed mass of black gram which I think is very high. Is it correct ? 2. What is the significance of taking 100-seed mass of black gram of the same line against different chemicals ?

M.A. Bakr: 2. The table has the reference below it. I have only cited the work. In my opinion the yield is not very high, we generally get even higher yields. 2. It has significance in assessing the efficiency of the chemicals.

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Pulse Disease Research at BAU - A Review

G.A. Fakir and G.M. Mujibur Rahman
Bangladesh Agricultural University, Mymensingh, Bangladesh

Abstract

*Research on the diseases of black gram (*Vigna mungo *(L.) Hepper), khesari (*Lathyrus sativus L.), *chickpea* (Cicer arietinum *L.), and lentil* (Lens culinaris *Medic.) has been conducted since 1976 at the Bangladesh Agricultural University. Twenty three diseases of black gram, 15 of khesari, and 5 of chickpea were detected in their seeds. Six seedborne pathogens were identified in black gram, 2 in khesari, and 3 in chickpea*[1]*. Timely sowing of lentil and chickpea after the first week of November reduced collar-rot damage, while application of nitrogen increased the incidence. Seed treatments to control various diseases have been worked out. Screening under field conditions and subsequent artificial inoculation of 216 black gram and khesari lines led to the identification of M 23 black gram and L 14 khesari, as moderately resistant to fusarium wilt and collar rot. Present on-going studies and future plans for research are discussed.*

Introduction

Research on pulse diseases began in the Department of Plant Pathology, Bangladesh Agricultural University (BAU), Mymensingh, in 1976. Four pulses, chickpea *(Cicer arietinum* L.), khesari (*Lathyrus sativus* L.), lentil *(Lens culinaris* Medic), and black gram *(Vigna mungo* (L.) Hepper) were included in these studies (BAU 1978). In 1987, BAU launched a research project entitled 'Coordinated Food Legume Improvement Project'. Lentil and lablabbean *(Lablabpurpureus* (L.) Sweet) have been included in this program. Research carried out on the diseases of these five pulses has been compiled in the present review.

Survey of Diseases

Surveys of the diseases affecting black gram, chickpea, khesari, and lentil were carried out in seven greater districts of Bangladesh viz., Faridpur, Jessore, Rajshahi, Jamalpur, Mymensingh, Khulna, and Chittagong from 1976/77 to 1982/83 and in five districts; Faridpur, Jessore, Mymensingh, Khulna, and Chittagong, from 1979 to 1983. Disease prevalence was further surveyed only on black gram and khesari in three districts: Rajshahi, Mymensingh, and Jamalpur during 1980/1981 to 1982/1983. In addition, occurrence of diseases was recorded on about 1000 germplasm lines of lentil received mostly from the International Center for Agricultural Research in Dry Areas (ICARDA) at the BAU Farm for 2 years, 1986/87 and 1987/88.

Forty-two different diseases were recorded on these pulses during the survey. Among these diseases, 28 are of major importance and 29 appear to be new records for Bangladesh. The major diseases were collar rot *(Sclerotium rolfsii)* and wilt (*Fusarium oxysporum)* in all the four pulses; blight *(Ascochyta rabeii)* in chickpea; leaf blight *(Leptosphaerulina trifolii)* in black gram and khesari; cercospora leaf spot *(Cercospora cruenta)* and yellow mosaic virus (YMV) in black gram; rusts *(Uromyces* sp) in chickpea and lentil; and downy mildew *(Peronospora viciae)* in khesari. Often these diseases broke out in epidemic form and caused considerable losses to the crops (Fakir and Rahman 1977; BAU 1978, 1988; Fakir and Bakr 1978; Fakir 1983a; Fakir and Hossain 1984.

1.There is only one report of Ascochyta blight occurrence from Bangladesh (BAU 1978).

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Study on the Impact of Blight and Wilt on Chickpea Yield

During 1976/77, ascochyta blight and wilt of chickpea broke out in epiphytotic form in certain areas of Mymensingh including the BAU Farm. Considering the importance of the diseases, crop-yield losses due to these two diseases were estimated (Fakir 1983b). Wilt caused 60% seed-yield loss while blight resulted in 49% loss. Almost similar losses were incurred in production of total number of pods and seeds by the two diseases.

Transmission of Fungal Pathogens through Pulse Seeds

A total of 498 seed samples of black gram, 122 of khesari, and 20 of chickpea, collected from different locations of Bangladesh, were used for studying the seed transmission of fungal pathogens. Seedborne infections of fungi were detected by using the blotter test (ISTA 1976)

Black gram

The important pathogenic fungi found to be transmitted through black gram seeds were: *Macrophomina phaseolina, Fusarium oxysporum, Colletotrichum dematium, Rhizoctonia solani,* and *Aspergillus flavus.* Among all the seedborne fungal organisms, *Macrophomina phaseolina* was highly pathogenic and in certain seed samples, 70% seeds were found infected (BAU 1978,1986; Fakir and Bakr 1978; Fakir 1983b; Kabir 1985).

Khesari

Of the 15 fungi encountered on khesari seeds, *Aspergillus flavus, Corynespora cassiicola, Fusarium moniliforme, Fusarium oxysporum,* and *Fusarium* sp were pathogenic (BAU 1978; Fakir and Rahman 1986).

Chickpea

Of the five fungi detected on chickpea seeds, *Aspergillus* sp were most predominant, and *Colletotrichum dematium* and *Fusarium* sp were pathogenic (BAU 1978). Among the fungi which were found in the seeds of the pulse crops mentioned above, pathogenic fungi like *Macrophomina, Fusarium,* and *Colletotrichum* were responsible for causing seed rot and seedling infection. On the other hand, *Aspergillus flavus* and other *Aspergillus* sp were commonly associated with stored seeds and were responsible for reduced germination. The prevalence of fungi varied with respect to location of collection of seeds and pulse species (BAU 1978, 1986).

Control of Diseases Through Cultural Practices

Effect of fertilizers and irrigation on collar rot and wilt-disease incidence in chickpea and lentil

An experiment was conducted with different levels of fertilizers (NPK) and irrigation to study the effect of fertilizers and irrigation on collar rot and wilt in chickpea and lentil under natural field conditions. In general, increased prevalence of collar rot and wilt diseases in both chickpea and lentil were observed with the application of nitrogenous fertilizer (urea) and with one or two irrigations.

Effect of sowing time on collar rot and wilt incidence in lentil and chickpea

The experiments were carried out at the BAU Farm during 1979/80. The prevalence of the diseases in lentil decreased with the advancement of date of sowing (Table 1). Of the six different dates of sowing, 29 October sowing was most favorable for fusarium wilt and collar rot disease development (15.5%) compared to the later sowing in November onwards. Maximum fusarium wilt and collar rot disease development were observed in chickpea in the 26 October sowing (13.3%) followed by 25 November (11.7%) while minimum (2.3%) diseases were recorded on 25 December (Fakir 1983b).

Effect of organic soil amendments on collar rot and wilt disease in khesari

Two experiments at two different dates (21 Nov 1980 and 6 Jan 1981) were conducted at the BAU Farm to study the effect of different organic soil amendments on collar rot and fusarium wilt-disease development in khesari. The organic soil amendments used were: ash (A), sawdust (SD), and mustard (*Brassica campestris*

Table 1. Effect of date of sowing time on fusarium wilt and collar rot disease incidence in lentil and chickpea observed at the BAU Farm, Mymemsingh, Bangladesh, 1979/80.

Crop	Date of sowing	Plants infected by fusarium wilt and collar rot diseases (%)
Lentil	29 Oct	15.5a[1]
	13 Nov	8.9b
	28 Nov	8.9b
	13Dec	7.7b
	28 Dec	5.3b
	12 Jan	6.5b
Chickpea	26 Oct	13.3a
	10 Nov	9.2bcd
	25 Nov	11.7ab
	10 Dec	7.5cd
	25 Dec	2.3e
	9 Jan	5.9de

1. Values followed by the same letter(s) do not differ significantly at the 0.01 level.

L.) oilcake (MOC), and combination of these three. The dose for each treatment was 350 g per unit plot (2.4m x 1.8m). The organic soil amendments had no influence on collar rot and wilt-disease development in khesari. However, there was significant difference in the incidence of disease development betweeen November and January sowing (BAU 1986).

Seed Treatment

Control of seedborne infection of Macrophomina phaseolina *in black gram*

Investigations were carried for controlling seedborne infection of M. *phaseolina* in black gram with different seed-dressing fungicides in the laboratory, glass house as well as in the field for 7 years from 1977/78 to 1984/85. Of the 13 different fungicides tested in the laboratory, Granosan M (0.5%), Vitavax-200® (0.5%), Panoctine CGT/401 (0.5%), and Homai 80 WP (0.5%) appeared promising. Based on pot-culture experiments in the glasshouse, two fungicides, Vitavax-200® and Homai 80 WP (0.5%) appeared promising. In the field, all the three doses (0.3,0.5, and 0.7%) of these two fungicides gave good control of seedbome infection *of Macrophomina phaseolina.* Both Homai 80 WP and Vitavax-200® @ 0.7% completely controlled the seedbome infection of the pathogen and increased germination by 48.4% and 46.0%. However, 0.7% Vitavax-200® had some phytotoxic effect on growing seedlings. Homai 80 WP and Vitavax-200® reduced seedbome infection of the pathogen by 91.7 - 98.3% and increased germination by 46.8 - 47.6%. No phytotoxic effect was observed with 0.5% dose of Vitavax-200® or with any of the doses of Homai 80 WP. Thus Vitavax-200® (0.5 or 0.3%) and any of the test doses of Homai 80% WP may be recommended for seed treatment of black gram for controlling seedbome infection of *Macrophomina phaseolina* (BAU 1978; Fakir et al. 1980; Fakir 1983a; Kabir 1985).

Control of root-rot disease of lentil by seed treatment

An experiment was designed to control fusarium wilt of lentil by seed treatment with Panoctine CG/450 (a Kenogaard compound with a.i. Guazatine) using heavily infested soil in potculture. An additional experiment was conducted in a heavily infested field at the BAU Farm to confirm the results of pot-culture. It was observed that only 1.6% seedlings of lentil were affected by wilt in the treated seeds in pot-culture, while 44.4% seedlings were attacked by the disease when nontreated seeds were used. Slightly better germination (92.5%) was also obtained in the treated set compared to the nontreated control (90%) in pots,. Significant reduction occured in wilt-disease development. This was also observed in the field with panoctine-treated seeds (Fakir 1983a).

Foliar Treatment

Control of powdery mildew of black gram

Four foliar fungicides, Copper Sandoz, Kumulus-S, Thiovit, and Tri-miltox forte each @ 0.1,0.3, and 0.5% were tested at the BAU Farm and in farmers' fields near BAU campus to control powdery mildew of black gram (Fakir et al.1988). All the three doses of the selected fungicides gave excellent control of powdery mildew of black gram in all the 3 years' trial when given four sprays at 7 days' intervals. Based on the 3 years' studies it may be concluded that 0.5% dose of any of the test fungicides or 0.3% dose of Kumulus-S or Tri-miltox forte may be recommended for controlling powdery mildew of black gram.

Control of cercospora leaf spot of black gram

Five foliar fungicides, Copper oxychloride, Copper Sandoz, Dithane M-45®, Topsin M, and Tri-miltox forte each @ 0.1., 0.3, and 0.5% were tried in farmers' fields near BAU Farm for controlling cercospora leaf spot of black gram. All the three doses of Topsin M gave the best results in reducing disease severity and increasing yield when applied four times at 7 days' intervals (BAU 1986).

Control of leptosphaerulina leaf blight of khesari

Efficacy of four foliar fungicides, Copper oxychloride, Dithane M-45®, Topsin M, and Tri-miltox forte each @ 0.1 and 0.5% was tested in controlling leptosphaerulina leaf blight of khesari at the Regional Agricultural Research Station at Jamalpur as well as in farmers' fields in the *char* area of Jamalpur for 3 years (1982-85). Both doses of the test fungicides reduced the incidence of blight by 30.8 to 80.9% and increased yields over the control (BAU 1986).

Control through Host Resistance

Screening of black gram and khesari for resistance to major diseases under field conditions

The reaction of 112 lines of black gram and 104 lines of khesari to major diseases at various research stations (Ishurdi, Mymensingh, Jamalpur, and Kishoregonj) of the country under natural field conditions was studied from 1980-86. The test diseases of black gram were collar rot, wilt, seedling blight, leaf spot, and YMV, and those of khesari, collar rot, leaf blight, leaf spot and downy mildew. In addition, 869 germplasm lines of Lentil mostly received from the International Center for Agricultural Research in Dry Areas (ICARDA) were screened against wilt, collar rot, and bushy stunt in the performance trial plots of the Genetics and Plant Breeding Department of BAU Farm during 1987/88.

Out of 112 lines of black gram tested, only M 25 was found resistant to yellow mosaic. Two lines, M 23 and M 25 were found resistant against collar rot and wilt. Of the 104 khesari lines, only L 11 showed resistant reaction to collar rot and wilt. Among 869 germplasm lines of lentil, only seven namely BM 155, BM 184, BM 180, BM 190, BM 194, BM 195 and BM 417 were found resistant against collar rot and wilt. In case of bushy stunt, 350 lines were found resistant to the disease (BAU 1986,1988).

Screening of promising lines of black gram and khesari to collar rot and wilt under artificial epiphytotic conditions

The reaction to wilt of 47 germplasm lines of black gram and 45 of khesari was determined through artificial inoculation by water culture in the laboratory for wilt and by pot culture for wilt and collar rot in the greenhouse using the screening technique followed by ICRISAT (Nene and Haware 1980). None of the lines was found resistant to both test pathogens. Out of 13 promising lines of black gram, 4 were found moderately resistant to wilt and 3 lines were found moderately resistant to collar rot. Two lines, M 25 and 3679 were found moderately resistant to both the pathogens. Among the 14 promising lines of khesari, 4 were moderately resistant to wilt; while 5 were found moderately resistant to collar rot. Of all the khesari lines, L 6 and L 14 were moderately resistant to both diseases (Rahman et al. 1987).

Suggestions

Considering the importance of pulses in the national economy and the research needs for the improvement of this group of crops the following suggestions are made:

1. More emphasis should be placed on breeding high-yielding, disease-resistant cultivars of pulses and management of major pulse diseases through integrated control.
2. Coordinated research establishing close linkage among the national and international institutes/ organizations needs to be undertaken.

Discussion

R. N. Malik: 1. What are the new findings in comparison to BARI results? 2. To what extent do other departments of BAU use your research findings for varietal develoment? 3. What percentage of your research was basic research?

G.A. Fakir: 1. There are a number of new findings in pulses-disease research at BAU. A good amount of work carried out by us at BAU has been included in the paper presented by Dr Hamizuddin Ahmed. You may go through the reports of the two institutions as well as through the two papers presented in this workshop.
2. Varietal screening trials for disease resistance have been carried out in collaboration with BINA and the Plant Breeding and Genetics Department of BAU. Our reports have been submitted to the concerned national authority.
3. A considerable amount of basic research has been done by us.

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Status of Insect and Vertebrate Pest-Management Research On Pulses

M.A. Karim and M. Mahbubur Rahman
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

In Bangladesh, pigeonpea (Cajanus cajan *(L.) Millsp.), chickpea* (Cicer arietinum *L.), cowpea* (Vigna unguiculata *(L.) Walp),mung bean (*Vigna radiata *(L.) Wilczek), and black gram (*Vignamungo *(L.) Hepper) face major pest problems in the fields while all pulses, including khesari* (Lathyrus sativus *L.) and lentil* (Lens culinaris *Medic), are seriously infested by pulse beetles* (Callosobruchus chinensis *Linn, and* C. maculatus *Fab.) in storage. Though the progress made so far has not been able to solve all these problems, it has been satisfactory if one considers the manpower, time, and other inputs. Most entomology research on pulses was done by the research entomologists of the Bangladesh Agricultural Research Institute. These studies which include insect pest surveys, crop loss assessments, biology of major pests, screening for host-plant resistance, insecticidal sprays, comparison of various pest-control measures, and vertebrate pest problems have been discussed in this paper. Future research needs on insects and vertebrate pests have been suggested.*

Monitoring and Surveillance of Insect Pests and their Natural Enemies

Monitoring and surveillance were carried out in some of the major pulse-growing districts to record the incidence of insect pests attacking pulses and the predators and the parasitoids of these insect pests. Alam et al. (1964) prepared the first published list of insect pests of different pulses in Bangladesh. That list was revised later on by Rahman et al. (1982) to include new species of insect pests. In the revised list, 9 species were included as pests of black gram (*Vigna mungo* (L.) Hepper), 10 of mung bean *(Vigna radiata* (L.) Wilczek), 11 of chickpea *(Cicer arietinum* L.), and 19 of pigeonpea *(Cajanus cajan* (L.) Millsp.). Later on, *Menochilus sexmaculatus* Feb., *Micraspis discolor* Feb., *Coccinella repunda* Thorn., and *Brumus susuralis* Fab. were reported as coccinelled predators of aphids in pulses (BARI 1984a) and the galerucid beetle *iMadurasia obscurella* Jacoby), hair-streak blue butterfly pod borer *(Euchrysops cnejus* Feb.), stem fly *(Ophiomyiaphaseoli* Tryon.), whitefly *(Bemisia tabaci* Genn.), and aphid *(Aphis medicaginis* Koch.) were reported as insect pests attacking cowpea *(Vigna unguiculata* (L.) Walp.) in Bangladesh (Rahman and Ramizuddin 1987).

Crop-Loss Assessments for Establishing Status of Insect Pests

Efforts were made to establish the status of the recorded insect pests of pulses by studying their incidence pattern, rate of infestation, and actual and avoidable grain-yield losses. Through such studies the following were established as the major insect pests: galerucid beetle, green jassid, hairy caterpillar, whitefly, bean stem fly, aphids, hair-streak blue butterfly pod borer, and spotted pod borer in cowpea, mung bean and black gram; the cutworm and chickpea pod borer in chickpea; pod borer complex (spotted pod borer, plume moth, hair-streak blue butterfly, and 'tur' pod fly) in pigeonpea; and two species of pulse beetles *iCallosobruchus chinensis* Linn, and C. *maculatus* Fab.) in stored pulses. (Rahman 1988, 1989b; Rahman ard Ramizuddin 1987). Among those major insect pests,

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

the pod borers caused grain-yield losses of 130 kg ha^{-1} in black gram, 136 kg ha^{-1} in mung bean, 191 kg ha^{-1} in cowpea, and 400 kg ha^{-1} in chickpea (Rahman 1989a). Avoidable grain-yield losses of 97 kg ha^{-1} in black gram, 109 kg ha^{-1} in mung bean, 95 kg ha^{-1} in cowpea, and 81 kg ha^{-1} in pigeonpea. were recorded by comparing these yields with those of crops treated with insecticides for the control of the pod borers. The bean stem fly and the galerucid beetle caused up to 97% plant infestation and 100% leaf infestations in black gram (BARI 1984a). Though 43% leaf infestations by the green jassid and 14% by the galerucid beetle were reported in cowpea (Rahman 1988), the effect of such leaf infestations on the grain yield could not be ascertained (BARI 1986; Rahman 1988). Grain infestations by pulse beetles at the rates of 98% in mung bean, 73% in khesari *(Lathyrus sativus* L.), 64% in chickpea, 46% in lentil *(Lens culinaris* Medic), 29% in black gram, and 4% in fieldpea *(Pisum sativum* subsp *arvense)* were recorded after 6-8 months of storage under farmers' storage conditions. The pest status of different insect pests as determined by crop-loss assessment studies will help identify the most damaging insect pests of pulses for further studies on their management.

Biology of Major Pest Species

Though studies on the biology of insect pests in relation to different ecological conditions are very important in developing pest-management strategies, such studies have not yet been started for insect pests of pulses in Bangladesh. However, some studies on the longevity, oviposition, growth, and development of *Callosobruchus* sp in different pulse grains have been completed. Remarkable effects on the developmental biology of the two species of the pulse beetles were observed on different pulses. *C. chinensis* laid their eggs on black gram, but the grubs did not develop after hatching from the eggs. Similarly, *C. maculatus* laid their eggs on lentil, but the subsequent development of the grubs after hatching from the eggs was totally stopped. Mung bean and cowpea served as the best hosts while fieldpea was not preferred as a host for the development of pulse beetles.

Varietal Screening for Host-Plant Resistance to Insect Pests

Screening germplasm to identify sources of resistance against major insect pests deserves attention, as this will help in breeding resistant varieties with good agronomic qualities. Well organized screening programs have not yet been undertaken. However, the pests against which such screening should be undertaken have been identified. These are: chickpea pod borer in chickpea; spotted pod borer and hair-streak blue butterfly pod borer in pigeonpea; galerucid beetle, green jassid, whitefly, spotted pod borer, and hair-streak blue butterfly pod borer in cowpea, black gram, and mung bean in the field; *C. chinensis* and *C. maculatus* for mung bean, cowpea, khesari, and pigeonpea; *C. chinensis* for lentil and chickpea; and *C. maculatus* for black gram in storage.

Studies were conducted on available germplasm of chickpea for resistance to the gram pod borer (BARI 1985,1986,1987). In these studies, chickpea cultivars Sabur 4 and Nabin were found to perform consistently better than other lines against pod borer. In another study, of 9 strains of black gram, 2038 showed the lowest per cent pod infestation by *E. cnejus.* But the results of the screening studies were inconclusive because of the low pest population pressure under natural field infestation. Such screening exercises are best conducted when the pest species can be reared in the laboratory for multiplication and release in the field in sufficient numbers. Identification of natural hot spots with high pest infestations in a particular year did not help screening studies as the pest infestation levels decreased the following year.

Evaluation of Need-Based Application Schedules for Insecticides

The use of insecticides in pulses as a prophylatic measure is highly discouraging. Overall, insecticide use has several negative aspects: it generates reluctance among pulse growers to adopt pest-control measures; their cost is very high; the cost-benefit ratio is high for insecticidal pest control; and insecticides have an adverse effect on natural enemies of insect pests and other beneficial organisms. Nevertheless, insecticides are a key component of the Integrated Pest Management Program in all crops including pulses. Judicious application of insecticides for insect-pest control will be helpful in reducing the number of applications, because though insecticides result in a high cost-benefit ratio for pest control, they have hazardous effects on the ecosystem, and their uncontrolled use presents a safety risk to the users/consumers.

Keeping the above points in view, several insecticides were tested at different population levels of major insect pests of pulses in the field to select effective insecticides, and to determine appropriate doses, minimum number of applications, and to assess the cost-benefit ratios of such insecticidal pest management. Results of these studies have been presented in another paper at this workshop. Determination of such need-based application schedules of insecticides for insect-pest management helped entomologists determine the economic threshold for initiating control measures against specific insect pests.

Testing the Efficacy of Various Pest-Control Measures

The efficacy of many insecticides were tested against the major insect pests of cowpea (Rahman and Ramizuddin 1987; Rahman 1988), pigeonpea (Rahman 1989b), and stored pulses (Rahman and Yadav 1985a, 1985b, 1987; Rahman 1989c). Plant oils, namely neem, mustard, coconut, soybean, linseed, sesame, etc., were tested for their effectiveness in controlling pulse-beetle infestation in stored.pulses (Das and Karim 1986; Rahman 1989c). Neem-oil treatment was found to be the most effective in protecting pulse seeds from damage by pulse beetles.

Some physical methods were tested for their efficacy in disinfecting pulse grains against pulse-beetle infestation. Heat treatment of pulse seeds with boiled water for 10 minutes or cold treatment of seeds at 12.5°C for 48 h fully disinfested seeds from the pulse-beetle infestation (Rahman 1989c). Seeds thus disinfested could be stored for long periods in sealed containers or polythene bags without becoming infested. A top layer of sand or ash over stored pulse seeds in glass containers was found to be effective in preventing the entry of adult pulse beetles. (BARI 1984b).

Vertebrate Pest Problems

Losses caused by vertebrate pests to pulses in the field or in storage have not been studied yet. Birds may cause damage to pulses in the field just after seeding. Various bird-repellent chemicals were tested in Bangladesh to drive away birds from seeded or sprouting crop fields (Poche et al. 1980; Sultana et al. 1986) but these chemicals could not be standardized for bird-damage control. Hiring manual laborers to drive away birds from crop fields is still a common practice in Bangladesh. Use of scarecrow devices to drive birds away from crop fields has only temporary success because birds quickly become familiar with such devices.

Future Research

The progress in research so far discussed clearly indicates that many problem areas are yet to be tackled. The appointment of more entomologists in the Pulses Project of BARI will broaden the research activity of the pulse entomologists. Future research will proceed along the following lines:

Monitoring and surveillance of insect pest populations of pulses in relation to the changing farming systems.

- Bioecology, bionomics, and life tables of major pest species of pulses.
- Artificial rearing of major pest species.
- Screening of germplasm varieties/strains against major pest species under optimum population pressure ensured by artificial release.
- Exploration and augmentation of natural enemies and evaluation of biological control agents.
- Testing the efficacy of cultural control measures such as manipulation of sowing dates, effects of intercrops and trap crops, and soil-, water-, and crop-management practices.
- Testing the efficacy of mechanical and physical control measures especially against the hairy caterpillar and the pulse beetle.
- Evaluation of pheromone traps and light traps, especially against *Helicoverpa* and *Maruca* spp of pod borers.
- Evaluation of cheap and safe pesticides for their effectiveness against major pest species.
- Determination of the economic threshold level/ spraying threshold levels of major pest species.
- Estimation of toxic residues of pesticides in edible portions of the pulse crops.
- Adverse effects of pesticides on predators, parasitoids, and pollinators.
- Integration of possible control measures into a package against the major pests(s)/pest complex.
- On-farm trials of the IPM package before final recommendation.

Successful implementation of the above programs will require enough trained manpower, relevant facilities, interdisciplinary coordination, and international collaboration.

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Control Measures for Important Insect Pests of Major Pulses

M. Mahbubur Rahman
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

*The need-based application of insecticides on major pulses was identified as the major component of the Integrated Pest Management program. Application of furadan 3G @ 33.0 kg ha[1] controlled the vegetative pests of cowpea (*Vigna unguiculata *(L.) Walp.), mung bean (*Vigna radiata *(L.) Wilczek), and black gram (*Vigna mungo *(L.) Hepper). But the control was profitable only at high levels of infestation by galerucid beetles (*Madurasia obscurella *Jacoby) and green jassids (*Empoasca kerri *Pruthi). The application of sumithion 50 EC @ 0.08% a.i.for the control* of Eurchrysops cnejus *when the egg number reached around 5 2m[1] crop row was most economical. In chickpea (*Cicer arietinum *L.), the application of azodrin 40 EC @ 0.05 % or dimethoate 40 EC @ 0.07 % or ripcord 10 EC @ 0.008 % offered good protection against* Helicoverpa armigera *when the infestation level was less than one larva or 5 damaged pods 2 m^{-1} crop row. In pigeonpea (*Cajanus cajan *(L.) Millsp.), foliar sprays of ripcord 10 EC @ 0.008 % or dimethoate 40 EC @ 0.07 % at flowering or when egg number* of Maruca *reached 2 m[1] crop row and then repeated at 10-15 days interval up to maturity offered the best protection. Nogos 100 EC @ 3 microlitre kg^{-1} capacity container, heat treatment with boiled water, and cold treatment at 12-15°C for 10 min worked as excellent disinfestants against pulse beetles (*Callosobruchus chinensis *Linn, and* C. maculatus *Fab.).* Neem, *linseed, mustard and coconut oils, and decis and sevin dusts were highly effective as grain protectants. Earthen containers with sealed lids or a top cover of sand or ash, or gunny bags lined with polythene protected the pulse seeds against bruchids. Based on the available information Integrated Pest Management (1PM) schemes for different pulses have been proposed.*

Introduction

The major insect pests effected pulse crops cause substantial losses in yield. In black gram (*Vigna mungo* (L.) Hepper) up to 97% plants were found to be infested by stem fly, 100% leaves by galerucid beetles *(Madurasia obscurella* Jacoby), and 17% pods by pod borers (BARI 1984a). Rahman (1988) found 43.4% leaf infestation by green jassids *(Empoasca kerri* Pruthi), 14.4 % galerucid beetles, and 47% pod infestation by pod borers in cowpea *(Vigna unguiculata* (L.) Walp.). Pod borers alone were reported to cause grain losses of 136 kg ha^{-1} in mung bean *(Vigna radiata* (L.) Wilczek), 191 kg ha^{-1} in cowpea (BARI 1986), and 400 kg ha^{-1} in *chickpea (Cicer arietinum L.) Rahman* 1989a). In storage a maximum infestation level of 98.4% in mung bean, 72.97% in khesari *(Lathyrus sativus* L.), 64.33% in chickpea, 46.48% in lentil *(Lens culinaris* Medic), 29.08% in black gram, and 4.0% in fieldpea *(Pisum sativum* subsp *arvense)* by pulse beetles *(Callosobruchus chinensis* Linn, and *C. maculatus* Fab.) were registered after 6-8 months of storage (BARI 1983, 1984a).

In spite of such losses caused by insect pests, pulse growers, in general, were highly reluctant to follow any pest-control measure. However, recently, due to the high prices of pulses and increased awareness, the demand for pest-control methods is on the rise. During the last few years, efforts have been made to develop pest-control methods to meet the immediate needs. A major emphasis has been given to the chemical-control component of Integrated Pest Management (IPM), while other components, like cultural practices, varietal resistance, and biological control agents have

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patanchem, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

received little attention. However, studies on chemical control were designed in a way such that simultaneously, much useful information was generated for use in designing IPM strategies for cowpea. For convenience, on the basis of similarity in pest problems, the information so far available is presented under four groups: (1) black gram, mung bean, and cowpea, (2) chickpea, (3) pigeonpea, and (4) stored pulses.

IPM Components

Black Gram, Mung Bean, and Cowpea

Galerucid beetle, green jassids, bean stem fly *(Ophiomyia phaseoli Tryon),* whitefly *(Bemisia tabaci* G.), hairy caterpillar (*Diacrisia obliqua* Walk), and aphids *(Aphis craccivora* Koch) infest the crop and the seedling stage and continue to flowering, while blue butterfly pod borer *(Euchrysops cnejus* Fab.) and spotted pod borer (*Maruca testulalis* Geyer) damage flower buds, flowers, and pods of three crops. As a control measure, several insecticides have been evaluated with the objective of keeping the pest population at the mirimum level with the minimum application of insecticides at the proper time or stage of the crop to obtain maximum benefit (BARI 1986; Rahman 1987, 1988, 1989a). In such a study with mung bean, handpicking and spot spraying against the hairy caterpillar, plus a foliar spray with methyl parathion (0.2%) at a population level of 10 stem fly 4m^{-1} crop row, 10 jassids and whiteflies plant^{-1} and also at 5% level of pod-borer infestation, was found to increase the grain yield by 170 kg ha^{-1} over control. However, the highest and most acceptable cost-benefit ratio was obtained by controlling the pod borers with the application of sumithion 50 EC @ 0.2% at 5% level of infestations (Table 1). Similarly, pod-borer control through sumithion application resulted in an acceptable cost-benefit ratio although control of the total pest complex including pod borers increased the grain yield by 220 kg hectare^{-1} in black gram (BARI 1986). Likewise in cowpea, soil application of carbofuran 1.5 kg ha^{*1} significantly reduced the galerucid beetle infestation but the effects were not reflected in yield.

Soil application of furadan 3 EC @ 1.5 kg a.i. ha^{-1} just prior to sowing followed by foliar application of azodrin 40 EC @ 0.07% at 50% flowering protected the crop from a reduction in yield, while cowpea plants in untreated plots were severely infested by green jassids and galerucid beetles (Table 2). In another trial on need-based application of insecticides against the pod borer in mung bean in 1987 at Joydebpur, it was found that the spraying of fenitrothion 0.1 % when egg number reached about 5.2m^{-1} crop row (0.21 egg plant^{-1}) or at flowering and the second spray either at an interval of 15 days or at podding offered the highest cost-benefit ratio (Rahman 1989a).

From the foregoing discussion it is clear that the control of vegetative pests is possible through furadan application but it is not a profitable proposition until the infestation level by green jassids and galerucid beetles becomes high. The incidence of green jassids, galerucid beetles and aphids is often high in cowpea and thus this crop may need protection.

Chickpea

The cutworm *(Agrotis ipsilon Hufn$_1$)* causes damage to the seedlings while the pod borer *(Helicoverpa armigera* Hubn.) destroys the foliage and pods, in particular, and poses the most serious problem in chickpea. A number of local and introduced lines have been screened to identify resistant varieties/lines against pod borers. Irregular and insufficient pest attack resulted in inconsistent results across years and locations. However, chickpea cultivars Sabur 4 and Nabin performed consistently well in terms of resistance and grain yield.

In an evaluation of management schedules against *Helicoverpa,* monocrotophos @ .05% at flowering and then repeated at an interval of 10 days offered good protection. The population was too low (1.25 larvae m^{-1}) and caused 84 kg ha^{-1} grain loss in nontreated plots. In another study during 1987/88, the author found that azodrin 40 EC @ 0.05% or ripcord 10 EC @ 0.008% or dimethoate 40 EC @ 0.07% applied when damage level reached 5 damaged pods 2 m^{-1} crop row also offered good protection. The population in this case also was less than one larva m^{-1} and it caused 3.5% pod infestation in nontreated plots. Thus the observed population and the corresponding levels of pod infestation and grain loss are inconsistent and do not tally well with the findings of other workers (Chaudhary and Sharma 1982) who reported that the continuous presence of even a single larva m^{-1} row during pod formation could cause about 6.9% pod damage, 6.2% grain loss, and 5.4% yield loss. This was perhaps due to the low population, causing uneven distribution of the pest in the crop.

The foregoing results suggest that for the successful evaluation of insecticides/varieties, either the natural population of *Helicoverpa armigera* needs to be

Table 1. The effect of different doses of Sumithion in Integrated Pest Managemente (IPM) of mung bean, Joydebpar, Bangladesh, 1985/86.

Treatments	Seed Yield (kg ha^{-1})	Increased Yield (kg ha^{-1})	Seed loss (kg ha^{-1})	Cost-Benefit ratio
T_1 0.05% spray at 10 stem fly $4m^{-1}$	562fg[1]	5	134ab	1.82
T_2 0.2% spray at 10 stem fly $4m^{-1}$	573f	17	131ab	2.27
T_3 0.5% spray at 10 stem fly $4m^{-1}$	573f	17	129b	0.90
T_4 Hand-picking and spot spray against hairy caterpillar; 0.05% Sumithion spray against jassids/ whitefly at 10 $plant^{-1}$	566g	10	133ab	0.38
T_5 Hand-picking and spot spray against hairy caterpillar; 0.2% Sumithion spray against jassids/ whitefly at 10 $plant^{-1}$	556fg	5	130	0.30
against hairy caterpillar, 0.5% Sumithion spray against jassids/ whitefly a' 10 $plant^{-1}$	559fg	3	131ab	0.32
T_7 0.05% Sumithion spray against pod borer at 5% level of infestation.	595d	38	63c	1.70
T_8 0.2% Sumithion spray against pod borer at 5% level of infestation.	694b	138	28d	6.11
T_9 0.5% Sumithion spray against pod borer at 5% level of infestation.	698b	142	23d	2.53
T_{10} Carbofuran 1.0 kg a.i. ha^{-1} 0.05% Sumithion spray at 40, 50, 60 and 80 DAP.	628c	72	59c	0.69
T_{11} (T_1+T_4 + T_7)	648c	92	65c	2.33
T_{12} (T_2 + T_5 + T_8)	728a	171	27d	3.79
T_{13} Nontreated Control	556g		136a	

1. Values followed by the same letters within a column do not differ significantly from each other at the 0.05 level.
Source: BARI (1986).

Table 2. Effects of insecticides on pest infestation and grain yield of cowpea, Joydebpur, Bangladesh, 1986/87.

Treatment[1]	Leaf infestation %		Jassid nymphs 10^{-1} plants	Pod infestation by pod borer(%)	Grain yield (kg ha^{-1})
	Beetle	Jassid			
Control	14.4	43.3	942	47	396
Carbofuran 1.5 kg a.i. ha^{-1} (Furadan 3G)a[2] + monocroto phos 0.07% (Azodrin 40 WSC)b	6.1	2.4	42	17	797
Monocrotophos 0.07% (Azodrin 40 WSC)c	4.5	23.2	569	21	594
Dimethoate 0.07% (Roger 40 WSC)c	11.0	25.6	500	16	625
Diazinon 0.07% (Diazinon 60 EC)c	14.9	34.9	612	34	524
Cypermethrin 0.007% (Ripcord 10 EC)c	5.9	16.2	500	16	625
Carbofuran 1.5 kg a.i. ha^{-1}	3.7	2.7	52	28	547
SE	±0.33	±2.93	±2.0	±6.8	±33.55

1. Trade names of products used are in parentheses.
2. a Applied in furrows just prior to sowing
   b Applied as foliar spray at flowering.
   c Applied as foliar spray at two-leaf stage and again at flowering

Source: Rahman (1988).

supplemented by artificial release or the studies should be conducted under controlled conditions with artificial release of the pest. As such no conclusion regarding the economic threshold level/spraying threshold level for *Helicoverpa armigera* could be drawn under our local conditions. However, a recommendation has been made in India to apply insecticides against *Helicoverpa armigera* when the larval population reaches one larva m^{-1} crop row (ESI 1981).

Pigeonpea

The pod-borer complex consisting of four species viz., spotted pod borer *(Maruca testulalis),* blue butterfly pod borer (*Euchrysops cnejus),* plume moth (*Exelastis atomosa* Walsh), and podfly *(Melanagromyza obtusa* Malloch), is a threat to the production of pigeonpea. Among them, *Maruca testulalis* poses the most serious problem, causing damage by boring into flower buds, webbing flowers and pods, and also feeding inside pods.

Thirteen insecticides have been tested for the control of the pod-borer complex. Decis, ripcord, or sumicidin @ 0.008% applied at flowering and again at podding were effective (Rahman 1989b). Cypermethrin @ 0.008% at flowering, 50% flowering, 100% flowering, and 100% pod-set gave complete protection to the crop, even at a high level of pest population (Table 3). In 1987/88, the author found that ripcord 0.008% a.i.

Table 3. Effect of cypermethrin and dimethoate on pod infestation and yield loss due to *Maruca testulatis* and on pod bearing and grain yield in pigeonpea, Joydebpur, Bangladesh, 1987/88.

Treatment (No. of spray with R & D)	Distinct clusters made by *Maruca* plot on 31.12.87. (No.1)	Damaged pods in cluster $plot^{-1}$s on 31.12.87 (no.)	% infestation of pods by *Maruca* on 4.2.88	Pods $plant^{-1}$ on 4.2.88 (no.)	Grain yield (t ha^{-1})	Avoidable yield loss (kg ha^{-1})	Cost-benefit ratio
T_1 (2-R)[2]	6.50[3]	7.25bc	14.94cd	18.48ab	1.84abc	414	4.36
T_2 (2-D)[2]	14.00	21.50abc	16.26c	17.11b	1.59bc	168	3.54
T,(3-R)	4.50c	9.0c	8.79e	19.10ab	2.30ab	871	6.12
T_4(2-D)	9.25abc	21.75abc	11.78de	19.48ab	1.87abc	461	4.86
T_6(2-D)	21.25ab	37.75ab	21.38ab	16.00b	1.81 bc	389	4.10
T_7(4-R)	0	0	0.10f	25.57a	2.61a	118	6.23
T_8(Control)	27.75a	48.00a	25.09a	15.74b	1.43c		

1. Data were analyzed after appropriate transformations.
2. R: Ripcord 10 EC @ 0.008% a.i., D: Perfecthion 40 EC @ 0.08% a.i.: applied at different times as per the set schedule.
3. Values followed by the same letters in each column are not significantly different from each other at the 0.05 level.

Source: Rahman and Rahman (1989).

applied when 2 eggs of *Maruca* m^{-1} crop row were observed and repeated after 10-15 days also gave full protection to pigeonpea from the pod-borer complex.

Stored Pulses

All pulses are severely infested by bruchid beetles. Mung bean, cowpea, pigeonpea, and chickpea are infested by both the species while lentil is infested only by *C. chinensis,* and black gram is infested only by *C. maculatus.* In a laboratory study during 1988/89, the author found that the initial presence of four larvae or eggs or one pair of *Callosobruchus* sp could completely damage 10 g of the pulse grains within 2-4 months depending on the type of pulses, stage of maturity, and species of the insect. Mung bean, cowpea, pigeonpea, and lentil required the least time. C. *chinensis* was more devastating than *C. maculatus.*

Pulse seeds may contain some or all of the four stages e.g. egg, larva, pupa, and adults of *Callosobruchus* sp. Thus a combination of different measures that are together effective against each of the above stages will effectively protect the pulse grains in storage. The results of some such studies are presented below,

Deltamethrin dust @ 3.0 ppm effectively protected mung bean, chickpea, and lentil from the adults of pulse beetles, (Rahman and Yadav 1985a, 1987). Deltamethrin emulsion 20 mg m^{-2} on the surface of a jute sack was effective for up to 180 days (Rahman and Yadav 1985b). Eight ml of neem oil kg^{-1} of chickpea seed was the most economic concentration, causing complete mortality of adults and also inhibiting oviposition by adults *of C.chinensis* (Das 1986). Fumigation by nogos 3.0 microlitre kg^{-1} capacity container with 2-5 days' exposure or heat treatment with boiled water for 10 min, or cold treatment at -12.5°C for 48h or sun drying for 22 h destroyed the four stages. Neem oil 10 ml kg^{-1} grain was effective against all stages except pupae and linseed oil of 10 ml kg^{*1} grain was effective against all stages except larvae and pupae infesting mung bean. Out of 9 treatments applied on cowpea seeds containing 20% infestation and 5 pairs of adults of *C. maculatus,* fumigation by nogos, or heat treatment or cold treatment as mentioned above and followed by storing in sealed polythene bags kept the seeds completely free from any infestation while storage in sealed polythene bags and treatment with neem oil 10 ml kg^{-1} grain offered 95.2% grain protection, linseed oil 10 ml kg^{-1} grain offered 90.7%, decis dust 3.0 ppm, 89.9%, and sevin dust 50 ppm, followed by storing in sealed polythene bags offered 87.9% protection, as against 92.4% grain infestation in control during 5 months of storage. None of the treatments affected the germination of cowpea while heat treatment for 10 min by boiled water seriously affected germination in mung bean (Rahman 1989c). Pulse grains stored in earthen containers sealed with cowdung, coal tar, or gunny bags with polythene lining and mud, remained free from external infestation. A cover of a layer of sand over the stored grains in earthen containers also prevented external infestation of pulse beetles (BARI 1984b).

Proposed Control Schemes

Based on the information generated so far through our studies and other available information (Dick 1987; Lal et al. 1980; Lal 1985; Reed et al. 1981), the following IPM schemes for different pulses have been formulated for testing on a large scale.

Black Gram, Mung Bean, and Cowpea

Normally, there is no need for any control measure against the vegetative pest complex. However, if severe infestation especially by green jassids, galerucid beetles, and hairy caterpillars is predicted, or has occurred, the following should be adopted:

1. Furadan 33 kg ha^{-1} may be applied in soil furrows prior to sowing or when necessary. This should ensure protection of the crop against the vegetative pest complex including bean stem fly, galerucid beetles, green jassids, aphids, and whitefly up to 25-30 days. Otherwise, foliar spray with ripcord 1.0 ml litre^{-1} water or azodrin 2.0 ml litre^{-1} water at 2 weeks' interval may be applied.
2. Hand-picking and destroying egg masses or clusters of star larvae of hairy caterpillars or spot spraying them with lebaycid or sumithion, 2.0 ml litre^{-1} water; foliar spray with sumithion 2.0 ml or ripcord 1.0 ml or dimethoate 2.0 ml litre^{-1} of water when eggs of *Euchrysops* number around 5 2m^{-1} crop row or at 50% flowering and repeated at an interval of 2 weeks.

Chickpea

1. Dried leaves and debris must be removed, and then big clods of mud should be pulverised before sowing.
2. Mechanical control can be effected by searching for and collecting cutworm caterpillars from near the cutplants and destroying them.
3. The infested fields may be flooded for a short time for controlling cutworm.
4. Basudin 10G 17.0 kg ha^{-1} or diazinon 14G 13.5 kg ha^{-1} may be mixed with the soil before sowing to prevent cutworm infestation.
5. Cultivars such as Sabur 4 and S 1 that perform better against pod borers should be utilized.
6. A foliar spray may be done with sumithion 2.0 ml or azodrin 2.0 ml or ripcord 1.0 ml or diazinon 3.0 ml litre^{-1} of water. The first spray is applied when the larval population reaches one or when the damage level reaches 5 pods 2^{-1}m crop row or at 50% flowering and then repeated at an interval of 2 weeks.

Pigeonpea

Since the crop can compensate for damage caused in the early stages no control measure is required at the vegetative stage against the pod borer complex. A foliar spray is applied with ripcord 1.0 ml or dimethoate 2.0 ml or sumithion 3.0 ml litre^{-1} of water. The first spray is just at flowering, the second at 50% flowering, the third at 100% flowering and the fourth spray is at 100% pod setting. When the egg number of *Maruca* reaches 1 m^{-1} of crop row, the first spray is applied, and then repeated at an interval of 10-15 days up to maturity.

Stored Pulses

The grains must be dried sufficiently to reduce the moisture content as far as possible before storage. The grains may be dried periodically at 2-month intervals.

Grains should be stored in earthen containers with sealed earthen lids or a top cover of sand or ash (7.5 cm thick) or in gunny bags with polythene lining, and closed tightly.

Grains should be inspected prior to storing and also at an interval of 2 months after storage, taking at least 5 samples each of 10-100g depending on the size of the lot, using a probe.

If 4 eggs or 2 larvae or a pair of adult pulse beetles 10g^{-1} seeds are observed, the control measures mentioned earlier should be adopted. Fumigation by nogos 3.0 ml kg^{-1} in an airtight container is recommended with 5 days' exposure or heat treatment for 10 min by boiled water or cold treatment at -12.5°C for 48 h or grain treatment with neem oil or linseed oil 10 ml kg^{-1} grain, followed by storage in containers as mentioned above or in jute bags, provided the bag surface is sprayed with decis 2.5 ml m^{-1} just after storage and again at an intervals of 6 months.

Heat treatment for 10 min by boiled water is not applicable for seeds of mung bean, black gram, and lentil because of its adverse effect on their germination. Seed treatment with decis dust 3 ppm or sevin dust 50 ppm at an interval of 4-5 months is recommended.

Discussion

M. A. Wahhab: You have used linseed oil and neem oil to control stored grain pests. Did you try groundnut oil?

M. M. Rahman: In my studies, I have not included groundnut. However, other workers have studied the efficacy of groundnut oils in controlling pulse beetles. To me, the use of groundnut oils is not promising.

A. Islam: 1. You have suggested growing chickpea cultivars Sabur 4 and S 1 (Nabin) to avoid pod borer. Dr Shaikh also suggested the use of chickpea cultivars like Hyprosola to avoid pod borer. Have you studied which is better among the cultivars - Sabur 4, Nabin, and Hyprosola?
2. In the study of mung bean, you have shown a higher cost-benefit ratio. Is it only considering insect control on variable cost basis?

M. M. Rahman: 1. I have studied the reactions of several cultivars/lines including Sabur 4, S 1, and Hyprosola. The performance of Sabur 4 and Nabin was always better than Hyprosola. However, in some trials Hyprosola also performed well. But in all cases, the results were inconsistent because of sporadic and low pest-population pressure. Thus, based on the studies done so far, no conclusion regarding their resistance could be drawn.
2. The cost-benefit ratio has been calculated based on the total costs of insecticides, labor, and equipment.

E. D. Magallona: The pyrethroid insecticides appear to be quite effective against the major pests of pulses. I would just like to sound a warning about these compounds. As a group, pyrethroids are notorious for inducing the insect to develop resistance. Good examples are *Helicoverpa* armigera and *Prodenia litura* in cotton and *Plutella xylostella* in cabbage. Maybe it is the opportune time for Bangladesh to adopt pesticide-resistance management schemes directed primarily at pyrethroid insecticides.

M. M. Rahman: Yes. I fully agree with the views of Dr Magallona regarding the effect of pyrethroid in inducing resistance in insects. However, this is true, to some extent, for other groups of insecticides too. Unfortunately, we do not have, at present, any basic toxological data of any insecticide for any pest. So comparative study to determine whether an insect has developed resistance to a particular insecticide cannot be done right now.

1 agree with Dr Magallona that Bangladesh should draw up a program for the study of pesticide-resistance management. Such programs may be developed under the Toxicology Laboratory of the Entomology Division, BARI.

M. O. Islam: I have observed this year that late-sown chickpea was badly damaged by *Heliicoverpa,* but the same genotype sown at optimum time was not affected. Would you please explain?

M.M. Rahman: The chickpea sown at optimum time avoided the time suitable for incidence of damaging population of *Helicoverpa* - this is simply an escape mechanism. But in case of late sowing, the crop flowered and set pods at this time when *Helicoverpa* appeared in large populations - this is simply a coincidence of the suitable host stage and critical pest population. However, this mechanism can also help in growing chickpea free *of Helicoverpa* infestation.

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Present Status And Future of Postharvest Technological Research on Pulses

M. Amiruzzaman and J.C. Shaha Chaudhury
Bangladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

Pulses are attacked by insects and pathogens during storage and thereby lose their viability and consumer acceptance. The postharvest technology project of BARI, funded by IDRC, surveyed the farmers' storage conditions in Bangladesh during 1981-1984. It was found that as much as 64% infestation of chickpea (Cicer arietinum *L.), 35% of lentil* (Lens culinaris *Medic), and 24% of mung bean (*Vigna radiata *(L.) Wilczek), by bruchids occurred within first 3 months of storage. Twenty four pathogens were isolatedfrom the storable seeds, of which* Alternaria *sp,* Cladosporium *sp, and* Curvularia *sp, were predominant. Viability of stored seeds was also reduced by 30% to 80% if the moisture content exceeded the safe level of 8%. High rainfall and high humidity (90%) in the 4 months of postrainy-season storage made them more vulnerable to fungal attacks. Traditional storage systems include kerosene tins, gunny bags, bamboo* doles, *earthen pitchers (motka), etc. Research indicated that proper drying and storage of seed under one inch of ash or sand helped better storage. Treatment of seeds with vegetable oils and leaves* of neem *and tobacco, and use of improved containers greatly reduced damage during storage. The future line of work is discussed in this paper .*

Introduction

Pulses play a vital role in the diet of the people of Bangladesh. This is due mainly to the fact that the group constitutes the major source of protein for the bulk of the population of the country. Unfortunately, the crops suffer serious postharvest losses mainly from inadequate storage, and inefficient drying and milling procedures.

The Legumes Postharvest Technology Project is the first of its kind on pulses in Bangladesh. An important feature of the project is that a number of disciplines such as entomology, plant pathology, agronomy, agricultural economics, and agricultural engineering have been applied to the various postharvest studies. This multidisciplinary approach to surveys of pest incidence, microbial association, seed viability, and socioeconomic constraints to farmers' methods of pulse storage has produced considerable information.

Farmers in Bangladesh store their pulses in different types of containers. There is hardly any scope for effective sun-drying of the agricultural produce during the rainy season when the mean relative humidity is more than 90%. This condition encourages the multiplication of insect pests and the development of various fungi. The storage of already infested seeds or seeds with high moisture content, use of non-disinfested containers/areas, and the inability of farmers to adopt effective protective measures against insect pests and microorganisms, are the major factors contributing to the spoilage of seeds in storage. This project therefore aimed at determining the extent of losses incurred in various methods of storage at the farmers' level and developing appropriate methods of storage that can easily be adopted by farmers.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Pest Incidence in Storage at the Farm Level

Insects pests responsible for damage to stored pulses are two species of *Callosobruchus,* i.e., (i) *Colloso-bruchus chinensis* (L.), and *Collosobruchus maculatus.* They are commonly known as pulse beetle and belong to the family Bruchidae and the order Coleoptera. The pulse beetle is a major pest causing heavy damage to stored pulses.

A survey was carried out at five locations: Jamalpur, Kishoregonj, Feni, Ishurdi, and Jessore, to determine the effectiveness of various containers used by farmers against damage by pulse beetle to six major pulses during 8 months' storage at the farm level. In almost all cases, basic samples drawn from these locations prior to storing showed either no or very low pest infestation. This indicates that farmers in general took sufficient care of their produce from harvest to storage. At the end of 2 months* storage at Ishurdi, chickpea *(Cicer arietinum* L.) stored in closed kerosene oil tins suffered a loss of 63.6% while the percentage of infestation in lentil *(Lens culinaris* Medic.) stored in open drums but covered with ash, was 34.80%. The infestation was only 0.19% when lentil was stored in bamboo made *aury* with the top covered by sand. All samples of other pulses from Feni, Ishurdi, and Jessore were infested to various extents.

The incidence of the insect during 6 to 8 months of storage, however, varied from less than 1% to 98%. Seeds stored in covered metallic containers, gunny bags with polythene lining, earthen containers with sealed mouths, bamboo containers made locally known as *aury* with the top covered with very dry sand, were almost free from beetle infestation for the entire 8 months' storage period.

Seeds stored in earthen containers or metallic drums covered with sand, gunny bags with polythene lining, very tightly-packed gunny bags, plastic bags, metallic pitchers with mud-sealed lids, or covered metallic drums were almost free from beetle infestation during the entire 6-month storage period. There was, however, considerable infestation in lentil and chickpea stored in earthen pots *(motka)* with ash, and open earthen pots.

Table 1. Intensity of pulse-beetle infestation and losses in stored chickpea seed treated with indigenous plant materials, Ishurdi, Bangladesh, 1981/82.

Treatment	Mean infestation (%)	Mean grain loss (%)
Tobacco	3.06a[1]	1.15a
Neem	13.33b	4.43b
Biskatali	15.21b	6.20b
Nishinda	50.93c	29.91c
Control	64.51d	35.11d

1. Values followed by the same letters do not differ significantly at the 0.01 level.

Control of Pulse Beetle

Plant materials

Indigenous plant materials having no hazardous effect may offer protection against the pulse beetle. Two experiments were conducted to evaluate the effectiveness of some indigenous plant materials against pulse beetles, the first with stored chickpea and the second with stored black gram *(Vigna mungo* (L.) Hepper) and khesari *(Lathyrus sativus* L.).

In the experiment with stored chickpea, 0.2 kg dried and powdered leaves of each of four indigenous plants viz, tobacco *(Nicotiana tabacum), neem (Azadirachta indica), biskatali (Polygonum serrulatum)* and *nishinda, (Vitex nequndo)* were throughly mixed with 4 kg chickpea seeds and put in earthen pots. Newly emerged beetles, 20 male and 20 female, were released in each container. After 3 months, the percentage of infestation was calculated from random samples.

In the experiments with black gram and khesari, *neem,* tamarind *(Tamarindus indica),* and datura *(Datura fastuosa)* were used as repellents. These materials were thoroughly dried and powdered, and 10 of each was used as surface top covering for 1 kg dry seed (with 10% moisture content) placed separately in 2-kg glass jars, then 10 pairs of newly-emerged male and female adult pulse beetles were introduced into each jar. The jars were kept inside a 22 mesh wire net enclosure. After 6 months in storage, insects, leaf powder, and frass were sieved off and the seeds were reweighed.

Experiments with chickpea indicated that tobacco offered the maximum protection followed by *neem, biskatali,* and *nishinda* (Table 1). The trend of grain loss was similar to that from infestation (BARI 1982).

In the experiment with stored black gram and khesari, results indicated that weight loss in black gram seeds treated with *neem* and tamarind was significantly lower than the control (Table 2). There was significantly less weight loss in khesari seeds treated with *neem* leaf powder. No significant differences in weight loss were, however, observed among tamarind, *datura,* and control treatments (BARI 1984).

Table 2. Effect of indigenous plant materials on the weight loss caused by and *Callosobruchus chinensis* in stored black gram and khesari seeds, Jamalpur, and Kishoregonj, Bangladesh, 1983/84.

	Black gram	Khesari
Treatment	Weight loss (%)	Weight loss (%)
Neem	0.35b[1]	1.23b
Tamarind	2.53ab	5.32a
Datura	5.22a	6.25a
Control	5.40a	7.21a

1. Values followed by the same letters within a column do not differ significantly at the 0.01 level.

Salt water

500 cowpea *(Vigna unguiculata* (L.) Walp.) seeds were thoroughly washed in warm water, salt water, and plain water separately, dried in the sun, and then kept in two types of containers, polythene bags and clean tin pots with lids. Pest incidences were determined from the number of infested seeds after 7 months of storage.

Warm water, salt water, and plain water-treated seeds stored in polythene bags were almost free from pulse beetles (Table 3). Plain-water treatment was not effective in controlling the pest when the seeds were stored in tin pots. Heavy insect infestation was observed in nontreated seeds (controls) in both containers.

In the case of nontreated seeds, pest infestation might have been initiated from fertile eggs adhering to the seed coat. It is very likely that the eggs in the treated seeds were eliminated due to washing with water (BARI 1983).

Edible oils

Some edible oils were assessed for their efficacy in controlling pulse beetles in seeds of chickpea, khesari, lentil, and black gram stored in glass jars. Seeds were treated with oils at the rate of 10 ml kg^{-1}. Three pairs of newly emerged pulse beetles were introduced into each glass jar. After 5 months pest incidence was determined. All oils used were highly effective in protecting the seeds against pulse beetles (Table.4)

Table 3. Infestation of cowpea seeds treated with warm water, plain water, and salt water, Fenl, Bangladesh, 1982/83.

Treatment	Infestation (%)	
	Polythene bag	Tin pot
Warm water	0.46a	0.4a[1]
Plain water	5.73a	29.66a
Salt water	4.12a	2.53a
Control	51.46b	72.6b

1. Values followed by same letters within a column differ do not differ significantly at the 0.01 level.

Relationship of Pulse Beetle, Fungal Incidence, and Moisture Content

To determine safe seed-moisture level for storage, fresh chickpea seeds with 8%, 12%, and 16% moisture content were placed in airtight tin containers. Samples were drawn after 6 months and examined for pest incidence and fungal infestation, using the standard blotter method. Chickpea seeds with 8% moisture content remained absolutely free from insect infestation, while those with 12% and 16% moisture showed pulse-beetle infestation ranging from 16% to 21.2% (Table 5) (BARI 1984). *Aspergillus* sp, *Penicillium* sp, *Alternaria* sp, and *Rhizopus* sp. were the dominant fungal species among the 12 genera recorded. These storage fungi could not multiply at the 8% moisture level, but could at 12% and 16% moisture, except *Alternaria* sp, which declined at higher moisture levels (Table 6) (BARI 1984).

Moisture content and fungal incidence

The incidence of *Aspergillus* sp, did not increase appreciably in seeds with 8% moisture content over the

Table 4. Infestation (%) of pulses seeds treated with edible oils as protectants against pulse beetle, various locations in Bangladesh, 1983/84.

Treatment	Infestation (%)				Overall mean infestation (%)
	Chickpea	Khesari	Lentil	Black gram	
Mustard oil	1.79	0.09	0.09	0.01	0.49a[1]
Soybean oil	0.03	0.04	0.94	0.04	0.26a
Coconut oil	3.22	0.00	0.13	0.01	0.84a
Control	97.31	92.94	38.08	12.74	60.26b

1. Values followed by the same letters do not differ significantly at the 0.01 level.

Table 5. Incidence of pulse beetle in stored chickpea seeds with different moisture contents, Ishurdi, Bangladesh, 1983/84.

Treatment	Mean infestation (%)
16% moisture	21.2a[1]
12% moisture	16.1a
8% moisture	0.0b

1. Values followed by the same letters do not differ significantly at the 0.0S level.

storage period, while an incidence greater by about 60% was recorded in seeds maintained at 12% moisture, and 70% in those maintained at 16% moisture. Similar behavior was shown by the other two genera. Incidence of *Alternaria* sp. decreased drastically in seeds with 12% or 16% moisture.

Initiation of Bruchid Infestation

In order to determine whether bruchid infestation in stored pulses starts in the field, three 1000-pod samples each from lentil and chickpea were randomly drawn from the field. The first sample was taken at 21 days before harvest, and the subsequent ones at 7-day intervals. These pods were examined for immature stages of the pest, particularly eggs, and then held in plastic jars, for the period needed for adult emergence. Since there was no such emergence, it clearly indicated that such infestation did not occur in the field. To determine whether bruchid infestation started at any stage between harvest and storage, 200 g of fresh seeds of lentil and khesari were dried in the sun for 6 h and each pulse was divided into two lots. In one lot, dried seeds were tightly tied in a cheesecloth bag, while seeds of the other lot were kept exposed overnight, after which both lots were dried in the sun. After 4 days of drying under exposed and protected conditions, seeds were held in plastic jars covered with finely

Table 6. Fungal incidence in chickpea seeds stored at different moisture levels, Ishurdi, Bangladesh, 1983/84.

Fungi	Fungal incidence (%) at					
	8% moisture		12% moisture		16% moisture	
	Initial	Final	Initial	Final	Initial	Final
Aspergillus sp	30.0	31.0	7.0	68.0	23.0	96.0
Alternaria sp	49.8	69.8	80.0	2.3	30.5	0.0
Penicillium sp	32.5	6.5	6.5	43.5	12.8	24.5
Rhizopus sp	0.0	5.8	0.0	4.3	0.0	37.0

perforated lids and examined for pest emergence after 30 days. There was no adult pest observed in both exposed and protected seeds of lentil, while in the exposed khesari seeds, pest incidence was high. This implies that khesari is the preferred host of the two pulses and pest incidence started prior to storage.

Viability and Moisture Content

The program was initiated during 1981/82 with a survey of farmers' storage containers and types of legume prestored at the five locations. Stored samples of various pulses were drawn from selected farmers of Jamalpur, Kishoregonj, Ishurdi, Jessore, and Feni. These were analyzed for purity, germination, and moisture content. No definite relationship could be established between type of storage container and viability, or between seed-moisture content and viability. Further studies undertaken the following year identified several containers for storage. Earthen pitchers with their tops covered with sand, polythene bags covered with gunny, earthen pots *(motkas),* and gunny bags with polythene lining proved effective in maintaining seed viability even after 8 months of storage.

A separate study in the laboratory on the relationship between physiological maturity (determined from stable maximum grain weight attained at a certain interval of time (days) after synthesis) and storability showed that germination of stored samples of physiologically mature seeds of lentil (30-32 days) and khesari (36 days) indeed improved with the period in storage. In case of chickpea, stored seeds from the later stages of maturity (42-46 days) continued to show 100% germination during the storage period. Further studies were undertaken and results of these studies are as follows:

1. Physiologically mature seeds of mung bean *(Vigna radiata* (L.) Wilczek) and black gram showed initial high germination (70%). However, for seeds harvested and stored during July (the month of high rainfall), viability dropped quickly to less than 10% by April (next sowing time). Black gram showed comparatively better storability than mung bean.
2. Physiologically mature seeds of chickpea continued to exhibit excellent germination (90%) during the whole period of storage. On the other hand, physiologically mature seeds of lentil continued to show improvement in germination during storage. (It is primarily due to a decrease in dormancy of hard-coated seeds with passage of time during storage.)
3. Lentil seeds with initial moisture content between 7.4 to 10.2% and chickpea seeds with initial moisture content between 8.8 to 12.8% retained viability (80%) during storage simulating the farmers' storage method. It took 9 days of sun-drying after harvest to reach a seed-moisture content of 7.4% in lentil and 8.8% in chickpea.

Fungal Infestation in Stored Pulses

Heavy microbial infestation, especially by storage molds, occurs particularly during the hot rainy season when drying is inadequate, insects are present, or stored grain is exposed to high humidity or seed rot. The development of storage molds normally does not

Table 7. Seed-moisture content and germination of pulse seeds stored in different containers, various locations in Bangladesh, 1982/83.

	Khesari		Chickpea		Lentil	
Container	Moisture (%)	Germination (%)	Moisture (%)	Germination (%)	Moisture (%)	Germination tion(%)
Coal tar-coated *motka*	11.52	57.0	8.02	0.3	9.4	64.7
Polythene-lined *motka*	9.72	84.0	8.42	1.7	9.63	88.0
Kerosene tin	8.47	54.3	11.55	84.3	8.71	65.3
Traditional earthen *motka* (control)	9.89	84.7	10.79	12.4	11.18	70.0

take place when the moisture content of the stored grain is below the ambient moisture content, i.e. equilibrium with a relative humidity of 70%. Seed samples were drawn every 2 months in the pulses survey and 200 seeds from each sample were examined in the laboratory, using the standard blotter method.

A total of 25 fungal species belonging to 21 genera were recorded from different pulses. Fungi like *Alternaria tenuis, Cladosporium* sp, and *Curvularia* sp, were found to be predominant in the initial samples, i.e., the samples which were drawn before storage. These fungi gradually decreased with the storage period. The incidences of *Aspergillus, Penicillium,* and *Rhizopus* was more common in the samples which were drawn after several months of storage. The incidence of storage molds was maximum during 4 months of storage, i.e. during the months of June, July, and August when maximum rainfall occurred and atmospheric humidity remained above 90%.

Storage Problems and New Storage Devices

Storage of chickpea is an acute problem in our country. Seeds lose their viability very quickly in storage. Infestation by molds and insects is a major cause for poor storability. Freshly harvested and dried chickpea seeds with 8% moisture were stored in five types of containers, viz, kerosene tins, earthen *motka,* plastic bags, gunny bags, and bamboo *dole.* Fifteen genera of fungi were recorded from the stored seed. *Alternaria* sp, and *Cladosporium* sp, were recorded as the major fungi in initial samples, while *Aspergillus* sp, *Penicillium* sp, and *Rhizopus* sp, were dominant after the storage period.

Development of Pulse Driers

Solar dryer

A solar dryer was designed and fabricated using locally available materials. The dryer consists of a solar heat collector, a drying bed, and a chimney. The dryer was tested with 40 kg of khesari seeds. The seeds were stirred at hourly intervals during drying. The temperature of the air leaving the collector increased by 11°C to 13°C and the ambient temperature was 31°C to 33°C. Occassional stirring helped expose all seeds uniformly to the heated air. Moisture content of the seeds was reduced from 14% to 9% within 6 h of the operation. Dried seeds had 85% viability (BARI 1983). The unit cost Tk 1000 in 1983.

Mechanical dryer utilizing agricultural waste as heat source

A mechanical dryer with the capacity to dry up to 190 kg of pulses in a single batch consists of a furnace where paddy husk is burnt to heat the incoming air, an ash separator which separates ash carried by the heated air, an axial blower, and an open drying bed. About 190 kg of black gram containing 18% moisture was dried by the fabricated dryer to a moisture content of 9.7% in 5 h. The temperature of the drying air could be controlled at 43°C - 45°C. About 21 kg of paddy husk was burnt to dry 190 kg of black gram. The cost of drying 100 kg[1] of black gram was Tk. 4.50. The percentage of germination of the seeds after drying was found to be 75% to 80%. Each unit of the dryer cost Tk. 9000 (~ US$270) in 1984.

Mechanical dryer with natural gas

This dryer was designed for pulses using natural gas as a heat source. With its three components (a furnace, an axial blower, and a drying bed) the cost of this dryer was only US$ 400.00. It can dry up to 190 kg of black gram seeds in one batch. It takes 3.5 h to reduce the moisture content from 19 to 11 %, and consumes 5.40 m^3 natural gas in this process. The cost of drying 100 kg black gram seeds was Tk 0.53. The germination percentage of the seeds dried in this process ranged from 80 to 85. This dryer can also be used for seeds of other crops like wheat, maize, etc. The air temperature inside the dryer is maintained within the range of 42°C to 48°C (BARI 1985).

Fabrication of Storage Containers

The traditional containers used by the farmers were slightly modified e.g., *motka* with coal tar coating, *motka* with polythene lining, and kerosene tin, and were tested against the traditional *motka.* The fabricated *motka* had a circular bottom with an open mouth used for loading and unloading seeds. The outer surface of the unit was coated with coal tar to make it impervious to moisture. The mouth of the container was developed to make it suitable for holding sealing materials. The lid had a glass window measuring 5cm x 2.5cm for regular checking of insect infestation or any other deterioration that might occur during storage. The lid was made airtight by plastering with mud or cowdung. A similar *motka* was covered by polythene lining inside.

The kerosene tin is a tall rectangular container made of GI sheet with a circular opening at the top for loading and unloading seeds. The lid of the container is made airtight by sealing with cowdung or mud held in a special device, as mentioned earlier. The wall of the unit was painted to prevent rusting. It was provided with a glass window to check damage of pulses during storage. Chickpea, lentil, and khesari seeds were dried well and stored in replicated containers. Seed samples were drawn twice: the first sample before storage and the second after 6 months of storage. The highest incidence of molds was noticed in case of chickpea seeds followed by khesari and lentil. High infestation by pulse beetle on chickpea and khesari seeds in some containers might enhance the growth of molds. Some incidence of unidentified bacteria was also noticed in all the three kinds of seeds. In respect of viability and mold incidence, the fabricated containers, the kerosene tin, *motka* with polythene lining and *motka* with coal tar coating were found to be more promising than traditional earthern *motka.* Khesari seeds showed the highest germination percentage when stored in traditional *motka* (84.7%), followed by the polythene-lined *motka* (84.0%). In chickpea, the highest germination percentage (84.3) was observed in the kerosene tin container. Lentil seeds stored in polythene-lined *motka* showed the highest germination percentage (88).

Areas of Future Research

- To develop an inexpensive and simple thresher.
- To develop inexpensive and simple milling devices.
- Further development, evaluation, and popularization of the fabricated pulse driyers.
- To evaluate the effectiveness of traditional and improved storage containers in controlling insect pests, microbes, and maintaining viability in pulse seeds during storage.
- To test the efficacy of indigenous plant and inert materials to protect stored pulses from insect pests and microbial infestation.
- To develop inexpensive and simple method(s) of detoxification of BOAA.
- To develop simple methods for processing pulses into various food products with higher nutritional status.
- To investigate the quality of pulses stored for seed and nonseed purposes.
- To conduct socioeconomic surveys on the marketing system, methods of milling, quantities of pulses stored by different catagories of farmers, and on consumption pattern of khesari in some selected areas.
- To demonstrate the new technologies at the farm level to encourage their adoption by farmers.

Acknowledgements

This work was carried out by scientists of various research divisions of BARI in the Legumes Postharvest Technology Project. The financial assistance rendered by International Development Research Centre (IDRC), Canada for implementation of the research programs of the project is acknowledged.

Discussion

M.P. Bharati: What was the inside and outside temperature, and the humidity in your storage experiments?

M. Amiruzzaman: It was ambient temperature and humidity for the entire 6-month period. The temperature and humidity inside the storage containers were not recorded because they were left in the farmers' conditions without disturbing anything.

M.O. Hyder: You have mentioned all the postharvest steps up to milling. But in my opinion it should also include handling in marketing at the consumer level.

M. Amiruzzaman: That is correct. Even after milling, handling, packaging, transportation, etc. should be included in postharvest technology. But since our program is primarily farmer-oriented, we have excluded this part for the time being.

M.O. Islam: So far you know that rice bran is bruchid resistant due to the presence of some essential oils in its seed coat. Do you have any plan to use the extract of seed coat of rice bran as repellent?

M. Amiruzzaman: If that extract has the property of repelling bruchid it should be included in our future research program.

M.R. Hoque: 1. Do you feel that biochemical and physiological aspects should be included in postharvest technology?
2. Biochemical changes associated with storage, processing etc. should come into the paper.

M. Amiruzzaman: 1. Biochemical aspects should come under postharvest technology, particularly the nutritional aspects. Physiological aspects viz. seed physiology, germination capacity, etc. are being looked after by the seed technology section of the agronomy division of BARI.
2. Since there was no study regarding biochemical changes in storage, it could not be reported in this paper. Future programs should include this important aspect also.

G.A. Fakir: Isolation and identification of fungi from stored seeds have not been done properly. Storage fungi cannot be isolated or detected by standard blotter methods. Salt-incorporated agar is the standard medium used for isolation of storage fungi as these are osmophilic fungi. Fungi like *Alternaria* sp, *Cladosporium* sp, *Curvularia* sp, and *Rhizopus* sp, have been designated as storage fungi; these are field fungi. They are found in storage as saprophytes and do not cause any harm to the stored seeds. Similarly, *Aspergillus* sp, and *Penicillium* sp, identified as stored fungi, may not be so because only a few of about 100 known species of each of these two genera belong to the storage group. These few species of *Aspergillus* and *Penicillium* are responsible for reducing germination of stored seeds and producing mycotoxins. So without identification at the species level, one cannot designate *Aspergillus* sp, and *Penicillium* sp. as storage fungi. The species of *Aspergillus* and *Penicillium* encountered by the authors may simply be saprophytes carried from the field or the threshing floor. I therefore feel that postharvest technology studies, particularly in relation to storage fungi, should be repeated to get a clear picture of harmful fungi in stored seeds as appropriate techniques have not been employed in isolating and identifying these.

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Session IV:
Seed Production and Consumer Quality

Pulses Seed Production and Distribution Program of the Bangladesh Agricultural Development Corporation

M. Mustafa Hussain

Bangladesh Agricultural Development Corporation, Dhaka, Bangladesh

Abstract

Bangladesh has so far achieved close to 90% self-sufficiency in cereals but the production of noncereal crops like pulses and oilseeds has not kept pace with the population growth and has either remained stagnant or has declined. While due importance has been given to the production of cereals, similar emphasis on pulses is lacking. The per capita consumption of pulses in Bangladesh is only about 5.5 g day^{-1} whereas in India the present per capita consumption is 45 g day^{-1}, which is considered to be low. The Bangladesh Agricultural Development Corporation (BADC) was set up to bring about a major and quick breakthrough in the agricultural development by production, procurement, and supply of agricultural inputs and by promoting modern technology. During the second Five-Year Plan period (198] -85) BADC undertook a scheme to produce foundation and certified seed of pulses and oilseeds. Very little was achieved during this period. At the request of the Government of Bangladesh the Canadian International Development Agency (CIDA) sponsored a feasibility study in J 984/85 for a crop-diversification program and concluded that such a project based on pulses, potatoes, and oilseeds would help increase production of these crops. The BADC proposed to operate the pulses and oilseeds project under this program in the third plan period (1987-92) with specific objectives. It is expected that the project will be implemented soon.

Introduction

Bangladesh has achieved close to 90% self-sufficiency in cereals, predominantly rice and wheat. The production of noncereal crops however, has remained either stagnant or has declined, resulting in a substantial decline in the general nutrition of the country's population. The present consumption of pulses in our country is only about 5.5 g day^{-1} per person as against the FAO/WHO recommended minimum pulse intake of 80 g day^{-1} per capita.

The Bangladesh Agricultural Development Corporation (BADC) was established in 1962 to bring about a major and quick breakthrough in agricultural development by production, procurement, and supply of agricultural inputs like seeds, fertilizer, and irrigation facilities, and promotion of modern technology. Considerable progress was made in the production of cereals like rice and wheat but pulses were neglected till 1980, until the establishment of the pulses and oilseeds scheme in the second Five-Year Plan period.

During the Second Five-Year Plan (1981-85) a scheme titled "Multiplication of pulses and oilseeds in Bangladesh" was undertaken by BADC in 1980 for the first time to produce and distribute foundation and certified seeds of pulses and oilseeds in order to raise the yield levels of these crops. Of the pulses, chickpea (*Cicer arietinum* L.) and mung bean (*Vigna radiata* (L.) Wilczek), and among the oil crops, mustard *(Brassica campestris* L.), rape seed *(Brassica napus* L.), and groundnut *(Arachis hypogaea* L.) were taken up for production by BADC. But very little was achieved under the project.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pukes Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

System of Seed Production

The National Seed Board recognized three classes of seed based on genetic identity and verified purity. BADC produces and distributes only foundation and certified seeds.

Production of Foundation Seed

The pulses and oilseeds project of BADC has three foundation seed farms, a 20-ha farm at Amjhupi, Meherpur, a 12-ha farm at Tebunia, Pabna, and a 3-ha farm at Faridpur for the production of oilseeds and pulses.

The Bangladesh Agricultural Research Institute (BARI), Joydebpur and the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh are responsible for the production, processing, preservation, and supply of breeders' seed of pulses, as well as for maintenance breeding. The concerned plant breeders/ organizations are required to supply the seed-producing agency with an indented quantity of breeders' seed. In principle, foundation seed is required to be produced in the foundation-seed multiplication farm (FSMF) of the pulses and oilseeds project out of breeders' seed. If for some reason breeders' seed is not available from the concerned breeders' organizations, then the best seed available with BADC is utilized for the production of foundation seed.

The target for production of foundation seed is fixed in advance of the actual requirement by the Member Director (Seed), BADC. The Project Director (Pulses and Oilseeds) maintains close liaison and submits indents for breeders' seed to the primary agricultural research institutes/breeders. The Pulses and Oilseeds Division collects breeders' seed and transports it to the foundation-seed farms, in conformity with the national target for seed production. On receipt of the breeders' seed, agronomists at the foundation-seed farms grow the same with special care. The Project Director (Pulses and Oilseeds) arranges to examine the foundation-seed plots with the help of a field inspection committee (FIC) constituted from the headquarters by the Member-Director (Seed), BADC and accepts the seed plots which meet the prescribed standards. The seed agronomist harvests, threshes, dries, and cleans the seed from the accepted seed plots with great care. Seeds are tested for germination, purity, and moisture. The seed lots which meet the procurement standard are preserved in the respective foundation-seed farm's pulses and oilseeds processing centres. Periodic drying and testing are done in the storage centres.

The lots of stored foundation seeds are offered to the seed agronomist, Central Seeds Testing Laboratory, BADC, Dhaka for testing. Seeds of only the accepted seed lots of prescribed standards are packed, labeled, and tagged for distribution as foundation seed.

Production of Certified Seed

The seed produced from the foundation seed is known as certified seed. Certified seed is also produced from the first generation of certified seed/first-class certified seed in case of shortage of foundation seed. Certified seed is meant for distribution to farmers in general.

The production, processing, and preservation of certified seed is controlled by the Pulses and Oilseeds Division under the Member-Director (Seed), BADC. The Divisional Headquarters is in Dhaka and is managed by the Project Director (Pulses and Oilseeds), Deputy Director, and Assistant Directors.

The target for production of certified seed of pulses is fixed by the Member-Director (Seed) one season in advance of the requirement. The following factors are taken into consideration when the target is fixed:

1. past distribution trend of seeds by variety;
2. indent of seed from Regional Manager (Seed) and Department of Agricultural Extension;
3. scheme provision for the distribution of certified seed; and
4. stock of carry-over seed, if any.

The production of certified seed of pulses is made in the Foundation Pulses and Oilseeds Farms, Seed Multiplication Farms, and Jute-Seed Multiplication Farms.

Quality Control System of Seed

Pulses seed has not yet been included in the certificate program of the Seed Certification Agency. However, to ensure supply of quality seed BADC has formed a system of quality control of its own which includes field inspection, testing, and labeling by assigned personnel of the corporation.

Processing, Preservation, and Packing of Seed

The certified-seed plots of pulses are inspected by a

Field Inspection Committee formed by the Member-Director (Seed). The accepted plots are harvested, threshed, cleaned, and dried by the respective officers. On the basis of a lifting program issued by the Member-Director (Seed) and the Seed Agronomist, the Seed Processing Centres lift only the seed which conforms to the specified quality.

The seeds are processed and stored in the Seed Processing Centres. Before sowing begins these seeds are offered to the Central Seed Testing Laboratory of BADC for testing and only the seed from the accepted lots is packed, labeled, and tagged for distribution as certified seed.

Seed Distribution and Sale

According to the distribution program issued from the headquarters, the seed agronomist despatches the seed to the Regional Manager (Seed), BADC. The seed is sold from the seed sale center directly to farmers on a first-come-first-served basis at the rate fixed by the headquarters.

Table 1. Production, procurement, and distribution figures of pulses seeds, Bangladesh, 1980-87.

Production year	Production target (t)	Procurement quantity (t)	Quantity received in the district (t)	Quantity distributed (t)
1980/81	69.04	16.79	Nil	Nil
1981/82	380.37	55.20	Nil	Nil
1982/83	314.80	23.89	23.83	21.79
1983/84	129.20	7.59	33.78	11.30
1984/85	120.00	6.28	3.96	1.54
1985/86	12.00	5.19	35.53	28.15
1986/87	7.50	8.15	6.32	6.16
1987/88	15.00	2.18	6.81	5.81

Availability and Distribution of Pulses Seed

So far a very small quantity of pulses seed has been produced and distributed to farmers. The quantity of seeds made available and seed sold is given in Table 1. Projections up to 1992 are given in Table 2.

Linkage with Research and Extension

As stated earlier the development and release of suitable cultivars as well as supply of breeders' seed to the Seed Production Agency is the responsibility of the research breeder. Motivating farmers to grow new cultivars through demonstration and to disseminate modern agricultural technology is the responsibility of the Extension Department.

Varietal Development and Acceptability by Farmers

A limited number of improved cultivars of pulses have so far been released. In chickpea one cultivar, Hyprosola, was developed by BINA and released in 1982. The cultivar has small seed (100-seed mass 7.6 g) and is not popular among farmers. The other chickpea cultivar Nabin was released by BARI in 1987. This cultivar has been found to be susceptible to collar rot and botrytis gray mold.

In the case of mung bean, the cultivar Mubarik which was released by BARI in 1982 has become susceptible to yellow mosaic virus and its seed production has been stopped by BADC. The other mung bean cultivar Kami which is specially recommended for the late monsoon (kharif-2) season to be grown as

Table 2. Physical Production Program for pulses as per Project Plan, Bangladesh, 1987-92.

Type of Seed	Annual phasing of seed production (t) 1987/88	1988/89	1989/90	1990/91	1991/92	Total
Breeder Seed	0.80	0.90	1.00	1.00	1.00	4.70
Foundation Seed	12.00	14.00	17.00	18.00	18.00	79.00
Certified Seed		300.00	375.00	450.00	525.00	1650.00

a cash crop between the rainy and postrainy season, is yet to be tested and accepted by farmers.

Finally it may be said that the release of some good cultivars is urgently required for all pulses.

Pulses and Oilseeds Project Under Crop Diversification Program

Taking into view the problems faced during the second plan period and the experience gathered, the "Pulses and Oilseed Project under Crop Diversification Program (CDP)" was proposed to operate in the Third Plan period (1987-92) with the objectives mentioned below:

1. To build up foundation seed stock.
2. To multiply foundation seed through contract growers and to produce certified seed.
3. To create facilities for processing and preserving pulses and oilseeds at processing plants.
4. To develop contract growers' zones and transfer modern seed-production technology to the contract growers.
5. To select suitable cultivars through observational trials on short-term basis at Foundation Seed Farms.
6. To supply modern cultivars of pulses and oilseeds to the farmers in order to increase the national production of pulses and oil crops.

The physical program for production of foundation and certified seed as envisaged in the project proforma in the 1987-92 period is given in Table 3.

Implementation of the Project

The plan is to produce foundation-seed in four foundation-seed farms and certified seed in four contract growers' zones. The processing and preservation of seed will take place in four processing centers. All the establishments mentioned are to be managed by the oil and pulses seed project of BADC.

Though this project was supposed to begin in 1987/88, administrative problems have delayed its implementation. But it is expected that from 1989/90, work will start in full swing.

Conclusion

The progress in the production and distribution of the pulses seed is slow. This is due to the release of a limited number of improved cultivars of pulses and lack of knowledge on the part of the farmers about the already released cultivars, as a result of poor extension work. Unless some good high-yielding cultivars of pulses are released and popularized among the farmers by extensive extension work, the situation cannot be improved. To make a real breakthrough in pulses production in the country, the Crop Diversification Program, which takes into consideration the activities of BARI, DAE, BADC, and agricultural marketing as a whole should be implemented very quickly.

Discussion

J. Kumar: How much seed of the chickpea cultivar Nabin, mung bean cultivar Kanti, and black gram cultivar MAK I can be made available by the Bangladesh Agricultural Research Council (BARC) in the next season?

M. M. Hussain: We have the following quantities: Nabin - 16 t, Kanti - 4 t, and MAK 1 - Nil.

Table 3. Present and proposed farms and facilities for the production of pulses and oilseeds foundation seed, Bangladesh, 1988.

Name of establishment	Numbers proposed in project proforma	Present position
Foundation Oil and Pulses Seed Farm	4	3 farms established. Require development of future physical facilities.
Oil and Pulses Processing Centre	4	Only one established and in operation. Further development required.
Oil and Pulses Contract Growers* Zone	4	4 contract growers' zones just established. Personnel are yet to be posted.

A, Sarker: You have mentioned that about 32% seeds of the improved cultivars are still unsold. Is this due to the high price or are other factors responsible?

M. M. Hussain: No, not high prices alone. The selling price is fixed at a reasonable level. Cultivars like Mubarik and Hyprosola are not known to the farmers. In other words the cultivars supplied are not popular at the farmers' level, so the seeds remain unsold.

G. A. Fakir: Foundation and certified seeds of pulses should be tested and certified for quality by the Seed Certification Agency. Considering the importance of seed quality for successful seed production in the country, this program should be started as soon as possible by the Seed Certification Agency. BADC may however test their seeds themselves for their own satisfaction.

M. M. Hussain: I completely agree with Dr G.A. Fakir's proposal. BADC is already testing the seeds. It is expected that as soon as SCA has the required manpower and facilities, they will take seeds of oilseeds and pulses in their certification program.

A. Islam: Would you please state how large a seed-production plan you have for Kanti during the late monsoon season of 1989.

M. M. Hussain: It is expected that about 3 t of Kanti seed will be produced.

Future Extension Strategies on Pulses

A.K.M. Anwarul Kibria
Field Service Division, Department of Agricultural Extension, Dhaka, Bangladesh

Abstract

Pulses have always played an important role in the agriculture of Bangladesh. Their importance is due to the fact that they can provide protein to those who cannot afford to obtain it from animal sources. They are an important component of rice-based cropping systems. In spite of these facts, the area devoted to pulses and the total output have declined in recent years because of competition for land, and lack of high-yielding cultivars, suitable technology packages and support services. Unless the status of pulses is changed from subsistence crops to cash crops substantial increases in production are not possible. A scheme called the Crop Diversification Project (CDP) has been launched to strengthen research, seed production, extension services, and credit and marketing channels to help increase pulses area and productivity. This paper describes the CDP and future extension strategies for pulses in Bangladesh.

Introduction

A large number of pulse crops are grown in Bangladesh, including chickpea (*Cicer arietinum* L.), khesari (*Lathyrus sativus* L.), black gram *(Vigna mungo* (L.) Hepper), lentil *{Lens culinaris* Medic), fieldpea *(Pisum sativum* subsp *arvense)* and mung bean *(Vigna radiata* (L.) Wilczek). Of the total area planted to pulses khesari constitutes 30%, lentil 25%, and chickpea 20%. The area under pulses averaged 300 000 ha in the last 5 years. Yields have also experienced a significant decline from a mean of 735 kg ha^{-1} in the mid 70s to 675 kg ha^{-1} in the past few years. The total production has declined from 220 000 t in the mid 70s to 212 000 t in 1982.

In recent years, the area devoted to these crops accounted for about 2.3% of the total cropped area (Table 1). Almost all the pulses are grown in winter. There is hardly any summer pulse crop to fit into the existing cropping pattern.

Pulses are grown in almost all the districts of Bangladesh. However, some districts are more prominent than others. The most important are:

- Greater Pabna for khesari, black gram, chickpea, lentil, and fieldpea;
- Greater Rajshahi for khesari and mung bean;
- Greater Jessore for chickpea and lentil;
- Greater Faridpur for chickpea, lentil, fieldpea, mung bean, black gram, and khesari; and
- Greater Kushtia for chickpea and lentil.

Despite the wide geographical dispersion, the first four districts account for more than 50% of the production of a given pulse crop. The more important

Table 1. Percentage of cultivated area occupied by major crops in Bangladesh, 1985.

Crop	Percentage (%) of area
Food Grains	83.8
Jute	4.3
Pulses	2.3
Oilseeds	2.3
Tubers	1.3
Others	6.0

Source: BBS (1986).

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

districts are in the western and west-central parts of the country. With the greatest emphasis on winter cereal crops, i.e., wheat and irrigated *boro* (winter) rice, the pulses have been pushed onto marginal land.

Pulses are grown almost entirely in the winter dry season, when they have to compete with a wide range of alternative crops. Increased area under irrigated upland high-yielding varieties (HYVs) of *boro* rice and wheat has been a significant factor in the reduction of the pulse area. Unless the economic relationship between the pulses and other winter crops changes drastically, only summer pulse varieties may hold promise — provided they can show an economic superiority over *aus* (rainfed) rice.

Issues Affecting Prospects for Greater Pulse Production

Competition for land

There is acute competition for land during the winter season, a factor which underlies the marked decline in the area devoted to pulses in recent years. Although there is scope for summer pulses there are no appropriate cultivars.

Lack of high-yielding cultivars

A breakthrough in pulses production is possible if HYVs are evolved. These should be economically competitive with the alternative crops grown during the same period. The ability to match and exceed the economic advantage of HYVs of rice and wheat is crucial for taking up a massive pulse-production program.

Suitable technology package

A suitable technology package is yet to be made available to enable higher production with the traditional winter pulses. The results of whatever research has been undertaken in the area have not been packaged or made ready for transmission by extension. Farmers need such packages.

Provision of support services

Expansion of pulses will require the development of adequate seed supply, and sufficient credit for inputs on easy terms. The availability of a low-cost, small irrigation device is an important feature that will contribute to the improvement of unit production.

Subsistence cultivation

Pulses are largely viewed as subsistence crops by most farmers. Changing the status of these crops from subsistence crops to cash crops is one of the major challenges facing the extension workers and planners who aim at substantial increases in pulses production.

Consumption

Consumption of pulses, on a per capita basis, has declined markedly in the last few years. The per capita daily intake has fallen from 11 g in the early 60s to 8 g in the mid 70s to about 6 g now. There is a strong consensus that pulses no longer play a substantive role in the diet of many Bangladeshis and consumption is now restricted mainly to farmers growing these crops and to urban residents.

Extension Strategies on Pulses

The fact that declining pulses production has seriously threatened the protein intake and health of the Bangladesh people has been considered and a scheme called the Crop Diversification Project (CDP) has been launched, primarily for areas known to be prominent in pulses cultivation. This involves the promotion of pulses cultivation through intensive training supports and demonstrations (Table 2). The project is designed to address the following issues:

- Low and uncertain returns from cultivation of traditional pulse varieties;
- Subsistence nature of pulses cultivation;
- Competition for land from other crops;
- Toxic effects of khesari
- The declining role of pulses in the diet, and its implication for nutrition;
- Lack of HYVs for winter pulses and non-availability of summer pulses; and
- Lack of institutional credit for pulses.

The analysis of the issues and their implications for increasing production has resulted in the identification of three primary themes for the pulses project.

Table 2. CDP supports to disseminate pulses-production technology in Bangladesh up to 1992.

Activity	No. of units
Organizing field demonstration plots	1 900 (spread over 5 years)
Training of	
a) Extension agents/supervisors on production technologies.	11 925 (spread over 5 years)
b) Contract farmers.	85 000 (spread over 5 years)
Organizing field days to disseminate the production technologies.	1 890
Providing audiovisual equipment.	362 (different types)

1. increasing the area planted to pulses, (Table 3),
2. increasing productivity, and
3. increasing consumption and markets.

These themes are not independent but they represent clearly identifiable elements that can be monitored and evaluated to reflect the success of the project.

Addressing the isssues affecting increased production provides the opportunity for project initiatives in a number of areas. The major emphases are on:

- irrigating suitable fallow land,
- ensuring supply of inputs to farmers,
- research,
- seed production,
- extension service, and
- increasing consumption and market.

Table 3. Crop area and fallow land in different months of the year in Bangladesh, 1984.

Month	Crop hectareage ('000 ha)	Fallow land ('000 ha)
January	2.915	6.235
February	2.902	6.248
March	3.757	5.393
April	5.231	3.919
May	6.154	2.996
June	6.207	2.943
July	6.316	2.834
August	6.377	2.773
September	6.437	2.713
October	6.988	2.162
November	7.097	2.053
December	4.551	4.599
Total	64.811	44.867

Source: BBS (1986).

The CDP for pulses aims at strengthening the linkage among the Bangladesh Agricultural Research Institute (BARI), Bangladesh Agricultural Development Corporation (BADC), and the Department of Agricultural Extension (DAE). The element would involve an augmented and enriched extension program, directed towards client farmers in the selected areas. The national Travel and Visit (T&V) system of extension service will operate on this program. There are a number of activities involved in the program implementation. Basic among these are: (i) establishing a strong linkage between CDP research and extension, (ii) organising seminars, (iii) development of audio-visual aids, newsletters, and extension manuals, (iv) development of extension workers on pulse-production technologies, (v) provision of operational supports to extension, (vi) developing and transmitting radio programs, (vii) establishing demonstration plots in the target areas, and (viii) familiarizing target farmers with the latest production technology developed through research.

Irrigation Support

Early or late sowing of pulses as is generally done with uncertain moisture availability, may result in farmers deciding not to cultivate these crops, but a small amount of irrigation will ensure that pulses are sown on time. Therefore, the pulses CDP aims to provide hand tube wells (HTWs) to target farmers in order to increase higher input practices in pulses cultivation.

Production

The pulses CDP projects an additional production of 132 000 t by 1995. The current production of pulses allows for a per capita daily consumption of pulses of about 6 g. This is only a fraction of the requirement, in contrast to 45 g in India. A projection of the production requirement based on the estimated per capita daily consumption is shown in Table 4 (in the year 2000, based on a population of 141 million).

The production target of 400 000 t of pulses will allow only a marginal increase in per capita daily consumption of pulses in Bangladesh to perhaps 7 g a day, by the end of the century.

Table 4. Production targets in terms of per capita consumption[1].

Production in 1981 ('000 t)	Pulses ('000 t) required in 2000 to achieve per capita daily consumption of				
	6 g	9 g	12g	15g	18g
216	350	525	700	875	1050

1. Population of 141 million.

Table 5. Pulses development in crop diversification project of Bangladesh, 1987.

	Verifiable indicators	Assumption
Project goal		
To improve the nutritional condition.	To increase protein quantity, calories, fat, and carbohydrates for consumption.	Domestic production is a desirable means of achieving the goal.
Project Purpose		
To increase pulses production and consumption.	Production of pulses will increase by 130 000 (57% higher than the 1985 base).	Production will be consumed within the country.
Outputs		
i) Increased pulses area under production from seasonally fallow land.	i) 106 000 ha (32% increase) by 1995.	i) Attractive price incentive
ii) Increased national pulses mean yields.	ii) 19% increase by 1995.	ii) Inclusion of Pulses in the GOB food procurement program.
iii) Increased pulses consumption and markets.	iii) Annual per capita consumption of pulses increased from 2.0 kg capita^{1} to 2.5 kg capita^{-1} by 1995.	iii) Improved varieties will be developed.

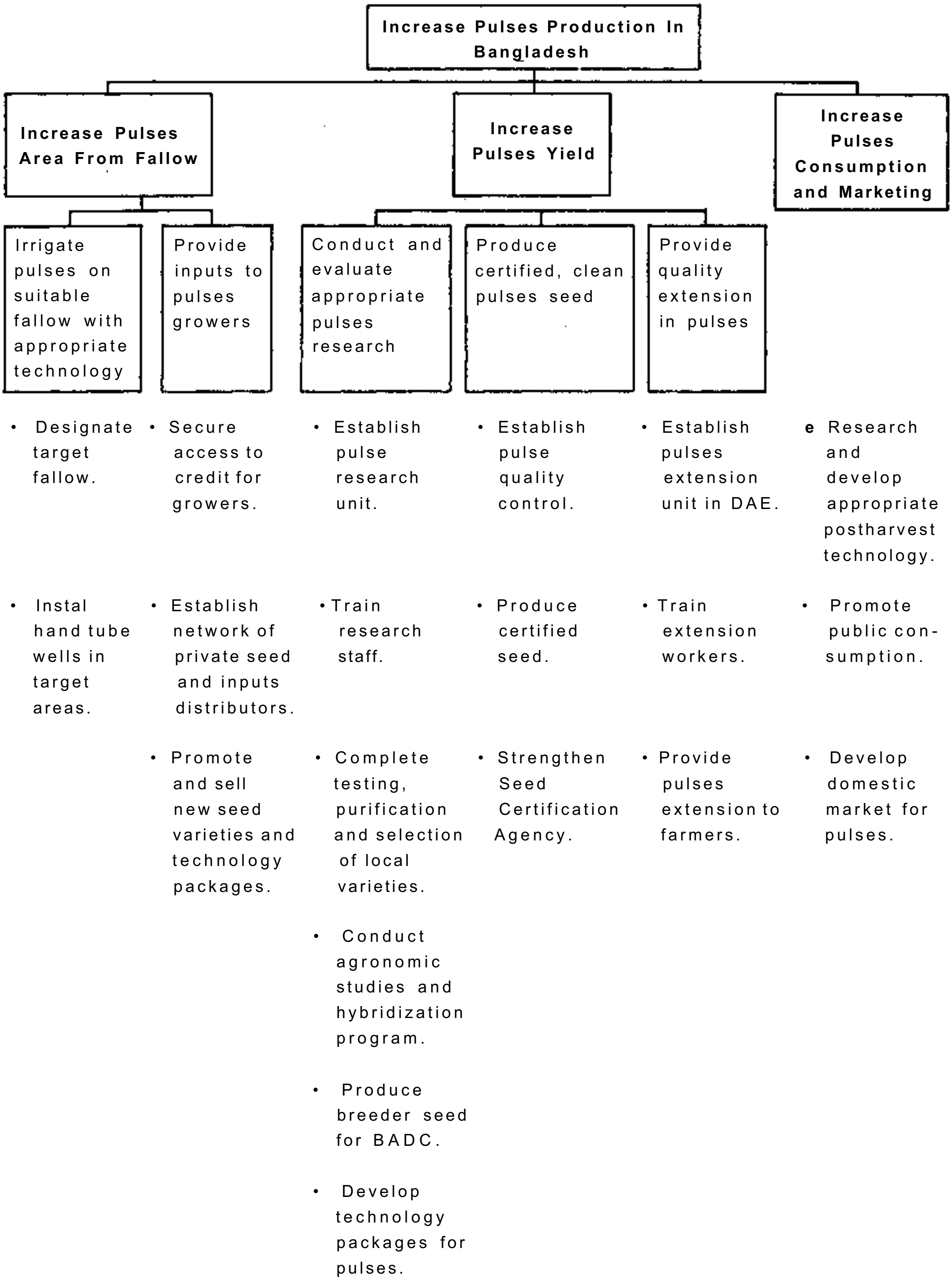

Figure 1. Pulses development work breakdown structure.

Reorganization of the DAE has resulted in the expansion of its focus to include all crops. In the case of pulses, special attention has been given to develop extension messages appropriate for the crop under the CDP. A model for the Project Framework is shown in Table 5. The work breakdown of the project has been done in Figure 1. The existing organizational set-up of DAE with specialist support at the national level has been entrusted with the execution of the project.

Discussion

M.M. Rahman: I understand that DAE conducted a farmers' field demonstration of the chickpea cultivar Nabin. Could you kindly provide us with some results of these trials with your comments?

A.K.M.A. Kibria: It is very encouraging. The mean yield ha^{-1} is about three times more than the national mean.

M.A. Khaleque: In Table 3 it has been mentioned that 5 to 15% fallow land is available during November - April. Have you any statistics about how much of the fallow land is suitable for pulses production?

A.K.M.A. Kibria: No. But we believe that there will be no problem for such land availability if irrigation is provided.

G.A. Fakir: Can we not accommodate pulses in the fallow land during December - March with irrigation without affecting *horo* rice?

A.K.M.A. Kibria: Without HYVs of pulses there is no room for such a proposition.

D.G. Faris: The connection of extensions in CDP looks very exciting. However, there is one area that does not come out clearly and that is interaction between research-extension-farmer in developing an appropriate package that will be accepted or adopted by farmers. There needs to be an immediate start using existing varieties and technology with researchers and adopting them to farmers' needs. Can you please comment on such an immediate start-up of extension?

A.K. M.A. Kibria: T & V is our national extension system with few modifications from Dr Benor's model. There are very strong links between District Technical Committee (DTC), Regional Technical Committee (RTC) and National Technical Coordination Committee (NTCC), and extension.

A. Razzaque: At present we do not have good varieties of pulses and no package of production technology. But through implementation of CDP, you are going to increase the per capita consumption of pulses from 6 g to 18 g. How can this be achieved?

A.K.M.A. Kibria: The CDP projects an increase in production to the extent of 18 g by 1995. This is very ambitious. The production availability is just to maintain the present level at the end of the project.

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Socioeconomic Constraints Limiting Pulses Production

S.M. Elias

Banagladesh Agricultural Research Institute, Joydebpur, Bangladesh

Abstract

The constant decline in the per capita availability of pulses has been a concern of policy makers, researchers, and consumers. Presently pulses are produced at the subsistence level with the bare minimum of modern inputs. Low yields, lack of good-quality seeds, and incidence of pests and diseases are major constraints to increased pulses production. Pulses grain moves from growers in the primary market, to the beparis *(traders) and* aratdars *(wholesalers) in the secondary market, to processors such as millers, to retailers, and finally to the consumers. The incidence of pests and rodents are the main problems of storage for both growers and traders. Low output price for the growers and traders' monopolies are the biggest handicaps. The problems range from high transport cost and lack of capital for the petty traders, to storage and unstable prices for the wholesalers, and an uncertain supply of electricity for the millers. To increase pulses production in the country, technological research in the field of breeding, agronomy, and pest management as well as socioeconomic research to assess the future demand and policy directions are necessary. Research into the appropriate cropping patterns that incorporate pulses will help to consolidate the position of these crops in the farming systems. Measures to control postharvest losses are essential. Improvement in the storage methods and maintenance of seed viability will improve the supply position. A national price policy will act as an incentive to the farmers to grow more pulses.*

Introduction

Pulses are a major and cheap source of protein in the daily diet of the people of Bangladesh (BARI 1980). They play a vital role in providing fodder for farm animals, either directly for grazing or as fodder after the grain has been threshed. After dehusking, bran is also used as a quality feed for animals. Pulses fit well into the existing cropping systems, due to their short duration, low input requirements, and drought-tolerant nature. As regular field crops, pulses cover more than 5% of the total cropped area.

However, in spite of their importance to semisubsistence of the farmers, the area and production of pulses is gradually declining (Table 1). Their stagnant nature of production coupled with the ever-growing population resulted in lower per capita consumption. Now it is less than 10 g capita^{-1} day^{-1}.

Table 1. Rate of change of pulses production and yield in Bangladesh, 1947-1983.

	1947/48-1982/83	1947/48-1970/71	1971/72-1982/83
Area	-0.72	-0.74	-0.21
Production	-0.60	-0.09	-1.55
Yield	+0.11	+0.67	-1.40

Information received from the Bangladesh Bureau of Statistics (BBS 1987) shows that since liberation the area under different major pulses has increased compared to 1973/74. During the period 1976/77 to 1979/80, all major pulses showed increasing trends of area and production. But later a declining trend set in, which continued up to 1982/83 (Table 2). However, in 1983/

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 2. Area and production of major poises in Bangladesh, 1973-88.

	Area('000 ha)[1]					Production('000 t)[2]				
	Khesari	Lentil	Chickpea	Black gram	Mung bean	Khesari	Lentil	Chickpea	Black gram	Mung bean
1973/74	74	60	56	47	10	57	42	40	37	7
1974/75	79	70	56	53	14	61	47	39	42	8
1975/76	82	66	54	53	14	62	44	38	41	9
1976/77	99	75	56	52	16	70	48	40	97	10
1977/78	99	79	57	52	17	70	51	44	38	10
1978/79	99	85	56	51	17	68	50	42	35	9
1979/80	93	85	58	47	17	64	49	39	33	9
1980/81	92	84	58	47	15	63	49	37	33	7
1981/82	91	75	53	43	15	63	48	36	29	8
1982/83	93	73	54	40	15	70	44	40	28	8
1983/84	242	240	113	84	60	170	161	87	59	34
1984/85	245	234	109	75	60	183	164	81	53	35
1985/86	232	225	104	69	59	167	160	78	44	33
1986/87	222	213	104	65	57	164	149	82	42	35
1987/88	232	216	104	70	58	182	159	75	51	33

1. Total pulse area in 1987/88: 734,102 ha. This covers 9% of the net cultivated area.
2. Total pulse production in 1987/88 : 538 784 t

Sources: BBS (1987), Bazlur Rahman (1990).

84, there was a house-to-house agricultural census, which revealed that earlier estimations on area of pulses were not correct, rather the area had increased by more than 300% compared to 1973/74. In 1983/84, BBS revised the estimates of pulses area and production based on census data. Area and production of major pulses in Bangladesh is shown in Table 2 from 1973 to 74 along with the revised estimation from 1983/84 to 1987/88 (Balur Rahman 1990). But again since 1983/84 the estimates of BBS show that the area under major pulses is gradually declining. Taking the 1984 figure to be 100, the area and production of all major pulses have decreased except in khesari *(Lathyrus sativus* L.) where the production has increased in 1987/88 mainly due to increased yield. The ratio of price of pulses to that of rice also increased from 1.00 in 1973/74 to 1.43 in 1982/83 (Elias 1988).

The Problem

The constant decline in the per capita availability of pulses has been a concern to policy makers, researchers, and consumers. To avoid protein deficiency, it is necessary to augment the per capita availability of pulses. For a massive drive toward the improvement of pulses, it is necessary to correctly identify the constraints to increased pulses production and to indicate policy directions for the future.

Design of the Paper

The present paper is based on a study made by the author in 1985/86 on the constraints to production of pulses (Elias 1988). Five major pulses viz., khesari, lentil *(Lens culinaris* Medic), chickpea *(Cicerarietinum* L.), black gram *(Vigna mungo* (L.) Hepper). and mung bean *(Vigna radiata* (L.) Wilczek), were included in the study. Altogether 508 pulse-growing farmers were surveyed in 10 different locations in 6 districts. The findings presented here highlight the socioeconomic constraints to pulses production, including marketing and storage problems.

Economics of Crop Production

Khesari

When all variable costs were included the mean cost of production of khesari was found to be Taka (Tk) 1564 ha^{-1}. The major cost items were: human labor (63%) and seeds (20%). However, only 33% of the total costs involved cash outlay (Table 3).

The mean seed yield was 794 kg ha^{-1} with a gross margin of Tk 787 ha^{-1}. The cost-benefit ratio on total variable cost basis was 1.5 while it was 4.57 when only cash costs were considered. This crop showed a high return on family labor which was Tk 48 day^{-1} which can be compared with the prevailing wage rate of Tk 20 (Table 3).

Lentil

When all variable costs of production were included, the mean cost of production of lentil was Tk 2911 ha^{-1}. The major cost item was human labor which constituted 49% of the cost followed by cost of draft power constituting 30% of the total cost. However, the cash cost was only 26% of the total cost.

The mean seed yield of lentil was 707 kg ha^{-1} with a gross margin of Tk 2073 ha^{-1}. The cost-benefit ratio on total variable cost basis was 1.71 while it was 6.47 on a cash cost basis. Although yield was higher and cost was lower in khesari, the profitability was higher in lentil due to its higher price (Table 3). This crop showed Tk 62 day^{-1} on family labor.

Chickpea

The mean variable cost of production of chickpea cultivation was Tk 2580 ha^{-1}. The major cost item was human labor, constituting 52% of the total cost (Table 3). Cash variable cost was only 27% of the total cost.

On an average, farmers received yield of 896 kg ha^{-1} with a gross margin of Tk 3058 ha^{-1}. The cost-benefit ratio was 2.18. But the cash-cost ratio went up to 8.15 when considered separately. The main reason for this high profitability is its higher price and higher yield (Table 3).

Black Gram

In black gram cultivation, the total variable cost of production was found to be Tk 1761 ha^{-1}. Human labor was the single major cost item. However, only 28% of the total cost was spent in cash. The rest were family inputs.

The mean seed yield of black gram was 693 kg ha^{-1} with a gross margin of Tk 2981 ha^{-1}. The cost-benefit ratio on full cost was 2.6. But it went up to 9.76 when only cash outlay was considered. This is mainly because of minimum cash involved in the cultivation (Table 3). Of all the pulse crops, this showed the highest returns (Tk 109 day^{-1}) on family labor.

Mung Bean

In mung bean cultivation, the total variable cost of

Table 3. Mean cost and return analysis of pulses, Bangladesh, 1985.

Parameter	Khesari	Lentil	Chickpea	Black gram	Mung bean
Cost of production (Tk ha^{-1})	1564	2911	2580	1761	2471
Cash outlay (%)	33	26	27	28	43
Yield (kg ha^{-1})	794	707	896	693	698
Price (Tk kg^{-1})	2.57	6.46	5.96	5.58	7.44
Gross margin (Tk ha^{-1})	787	2073	3058	2981	2911
Cost-benefit ratio					
Full cost	1.51	1.71	2.18	2.61	2.18
Cash cost	4.57	6.47	8.15	9.76	5.06
Returns to family labor	48	62	82	109	99

production was Tk 2471 ha^{-1}. Human labor constituted 57% and draft power comprised 22% of the total cost. Cash cost was 43% of the total variable cost.

The mean seed yield of mung bean was 698 kg ha^{-1} with a gross margin of Tk 2911 ha^{-1}. Cost-benefit ratio when considered on the basis of all variable cost was 2.18 and when only cash cost was considered it was 5.06 (Table 3). This crop showed second highest returns of Tk 99 day^{-1} on family labor.

Disposal Pattern

Disposal of pulses varied from crop to crop depending upon the price of output and need of the farmers. While in khesari 56% of the total produce was consumed and kept as seed, in lentil and black gram 65% of the produce was sold in the market. It was observed that 55% of the farmers cultivating khesari, 21% of the lentil, 30% of the chickpea, 32% of the black gram, and 45% of the mung bean did not sell their produce. Those who sold, did so only partly selling the produce ranging from 44% to 65% of their production (Table 4).

Marketing Channel

Like many other crops, pulses also pass through many intermediaries to reach consumers. The major channel through which whole pulses move goes from growers to *beparis* (traders) to *aratdars* (wholesalers) to millers. At this point the pulses are dehusked. The dehusked pulses pass to *aratdars* to retailers to consumers. *Aratdars* perform an important function in moving whole pulses from the growers and *beparis* to the millers and dehusked pulses from the millers to the retailers and *beparis.* They do not deal directly with the consumers (Fig. 1).

Table 4. Disposal of pulses (%), 1985.

Pattern	Khesari	Lentil	Chickpea	Black gram	Mung bean
Sold	44	65	48	65	51
Consumed + kept for seed	56	35	52	35	49
Not sold (% of farmer)	55	21	38	32	45

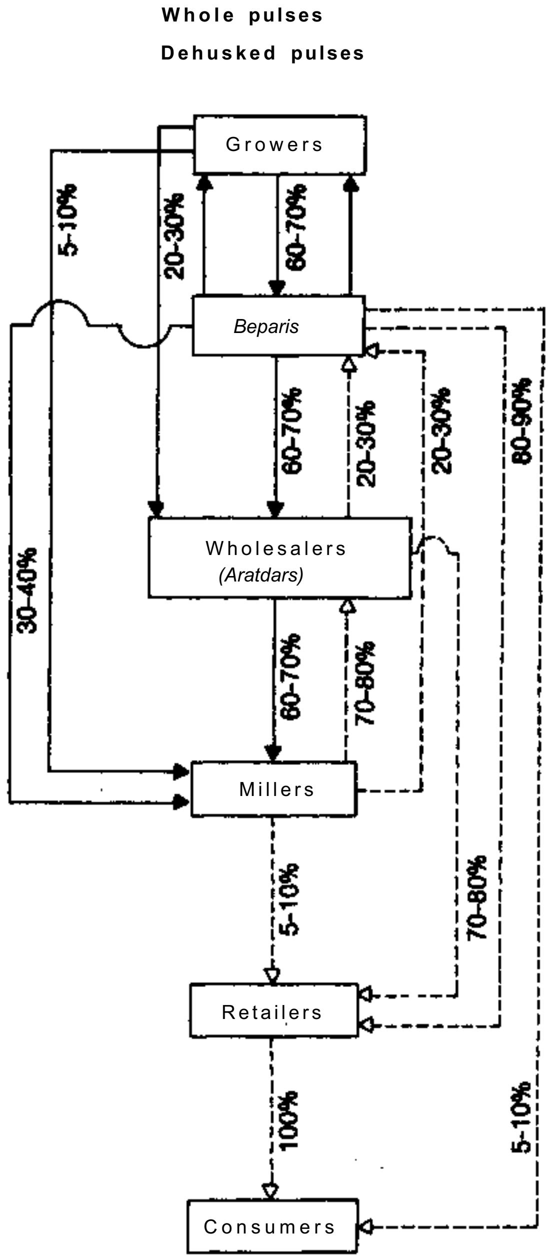

Figure 1. Pulses marketing channels in Bangladesh.

Storage

Pulse grains are stored both at growers* and traders' levels. About 85% of the growers stored pulses in their living room. *Beparis* do not usually store pulses. They try to sell the grain immediately after purchase either in

Table 5. Type of containers used for pulses, 1985.

Container	% of Response				
	Grower	*Bepari*	*Aratdar*	Miller	Retailer
Gunny bag	26	95	70	85	85
Earthen pot	58	-	-	-	-
Tin	19	-	-	-	-
Oil drum		-	20	-	10
Bamboo basket	4	-	10	10	5
Others	1	5	-	-	-

Table 6. Mean marketing cost for growers and aratdars, 1985.

Category	Cost ($Tk\ kg^{-1}$)
Growers	0.09
Beparis	0.20
Aratdars	0.26
Millers	0.43
Retailers	0.12
Total	1.10

the same or a different market. However, all the *aratdars* store pulses for periods ranging from 15 days to 3 months. Retailers do not store pulses for a long period (Sikder and Elias 1988).

Earthen pots are the common containers used for storage of pulses by majority of the growers. Most of the traders used gunny bags to store pulses (Table 5).

Processing

All growers dehusk pulse grains by means of an indigenous manually operated appliance called the *Jata.* The time required to dehusk 1 kg of whole pulse varies from 20 to 40 mins depending on the kind of pulse and amount of energy spent. Consumers with small quantity of whole pulses are not able to use pulse-husking mills and growers have no alternative than to using the *Jata* for their own produce (Sikder and Elias 1985).

For commercial use, the dehusking of pulses is done by electric or diesel-operated machines. These mills are located only in secondary or terminal markets. Normally a mill with a 30 horsepower motor can dehusk 200 to 250 kg of whole pulses $hour^{1}$.

Price Spread

After harvesting the crop, growers have to sell it in the market for which costs are involved. It was found that costs at the growers' level were in the form of transport, loading, unloading and market tolls. On the average Tk 0.09 kg^{-1} was found to be the marketing cost at the growers' level. However, at traders' level (combined for all) the mean cost of marketing was found to be Tk 1.01 kg^{-1} (Table 6).

Now, if cost of production and marketing is deducted from the price paid by the consumers, the absolute profit to growers and traders comes to Tk 7.17 kg^{-1}. This profit is about 64% of the consumers' price. Again out of the total profit, growers received only 26% and the rest goes to the traders' pocket (Table 7).

Constraints to Production and Marketing

For the production of pulses it was observed that incidence of pest and diseases, lack of good-quality seeds, poor yield in general, and low output price, excess rainfall after flowering specific to khesari and black gram, acted as major barriers (Hussain and Ahsan 1985). Pests, diseases and rodents were found to be the major storage problems at growers' level. However, growers reported some other major marketing problems like monopoly of traders, low price, defective weighing system, lack of market facilities and high market tolls. Traders reported some major marketing and storage problems which include nonstable price specific to *beparis* and *aratdars,* lack of capital specific to *beparis, aratdars* and millers, and pest and disease infestation specific to *aratdars,* millers and retailers.

Table 7. Price spread of pulses in 1985.

Cost of production ($Tk\ kg^{-1}$)	3.00
Marketing cost at growers' level ($Tk\ kg^{-1}$)	0.09
Marketing cost at traders' level ($Tk\ kg^{-1}$)	1.01
Total investment ($Tk\ kg^{-1}$)	4.10
Price received by growers ($Tk\ kg^{-1}$)	5.75
Price paid by consumer ($Tk\ kg^{-1}$)	11.27
Absolute profit ($Tk\ kg^{-1}$)	7.17
Profit share of growers	26%
Profit share of traders	74%

Lack of market information, high transport cost, and uncertain electric supply was a major problem but specific to millers only.

Conclusions

With uncertain weather and in a risky socioeconomic environment, farmers preferred to use traditional farm practices requiring minimum cash input. The present pulses production is solely dependent on traditional seeds, soil, and type as well as time of sowing. Under the existing traditional technology farmers try to maximize yield by careful selection of seeds, seed germination tests, and treatment of seeds by local methods.

On an average, pulses were found profitable when returns on investment were considered. This is mainly because minimum investment is made on production. The average return was highest for chickpea and lowest for khesari. However, as the farming is of a subsistence nature, and the major part of the produce was consumed, profitability seemed to have little influence on production decision, rather, production with minimum input and cash cost seemed to be the aim.

Because of the small number of processing mills in Bangladesh, there is evidently a certain traders' monopoly in the pulses marketing process. More processing mills in the intensive pulse-growing areas would help to increase employment, reduce marketing costs and break the traders' monopoly.

To reduce marketing costs and simplify the marketing channel a contract growing system is advocated. Under this system, growers are assured of price and market of their products much ahead of sowing time. Policy makers would be of service here.

Future Strategy

To develop improved technology for pulses, research should receive highest priority. Multidisciplinary research is needed to develop and test technology in the field. Apart from breeding, agronomic, disease and pest management, farming systems and socioeconomic researches are necessary.

A definite price policy for pulses is essential. Procurement price should be forecast before crops are sown, and the grain should be procured after harvesting. For this, a price commission should be formed. To reduce the market margin and profit of middlemen, it is suggested that contract system of marketing should be practised in which growers and processors will have direct contact In this system, growers will be assured of their output price. At present there is no credit available for pulses cultivation. When improved technology of pulses is evolved, farm credit will have to be ensured.

In the fanning systems approach, socioeconomic research has to play a dominant role in considering the effect of pulses production on the nutritional status of farm family, supply of feed to livestock and improvement of the conditions of the soil.

Research on production economics as well as on the processing, distribution, and marketing systems would help the policy makers and researchers to take appropriate steps. Demand analysis, marketing research, and profitability analysis will help the policy makers to make macroeconomic decisions on pulses production.

At present extension services are absent for pulses cultivation. Regular training to the extension workers on recommended technology and extension methods will help to effectively disseminate the technology package to farmers.

Discussion

A. Sarker: In Table 3, you have mentioned the cost of production of pulses at Tk 3.0. Why have you generalized this cost of production for khesari, mung bean and chickpea?

S.M. Elias: In Table 3, I have shown the cost of production for the five different pulses separately. However, in Table 7, for an idea of the cost of production and marketing of pulses, I have shown the average of those five pulses.

M. M. Rahman: Do you think the high price of khesari (above rice and wheat) would help reduce risk of lathyrism?

S.M. Elias: To control lathyrism, it is not necessary to increase the price of khesari. Rather, with improvement in the cooking process, it can be controlled. Controlling lathyrism through increased price is an indirect method which will have many other effects.

M.A.Islam: Who is to be trained ?

1. Subject Matter Specialist (SMS)/Deputy Director of Agriculture (DDA)/ Assistant Director of Agriculture (ADA)

2. Subject Matter Officer (SMO)/Upzila Agricultural Officer (UAO)
3. Block Supervisor (BS)/Farmers.

S.M. Elias: I have mentioned in my paper that at present extension services give very little attention to pulse crops. So to expand pulses with improved technology or even to transfer existing innovative fanning practices among other farmers, we need extension support. So any thrust on pulse production will require proper training to the farmers and extension workers. In this regard, all the workers mentioned above need to be trained. Of course, the nature and magnitude of training will differ for different categories.

M. O. Islam: According to a statement from BBS (1987), about 10 000 ha. of pulses were grown under irrigated conditions during 1985/86. Please give us your opinion, do our farmers irrigate pulse crops or not?

S.M. Elias: In our survey data we did not find any farmer irrigating pulse plots. I have already mentioned in my paper that after the agricultural census of 1983 and 1984, the Bureau of Statistics had to revise their earlier data.

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Status of Pulses Marketing in Bangladesh

A.K.M, Bazlur Rahman

Department of Agricultural Marketing, Khamarbari, Dhaka, Bangladesh

Abstract

Bangladesh is deficient in pulses, which it imports to supplement local supplies. The domestic production is distributed through the age-old marketing chain: growers-assembly-traders-wholesalers-millers-retailers-consumers. Private parties import pulses from different countries and market them through wholesalers, millers, and retailers to consumers. The Trading Corporation of Bangladesh (TCB) imports pulses, and markets them through selected shops. In recent years, small farmers from producing areas have started trading as mobile retailers, selling directly to consumers in the metropolitan cities. They sell at comparatively lower prices than other retail shops. The present daily consumption of pulses in Bangladesh is only 12.5[1] g capita^{-1}, against the recommended rate of 80 g capita^{-1} day^{-1}. The demand for pulses as per recommended rates is 3.63 million t in 1990 and 4.40 million t in 1995 for the projected population. The present production (1987/88) is only 0566 million t. In 1987/88, 34 553 t of pulses/dhals were imported from different countries and the cost was Tk 360.3 million. Imports are likely to increase in future. During 1982-1987 the prices of pulses and vegetables increased faster than those of other agricultural products. It is understood that the country will continue to import pulses to supplement domestic supplies and to keep the prices under control.

Introduction

Pulses are second only to cereals as a source of calories as well as protein in the diet of the people of Bangladesh. Being the cheapest source of protein, they are considered to be the "poor man's meat". They not only have twice as much protein content as cereals, but also contain more on weight basis than eggs, fish, and flesh foods. They also play an important role in providing valuable fooder and feed to cattle and poultry. The per capita daily consumption of pulses is only 12.5 g in Bangladesh (BBS 1989) while in neighboring India it is 45 g. The production of food has been given the highest priority in the previous plan periods, in order to attain self-sufficiency in the country. As a result cereals production has increased significantly over the years, while pulses production has not increased. Land has been diverted from pulses to wheat, *boro* (winter) rice, tobacco, sugarcane, and cotton. As such production of

Present Production

The area and production of pulses during 1983/84 to 1987/88 are shown in Table 1. It appears that the area and production of pulses have remained stagnant over the years. A good number of pulses are grown in

1. Revised statistics (BBS 1989).

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Bangladesh, the major ones being: khesari (*Lathyrus sativus* L.), lentil (*Lens culinaris* Medic), mung bean (*Vigna radiata* (*L.*) Wilczek),chickpea(Cicer arietinum L.), fieldpea (*Pisum sativum* subsp *arvense*), and pigeonpea (*Cajanus cajan* (L.) Millsp.). These account for about 90-92% of all pulse crops. Their shares in total production are 32%, 30%, 6%, 15%, 3%, and 1% respectively (Table 1). The production of pulses is concentrated in a few districts, viz., Faridpur, Pabna, Jessore, Kushtia, Rajshahi, Dhaka, Tangail, Barisal, and Noakhali. The crops are grown mainly during the dry winter months (postrainy season). Wheat and *boro* (winter) rice do not leave much scope for pulses particularly where irrigation is available. Cotton, tobacco, and sugarcane are also favored by growers due to their relatively high economic returns. The average national yields of pulses are also quite low.

The per capita consumption of pulses in Bangladesh by rural and urban people are shown in Table 2 (BBS 1986). The recommended per capita rate of pulses is 80 g day^{-1} (Ahmed 1989). The total requirements as per recommendation are 3.63 million t in 1990 and 4.40 million t in 1995.

The 1987/88 production was only 0.539 million t. Quantities of pulses imported from various countries between 1985/86 and 1988/89 and their values for the last 4 years are shown in Table 3 (Collector of Customs, Chittagong and Khulna Ports, 1989).

In 1987/88 the import of pulses exceeded the previous import record. There were floods during the 1987 monsoons which damaged vegetable crops. Therefore, the prices of vegetables increased sharply, which resulted in excess demand for pulses. To check the rising prices, the import of pulses was increased and stood at 34 5331. The country faced an unprecedented flood in the monsoon of 1988, a severe cyclone in November,

Table 1. Area ('000 ha), production (' 000 t), and productivity (kg ha^{-1}) of pulses in Bangladesh, 1983/84 to 1987/88.

Crop		Year 1983/84	1984/85	1985/86	1986/87	1987/88	5 -year mean	% of total
Lentil	A[1]	240	234	225	213	216	225	30
	P	161	164	160	149	159	159	30
	Y	671	704	717	699	736	707	-
Chickpea	A	113	109	104	104	104	107	14
	P	87	81	78	82	75	81	15
	Y	770	743	750	788	721	757	-
Khesari	A	242	245	232	222	232	235	31
	P	170	183	167	164	182	173	32
	Y	702	747	720	739	784	736	-
Mung bean	A	60	60	59	57	58	59	8
	P	34	35	33	35	33	34	6
	Y	567	583	559	614	567	576	-
Pigeonpea	A	7	7	6	6	6	6	1
	P	6	5	4	4	4	5	1
	Y	857	714	667	667	667	833	-
Total[2] pulses	A	802	785	743	717	740	757	100
	P	552	598	520	506	539	535	100
	Y	688	711	699	706	728	707	-

1. A = area, P = production, and Y = yield.
2. Includes other pulses.
Source: BBS (1989).

Table 2. The per capita consumption[1] of pulses by the rural and urban population in Bangladesh, 1973/74 to 1985/86.

Year	Rural (g day-1)	Urban (g day-1)
1973/74[2]	20.1	18.9
1976777	13.1	18.7
1981/82	12.0	18.6
1983/84	25.9	21.6
1985/86	18.1	20.4

1. The per capita availability of pulses for 1987/88 is 12.5 g day[1].
2. 539 000 t (National Production) - 8 850 t (15% less for seed and storage loss) + 34 553 t (import) and 105.28 million (population for 1988).

Source: BBS (1988).

1988, and again an unprecedented drought that lasted the spring and summer of 1989. These affected all winter and summer crops including vegetables during the current year (1988/89). The prices of pulses which began to increase in July 1986 are still continuing to rise as shown in Table 4 (Department of Agricultural Marketing 1989). The prices were considerably higher in the current harvest season compared to any other previous year (February-April 1989).

Future Import Policy

In 1988/89 the import of pulses exceeded that of 1987/88 (Table 3). Private parties have imported 8000 t and the Trading Corporation of Bangladesh (TCB) arranged

Table 3. Import of pulses from various countries, 1985/86 to 1988/89.

	1985/86		1986/87		1987/88		1988/89		
Pulse	Quantity (t)	Value (M.Tk)	Quantity (t)	Value (M.Tk)	Quantity (t)	Value (M.Tk)	Quantity (t)	Value (M.Tk)	Imported from
Lentil (*dhal*)	0	0	209	2.9	18 456	205.0	1916	109.5	Thailand China Turkey
Mung bean	660	7.2	2 663	23.1	0	0	1 132	15.7	Vietnam Singapore ChinaAustralia
Chickpea	0	0	0	0	15 806	159.1	33 897	318.2	Myanmar Turkey Australia Thailand
Chickpea (*dhal*)	0	0	564	6.2	31	0.4	157	2.8	Australia
Black gram	0	0	100	1.0	50	0.5	0	0	Thailand
Other pulses	1965	10.7	107	0.8	210	2.4	21	0.3	China Vietnam Thailand Australia
Total	2625	17.9	3 643	34.0	34 553	367.4	37 123	446.5	

Source: Collector of Customs, Chittagong, and Khulna Ports (1989).

Table 4. Index of wholesale prices of lentil dhal, Bangladesh, Jan 1983 - Apr 1989 (Base year: 1983 as 100).

Month	1983	1984	1985	1986	1987	1988	1989
January	100	121	102	177	100	177	200
February	100	122	98	169	165	170	209
March	100	111	99	130	173	166	201
April	100	111	104	104	196	180	204
May	100	107	106	106	194	180	
June	100	105	105	105	191	180	
July	100	109	109	180	187	181	
August	100	106	108	179	205	177	
September	100	103	109	182	204	184	
October	100	104	117	177	188	168	
November	100	91	123	161	164	144	
December	100	89	139	160	162	159	

Source: Department of Agricultural Marketing, Government of Bangladesh (1989).

to import 2000 t of pulses up to April, 1989. Lentil is now freely imported by private traders. The prices of pulses increased faster than those of any other food commodity group, except vegetables (Table 5) (Orr and Islam 1988). This indicates heavy shortage of pulses in the internal market. Potato is available in the markets throughout the year. The production of winter vegetables is about three times higher than that of summer vegetables. As a result, consumers use potato and pulses in larger quantities during the period from May to October, with seasonal vegetables. In a normal year with substantial production of vegetables, fish, the demand for pulses is lower and the import requirement is minimal. Consumers get fish (small and dry) and vegetables at lower prices than pulses.

In the long run the country is not in a position to import pulses to increase the capita^{-1} consumption by its population. These are imported only to supplement domestic production and to reduce the internal market prices. However, in the short run there is no way to

Table 5. Growth rate of prices of pulses and other crops between 1970/74 and 1984/85 and their relative price index.

Crops	Growth rate of prices (% year^{-1})	Mean 1972/74	Mean 1984/85	Relative price index (1972/74=100)
Cereal	9.39	100	337	69
Pulses	13.82	100	440	90
Jute	12.65	100	959	122
Mustard	8.22	100	316	65
Potato	5.54	100	236	48
Sugarcane	10.77	100	440	90
Spices	11.96	100	508	104
Tobacco	7.39	100	309	63
Vegetables	15.57	100	612	125
All agricultural products	11.35	100	489	100

Source: Orr and Islam (1988).

meet the nation's demand for pulses except through imports. Prices of pulses are likely to increase during the fourth plan period for the following reasons:

1. The declining trend in the production of pulses and diversion of land to high-value crops.
2. Increasing demand due to rise in population.
3. Relatively low growth in the production of other protein-rich foods such as meat, fish, and eggs. The production of these does not match population growth resulting in a steep rise in their price.
4. Increased probability of floods and droughts as a result of deforestation.
5. Increased cost of production and marketing.

Change of Marketing Channel

Black gram (*Vigna mungo* (L.) Hepper) and mung bean (early) are harvested in December but most of the other pulses are harvested in February and March. All these pulses are distributed in the market through the age-old channel of marketing. The imported *pulses/dhals* come to metropolitan cities through importers and are marketed through the wholesaler, *aratdar,* and retailer. Pulses imported by the TCB are marketed by its selected shops. At present many mobile retailers buy pulses from the producing areas, process these in local mills and sell them in the form of *dhal* to the urban and metropolitan population. The sale price of *dhal* through this channel is lower by Tk. 1.00 to Tk. 1.25 kg^{-1} than the price at the retail shops. This has emerged as a new channel of marketing in recent years and has added new dimension to the traditional channel.

Recommendation

The Bangladesh Government Departments purchase pulses through contractors. It is suggested that these organizations should buy the required quantity of pulses in the harvest season directly from the farmers, which will help the farmers get a reasonable price.

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Future of Khesari Cultivation in Bangladesh

M. Hussain
Bangladesh Agricultural University, Mymensingh, Bangladesh

Abstract

*Khesari (*Lathyrus sativus *L.) is the most important pulse crop of Bangladesh. A strong epidemiological association is known to exist between human consumption of khesari and the incidence of lathyrism. A toxin in its seed called ß-N-oxalyl-L- a, ß-diaminopropionic acid (ODAP) is believed to be the causative principle. About 6000 patients are affected by lathyrism in this country. Often malnourished young males are the victims. The area under khesari cultivation remains high because of its drought resistance, its minimal managerial requirement, and its protein-rich seeds. Of all the processing procedures, lime water is reported to remove the toxin from the seeds to a great extent. Vitamin C is reported to protect consumers from lathyrism. Attempts to develop a toxin-free cultivar have so far proved unsuccessful. Oxalyl derivatives of some amino acids as well as isoxazolinone derivatives were found in the synthesis of ODAP but its biosynthetic pathway is still not understood. This may in part offer an explanation for the unsuccessful search for toxin-free cultivars. Research efforts should be made to determine the threshold levels of ODAP and safe levels of toxicity resulting from the intake of various forms of khesari. The search should continue for low-toxin lines with high seed yield, and for easy, effective procedures to remove the toxin before the seeds are consumed. Studies on the relationship between drought and salinity resistance and the ß-N-oxalyl aminoalanine (BOAA) content may be carried out.*

Introduction

The genus *Lathyrus* comprises about 150 species that include food, feed, and ornamental plants. The species commonly known as khesari (*Lathyrus sativus* L.) is of agricultural importance for its food and feed value. It is known to be a native of southern Europe and West Asia. It is cultivated in the Mediterranean zone and near temperate as well as tropical countries from the Canary Islands in the West through Germany in the north and Ethiopia in the south, to India and Central Asia in the east (Kislev 1986). About 56 varieties of khesari are known in the Indian sub-continent. There are a good number of germplasm lines, both local and exotic, available in Bangladesh.

Present Production and Utilization of Khesari

Production

Khesari covers about 30% of the area and production of all pulses in Bangladesh. There is a gradual decline in both hectarage and production of this crop (Islam and Rahman 1990). This decline is associated with the overall reduction in the total hectarage and production of all pulses.

It is one of the major sources of protein in the diet of the poor people of Bangladesh where 59% of the households suffer from protein deficiency. It is also the cheapest of all pulses although its present price is likely to go beyond the reach of the common people soon. It

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

is a tasty food. It may contain up to 35% protein and has a good amount of lysine, which improves the usual rice-based diet. Khesari therefore provides a nourishing diet of good-quality protein and carbohydrate (350 cal 100^{-1} g). According to Misra (1978), khesari may be deficient in methionine but not in tryptophan like other pulses. Hence its protein is of good quality.

Utilization

Khesari is often a common ingredient of the menu of the daily diet of the people of Bangladesh, especially the poor. Most often khesari seeds are eaten as *dhal* which is an aqueous slurry cooked with spices. It is also eaten as cooked paste mixed with vegetables or occasionally with dry fish in some regions of Bangladesh along with the major meal. Khesari is consumed quite often in the form of *chapati* (unleavened bread) or *dhalpuri* containing varying proportions of wheat and khesari and also as *bora* prepared in the form of deep-fried paste balls. Often this *bora* contains different proportions of lentil *(Lens culinaris* Medic.) and khesari seed powder. In addition, khesari is also consumed by boiling the mature pods and as roasted seed with roasted rice. *Khichuri,* a Bengali dish, is prepared by cooking rice with variable proportions of khesari seed. This is a really nutritious meal in terms of quality and quantity of protein. Sometimes whole or crushed khesari seeds are boiled in water and eaten as a porridge. The young khesari plant is a very nutritious and tasty leafy vegetable eaten with rice meal. During the lean period, especially in the northern region of Bangladesh, poor people live on khesari. It is known to be a survival food item during famine. Often the farm laborers are given their daily wage in the form of khesari seed, a factor which seems to contribute to the incidence of lathyrism.

Khesari makes an excellent fodder crop. Lactating cows grazing on young khesari plants are often believed to yield more milk. After harvest, the plants are dried and stored for future use as feed. Khesari grain and bran are known to be fattening feed concentrates.

Khesari and Lathyrism

Lathyrism

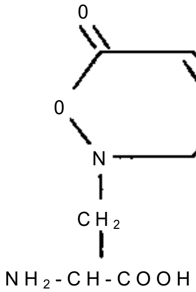
Lathyrism is a neurologic disease which results from excessive consumption of khesari seed. This disease is characterized by muscular rigidity, weakness, and paralysis of the leg muscles. The onset of the disease is often sudden. A laborer while trying to resume his work after a rest at the end of hard work for a couple of hours or after a night's sleep, suddenly stumbles and falls. He complains of pain in the back. His lower limbs become stiff. A physician may term this disability as spastic paralysis of lower limbs. Reports of lathyrism were found in many countries including some in Europe and Africa. It has been eradicated in European countries by a ban on khesari cultivation. But it is still a crippling disease in India and Bangladesh. Legislative measures to ban khesari in India failed to discourage farmers from growing it. There are now about 10000 patients of lathyrism in Bangladesh (Kaul and Islam 1982).

Several factors are believed to cause lathyrism. These include phytates, alkaloids, lack of vitamins A, B and C, and virus infection (Sarma and Padmanabhan 1969). High selenium and low methionine in the lathyrus seeds were considered to cause lathyrism. Also the seeds of *Vicia* species present as contaminants of market samples of khesari seeds were claimed to cause toxicity. The main problem in identifying the toxic factor was the lack of a suitable experimental animal which responds to the toxic factor in khesari seed. Roy et al. (1963) devised an assay procedure using khesari extract on 1-day old chicks when symptoms similar to human lathyrism appeared. This assay procedure led to the identification in khesari of the toxic factor ß-N-oxalyl-L α, ß-diaminopropionic acid (ODAP), otherwise designated as ß-N-oxalyl aminoalanine (BOAA). The chemical structure of this substance is as follows:

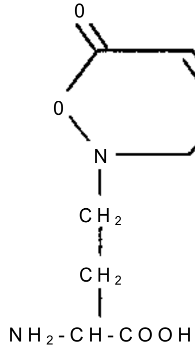
$$\begin{array}{l} \mathrm{HOOC - CO\,NH - CH_2 - \underset{\displaystyle \overset{|}{NH_2}}{CH} - COOH} \end{array}$$

An intraperitoneal injection of this factor elicited in chicks some neurological symptoms. Ahmad et al. (1981) viewed that it was a matter of opinion whether these symptoms in chicks were to be taken to be equivalent to neurolathyrism in human beings.

Neurolathyrism appears when khesari forms the main item of the diet, contributing at least 30% of the calories intake for a period of 3-4 months. A survey conducted in India showed that the affected families ate more than four times the amount of khesari compared to the nonaffected families (NIN 1983). A survey performed jointly by a voluntary organization, Shaw Unnayan Saangstha, and the Department of Sociology, Rajshahi University, revealed that most of the affected persons were landless and the affected persons suffered from malnutrition. Hence lathyrism is considered to be



(I)



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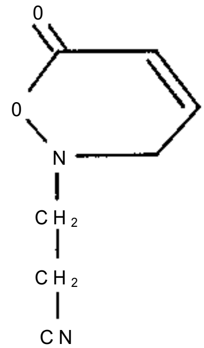

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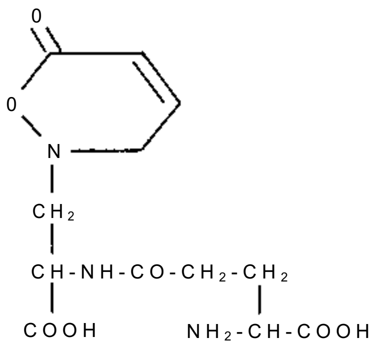

(IV)

intimately associated with malnutrition. A well-nourished person has not so far been found to be afflicted with this disease. During the lean period when cereals are scarce and vegetables are rarely available, poor people survive only on khesari consuming it in various forms for up to 3-4 months. Then, the incidence of lathyrism sets in. The highest incidence of the disease occurred in 1974 when a widespread famine broke out in Bangladesh. It was also observed that incidence of lathyrism follows a period of drought. It mainly affects young males who are more prone to lathyrism than females, the ratio being 10:1. In females, the onset is generally before puberty and after menopause. It seems that the female hormone estrogen protects them during the active reproductive period (Dwivedi 1983).

Vitamin C and lathyrism

Ahmad and Jahan (1983) reported that adult guinea pigs and monkeys when fed on cooked khesari supplemented with all vitamins except vitamin C became paralyzed in 3-7 weeks while those on the same diet supplemented daily with 5 mg of vitamin C remained healthy. When khesari was replaced by any other legume or cereal in a vitamin C-deficient diet neurolathyrism symptoms or neurolathyrism did not appear. They claimed to have cured fresh cases of human lathyrism by intravenous administration of 500 to 1000 mg of ascorbic acid daily. Reports corroborating these findings are yet to be published. These findings, however, lend support to the view that incidence of lathyrism is closely linked to the deficiency of nutrients (Islam 1983).

Quantitities and Procedures for Safe Consumption

It has been found that harmful effects of neurolathyrism are produced in 2-4 months with a diet of which 40% or more is made up of khesari seeds. In order to avoid its toxic effects, khesari should never form more than one fourth of the total amount of cereals and pulses eaten each day. Ahmad and Jahan (1982) opined that a population well nourished in respect of vitamin C will not develop neurolathyrism in spite of the use of khesari as a principal item in the diet.

A number of procedures were suggested to eliminate the toxins from khesari for safe consumption. Mohan et al. (1966) suggested the removal of the toxin by, (a) steeping dehusked seed in hot water for several hours, (b) boiling the seed in water and draining the supernatant, and (c) parboiling. These methods of detoxification would remove several of the useful water-soluble nutrients, reduce the weight (of pulse grain), and affect taste and glutinous property required for the preparation of dough for *chapatis.* Roy et al. (1963) recommended roasting of seeds. However, it adversely affects the *chapati-making* property.

Ahmad and Jahan (1982) reported that khesari is not fully detoxicated if it is treated with hot water to wash out the toxin which is, nevertheless, a water-soluble substance. They found that residues of washing caused lathyritic symptoms in animals suggesting that either a considerable amount of it exists in bound form not removed by hot water or there are other toxins which are not soluble in water. Thus a variety of khesari having less ODAP may not necessarily be nontoxic.

Ahmad and Jahan (1984) reported a procedure for complete detoxication of khesari. Decorticated ground khesari seeds were soaked in saturated lime water for 2-3 h (using just enough clean supernatant to soak) and then soaked material is autoclaved for about 10 min at 103.5 K pa (15 lbs pressure inch^2). This procedure destroyed ODAP completely. If pure ODAP was treated in the same way with lime, it was also lost. Autoclaving the seeds with water in lieu of lime water would not destroy ODAP in the seed. Just boiling in lime water for about 30 min (instead of autoclaving) would also remove the toxin from the powdered seeds, but the taste of the meal is highly limy.

Development of Low-toxin or Toxin-free Cultivars of Khesari

Use of mutagens like gamma rays, degerming of cotyledons, development of pure lines by selection, selection by morphological characteristics, and use of micronutrients at the vegetative stage were adopted to develop cultivars with no or low neurotoxin. In an attempt to isolate and identify low-toxin or toxin-free cultivars, screening programs were initiated in Bangladesh. Kaul et al. (1986) reported that ODAP contents of 127 local germplamsm lines ranged between 0.45 -1.4 mg %. They identified two lines, 3906 and 3968, as low-toxin lines with 0.35 and 0.62% ODAP. They even recommended release of these lines to the farmers as an interim measure until lower-neurotoxin cultivars were identified. Hussain and Khatun (1987) obtained ODAP contents of 133 germplasm lines, both local and exotic, in which ODAP contents varied from 0.62% to 1.55%. They identified 10 cultivars with low neurotoxin ranging from 0.62-0.79%. There were some overlapping cultivars in the reports of Kaul et al. (1986) and Hussain and Khatun (1987). Different growth conditions and storage periods appeared to influence the ODAP contents. A comparative bioassay with chicks using low- and high-toxin khesari showed that 24 g of low-toxin cultivar P 24 was required to produce symptoms similar to those produced by 5-6 g of the local high-toxin variety.

On the basis of the color of the flowers, three varieties of khesari have been distinguished : albus (white), roseus (pink), and cyaneus (blue). The albus is rare while cyaneus is common. Preliminary studies by Quader et al. (1986) showed that white-flowered plants had more toxin as compared to those with blue flowers. Dahiya (1976) reported that light cream-colored seed had the lowest ODAP content. So flower color and seed-coat color could be used as indices for identifying low-toxin varieties. ODAP was present in all tissues, but its maximum concentration was present in the leaf during the vegetative phase and in the embryo during the reproductive phase.

An international association called the International Network for the Improvement of *Lathyrus sativus* L. and the Eradication of Lathyrism (INILSEL) has been formed (Kaul and Combes 1986). INILSEL aims at developing toxin-free strains of khesari. According to Prof Bell, Director of the Royal Botanic Gardens at Kew, UK, a toxin-free strain of *Lathyrus sativus* L. can become a wonder crop in the semi-arid areas of the world.

Biosynthesis of ODAP

To evolve a cultivar free from neurotoxin, information on the biosynthetic pathway and the enzymes involved in its biosynthesis may eventually become important, if modern technology, including genetic engineering, is to be utilized. Biosynthesis of ODAP is a challenging problem which has so far defied most approaches used for tracing its biosynthetic pathway. Malathi et al. (1967 and 1970) proposed a two-step process for the biosynthesis of ODAP.

$$\text{Oxalate} + \text{C o} \xrightarrow[\text{Mg}^{2}+]{\text{ATP}} \text{l y l CoA} + \text{AMP} + \text{PP} \quad \text{..........(i)}$$

$$\text{Oxalyl CoA} + \text{DAP} \xrightarrow{\text{ATP}} \text{ODAP} + \text{CoA} \quad \text{..................(ii)}$$

The first reaction involves oxalyl CoA synthetase and the second step involves ODAP synthase. Misra et al. (1981) failed to detect the activity of ODAP synthase. Certain doubts were raised regarding the involvement of the enzymes oxalyl CoA synthetase and ODAP synthase. The two-step process was claimed to be chemical rather than enzymatic in nature. The absence of αß-diamino propionic acid (DAP) may possibly be due to its rapid synthesis and quick attachment to the oxalyl group leading to the formation of ODAP. No traceable amount of DAP in free form could be detected in plants or seeds of khesari. Two potential precursors for the biosynthesis of ODAP are presently given attention. These are α-arabionosyl ß-glucosyl-α, ß-diaminopropionitrite, and p-(isoxazolin-5-one-z-oyl)-alanine (Lambien et al. 1976). Both these compounds release DAP by chemical hydrolysis. The Lambien group proposed the following biosynthetic pathway for ODAP:

$$\text{1.Asparagine} \xrightarrow{1} \text{Isoxozalinone} \xrightarrow{2} \text{Acetyl serine ß-Isoxazolinone-alanine} \xrightarrow{3} \text{Diaminopropionic acid (DDAPA)} \xrightarrow{4} \text{Oxalyl CoA ODAP.}$$

According to Lambien (1988) in this pathway only the third step remains to be proven. The last step forming the toxin is not necessarily enzymatic, the key enzyme should thus be the one eventually catalyzing the formation of diaminopropionic acid. The isoxazolinone derivatives detected in khesari are the following:

In khesari, there seems to be a negative correlation between the concentration of (IV) and ODAP in the seedling stage. It is of interest to mention that both compounds (I) and (IV) can be broken down to α, ß-diaminopropionic acid (DABA) by acid hydrolysis or by UV-light (Lambien et al. 1976). When compound (II) is given to young chicks with the feed or by intraperitoneal injection, symptoms of neurolathyrism develop. In the brain and in the blood of the chicks free DABA is found together with compound (II). Probably compound (II) is toxic because it is metabolically broken down to the toxic DABA.

Some important findings of biosynthetic studies that require attention are as follows:

1. Homoserine and acetyl derivatives are found to accumulate during germination and in young seedlings of khesari.
2. Homoarginine is the major nonprotein amino acid in dry khesari seeds.
3. Four major isoxazolinone derivatives are known to accumulate in khesari seedlings which disappear in mature plants.
4. Glutamyl derivative of isoxazolinone compound is inversely proportional to ODAP in the seedling stage.
5. During early germination stage, there is a rapid increase of the isoxazolinone derivatives and homoserine.
6. O-oxalyl-homoserine disappears during ripening while ODAP increases. This may be a storage compound for oxalate needed for ODAP synthesis.
7. High biosynthetic rate of ODAP occurs during young seedlings and ripening seeds.

Arguments in Favor of Khesari Cultivation

1. It can be grown with remarkable ease. It has a firm place in the agroeconomy of Bangladesh.
2. It has a high degree of stability under extreme conditions like drought and waterlogging.
3. Since it is often used as a relay crop, it utilizes the available moisture to its best advantage particularly during a drought.
4. It fixes 32-50 kg of atmospheric nitrogen ha^{-1}.
5. It is an excellent fodder crop. It is believed to augment milk yield.
6. It is a traditionally favored item of food among economically poor segments of society.
7. It is a nutritious and tasty food item containing up to 35% protein with good amount of lysine for supplementing rice-based diets. It has higher tryptophan content than other common pulses.
8. The people on nutritionally adequate diets are not likely to suffer from neurolathyrism on consumption of its seeds. If khesari does not form more than 25% of diet, it is not likely to cause lathyrism. Use of enough vitamin C may reduce this danger substantially.
9. Proper processing of khesari seeds or flour may eliminate or reduce the neurotoxin content.

Future Strategy

Attempts to develop a toxin-free cultivar have yet to meet with success. Basic research on the threshold levels of ODAP toxins as influenced by age, sex, and nutritional status is needed. A safe level of toxicity should be determined. It is also necessary to establish the relationship between oral intake of the various forms of khesari (*dhal, bora,* and *chapati),* and absorption of ODAP into blood and transfer ODAP to cerebrospinal fluid. Biosynthetic pathway of ODAP needs to be deciphered in order to develop a toxin-free khesari by utilizing modern techniques like genetic engineering. Studies should be undertaken to investigate the relationship between drought and salinity resistance with ODAP content.

Discussion

J. Kumar: Would you please comment on the screening procedures for BOAA determination ?

M. Hussain: The OPT method proposed by SLN Roy is now being used for the quantification of BOAA. HPLC may be used for faster screening of breeding materials.

H. Islam: 1. You have mentioned that in khesari there is 35% protein. How much of the protein is digestible? What is the prospect of changing the nondigestible protein to grain yield through breeding ? Please comment.
2. What morphological characters are associated with BOAA content ?

M. Hussain: 1. Digestibility of khesari protein is low due to limiting sulphur-containing amino acids and other antinutritional factors. Breeding program for eliminating BOAA and for incorporating desirable characteristics is now being pursued.
2. Some reports indicate that flower color and seed coat color may be used as indices for BOAA content. But these reports are not always consistent.

M. M. Rahman: You mentioned that 500 -1000 mg vitamin C intake (intravenous) helps recovery of lathyrism-affected patients. Has this been verified?

M. Hussain: Recovery on administration of vitamin C in megadoses has been suggested. However, neural changes are often irreversible. So recovery from lathyrism by vitamin C depends on the stage of application.

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Pulses as a Substitute for Animal Protein[1]

Umaid Singh and R. Jambunathan

Internationa] Crops Research Institute for the Semi-Arid Tropics
(ICRISAT), P.O. Patancheru, 502 324, Andhra Pradesh, India

Abstract

Nearly 80% of proteins and 90% of calories consumed by humans in the developing countries are supplied by plants or plant products; therefore, pulses are an important source of cheap proteins in their diets. In addition, pulses are also good sources of carbohydrates, minerals, and vitamins. The protein quality of pulses is considerably lower than that of animal proteins but increased quantity of intake can partially overcome this deficiency. Methionine and cystine are the first limiting amino acids in pulse proteins. Globulin is the major storage protein of pulses and is deficient in methionine and cystine. Therefore, the proportion of globulin fraction in pulses plays an important role in determining the overall protein quality. Some antinutritional factors and toxic constituents such as protease inhibitors, amylase inhibitors, polyphenols, oligosaccharides, phytolectins, lathyrogens, glucosides, and aflatoxins are reported to be present in pulses. Primary processing, such as dehulling, and secondary processing, such as cooking, influences the nutritive value and acceptability of pulses. These processes improve the bioavailability of nutrients (though some of these nutrients may be lost while undergoing these changes) and partly or wholly removes some of the antinutritional factors and toxic constituents.

There are also well recognized shortcomings in consuming animal proteins in the developing countries. Some of them are: the cost of the product which is mainly due to the inefficient conversion of plant into animal product; the fact that animal proteins can be the source of potential diseases if stored and consumed under unhygienic conditions; and the quality of the available product. On the other hand, pulses have been reported to reduce the levels of cholesterol and blood glucose. Therefore, pulses are and will continue to be important sources of proteins in the diets of people in developing countries.

Introduction

The existing knowledge of world protein resources in relation to human requirements has been reviewed in the past (Porter and Rolls 1973). Foods of animal origin such as meat, milk, eggs, and fish provide the essential amino acids as well as minerals, fats, and vitamins in human diets. Animal products are preferred because of their flavor and texture. Although there is no specific requirement for animal proteins in the diet *per se,* dietary protein from animal sources is taken as an index of the overall protein quality of the diet. However, in developing countries, the availability of animal proteins is considerably less, due to economic and social reasons.

Plant proteins are the major substitute for animal proteins and in this context, grain legumes occupy an important place as sources of dietary proteins. On an average, about 80% of proteins and 90% of calories consumed by the humans in the developing countries are supplied by plants (Table 1). In all developing countries including India and Bangladesh on an average animal proteins constitute only about 11% of the total proteins in the diets of people (Table 1). Pulses like chickpea (*Cicer arietinum* L.), mung bean *(Vigna radiata* (L.) Wilczek), black gram (*Vigna mungo* (L.)

1. ICRISAT Conference Paper no. 556.

Citation: BAR! (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workahop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropica.

Table 1. Availability of protein and calories in some Asian countries[1].

	Person^{-1} day^{-1}			
	Protein (g)		Calories	
Country	Plant	Animal	Plant	Animal
Bangladesh	34.3	4.3	17%	64
	57.6	8.4	2409	109
China	51.9	8.4	2367	198
India	46.1	6.3	2036	125
Indonesia	46.0	5.5	2450	54
Japan	41.9	43.7	2263	541
Malaysia	32.2	22.3	2270	364
Nepal	44.9	8.1	1906	142
Pakistan	42.6	13.8	1947	238
Developed countries (All)	42.4	54.9	2364	1010
Developing countries (All)	46.9	11.3	2222	202

1.FAO (1986).

Hepper), khesari (*Lathyrus sativus* L.), and lentil (*Lens culinaris* Medic.) are largely grown and consumed in Bangladesh and India. Some important aspects of the nutritional quality of these pulses are discussed in this paper. •

Protein quality

The protein quality of food crops is governed by the protein content, its amino acid composition and digestibility (Eggum and Beame 1983; Singh and Eggum 1984). Among the food crops, legume grains contain the highest quantity of protein which is generally twice or three times the amount found in cereal grains. The proteins of the legume grains are rich sources of lysine, but are usually deficient in sulphur-containing amino acids, methionine and cystine. There are large differences in the protein content of pulses (Table 2) and wider variations (12.6 to 30.5%) were observed in the chickpea seed protein content (Singh 1985), and in the amino acid composition (Chatterjee and Abrol 1975). Both locations and agronomic practices influence the protein content and quality. Although high-protein cultivars of pulses have been identified, little progress has been made in developing high-protein cultivars of improved agronomic performance capable of producing more protein per unit area per unit time.

Protein quality of a pulse can be assessed by comparing its amino acid composition with a standard reference pattern, usually casein. Methionine and cystine, including tryptophan and threonine in some pulses, have been reported as the limiting amino acids (Shobhana et al. 1976) (Table 2). Although some variations exist in the concentration of these amino acids, no genotypes rich in sulphur-containing amino acids have been identified and used in the breeding program for improving the protein quality of pulses. A recent report of FAO/WHO/UNU (1985) has indicated variable requirements for different amino acids depending on the age of person (Table 3) and these are compared with the amino acid composition of lentil, chickpea, and khesari.

The biological value of a dietary protein, which is defined as the fraction of absorbed nitrogen retained in the body for maintenance and growth, is one of the most useful measurements of protein quality. A comparison of biological values of some pulse and animal proteins indicates that pulses have lower biological values as compared to animal proteins. However, the supplementation of cereal proteins with pulse proteins would improve the nutritional quality of the dietary proteins as the amino acid composition of cereals and pulses complement each other. The biological value of egg proteins is the highest followed by milk, fish, and meat proteins (Table 4). There is a large variation in protein digestibility, biological value, and net protein utilization of the various legumes (Porter and Rolls 1973). Biological value of lentil has been reported to be the lowest, and biological values of pigeonpea (*Cajanus cajan* (L.) Millsp.), cowpea *(Vigna unguiculata* (L.) Walp), and mung bean are compa-

Table 2. Ranges and means (parentheses) of protein, methionine, threonine, and tryptophan of commonly consumed

Pulse	Number of cultivars	Protein (%)	g 100 g-1 protein		
			Methionine	Threonine	Tryptophan
Chickpea	6	20.1-24.6 (22.0)	1.0-1.3 (1.1)	3.3-4.7 (3.9)	0.4-0.9 (0.7)
Pigeonpea	2	18.2-20.5 (19.4)	0.8-1.0 (0.9)	4.0-4.1 (4.1)	0.4-0.5 (0.5)
Mungbean (green gram)	5	25.2-28.2 (26.6)	1.0-1.7 (1.4)	2.7-3.0 (2.9)	0.6-0.8 (0.7)
Black gram	3	23.2-24.4 (23.7)	1.0-1.1 (1.0)	3.0-3.7 (3.4)	0.6-0.8 (0.7)
Khesari (grass pea)	3	30.6-33.9 (32.6)	0.3-0.4 (0.4)	2.7-2.8 (2.8)	0.4-0.5 (0.4)

I.Shobhana et al. (1976).

Table 3. Essential amino acid requirements for humans - Food and Nutrition Board and FAO/WHO/UNU.

Essential amino acid	FNB pattern for high quality proteins (mg g-1 protein)[1]	FAO/WHO/UNU2 suggested pattern (mg g^{-1} protein)			Amino acid composition (mg g^{-1} protein)		
		2-5 yr	10-12 yr	Adult	Lentil[3]	Chickpea[2]	Khesari[3]
Lysine	51	58	44	16	70	70	75
Threonine	35	34	28	9	35	35	22
Methionine +Cystine	26	25	22	17	19	26	16
Tryptophan	11	11	9	5	10	8	8
Valine	48	35	25	13	50	50	40
Leucine	70	66	44	19	75	93	66
Isoleucine	42	28	28	13	43	51	66
Tyrosine +Phenylalanine	73	63	22	19	75	86	42
Safe level of protein intake (g kg^{-1})	2.0	1.10	0.99	0.75			

1. NAS (1980).
2. FAO/WHO/UNU (1985).
3. Goplan et al. (1971).

Table 4. Biological value (BV) and protein efficiency ratio (PER) of different foodstuffs[1].

Foodstuff	Biological value (%)	PER
Rice	68	2.2
Wheat	65	1.5
Maize	59	1.2
Chickpea	68	1.7
Pigeonpea	57	1.5
Groundnut	55	1.7
Egg	94	3.9
Milk	84	3.1
Meat	74	2.3
Fish	76	3.5

1. FAO/WHO (1973).

rable, but considerably lower than chickpea (Eggum and Beame 1983). The biological value of legume seeds is positively and significantly correlated with sulphur-containing amino acids (Eggum and Beame 1983).

The relative proportions of different protein solubility fractions also influence the protein quality of pulses. A pulse crop with an improved nutritional quality will be a better substitute for animal proteins and would be desirable. The globulins which are the storage proteins, constitute about 60 to 65% of the total seed proteins of chickpea and pigeonpea, the two important pulse crops in the Indian subcontinent (Singh and Jambunathan 1982). The globulin proteins are also the most deficient in sulphur amino acids and thus affect the overall protein quality. Albumin fraction, although representing a small proportion of proteins of pigeonpea and chickpea, is a very rich source of methionine and cystine. Therefore, the selection of cultivars containing higher concentration of this fraction will be desirable to improve the protein quality. In addition, glutelin fraction also contains higher levels of methionine and cystine, suggesting that cultivars with a higher ratio of glutelin to globulin should be identified to improve the protein quality (Singh and Jambunathan 1982).

Supplementary Effect of Pulses on Nutritive Value

Cereal-grain proteins are low in lysine buthaveadequate amounts of sulphur-containing amino acids. On the other hand, the proteins of legume grains are rich sources of lysine. It is therefore often emphasized that legume-grain proteins are the natural supplement of cereal-grain proteins. A combination of wheat and chickpea in appropriate proportion improved the protein efficiency ratio of the dietary protein (Angel and Del Sotelo 1978). In wheat-pulse combination, a maximum chemical score was obtained when the pulse content was around 10% in the diet, and with rice, maize or barley, the maximum scores were obtained when the pulse content was around 20% in the diet (Chatterjee and Abrol 1975). Supplementation with 10, 20, 30, 40, and 50% chickpea flour significantly enhanced the nutritive value of Arabic bread, but 20% chickpea supplementation was satisfactory in terms of its organoleptic properties (Hallab et al. 1974).

Antinutritional Factors

Pulses contain various antinutritional factors such as trypsin and chymotrypsin inhibitors, amylase inhibitors, polyphenols, phyto-hemagglutinins, and glycosides. Of these, trypsin and chymotrypsin inhibitors have been studied extensively. Trypsin inhibitor activity was reported to be in the following decreasing order soybean, common bean, broad bean, peas, lentil, and chickpea (Gallardo et al. 1974). Pak and Barja (1974) reported that the trypsin inhibitor activity was in decreasing order in black gram, kidney bean, pigeonpea, mung bean, and chickpea.

The ability of pulses to stimulate intestinal gas formation has been recognized for many years. Gas production was higher in the case of chickpea than from other pulses (Singh 1985). Galactose-containing oligosaccharides, raffmose, stachyose, and verbascose are the sugars in pulse seeds that are responsible for flatulence. These three sugars together constituted about 53% of the total soluble sugars in pigeonpea whereas stachyose and raffmose accounted for about 37% of the total soluble sugars in chickpea (Singh 1988).

Polyphenols of legumes decrease the protein digestibility in animals and humans probably by making protein partially unavailable or by inhibiting digestive enzymes. Chickpea and pigeonpea contain considerable amounts of polyphenolic compounds that showed genotypic variation (Singh 1984). Phytolectins are toxic factors that interact with glycoprotein on the surface of red blood cells and cause agglutination. In general, it has been observed that pulses have low phytolectin activity, i.e., below the toxicity level.

Chickpea contains a certain amount of agglutinating activity, although not at toxic level (Singh 1988). Pulses also contain substances that bind with metal ions, particularly divalent cations, such as calcium, zinc, and magnesium. Among these are phytic acid, an organic form of phosphorus, which chelates with minerals and inhibits their absorption.

Some species such as khesari contain a potent neurotoxin. Lathyrism, as it is known to occur in humans, is a paralytic disease associated with the consumption of khesari, also called as kesari *dhal* or chickling vetch. This pulse is largely grown and consumed in Bangladesh, Nepal, and India as it is drought resistant. A simple parboiling processing method is reported to remove or destroy this toxic compound.

There are some beneficial effects of consuming legumes. For example, dietary fiber from bengal gram has been reported to reduce the level of cholesterol (Thomas et al. 1987). Bengal gram *dhal* and *rajmash (Phaseolus vulgaris* L.) have been reported to reduce plasma glucose level in humans (Dilawari et al. 1981). Mung bean and chickpea reduced the cholesterol level in rats (Jaya et al. 1979). Therefore, in addition to providing a cheap substitute to animal proteins, pulses have the dual advantage of reducing the cholesterol and blood sugar, the two major causes concern for the present-day human population.

Conclusion

Pulses are important sources of protein and in a cereal-legume based diet, pulses improve the nutritive value of the diet. Most of the antinutrients in pulses could be removed by suitable processing methods and hence pose no serious problem. For example, kesari *dhal* should be properly processed so that toxic substances are removed before human consumption.

Pulses are the cheapest source of protein when compared to animal protein. The conversion of vegetable protein to animal protein is also very inefficient. Pulses such as chickpea also offer certain reported beneficial effects such as lowering cholesterol levels. Therefore pulses will continue to be an important and indispensable source of proteins to millions of people living in the developing countries of the world. Any improvement in their quality will only be an additional bonus which may help to improve the status of malnutrition among these people.

Discussion

M.M. Rahman: Did you find any relationship between the nutritional value and insect pest resistance of chickpea and pigeonpea? If so, what was the relationship?

U. Singh: No, we have not observed any relationship between nutritional value and insect-pest resistance.

M. M. Rahman: You have not shown any table of pulse balanced diet, i.e., how much pulses (g), cereals and vegetables should be taken for a standard calorie requirement and what is the standard calorie requirement for an adult?

U. Singh: In one of the slides, it was shown that a combination of rice with pulses in a mixed diet would improve the nutritional quality of protein. However, calories need is not the important consideration in this context.

M. A. Zaman: When pulses are exposed to high temperature, e.g., frying in oil or dry roasting, don't you think the protein will be denatured and reduced in quality?

U. Singh: Yes, by heating at high temperature, proteins will be denatured and this would affect the protein digestibility.

O. Islam: You have talked about high protein content (29%) genotypes of chickpea. So far we know that protein content and yield are negatively correlated. On the other hand, only about 60% of the pulse proteins are digestible. 1. Would you please give me an idea up to what extent protein can be increased in chickpea without sacrificing yield?
2. Is there a breeding program at ICRISAT for increasing the digestible protein only?

U. Singh: It is difficult to say to what level protein content can be increased. But the normal protein content is about 20% and if protein content be increased up to 25% it would be useful from the nutrition point of view. No, we don't have any breeding program to increase digestibility of protein. But we are studying the factors that affect the protein digestibility of legumes.

H. Islam: Lentil causes some heartburn while mung bean does not. Would you explain the biochemical reasons or the difference in digestibility of protein from these two sources?

U. Singh: I am not aware of any biochemical differences associated with such effects.

M. A. Aziz: 1. Is protein content related to yield?
2. If you increase the protein content the yield may decrease. Please comment.

U. Singh: Yes it is true. There is a negative correlation between yield and protein. But the magnitude of correlation is very low and it may vary with locations and genotypes.

T. Bruulseme: Your data show that soybeans have higher protein content as well as higher protein digestibility, relative to chickpea. Does this not justify consideration of soybean as a pulse? Is not the main concern in declining pulse production the decline in available protein nutrition?

U. Singh: It is not under consideration whether soybean could be called a pulse crop and also this is not related to the declining trend in pulse production.

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Session V:
Regional Pulses Research Links

Networking and the Asian Grain Legumes Network's Role in Strengthening Pulses Research in Bangladesh[1]

D. G. Faris and C. L. L. Gowda
International Crops Research Institute for the Semi-Arid Tropics
Patancheru P.O., Andhra Pradesh 502 324, India

Abstract

Agricultural Research Networks (ARNETs) are becoming popular with agricultural research scientists all over the world. An ARNET is a cluster of scientists or institutions linked together by a common interest in working dependently or interdependently on an identified shared problem or problems. The overall objective of a network is to strengthen the research capability of national agricultural research systems and to identify, address, and solve farmers' problems. An effective network will facilitate sharing of research information, help to reduce unnecessary duplication, provide the critical mass of effort needed to give quick answers to pressing problems, and hasten scientific breakthroughs. ARNETs have five important components: membership, research, coordination, communication, and assets. Networks are dynamic and responsive to changing needs in agricultural systems. There are many types of ARNETs depending on the problems that need to be addressed, the membership and its requirements, the extent of coordination available or needed, the research strategy developed, and the assets available.

*The Asian Grain Legumes Network (AGLN) established in 1986 is coordinated from ICRISAT Center, Patancheru, Andhra Pradesh, India. AGLN is now operating in 11 countries of Asia including Bangladesh. All Bangladesh scientists and administrators working on chickpea (*Cicer arietinum *L.), pigeonpea (*Cajanus cajan *(L.) Millsp.) and groundnut (*Arachis hypogaea *L.) are invited to become members of the AGLN. Although AGLN is presently coordinated at ICRISAT, it belongs to the members. It aims to improve the research capability, and transfer of technology related to AGLN legume crops in Bangladesh, including supply of germplasm, breeding material, training, and literature. AGLN also assists in developing collaborative research projects, and helps to find financial assistance for special research projects. These activities have already been initiated in Bangladesh and will be strengthened with the establishment of a Technical Assistance Project Proposal (TAPP).*

Introduction

Networks and networking have become increasingly popular in recent years. Much *of* this increase in activity has been in agricultural research networks (ARNETs), of which the Asian Grain Legumes Network (AGLN) is an example. In this paper we will examine the structure and activities of AGLN in relation to other networks and countries, and explore how AGLN might collaborate more fully with the Pulses Improvement Program in Bangladesh.

Definition

ARNETs have been defined as "a cluster of scientists or institutions linked together by a common interest in working dependently or interdependently on identified shared problems'' (Faris and Ker 1988).

1. ICRISAT Conference Paper no. 528.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patanchem, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Objectives of ARNETs

ARNETs are generally organized to strengthen research that aims to develop the technology needed to increase world food supplies and provide farmers with a steady income. A set of more specific objectives was spelt out at a Network Coordinators' Review in Nairobi In May 1988 (Faris and Ker 1988). These were as follows:

- to strengthen the applied research capability of national agricultural research systems to identify, address, and solve farmers' problems;
- to generate appropriate technology by more effectively utilizing existing research personnel, facilities, and other resources;
- to ensure stability of agricultural production through a responsive research capability; and
- to provide the support, both technical and financial, required to facilitate the coordination of activities on a regional basis.

ARNET Structure

Although each ARNET is unique, virtually all involve the following five components:

1. **Membership:** The membership component comprises the body of the network. Members can be individual scientists, policy makers and cooperators, or groups consisting of national agricultural research systems (NARSs), international agricultural research centers (IARCs), regional programs, laboratories in developed countries, and bilateral projects. The network is organized to meet its members' needs. The members provide the input and use the resulting output.

2. **Research:** ARNETs are established to provide answers to identified problems. The research component is the main part of the network that provides answers to these problems. The research component can identify information in the form of literature that already exists, or it can generate new products, such as new technologies or varieties. Alternatively it can forge a new research method or create a new type of database. Almost invariably, however, the research component includes some type of active research specific to the network. This research may be basic, strategic, applied, or adaptive. It is normally carried out by the network members, using their own staff and resources.

3. **Coordination:** The coordination component consists of a unit or secretariat that organizes and harmonizes the activities of the network, and a steering committee that provides guidance for the coordination unit and hence for the activities of the network. The coordination unit usually consists of a network coordinator and some staff. The coordinator's role is typically to act as executive officer for the network. The steering committee normally consists of representatives of the network membership, including research managers, network scientists, outside consultants, and donor representatives. This guiding body can undertake many functions including arranging for annual meetings of the network coordinators from each country or a workshop involving all members.

4. **Communication:** The communication component consists of the various links within and between the other components. These links include correspondence, publications such as newsletters and research reports, visits, workshops, monitoring tours, and training. They furnish the means for the exchange of ideas, information, data, methods, materials, and technology.

5. **Assets:** The assets component consists of the resources already in place and the additional external finances required to allow the network to operate effectively. The external funding is mainly required for the communication and coordination components, but frequently small amounts are also used for the research component.

A major reason for organizing networks is so that network members can pool their resources to provide the critical mass needed to efficiently provide research to answer the members' needs. The network also helps reduce unnecessary duplication of effort.

Networks as Organisms

Using diagrams to depict network structure can obscure the fact that networks are dynamic. To illustrate this point, let us compare a network to a living organism that is conceived and born, that grows, develops, and goes through a learning process that includes the ability to learn by its mistakes and gain from the experiences of similar organisms. Carrying this analogy further, the network membership component can be thought of as the body of this organism, providing the bulk and muscle power to carry out activities. The research component is like the blood and cell metabolism which gives life to the body. The communication component is like the blood vessels and nerves; it "moves" the research component to the membership component. The coordination component acts as the nerve center, processing information and harmonizing the activities of the body. The assets component is like food that provides the energy to keep the network organism alive and active.

ARNET Prospects

With some understanding of how networks are organized, we shall now move on to examine some of the important traits that have contributed to ARNET's success. These include:

- a purpose recognized by all members as both important and achievable;
- a clearly focused strategy;
- an existing or potential source of improved technology, including the capability to generate technology through research;
- a realistic research agenda;
- strong and effective coordination;
- a steering committee that represents members' views and can commit member and national program resources to network activities;
- training to ensure that members will be able to carry out the network's research agenda effectively;
- regular meetings, workshops, and monitoring tours to share ideas, review progress, and plan future activities;
- free exchange of results, materials, and members among network countries;
- strong self-interest of members served by the network;
- capacity of membership to make a meaningful contribution to the network;
- commitment by NARSs to provide the funds, resources, and staff needed to meet network activities;
- necessary logistic support from administrators; and
- adequate and flexible outside funding.

The Asian Grain Legumes Network (AGLN)

The AGLN is a good example of how a successful network is conceived and organized, and how its operations start to develop.

In 1983 a Consultative Group Meeting at ICRISAT involving legume scientists from several Asian countries and regional donor agencies identified the major constraints to the production of groundnut *(Arachis hypogaea* L.), chickpea (*Cicer arietinum* L.), and pigeonpea *(Cajanus cajan* (L.) Millsp.) in Asia and the priority research needed to overcome those constraints (ICRISAT 1984). With these needs in mind, the group endorsed ICRISAT's concept of an Asian Regional Legume Research Program and recommended that ICRISAT appoint a coordinator for the program. This was done in a Review and Planning Meeting in 1985 (ICRISAT 1987a). This meeting also provided recommendations in the form of a general plan of action and a list of specific activities to be undertaken. The Coordinator assumed his duties on 1 January 1986. Since then, AGLN has evolved a series of activities based on the recommendations of the two earlier meetings. We will now review these activities.

Objectives

AGLN was set up to facilitate the interchange of material and information among grain legume scientists at ICRISAT and in Asian countries. The ultimate aim of the network is to help the farmers of the region increase their legume production.

The specific objectives of the network were to:

- produce a directory of AGLN cooperators;
- operate an information bank for the cooperators;
- support identification of adapted grain legume lines and the appropriate agronomy for their cultivation in each AGLN country;
- promote training of legume scientists from AGLN countries; and
- foster special research support projects.

AGLN is presently active in 10 countries: Bangladesh, Burma, India, Nepal, Pakistan, and Sri Lanka (in South Asia); People's Republic of China, Indonesia, the Philippines, and Thailand (in East and Southeast Asia). It also works with other Asian countries when its assistance is requested.

Network structure and operation

The structure and activities of AGLN are based on strong contacts between ICRISAT and national program scientists based on a formal Memorandum of Understanding (MOU) with each country.

Work plans with each country have been developed as part of each MOU (ICRISAT 1987b). Wherever possible these plans have been developed at review and planning meetings in each country. The work plans set out specific commitments by both ICRISAT and the member country as follows:

- enlist country AGLN coordinator and cooperators;
- determine research priorities;
- decide collaborative research programs;
- identify needs, individuals, and responsibilities for network activities.

An important feature of AGLN's structure is the country-AGLN coordinator. The coordinators are the administrative contact persons with ICRISAT in each country. Decentralization of the responsibility for network operations increases the effectiveness of AGLN's Coordination Unit. For Bangladesh, we have one Coordinator each for groundnut (M.A. Khaleque) and pulses (M. Matiur Rahman).

Donor and international institute representatives are integral parts of AGLN's structure. The continued interaction of AGLN with this group was a major recommendation of the 1985 meeting (ICRISAT 1987a). The AGLN Coordination Unit has found contacts and joint activities with this group very fruitful.

The AGLN Coordination Unit consists of a Network Coordinator, a Breeder who acts as a deputy coordinator, and a Secretary. The unit receives guidance for its activities from an Advisory Committee at ICRISAT; from meetings with national program scientists; country coordinators, and administrators in each country, and from meetings such as the Chickpea Coordinators' Meeting held in 1987 or the Regional Legumes Network Coordinators' Meeting in Dec 1988 (ICRISAT 1989). These groups have fulfilled the role of the steering committee, which will be formally organized in 1990 as recommended by the Legumes Network Coordinators' meeting (ICRISAT 1989).

The main mode of action of the coordination unit is to facilitate contacts between legume scientists working on groundnut, chickpea, and pigeonpea in AGLN countries, and those at ICRISAT. Scientifically, the most productive contact is a direct one between scientists. Therefore after initially facilitating a contact between scientists, the input of the coordination unit becomes secondary or nonexistent. New initiatives are now relatively easy to launch because the contacts and agreements with each country have already been made.

The AGLN coordination unit and its activities are supported by ICRISAT. ICRISAT also provides funds for its scientists to visit AGLN countries and to train scientists from AGLN countries. The value of outside funding is demonstrated by the large number of activities and additional research made possible in the South Asian countries by a grant from the Asian Development Bank (ADB>. This grant was for the strengthening of legume research programs in Bangladesh, Burma, Nepal, and Sri Lanka through the activities of the AGLN. Similarly, money made available by the Australian International Development Assistance Bureau (AIDAB) through its support of CGIAR-Australian Centre for International Agricultural Research (ACIAR) activities has resulted in several important activities in Indonesia on peanut stripe virus, and in Thailand on pigeonpea.

AGLN and pulses improvement in Bangladesh

In their consultancy report, Green and Hawtin (1979) recommended that the Bangladesh Agricultural Research Institute (BARI) establish links with ICRISAT for chickpea and pigeonpea improvement. Effective research collaboration with ICRISAT began when the BARI Pulses Improvement Program was initiated in 1980. These links were further strengthened after the formation of the AGLN in 1986.

Germplasm and breeding material

Chickpea seed material was supplied through international nurseries from 1975/76 onwards. However, systematic testing and use of breeding material was streamlined only after the establishment of the Bangladesh Pulses Improvement Program in 1980. During the period 1980-1988, 78 sets of trials, 133 F_2-F_4 bulks, and 215 parental and advanced lines of chickpeas were sent to Bangladesh. However, only two sets of trials and many lines of pigeonpea have been sent. These materials were extensively tested and one cultivar of chickpea, Nabin, was subsequently released. Additional trials identified two kabuli lines and four desi lines as promising.

Training

For various reasons, ICRISAT has not recruited many Bangladesh trainees. From 1983 to 1988, there were only 6 trainees from Bangladesh, two for 6-month in-service training, and four for 2- or 3-week specialized training courses. We feel that the Bangladesh program would improve if more of their scientists received training at ICRISAT at all levels; in-service trainees, in-service fellows, research scholars, and post-doctoral fellows.

Workshops and meetings

In comparison to the training activities, many Bangladeshi scientists have participated in workshops and conferences organized by ICRISAT. The following meetings organized or sponsored by AGLN included participants from Bangladesh:

- AGLN Chickpea Coordinators' Work Planning Meeting, 4-6 Aug 1987, ICRISAT Center;
- Agroclimatology of Asian Grain Legume Growing Areas, 5-17 Dec 1988, ICRISAT Center;
- Regional Legumes Network Coordinators Meeting, 15-17 Dec 1988, ICRISAT Center;
- Nepal/AGLN Chickpea and Pigeonpea Monitoring Tour, 12-18 Mar 1989, Nepal;
- International Workshop on Varietal Improvement of Chickpea, Pigeonpea and Other Upland Crops in Rice-Based and Other Cropping Systems, 19-22 Mar 1989, Kathmandu, Nepal: and
- Consultants' Meeting on Uses of Grain Legumes, 27-30 Mar, 1989, ICRISAT Center.

Consultancies and visits

ICRISAT staff have received short-term assignments to assist in developing the pulse improvement program in Bangladesh. C. L. L. Gowda worked as an FAO-sponsored consultant during Jan-Jul 1982. He assisted in training the young pulse scientists. During his consultancy, he helped to compile a monograph "Pulses in Bangladesh", which is now widely used as a reference by scientists in that country. Jagdish Kumar worked as a Winrock International-sponsored consultant in Jan-Feb and again from Jul 1984 to Jun 1985 at the Regional Agricultural Research Station, Ishurdi. During this period, he assisted in developing and strengthening the pulses improvement research in Bangladesh. Another scientist was located at Bangladesh Institute of Nuclear Agriculture, Mymensingh during 1985/86 in order to assist the groundnut improvement program.

ICRISAT scientists have visited Bangladesh to participate in meetings and workshops, to monitor trials, and to conduct surveys. More than 10 scientists have visited Bangladesh, held discussions, and offered advice on various topics.

Germplasm collection

The Genetic Resources Unit of ICRISAT, in collaboration with BARI, organized a germplasm collection expedition during Mar 1985, collecting 279 legume samples, including 138 chickpea samples. Half of the seed was deposited with the Germplasm Resource Center at BARI, and the remainder was evaluated, characterized, and stored at ICRISAT.

Conclusion

All these activities indicate that the Bangladesh Agricultural Research System and AGLN/ICRISAT have established a firm foundation over the last 10 years for the improvement of chickpea and pigeonpea. We must now build on these collaborative efforts and take the successes to the farmers' fields.

A 3-year Technical Assistance Project Proposal (TAPP) is being set up by BARI and AGLN to cover crop improvement research and the transfer of technology aspects of chickpea, pigeonpea, and groundnut in Bangladesh. The TAPP details the work plan that will be carried out by Bangladesh scientists in collaboration with AGLN/ICRISAT. We trust that this work will further increase legume production in Bangladesh.

Acknowledgments

We would like to express our thanks to all AGLN pulse scientists in Bangladesh who have been associated with the collaborative activities of the network for their contribution to the success of this effort.

Discussion

M. Amiruzzaman: What is the procedure for applying for a short-term training (<3 month) at ICRISAT on pulses quality and analysis work?

D.G. Faris: 1. Send a proposal to the Director of Training at BARI and have it included in the Bangladesh-AGLN work plan.
2. Send a proposal directly to the Training Officer at ICRISAT with a copy to the AGLN Coordinator at ICRISAT. It will then be considered in consultation with the Director of Training at BARI.

A. Sarker: AGLN works only with 3 grain legumes. Why don't you include other grain legumes like lentil *(Lens culinaris* Medic), black gram *(Vigna mungo* (L.) Hepper), and mung bean *(Vigna radiata* (L.) Wilczek) in the network?

D. G. Faris: At present the AGLN is constrained to work only on chickpea, pigeonpea, and groundnut because they are the mandate crops of ICRISAT which is providing the coordination unit for the AGLN. We are presently looking at ways of expanding the AGLN's responsibility to other grain legumes including collaboration with other international institutes such as ICARDA for lentil and AVRDC for mung bean and with strong national programs to provide scientific backstopping such as providing germplasm. There is also another initiative being considered by some donors and national programs to bring together a Steering Committee to coordinate the activities of all groups working on grain legumes in Asia.

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The Role of ICRISAT in the Improvement of Chickpea in Bangladesh[1]

Jagdish Kumar
International Crops Research Institute for the Semi-Arid Tropics
(ICRISAT), Patancheru P.O., Andhra Pradesh 502 324, India

Abstract

Short- and medium-duration chickpea (Cicer arietinum *L.*) *materials suit Bangladesh environments, where almost all production of this crop occurs between 22° and 25°N latitudes. Productivity is limited by several biotic and abiotic stresses. At the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), facilities have been developed for disease and insect screening. Some facilities are being developed in Bangladesh. ICRISAT has developed populations of chickpea with multiple stress resistances. Such breeding materials, international trials and nurseries, and information have been shared with scientists in Bangladesh. Specific crosses for Bangladesh have been made. These were advanced through the rapid generation-turnover facilities at ICRISAT. This cooperation has resulted in the identification for Bangladesh conditions, of several disease-resistant and high-yielding lines. Extra short-duration, wilt-resistant cultivars developed at ICRISAT appear suitable for normal and late sowing in jute- and rice-based cropping systems. A kabuli cultivar, which matures in 80 to 85 days (rainfed) has produced two normal crops between September and March at ICRISAT Center. Such cultivars may be suitable in short rotations in rice fallows in the* Barind *tract. In Bangladesh, where the cropping intensity can be as high as 300% or more, this development has the potential to extend chickpea cultivation outside its normal adaptation areas.*

Introduction

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has a world mandate for the improvement of chickpea *(Cicer arietinum* L.). The crop is cultivated in about 50 countries between ~ 45° latitudes north and south. In the subtropics it is grown in the winter season and in the temperate zones during spring and summer. Nearly 6 million t of chickpea was produced in about 9 million ha in 1988 (FAO 1989). The mean productivity was 671 kg ha^{-1}. The Indian subcontinent accounted for 77.5% of the production and 82.5% of the area. The mean productivity in some middle-east countries is nearly 2000 kg ha^{-1} (Table 1). High experimental yields of about 5 t ha^{-1} have been reported from Bangladesh and India, although the mean productivity in these countries is low and the crop is losing ground to higher-yielding crops, particularly cereals (Islam et al. 1990). Two types of chickpea are recognized: *desi* and *kabuli.* I have not come across any report of kabuli production in Bangladesh. Among all the pulses grown in Bangladesh, chickpea appears to have the greatest potential but it is probably also the most unstable among this group of crops. Therefore, a major objective of chickpea research in Bangladesh and at ICRISAT is to increase the productivity and stability of this crop by incorporating resistances to biotic and abiotic stresses. This paper describes reasons

1. ICRISAT Conference Paper no. 533.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydcbpur, Bangladesh, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Area, production, and productivity of chickpeas in Bangladesh, other countries of the Indian subcontinent, and the Middle East, 1988.

	Area ('000 ha)	Production ('000 t)	Productivity ($t\ ha^{-1}$)
World	8650	5803	0.67
Bangladesh	46	37	0.80[1]
Burma	255	240	0.94[2]
India	5806	3622	0.62
Nepal	41	18	0.45
Pakistan	817	360	0.44
Israel	5	8	1.46
Egypt	9	15	1.77
Lebenon	2	3	1.33
Turkey	665	778	1.17

1. According to the revised statistics the area planted to chickpea in Bangladesh in 1987 was 103 239 ha, production 75 000t and productivity 0.73 $t\ ha^{-1}$ (please see editor's note in these proceedings).
2. These figures do not match with the country paper from Myanmar. (Please see Thaung Pe, 1990 for possible explanation.)

for low productivity in Bangladesh and recent efforts at ICRISAT to overcome these constraints.

Major Constraints to Higher Productivity in Bangladesh

Biotic Stresses

Susceptibility to various diseases and *Helicoverpa* pod borer are major yield reducers. Fusarium wilt (*Fusarium oxysporum* f.sp. *ciceri), dry root rot (Rhizoctonia bataticola),* botrytis gray mold (*Botrytis* cineria), collar rot *(Sclerotium rolfsii),* and chickpea stunt (bean leaf roll virus) are the most important diseases in Bangladesh. Among insects, pod borer *(Helicoverpa armigera)* can reduce yields substantially in the field. Bruchids (*Callosobruchus* sp) can infest as much as 80 % of seeds in a lot within the first 3 months of storage in ambient conditions. Relatively high temperatures and more than 85 % relative humidity favor the growth of seed pathogens and bruchids. As many as 24 seed pathogens have been recorded on chickpea (Amiruzzaman and Shaha Chowdhury 1990). Under these conditions, seeds are liable to lose their viability and consumer acceptance. The loss of seed viability affects the crop establisment adversely.

Abiotic Stresses

A number of abiotic stresses can seriously affect chickpea productivity. These include moisture status of the soil, temperature regimes and humidity at sowing, flowering and podding, soil pH, texture, nutrient status, and reduced daylength (cloudy days), especially at the reproductive stage.

Lack of Proper Management

Poor plant stands in farmers' fields is probably the most important single factor limiting productivity in Bangladesh (Kumar 1984, 1985). Poor seed quality, too little or excess soil moisture at sowing, improper land preparation and methods of sowing, and attack by various seed and seedling pathogens can seriously reduce the plant stands, even when proper seeding rates are used. Farmers give the lowest preference to pulses in terms of land allocation, weed control, and inputs. Therefore, these crops are often grown in problem soils and outside their normal sowing time. For example, late sowing exposes the chickpea crop to early rains at maturity. Fields with poor soils, low in organic matter content and other macro and micronutrients and having low moisture-holding capacity or improper drainage are utilized for pulses. Irrigation, if at all available, is given to cereal and/or cash crops. Under these conditions, plant growth is often stunted and their full yield potential cannot be realized. However chickpeas, being indeterminate like other pulses, do not respond to high-input conditions. Rather, under such conditions they often produce excessive vegetative growth, which leads to lodging, development of diseases, and ultimately poor yields.

Farmers generally sow chickpea after rice. At most research stations trials are planted in well-prepared fallow fields. Therefore before a chickpea technology is given to farmers, it must be tested under experimental conditions that are similar to those where it is to be applied. There is a need to develop short-duration cultivars, which may escape various end-season stresses. In addition, some cultivars which respond to high inputs should be bred so that chickpea can compete with modem cultivars of wheat and rice in terms of stability of production and economic returns.

Chickpea Improvement at ICRISAT and its Role in Bangladesh

ICRISAT Center near Hyderabad (17.6°N) is almost at the fringes of the chickpea adaptation areas in India as the growing season is really too short for this crop. Here mainly short-duration materials (90-110 days) are bred. A major station at the Haryana Agricultural University, Hisar (29.4°N) for long-duration (150-180 days) and another one at the Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), College of Agriculture, Gwalior (26.0°N) for medium-duration (120-140 days) chickpea have been established. Advanced breeding lines for short- and long-duration materials are also tested at Gwalior. We have facilities for off-season advancement of important breeding materials. Short- and medium-duration materials developed at ICRISAT Center and found promising at locations in central India generally suit Bangladesh environments because in this country the crop is cultivated in similar (22° to 25°N) latitudes.

Germplasm Collection, Supply, and Utilization

Bangladesh Agricultural Research Institute (BARI) and ICRISAT jointly organized chickpea germplasm collections in Bangladesh in 1979 and 1985. A total of 201 accessions were collected and the seed of each was shared between the two organizations. These have been evaluated, characterized, catalogued, and maintained at ICRISAT. Their evaluation at BARI, RARS, Ishurdi, led to the selection of two promising lines RBH 121 and 135B. These have been crossed to sources of fusarium-wilt resistance. ICRISAT maintains over 15 000 germplasm lines of chickpea. We have supplied a large number of germplasm collections to local scientists on their request. These include sources of resistance to various biotic and abiotic stresses, genetic diversity, and high yield potential.

Breeding Materials, Nurseries, and Trials

Scientists at BARI, Bangladesh Institute of Nuclear Agriculture (BINA), and ICRISAT have cooperated in growing a number of international trials and nurseries at various locations in Bangladesh. International chickpea screening nurseries of short- and medium-duration, international chickpea cooperative trials of short- and medium-duration, F_2 and F_3 multilocation trials, promising parental lines, segregating populations, and disease and *Helicoverpa* pod borer nurseries have been grown here for over a decade. We at ICRISAT are very happy that BARI scientists have released a chickpea cultivar Nabin (S-1, ICCL 81248) recently (Rahman et al. 1990). They have also identified a number of other lines as promising in their multilocation trials. One or more of these may be released in the near future. Two kabuli lines, ICCL 83007 and 83008, with large attractive seeds have also done well in these trials (Islam et al. 1990). Hopefully the first kabuli cultivar in this country may be available soon.

Special facilities

Rapid generation advancement. Chickpea is a quantitatively long-day plant. We have developed capacity for rapid generation turnover by providing an extra 4 h of light to advance the growth cycle (Sethi et al. 1981). Physiologically mature seed can be harvested within 75 days. Protection against rain under polythene tunnels has made it possible to grow 3-4 experimental crops a year. Special crosses made for Bangladesh are being advanced in this manner to speed the breeding process.

Wide crosses and biotechnology. A number of wild species of chickpea are available in the Genetic Resources Unit at ICRISAT. These have useful characteristics. Only one wild species, *C. reticulatum* has been successfully crossed with cultivated chickpea. We have a close collaboration with organizations working on these aspects, who have an interest in the mechanisms of pod-borer resistance and wide hybridization. When some progress is made, for instance, in the transfer of Bt genes, such material can be made readily available to the cooperators in Bangladesh.

Resistance/tolerance to biotic stresses

Fusarium wilt. ICRISAT has developed good field and laboratory screening facilities for fusarium wilt. Five races of this pathogen have been identified (Haware and Nene 1982). Many of the lines found resistant at ICRISAT Center are also resistant in Bangladesh (Islam et al. 1990). Genetic studies indicate the operation of at least three genes which impart partial resistance to race 1. Two of these are recessive and one dominant. Combination of any two of these imparts complete resistance. Indications are that the system has more genes in operation. Further studies are in progress. A large number of resistance sources have been crossed to adapted types including ones from Bangladesh. Resistant segregants are available for agronomic evaluation.

Botrytis gray mold. High level of resistance to this disease has not been obtained in the available germplasm. Enhancement of resistance through multiple crosses among tolerant lines such as ICC 1069, NEC 138-2, ICC 4074, and ICC 8383 is being attempted. A growth room that can handle 40 000 seedlings every month, round the year is now in operation at ICRISAT Center. Part of this facility is available for botrytis gray mold screening. In the meantime crosses of tolerant lines and adapted cultivars have been screened at the G.B. Pant University of Agriculture and Technology at Pantnagar, India, in Bangladesh, and in Nepal, Promising segregants have subsequently been sent to Bangladesh. Recently a segregant from a cross of cultivars Dhanush and K 850, and a line ICCL 86237 have shown much promise. The material can be sent for testing in Bangladesh. We hope to strengthen facilities for botrytis screening in India and Bangladesh.

Other diseases. Screening for dry root rot is done in the multiple-disease sick plot, where highly susceptible lines are eliminated. Laboratory screening procedure is available for dry root rot and is being developed for collar rot. Field-screening facilities against chickpea stunt are available at the ICRISAT station at Hisar.

***Helicoverpa* pod borer.** Several sources of resistance have been identified at ICRISAT for this insect pest which attacks at both vegetative and reproductive stages. Segregating materials from crosses involving the various sources of resistance are screened in unsprayed fields and also under screened cages, where larvae are released. There are indications that the resistance is governed by additive genes and that the resistance to pod borer is linked to susceptibility to fusarium wilt (ICRISAT 1984, p. 128). Through breeding, combined resistance to the two biotic stresses has been developed, notably in ICCL 86102 and ICCX 730020-11-1-1H-BH. Efforts are also underway for germplasm enhancement for pod borer resistance.

Resistance!tolerance to abiotic stresses

Screening for drought resistance and ability to germinate under limiting moisture. Increased volume and length of roots appear to impart resistance to terminal drought stress. There are indications (ICRISAT 1989, p. 60) that ICC 4958 is more drought resistant than other lines because of its root length and volume. At present F_4 generation crosses with high-yielding cultivars are being screened for the character. We are also screening germplasm lines for their ability to emerge with limited soil moisture.

Development of extra short-duration cultivars. Efforts to look for more determinate chickpea lines are underway. We have bred cultivars which mature in about 85 days at ICRISAT Center. These have shown rapid vegetative growth and earlier maturity than conventional cultivars. In addition these may avoid the ill effects of early rains on maturing crop that can damage the seed of this crop. These are being tested in rice fallows. This development can help introduce chickpea as a postrainy-season crop after *aman* (rainy-season) rice in the *Barind* tract, where late sowing is a necessity. Double cropping in the traditional chickpea-growing areas may also be possible if moisture can be ensured for the second crop. Preliminary reports from India, Ethiopia, and Burma indicate that the extra short-duration cultivars escape end-season drought and utilize the available soil moisture to their advantage by growing quickly in early stages. These extra short-duration types may therefore, be suitable in short rotations with rice. These cultivars also appear to tolerate relatively high temperatures better than the traditional cultivars. We have successfully grown two crops of ICCV 2 at ICRISAT Center between October and March with irrigation. Such cultivars may be suitable for cultivation in Barisal, Patuakhali, Noakhali, and Chittagong region, where chickpea has not been cultivated earlier.

Another development is tolerance to relatively cold conditions. Traditional chickpea cultivars do not set pods in the coldest months in northwestern Bangladesh. Instead they produce excessive vegetative growth. At ICRISAT a number of lines have been identified and segregating populations developed which set pods in relatively cold temperatures (ICRISAT 1980 p. 125). Some of these lines also flower and mature early. In future, cultivars may be available which should allow late sowing and early harvest of chickpea in this country.

Training, Seminars, and Information Exchange

Bangladesh Agricultural Research Council (BARC) and ICRISAT signed a memorandum of understanding in 1988 for collaborative research on chickpea, pigeonpea (*Cajanus cajan* (L.) Millsp), and groundnut *(Arachis hypogaea* L.). Regular meetings at ICRISAT or in other countries are held where chickpea scientists can discuss their research work, make selections in experimental plots, and share their findings. Scientists from Bangladesh have been visiting ICRISAT for such meetings and for training. Recently a workshop was held at ICRISAT Center to characterize environments for the three ICRISAT legume crops in Asian countries. ICRISAT also has research fellowships leading to degrees and post-doctoral fellowships, in which Bangladesh scientists also participate.

Looking Ahead

In collaboration with pulse scientists in Bangladesh, ICRISAT will assist in the following activities:

1. Development of short-duration multiple-disease resistant chickpea cultivars suitable for rice-based cropping systems.
2. Introduction of large-scale chickpea cultivation after rice in the floodplain areas, parts of which presently remain fallow.
3. Development of higher levels of resistance to botrytis gray mold and pod borer through germplasm enhancement, and creation of large-scale field facilities for screening at Ishurdi.
4. Augmentation of field and laboratory facilities for screening for resistance to dry root rot, collar rot and chickpea stunt at Ishurdi.
5. Extension of chickpea cultivation to other areas of Bangladesh where this crop is not traditionally grown.
6. Breeding for drought tolerance and ability to emerge under limited moisture.
7. Creation and strengthening of facilities for large-scale multiplication of chickpea seed in Bangladesh.
8. Research on consumer acceptance and development of cultivars of kabuli types and those with relatively larger seed size.
9. Development of cultivars responsive to high management for irrigated conditions.
10. Provide training opportunities in various aspects of chickpea improvement.

Acknowledgments

I wish to acknowledge the useful comments on an earlier draft of this paper by Drs D.G. Faris, and M. Matiur Rahman.

Discussion

A. Sarker: From ICRISAT's information we know that JG 74 is resistant to wilt. But during 1986/87, at the Joydebpur farm, we found the line was susceptible to wilt. I think ICRISAT's resistant lines may not perform well in our condition.

J. Kumar: There are several races of fusarium wilt of chickpea. JG 74 is resistant to race 1. It was also resistant at RARS, Ishurdi and has been used in crosses with some cultivars of Bangladesh. Many of its segregants have been selected through the wilt-sick plot at Ishurdi and are resistant. I do not know whether Joydebpur has a different race or there are other root pathogens causing mortality.

M.M. Rahman: Participation of entomologists from ICRISAT in BARI's program is always neglected, why?

J. Kumar: In the mid 1980s you had a joint pheromone trap network. You may initiate a common program with ICRISAT entomologists.

A.A. Mian: You have said that at ICRISAT chickpeas, can be grown well from October to January. What about the yield potential at different months? We are searching for chickpea varieties having late-sowing potential with high yield. Do you think those varieties of ICRISAT would be useful for this purpose?

J. Kumar: If proper plant stands are established in rainfed situations or with presowing irrigation, yields of up to 1.5 t ha^{-1} can be harvested from the October-sown crop. Mean yields in Andhra Pradesh are less than 0.3 t ha^{-1}. The January-sown crop requires irrigation as the temperatures rise fast. These cultivars will have to be tried in Bangladesh conditions. Your postrainy season is much cooler than that at ICRISAT Center; this may result in higher productivity.

S.K. Roy: Lack of flowering and pod set in chickpea could be due more to environmental than soil factors. Please comment on it.

J. Kumar: Relatively high humidity and cloudy weather during reproductive phase prevents effective pod set in chickpeas. If soils lack micronutrients and there is relatively high humidity there can be reduced pod setting as well. Botrytis gray moid which may occur in damp warm weather also attacks young vegetative and reproductive parts leading to lower fruiting.

M.S. Hoque: 1. You have shown the possibility of growing chickpea in rice fields without opening the land. Was it done by dibbling or by broadcasting? How much yield was obtained?
2. Can you please tell us whether the farmers use *Rhizobium* inoculants extensively for growing chickpea in India. If they use inoculants, then how are these distributed to the farmers?

J. Kumar: 1. Yes, Both possibilities exist. I saw a dibbled crop at Jamalpur last March. They may have harvested more than 11 ha^{-1}. I have also seen some good fields where chickpea was relay cropped in paddy in eastern India. Cultivar JG 74 does well under these conditions.
2. Some farmers use rhizobia inoculants, but not as a routine.

M. A. Sattar: In our country we get very good response of pulses to *Rhizobium* inoculations in almost all the areas including Ishurdi and Jessore. Yield increase in farmers* fields was more than 55% due to inoculations. You may have watched some slides shown in our presentation yesterday. Do you think this low-cost technology could not be profitable in future as ICRISAT is discouraging inoculant use due to their nonresponse in some parts of India?

J. Kumar: I am glad to hear of your successes. During my tours in India, Bangladesh, and other countries, I have not observed spectacular increases in yield because of nodulation, maybe native rhizobia already exist. At ICRISAT microbiological work was reviewed a couple of years back, and emphasis on this research has been scaled down because the administration did not see much pay-off in this area of research.

M.O. Islam: You mentioned a variety which can be grown twice in a single cropping season at ICRISAT Center. Is this variety thermoinsensitive?

J. Kumar: Yes we have grown ICCV 2 twice between October and March at ICRISAT Center. There was no problem with its growth during this period. However, temperature variations in southern India are not extreme. We have not done precise studies on its temperature tolerance.

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Integrated Control of Pulse Diseases[1]

M .V. Reddy
International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India.

Abstract

In pulse crops, in recent years considerable progress has been made in the identification of resistance sources and in breeding high-yielding cultivars resistant to some of the major diseases. Progress has also been made in the identification of broad-based and multiple-disease resistance sources. However, work on the integrated control of diseases utilizing host-plant resistance combined with other control practices has been very limited and needs to be strengthened. To achieve a breakthrough in the management of pulse diseases, work on multiple-disease control and integration of disease control measures with varietal improvement and agronomic practices leading to an integrated crop-management system is essential.

Introduction

As I have not visited Bangladesh earlier, my knowledge of Bangladesh pulse crops and their diseases is based only upon the tour reports of my ICRISAT colleagues who visited your country and on the book on pulses in Bangladesh by Gowda and Kaul (1982). In this paper I will attempt to review the progress on control of diseases with special reference to host-plant resistance in pulse crops important to Bangladesh, The need for work on multiple-disease control and integrated management, and directions for future work are brought out. For crops other than chickpea *(Cicer arietinum* L.) and pigeonpea *(Cajanus cajan* (L.) Millsp.), I have had to depend on the reports of the rainy and postrainy Pulses Workshops of the All India Coordinated Pulses Improvement Project (AICPIP) (ICAR 1988). For pigeonpea and chickpea, the results of evaluation of germplasm and breeding materials for resistance to major diseases at ICRISAT Center and in multilocational trials are summarized. It is hoped that lines that have shown resistance in India and elsewhere will be of use to Bangladesh.

Pigeonpea

The crop is currently not important in Bangladesh. If the need arises, the results of the extensive work on disease resistance carried out at ICRISAT and AICPIP should be useful. Good progress has been made on the identification of resistance sources and cultivars resistant to fusarium wilt and sterility mosaic (SM), the two most important diseases of the crop in India. Lines resistant to both these diseases have been bred in the short- (e.g. ICPL 8324), medium-(e.g. ICPL 227), and long-duration (e.g. ICPL 9174) pigeonpea types (Reddy 1987). Lines with broad-based resistance to will and SM are also available. Lines that have shown resistance to wilt in multilocational evaluations in India are ICP 4769, ICP 7118, ICP 7182, ICP 8863, ICP 9168, ICP 10958, and ICP 11299, For SM, the lines ICP 7867, ICP 10976, ICP 10977, ICP 10983, and ICP 11146 have shown resistance at all the locations in India. For Phytophthora blight (PB), the third important disease of the crop in India, lines with high and stable resistance are not yet available, but lines such as KPBR 80-1-4, KPB 8-2-1, and ICP 113-4 with field tolerance to the

1. ICRISAT Conference Paper no. 530.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh, Patancheru, A.P. S02 324, India: International Crops Research Institute for the Semi-Arid Tropics.

disease have been identified. Seed dressing with Ridomil or Aleitte (0.3%) followed by two foliar sprays at 15-day intervals after sowing have resulted in a significant reduction in disease incidence and have increased yields. There is scope for integration of host-plant tolerance and use of fungicide for the management of PB. Choosing fields with good drainage and avoiding low lying ones, helps further. Management practices for collar rot (*Sclerotium rolfsii)* need to be worked out. Seed dressing with Rizolex (0.3%) showed good promise in laboratory tests. To consolidate the progress made on wilt and SM resistance, development of integrated-management practices involving host-plant resistance and such cultural practices as crop rotations and intercropping is desirable.

Chickpea

Much progress has been made in the identification of resistance sources, and lines have been bred that are reistant to fusarium wilt and tolerant to dry root rot (e.g. ICCC 32, ICCC 37) and resistant to wilt and field resistant to stunt (e.g. ICC 10466) (Reddy 1987). Lines with broad-based resistance to wilt and tolerant to root rots are also available (Table 1). Lines tolerant

Table 1. Chickpea lines with broad-based resistance to wilt and root-rots identified through the International Chickpea Root Rot and Wilt Nursery (ICRRWN).

	Reaction of line					
Location	ICC 2862	ICC 9023	ICC 9032	ICC 10803	ICC 11550	ICC 11551
Bangladesh-Joydebpur	S[1]	S	S	R[2]	R	R
Ethiopia-Debrezeit	R	S	R	R	R	R
India						
Bcrhampore	S	S	S	S	R	S
Dahod	R	R	R	R	R	S
Delhi	R	R	S	S	R	R
Dholi	R	R	R	R	R	R
Durgapur	R	R	S	R	R	R
Faizabad	S	R	R	S	S	S
Gurdaspur	S	R	S	S	S	S
Hisar	R	R	R	R	S	S
Jabalpur	R	R	R	S	R	R
Kanpur	S	R	R	S	R	R
Ludhiana	S	R	R	R	R	R
Patancheru (ICRISAT)	R	S	R	R	S	S
Varanasi	S	S	S	S	S	R
Mexico-Culican	R	R	R	R	S	R
Peru-Chiclayo	R	R	R	R	S	R
USA-San Luis Obispo	R	R	R	R	R	R
No. of locations tested	18	18	18	18	18	18
No. of locations resistant	11	12	12	11	11	12

1.S= ≥10% mortality
2.R= ≤10% mortality

to ascochyta blight (AB) in the vegetative stage are available (e.g. G 235, G 543, Gaurav, GNG 146, BG 261) but there is need for lines with tolerance in both the vegetative and podding stages. Work on resistance to botrytis gray mold (BGM) is in the preliminary stage. Lines having some tolerance in the vegetative stage under field conditions at Rampur in Nepal have been identified (ICCC 4, ICC 9033, ICC 2664, ICCL 86237, ICCL 83149, ICCL 86326, ICC 3075, Pusa 256, ICC 6827, ICCL 86242, ICC 1931, ICCV 5, ICC 2550, ICCL 83128, ICC 1069, ICCV 11, ICC 3208, ICC 1894, ICC 11223, ICCL 86226, Pant G 114, ICC 3630, Dhanush, ICC 3099, ICC 2595, ICC 11324, ICCL 11324, ICCL 86332, ICCL 86215, ICCL 86332, ICC 4105, ICC 1918, ICCL 85409). Further studies are needed to determine their reactions under artificial inoculation conditions in the reproductive stage, and in different locations. It appears that it is difficult to find higher levels of resistance to AB and BGM in available chickpea germplasm. Emphasis should therefore be on the integrated management of these diseases. Use of tolerant cultivars with compact and erect canopy, sown not too close together can be useful. Early sowing and excessive irrigation need to be avoided; Application of one or two fungicidal sprays in the reproductive stage (e.g. Bravo for AB and Ronilan for BGM) should also be very helpful in the management of these diseases. Better management practices for collar rot, wet, and black root rots are needed. Very little variation in reaction to collar rot has been observed in limited screening of germplasm at ICRISAT. Rizolex (0.3%) was found as effective a seed dressing fungicide for chickpea as it was for pigeonpea.

Other Pulses

Disease-resistant varieties of black gram *(Vigna radiata* (L.) Hepper), fieldpea *(Pisum sativum* subsp. *arvense),* lentil *(Lens culinaris* (L.) Medic), and mung bean *(Vigna radiata* (L.) Wilczek) released in India are listed in Table 2. Lines of fieldpea, lentil, pigeonpea, and chickpea with multiple disease resistance are listed in Table 3 (Nene 1988). Testing of these lines under Bangladesh conditions may be useful.

Integrated Control

In recent years, good progress has been made in the identification of resistance sources and breeding of high-yielding pulse cultivars resistant to some of the

Table 2. List of disease-resistant varieties of different pulse crops released in India (ICAR 1988).

Crop	Varieties	Diseases resistant to
Pigeonpea	NP(WR) 15	Wilt
	BDN 1	Wilt
	BDN 2	Wilt
	Mukta	Wilt (tolerant)
	Sharda	Wilt (tolerant)
	C 11	Wilt
	Bahar	Sterility mosaic
	WJB.20(105)	Altemaria leaf blight
	Hy 3C	Sterility mosaic
	Maruthi (ICP 8863)	Wilt
Chickpea	Gaurav (H 75-35)	Ascochyta blight (tolerant)
	Pusa 212	Wilt
	JG 315	Wilt, root rot
	H 355	Ascochyta blight (tolerant)
	C 235	Ascochyta blight (tolerant)
	GNG 146	Wilt
	G 543	Wilt
	ICCC 32(Kabuli)	Wilt
	BG 261	Ascochyta blight (tolerant)
	Phule G 5	Wilt (tolerant)
	BG 244	Wilt
	Avrodhi	Wilt
Black gram	Pant U 19	Yellow mosaic
	Pant U 30	Yellow mosaic
	UG 218	Yellow mosaic
	Co 4	Powdery mildew
	ADT 3	Leaf crinkle
	LBG	Powdery mildew
Fieldpea	Rachna	Powdery mildew
	DMR 11	Powdery mildew
	Pant P5	Powdery mildew
Lentil	Pant L 406	Rust
	Pant L 639	Rust
	PL 77-2	Wilt
Mung bean	Pant Mung 1	Macrophomina blight, Yellow mosaic
	Pant Mung 2	Yellow mosaic
	Pant Mung 3	Yellow mosaic Macrophomina blight
	ML 131	Yellow mosaic Powdery mildew
	Co 4	Tip blight, Powdery mildew, root rot
	ML 5	Yellow mosaic
	ML 267	Yellow mosaic
	ML 337	Yellow mosaic
	Pusa 105	Macrophomina blight
	Sabarmati	Powdery mildew (tolerant)

Table 3. Some lines of pulse crops with multiple disease resistance.

Crop	Diseases	Variety
Pigeonpea	Wilt, SM[1]	ICP 7198, 8024, 8860, 8861, 8862, 9142,10960, PR 5149, ICPL 227
	Wilt, SM, PB Wilt, SM, AB	ICP, 1302, ICP 11303, 11304 ICP 8861, 8862, 10960
	Rust, leaf spots	64-16A
Chickpea	Wilt, dry root rot black root rot	ICC 12237 to 12269
	Wilt, AB, BGM	ICC 1069
	Wilt, dry root rot stunt	ICC 10466
	Wilt, Sclerotinia stem rot	ICC 858, 959, 4918, 8933, 9001
Fieldpea	Brown blotch, root knot	VITA 1
	Bacterial blight. Scab, Septoria sp, Colletorichum sp	VITA 4
	Powdery mildew, rust	JP, DP 1
	Wilt, root knot, anthracrose, rust, cercospora leaf spot, bacterial pustule, bacterial blight, cowpea banding mosaic, CPMV, southern bean mosaic	Iron
Lentil	Wilt, rust	LP 12, Bombay 18, Pant L 406, GL 534, GL 535, CP 212

1. SM = Sterility mosaic: PB = Phytophthora blight: ALB = Alternaria blight: AB = Ascochyta blight: BGM = Botrytis gray mold.

major diseases. However, information on the integrated use of resistance and other methods of control is limited. Moreover, work on control of several diseases occurring together is meagre. This line of work is very important if we are to achieve any breakthrough in the management of pulse diseases because it is common for more than one major disease to affect these crops at the same time (e.g. ascochyta blight and botrytis gray mold in chickpea, wilt and SM in pigeonpea). We should also ensure that a particular practice/treatment recommended for reducing one disease does not aggravate another disease. For example, while higher plant stand reduces stunt disease, it can increase the problem of BGM in chickpea (Table 4). For all the legumes seed dressing with fungicides is necessary as diseases that affect seeds and seedlings can drastically reduce plant stands.

Integrated Crop Management

Another problem in the management of pulse diseases is that many of the optimum agronomic practices for high yield can favor disease buildup. For example, in the case of chickpea (Table 4), early sowing and irrigation which are recommended for obtaining higher yields, favor ascochyta blight and botrytis gray mold buildup by inducing heavy vegetative growth. Also, high-yielding cultivars of the spreading type favor these diseases more than the tall and erect types which have lower yield potential. Hence it is essential to integrate varietal improvement, agronomic practices, and disease management aspects for developing practical disease-management systems.

Discussion

M. Matiur Rahman: The root-rot resistant materials of ICRISAT do not show resistance at Ishurdi. But some of the wilt-resistant lines show resistance. Should we release the wilt-resistant lines which lack root-rot resistance?

M.V. Reddy: The lines from ICRISAT are resistant to fusarium wilt and tolerant to dry root rot (*Rhizoctonia bataticola).* They may not have same level of resistance to collar rot *(Sclerotium rolfsii),* black root rot (*Fusarium solani),* and wet root rot *(Rhizoctonia solani).* Any line showing better performance against wilt and/ or root rot fungi than the check cultivars should be considered for release.

Table 4. Gaps in knowledge on integrated management of chickpea diseases.

Operation	Wilt	Dry root rot	Collar rot	Stunt	Ascochyta blight	Botrytis gray mold
Crop rotation	6 years	-[1]	-	-	1 year	-
Variety	ICCV 2 ICCV 5 ICCV 32	ICCV 2 ICCV 5 ICCV 32	- - -	ICCV 5 ICCV 32 -	Gaurav[2] ICCV 32[2]	ICCV 5[2] BG 267[2]
Maturity of variety	-	Early	-	-	Early[2]	Early[2]
Land preparation	-	-	Free of undecom posed Organic Matter	- -	Destroy diseased debris	
Seed Dressing	Benlate (0.15%)	1Thiram (3g ha^{-1})	Thiram (3g kg^{-1})	-	Thiaben-dazole	Bavistin 1IMTD
Sowing date	Normal-Late	Early[2] Late	Normal-Late	Normal-excessive	Not excessive	Not
Foliar sprays	-	-	-	Insec-ticide sprays if nec-essary.	Daconil (3g kg^{-1}) after each rain	Ronilan (3g kg^{-1}) after each rain
Irrigation	More	More	Less	-	Less	Less

1. No information available.
2. Based on observations, experimental evidence lacking.

M.P. Bharati: In Bangladesh, wilt has always been rated as one of the major diseases both in chickpea and lentil but won't the flooding conditions prevalent in Bangladesh reduce the level of inoculum?

M.V. Reddy: Flooding in general is known to supress *Fusarium.* The *effects* of flooding on chickpea and lentil fusaria need to be studied. Temporary flooding may not be able to drastically reduce the population. In India, in Gujarat State, chickpea wilt is a problem where temporary flooding in the rainy season occurs.

Mahabubur Rahman: At ICRISAT, pathologists and entomologists have developed combined nursery for wilt and *Heliothis* resistance screening of chickpea. Could the same program and facilities be extended to BARI's program?

M.V. Reddy: A limited amount of materials of chickpea andpigeonpearrom BARI can be evaluated at ICRISAT and the results will be provided.

H.U. Ahmed: As *Fusarium and Sclerotium* are soil-borne pathogens and causing serious problems for chickpea cultivation, do you suggest any control measure other than resistant varieties? Do you have any experiment on polythene mulch? Botrytis gray mold does not occur seriously every year in this country.

Could you kindly tell us the predisposing factors by which we can forecast the disease incidence?

M.V. Reddy: 1. Lines resistant to fusarium wilt are available. Seed dressing and clean cultivation of wilt-resistant lines should help in minimizing the collar rot problem.
2. Experiments on soil solarization with polythene mulch at ICRISAT have shown that soilborne diseases can be controlled but the economics should be looked into before suggesting it as a control measure.
3. Temperatures around 25°C and high humidity favor gray mold.

M.A. Bakr: I understand work on resistance screening against downy mildew of millets is done at ICRIS AT. Do you think that procedure will be equally applicable in case of resistance screening against downy mildew of khesari (*Lathyrus sativus* L.)? If so, how ICRISAT can assist in equipping the pulse pathologists in Bangladesh with the technologies available at ICRISAT?

M.V. Reddy: Spreader rows and perfo-irrigation can be useful in creating higher disease levels in endemic areas.

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Problems and Prospects of Increasing Pulses Production in India[1]

P.N. Bahl

Indian Council of Agricultural Research, New Delhi, 110001, India.

Abstract

Pulses are complementary to cereals in terms of pattern and profile of amino acids. That would probably explain the adoption of dhal-roti *or* dhal-bhat *as the staple food in the diet of the people of Indian subcontinent. When India was faced with massive food shortages in the 1960s, it took some bold policy decisions to change the outlook of traditional agriculture. In pursuance of this policy, India has developed a massive research and development infrastructure during the last 25 years. In fact, during the 1940s and 1950s pulse breeders were working mostly in isolation with limited germplasm and limited situations. However, pulse-improvement work received afresh impetus in the mid-60s when the All India Coordinated Project for Improvement of Pulses (AICPIP) was initiated. Since then a number of high-yielding varieties of most pulse crops have been developed. But production of pulses still hovered around 12 million t for many years. However, the 1988/89 production is estimated to be 15.4 million t. A critical analysis of production gaps showed that there are large differences in yields recorded at researchfarms and those obtained at farmers' fields. Evidently, advantage of improved varieties and improved agricultural practices have not been transferred to the farming community. To achieve these results, India has launched the National Pulses Development Project on a massive scale to extend the high-yield technology in 28 potential districts for chickpea (*Cicer arietinum *L.) and 20 for pigeonpea (*Cajanus cajan *(L.) Millsp.). During the 1990s, India will further strengthen the pulses research improvement work by establishing an independent pulses research institute with emphasis on multidisciplinary approach, which will help to meet our production targets for 2000 AD.*

Discussion

M. P. Bharati: India has generated considerable improved pulse-production technology including high-yielding varieties (HYVs). However, the yield gap has still remained large and this may be related to coverage of pulse area with high-yielding varieties. What is the estimate of coverage by HYVs?

P. N. Bahl: The yield gaps you are referring to are due to various factors including lack of spread of HYVs. I think concerted efforts have to be made to popularize the newly evolved HYVs and to transfer the improved agricultural technologies to bridge the yield gaps. I don't have any estimate of the coverage of HYVs of pulses in India.

A. Ahad Miah: In research needs, you have mentioned synchronous podding in case of mung bean (*Vigna radiata* (L.) Wilczek), but you did not mention this for black gram (*Vigna mungo* (L.) Hepper). Do you have synchronous varieties of black gram?

P. N. Bahl: At present we do not have synchronous varieties in black gram. Variety T 9 may be the best-available commercial cultivar in this context, espe-

1. Only the abstract is published as the full paper was not available.

Citatum: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

cially when grown in summer.

M. A. Aziz: 1. What are the cropping patterns that the farmers of India follow for mung bean and black gram? 2. What are the yield potentials of these two crops during summer?

P. N. Bahl: By virtue of its early duration, mung bean provides an excellent choice as a catch crop in several niches both under rainfed and irrigated situations. It has shown promise in rice fallows. Black gram is preferred where a longer crop season in comparison to mung bean is available, particularly in humid areas. Black gram is widely grown on rice bunds. During the summer season, mung bean mean yields ranged from 600 to 1000 kg ha^{-1}.

M. M. Rahman: Are you not breeding for resistance to any diseases of khesari (*Lathyrus sativus* L.)?

P. N. Bahl: Yes, we try to breed varieties resistant to rust and powdery mildew. However, the priority area is to breed varieties with low BOAA content.

Status of Pulses Research and Future Strategies in Nepal

M. P. Bharati

National Grain Legumes Improvement Program G.P.O. Box 404, Khumaltar, Kathmandu, Nepal

Abstract

Pulses are very important crops in Nepal in terms of their contribution to human and animal nutrition, as components of indigenous cropping systems, and restorers of soil fertility. They rank fourth in area and production. Diverse agroclimatic conditions ranging from warm subtropical to temperate allow Nepal to grow many pulse crops. Yields of these crops have remained low due to several production constraints. Research on pulses has been limited and unorganized in the past and efforts to develop improved production technologies have been recent. Research in the past concentrated mainly on varietal improvement. The National Grain Legumes Improvement Program (NGUP) was established in 1985 to coordinate pulses research nationally in an organized and systematic way. A few improved varieties of some crops have been recommended and some more have been identified. Some management practices for higher productivity have also been recommended. More significantly, major biotic and abiotic production constraints have been identified from past research. Therefore, future research strategies have been developed in order to overcome the identified constraints which include strengthening institutional capacity, development of improved varieties and area-specific production technologies with the overall objective of increasing pulses production in the country.

Introduction

Pulses or grain legumes including soybean *(Glycine max* (L.) Merr.) occupy a very important place in the Nepalese agricultural system. They meet the bulk of the protein requirement for the majority of the human and animal population and restore to a great extent the degraded soil fertility. They also constitute an integral part of the various cropping systems followed in the country and possess considerable potential as an export commodity in surplus years. These rank fourth in area and production among the major food crops grown in Nepal. The major pulse crops are lentil *(Lens culinaris* Medic), khesari *(Lathyrus sativus* L.), chickpea *(Cicer arietinum* L.), pigeonpea *(Cajanus cajan* (L.) Millsp.), mung bean (*Vigna radiata* (L.) Wilczek), black gram (*Vigna mungo* (L.) Hepper), horse gram *(Macrotyloma uniflorum* (Lam.) Verde), and cowpea *(Vigna unguiculata* (L.) Walp.). The area, production, and productivity of these crops for the past 3 years have shown an upward trend (Table 1). The unfavorable weather conditions during the year i987/88 have slightly reduced the production and productivity in that year.

The growing environments range between latitudes 27° and 30°N and longitudes 80° and 86°E with varying climates and topography ranging from the humid subtropical lowlands to alpine elevations above 4000 m. The annual precipitation ranges from 1000mm to more than 5000 mm.

The State of Pulses Improvement

The National Grain Legumes Improvement Program (NGLIP) has recently (1988/ 89); joined the group of National Programs under the newly formed National Agricultural Research and Services Centre (NARSC) of the Ministry of Agriculture (NGLIP 1988). Prior to the augmentation to the National Commodity Program, limited research on some food legume crops was being

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Area, production, and productivity of grain legumes in Nepal, 1985/86 -1987/88.

	Area ('000 ha)			Production ('0000 t)			Productivity (kg ha^{-1})		
Crop	1985/86	1986/87	1987/88	1985/86	1986/87	1987/88	1985/86	1986/87	1987/88
Lentil	103.2	107.3	112.8	61.2	73.1	63.1	593	682	56
Khesari	53.3	53.9	44.0	28.1	28.9	19.5	527	536	443
	29.4	31.1	29.6	18.1	21.1	15.6	619	679	527
Soybean	13.2	15.9	18.7	7.6	9.2	10.1	576	578	540
Black gram	13.6	15.4	18.3	6.6	9.0	10.3	485	584	562
Horse gram	12.3	12.1	10.3	7.0	6.6	5.0	569	545	485
Pigeonpea	16.0	17.4	18.5	12.1	13.4	9.1	758	764	492
Others	25.0	25.5	12.2	12.8	13.5	6.5	500	529	532
Total	253.6	262.9	264.5	146.1	166.1	139.4	576	631	527

Source: DFAMS (1988).

carried out under the leadership of the Agronomy Division with no outside support.

NGLIP received priority in the current Five Year Plan (1985/86-1989/90) and in the Basic Need Program from HMG/N, and the support has now been increased. In addition to this, NGLIP has been receiving help from the International Development Research Centre (IDRC), Winrock International/ Agricultural Research and Production Project (WI/ARPP), USAID-Nepal. More recently, ICRISAT's Asian Grain Legumes Network (AGLN) has provided some operational funds for the research work on chickpea and pigeonpea and frequent technical services. Other International Agricultural Research Centres (IARCs) such as International Center for Agricultural Research in Dry Areas (ICARDA), International Institute of Tropical Agriculture (IITA), International Rice Research Institute (IRRI), Asian Vegetable Research and Development Center (AVRDC), and International Soybean Program (INTSOY) have been providing germplasm, information, training, and exchange of visits (Bharati and Joyaswal 1989).

Research Accomplishments

In spite of the several major constraints, operational problems, and lack of adequate staff, NGLIP has made some important advances in the pulses improvement technologies in Nepal. These achievements are summarized below.

Germplasm collection, characterization ,and preservation

NGLIP is giving increasing priority to this activity. So far, there has been systematic collection made on pigeonpea (225), chickpea (250), and khesari (88). The other food legume species have not been systematically collected. However, some collection has been made for lentil (63). NGLIP is presently keenly involved in collecting, characterizing, and preserving these valuable local germplasm. We plan to publish a small catalogue.

Varietal improvement

As a result of extensive testing on agricultural stations/ farms and in the farmers' fields, the following varietal recommendations and identifications have been made:

Recommended

Crop	Cultivar	Year	Source
Chickpea	Dhanush, Trishul	1979	Local
	Sita,Radha	1987	India and ICRISAT
Mung bean	Pusa Baisakhi	1976	India
Lentil	Sindoor, Shishir, Simrik	1978	Local and India
Black gram	Kalu	1980	India

Identified		
Cowpea	IT 82 D 889, IT 82 D 752, All-season	IITA and The Philippines
Pigeonpea	ICPL 366, Rampur Local	ICRISAT, local
Lentil	LG 7, ILL 4404	India, ICARDA
Chickpea	ICCL 82108, K 850	ICRISAT, India

Khesari remains an important legume crop. Improvement work has been initiated through collection of local germplasm and introduction of low-neurotoxin lines from Canada, followed by evaluation and selection. NGLIP has become a member of the Coordinating Committee of the International Network for the Improvement of Lathyrus and the Eradication of Lathyrism (INISEL).

Diseases and Pests

The following pests and diseases have been found to be most damaging to legume crops:

Crops	Pests	Diseases
Lentils	Nematodes	Wilt, rust, botrytis
Cowpea	Thrips, nematodes	Bacterial blight, frog eye
Chickpea	Nematodes, pod borer	Botrytis, wilt
Pigeonpea	Nematodes, pod borers	Sterility mosaic, botrytis, stem canker
Mung bean/ Black gram	Nematodes, hairy caterpillar	Frog eye, yellow mosaic virus

Effective screening techniques have been developed and used for wilt disease in lentil and chickpea, for botrytis in chickpea, sterility-mosaic disease in pigeonpea, and for nematodes in various crops, in cooperation with ICRISAT. In fact a number of local lines have been identified as resistant. Chemical control methods have been developed for nematodes and major insects.

Management practices

Management practices like chemical weed control in summer legumes, date and ratio of relay cropping of lentil in paddy, intercropping ratio of lentil and chickpea with other winter crops, alley cropping of pigeonpea and other summer crops, have been developed and recommended. In addition, information on planting times and planting methods for other grain legumes has been generated. Successful inoculation methodologies for lentil in the hills have been developed and recommended. Isolation of rhizobial strains from different agroclimatic zones and for different crops is under way. Low pH, inadequate nodulation, and low organic matter were found to be major soil-related constraints at Rampur (Inner *terai)* and other hill areas.

Various sites of the Farming Systems Research Division have been used to verify the grain-legume technology. Feedback from these testing sites and farmers' fields has enabled NGLIP to tailor its research technology to farmers' needs. The distribution of minikits has enabled a quick and large-scale dissemination of proven technology.

NGLIP has demonstrated the good adaptation and high yield potential of lentil in the hills and valleys (up to 2000 m). Lentil is currently used in the production program in the hills.

Future Strategies

NGLIP will follow the following strategies with the general objective of increasing pulses production on a sustained basis.

Institutional Development

The major functions of research, outreach production, and training/information will be carried out from Rampur, the headquarters for *terai* and from Khumaltar, the headquarters for the hills. Presently, NGLIP is functioning under NARSC which is directly under the Ministry of Agriculture. In the future, National Agricultural Research Coordination Committee (NARCC) and NARSC are expected to be merged together to form one autonomous institution and NGLIP will operate directly under the new institution.

Linkage with International Agricultural Research Centers besides 1CRISAT and ICARDA will be explored and formalized. Additional infrastructure will be completed at Rampur.

Technical Program

Development of improved varieties

Development of improved varieties will continue to remain a major activity of NGLIP. Emphasis will be given to the development of:

- bold-seeded and early lentil varieties,
- khesari varieties with low neurotoxin,
- adapted kabuli types of chickpea,
- pigeonpea varieties of short and medium duration, and
- stable and high-yielding varieties of black gram, mung bean and cowpea under rice-and maize-based cropping patterns suitable to diverse agroclimatic conditions.

Resistance to hiotic constraints

Hybridization (involving local and exotic lines) to incorporate resistance to already identified diseases will be initiated. Priority will be given to breed resistance for:

- wilt disease in lentil and chickpea
- botrytis gray mold in chickpea
- sterility-mosaic disease and stem canker in pigeonpea
- yellow mosaic virus disease in black gram and mung bean.

Pest control through the development of proper management methods like escape mechanism, manual control in early instar stages of hairy caterpillar incidence on mung bean and black gram, and varietal screening for resistance will receive topmost priority. In cases of control by pesticides as in the case of pod borers in chickpea and pigeonpea, different pesticides will be screened to find out the most economical and effective doses.

Severities of pest incidences have been found to vary across years. Yearly entomological surveys will be conducted to find out the dynamics of pest incidence and also to identify new pests.

Management practices

Management studies will concentrate upon:

- method of land preparation and planting date studies on lentil in the hills;
- plant density and spacing studies on short and medium-duration pigeonpea planted as a postrainy-season crop in *terai;*
- management of perennial pigeonpea, including number of prunings planted in the bunds of hills;
- date and rate of seeding of lentil and chickpea in both *terai* and hills;
- intercropping and alleycropping studies of various legumes with maize and pigeonpea;
- evaluation initiated to determine inoculation technology for acidic soils at Rampur (including crop species, varieties, rhizobia strains and rhizobial carriers) will continue. Special studies like Mo nutrition, and strain survival under acidic soil conditions of Rampur will also be undertaken; and
- studies will be initiated in liming, application of phosphorous, zinc, and molybdenum, and incorporation of different sources of organic matter.

Biochemical studies

Nutritionally, grain legumes rank far better than cereals. However, many legumes also contain antinutritional factors. Studies will be initiated in collaboration with the Central Food Research Laboratory in the areas of determination of antinutritional factors and development of simple methods of detoxification.

Seed production

NGLIP will be responsible for producing nucleus, breeders' and some foundation seed of varieties that are to be released. Foundation seed will also be produced on other farms. Certified seed of released varieties will be produced by the Agricultural Input Corporation in farmers' field.

On-farm work

On-farm replicated trials, often in coordination with the Farming Systems Research Division, will be conducted in the major agroclimatic zones. Trials will address either the evaluation of improved germplasm, management practices, or both. Farmers are expected to participate actively in this process which will enhance the dessemination of improved technology.

Transfer of technology, training, and publications

Transfer of technology will be accomplished in collaboration with the extension service and by distributing "minikits". Distribution of minikits has had good impact. At least 1000 packets will be distributed each year. Training and publications especially suited to farmers will be arranged on a regular basis.

Discussion

O. Islam: You mentioned that you have successfully introduced lentil at 2000 m altitude in your country. Is it the same variety for higher altitudes which is grown in the inner *terai?*

M.P. Bharati: Same varieties are doing well in both environments. However, the lentil cultivar 'Shrink' performs well in the hills and is recommended for those areas.

M.A. Zaman: You have not said anything about postharvest research strategies. Don't you have any problems regarding drying of pulses during monsoons or in farm-level storage or for milling?

M.P. Bharati: Harvesting does not coincide with the monsoon in Nepal. So we do not have the problem of drying. Long-term storage poses pest problems. This problem will be tackled as we strengthen NGLIP with technical manpower.

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Status of Pulses Research and Future Strategies in Myanmar

U. Thaung Pe
Myanmar Agricultural Service, Rangoon, Myanmar

Abstract

*Pulses are important in the agriculture of Myanmar. These cover about 85% of the total cultivated area. Chickpea (*Cicer arietinum *L.), lima bean (*Phaseolus lunatis *L.), black gram (* Vigna mungo *(L.) Hepper), pigeonpea (*Cajanus cajan *(L.) Millsp.), lablab bean (*Lablabpurpureus *(L.) Sweet), and mung bean (*Vigna radiata *(L.) Wilczek) account for 80% of all pulse crops. The central part of Myanmar accounts for 80% and the delta region 10% of the total pulses area. The productivity in general is low because of: (a) lack of high-yielding cultivars, (b)poor cultural management, (c) inadequate plant-protection measures, (d) poor postharvcst handling and storage facilities, and (e) price instability. Recently high-yielding chickpea cultivars such as Yezin 1 (P 436), Shwekyimon (K 850 x F 378), ICCV2, ICCC4, ICCC 32, and ICCC 42 have shown promise. Similarly in black gram, Yezin 1, and Yezin 2; in mung bean, Pedisein 1 to 4; in pigeonpea, Yezin 1 and Yezin 2; and in cowpea (*Vigna unguiculata *(L.) Walp.) Yezin 1 produced high yields at research stations. Farmers' field demonstrations of these have been carried out in 164 townships. Future strategies include: subzoning of the country into four zones for better management, introduction and breeding of high-yielding disease-resistant cultivars, and development of packages for higher production that will be demonstrated to the farmers.*

Introduction

In the economy of Myanmar the importance of food legumes has long been recognized both in agriculture as a traditional component and as a source of protein in the diet. These occupied 8.4% (846 086 ha in 1986/87) of the total cultivated area of 10 million ha. Despite the present status of low productivity per hectare, the total production of 613 000 t is sufficient to meet the domestic needs and we were able to export 97 000 t of pulses in 1986/87.

Eleven species make up the family of food legumes in Myanmar. However, chickpea (*Cicer arietinum* L.), lima bean *(Phaseolus lunatis* L.), black gram *(Vigna mungo* (L.) Hepper), pigeonpea *(Cajanus cajan* (L.) Millsp.), lablab bean (*Lablab purpureus* (L.) Sweet), and mung bean *(Vigna radiata* (L.) Wilczek), constitute 80% of all food legumes, and are under more intensive study. It is hoped that other legumes of equal importance will be incorporated as the Pulses Division of the Agriculture Research Institute is strengthened with more trained personnel. The pulses are confined to two major zones. About 80% of the area is in the dry zone or central part of Myanmar and 10% is in the delta region. Both regions have tremendous potential for improvement, but the nontraditional area, i.e., the delta region, can be regarded as the new frontier for expansion of these crops. Pulses are normally classified into three categories, depending on the nature of cropping system:

1. as catch cropsin the multiple-cropping system;
2. as contingent crops when there is a main-crop failure; and
3. as main crops, as in the dry zone.

The cultivation is spread over a large area and in different seasons. Therefore productivity and profitability can also be expected to vary, for example, pigeonpea is planted with the onset of rains, lima bean as a mid-season crop, and chickpea, which has the

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Mean area, production, and productivity of food legumes in Myanmar, 1985/86.

	Area ('000 ha)	Productivity (t ha^{-1})	Production ('000 t)
Black gram	78.01	0.76	51.62
Mung bean	36.99	0.41	14.56
Pigeonpea	62.23	0.52	28.42
Lima bean	66.14	1.02	633.99
Lablab bean	83.12	0.61	46.60
Chickpea	177.30	0.72	109.55

largest hectarage, is a late rainy-season crop. The area distribution and relating cropping systems are shown in Tables 1 and 2.

The first attempts to establish research and the improvement of the pulses in Myanmarwere recorded by several scientists and economic botanists before World War II. This period is regarded as the first phase in food-legume research. Karachi, a chickpea cultivar, and Mokilima, a lima bean cultivar introduced in 1923, are still[1] being grown widely although, as can be seen from several yield trials carried out, their productivity under the simple growth index (SGI) indicated low efficiency in grain production. The postwar years until 1974 can be assumed to be the secopd phase in the food legume research of Myanmar. Activities during this period, though they produced numerous data on fertilizer trials and date of sowing, did not have the desired impact on food-legumes improvement, since priority was given to research on cereals and oil crops. Results from these trials also did not show other factors such as soil moisture, daylength sensitivity, or effects of these variables on seed size. The lack of these is not so much a question of ommision by researchers but the lack of development of these concepts. As pointed out by Rajan (1978) in his report, research on food legumes was carried out on 16 experiment stations and 54 farms. Prominent cultivars that were released during this period were Madagascar, Mahlaing flat, and white lima bean; and P 11-30 black gram. From 1974 onwards to the present is the third phase in food-legumes research. This period is marked by the introduction of the Food Crops Development Project, assisted by FAO/UNDP. This constitutes the first time that exclusive research on pulses was organized. The project aimed at strengthening the Agriculture Research Institute, which previously did not have a research program for these crops because it was not yet fully staffed.

The Food Legume Specialist of the FAO/UNDP/FCDP/Project, working with the Agriculture Research Institute (ARI), has been able to identify the problems and constraints on production of food legumes and, based on this study, long- and short-term recommendations were formulated. The project also opened contacts with other international organizations and agencies. This has helped the pulses project in the exchange of scientists, introduction of genetic stocks, and the training of national scientists.

Table 2. Area, and cropping systems for major food legumes in Myanmar, 1984/85.

	Total area sown (ha)	Mixed+mono %	Multiple-rice-based (%)	Upland crop-based (%)
Chickpea	198 865	35	31	34
Pigeonpea	81 386	99	nil	1
Mung bean	91 800	13	85	2
Lima bean	223 398	26	2	72

Constraints to Production

In many ways the problem of low yields in the central or dry zone region of Myanmar, where 80% of the food legumes are cultivated, lies with the attitude of the fanners themselves towards food legumes. These farmers, although noted for their perseverance and intelligence in the cultivation of other dry-zone crops, have not given food legumes the attention or the intensity of farming practices equal to other crops. The reasons are that crop failures are often experienced due to inadequate moisture: rainfall is irregular, and there are droughts. Legume crops are therefore not given the priority they deserve, resulting in a further lowering of yields.

The limiting factors have been identified as below:

1. Poor crop management and husbandry;
2. Low yield potential of the indigenous landraces, these being highly variable;
3. Narrow genetic resources and slow and limited availability of exotic germplasm;
4. Low levels of inputs;
5. Inadequate plant-protection measures;
6. Low priority status of the crops;

7. Inadequate postharvest handling and storage; and
8. Economic problems such as price instability, quality control, and grading

The above factors, either individually or in combination, contributed to low levels of production. Therefore, the Agriculture Research Institute has formulated long- and short-term programs based on the following research priorities:

1. Selection of specific field crops (chickpea, black gram, mung bean, pigeonpea, lima bean, and cowpea *(Vigna unguiculata* (L.) Walp.).
2. Cropping systems (mono, mixed, multiple cropping).
3. Cropping region (dry zone, delta region, and others).
4. Specific export requirement, with particular reference to quality and quantity.
5. Specific domestic requirement.
6. Regional and seasonal requirement.
7. Proper cropping systems.
8. End-use pattern requirement (nutritional values and antinutritional factors).

Varietal Status of Pulse Crops

Chickpea

Present cultivar	Karachi: introduced in 1923.
New selections	P 436 released in 1982 as Yezin 1. K 850 x F 378 is a promising cultivar under consideration; released cultivar will be given the name-Shwekyimon. Other promising cultivars are: ICCV 2, ICCC 4, ICCC 42, and ICCC 32. ICCV 2 is able to stand stress and is of short maturity; it is well suited as a second crop in problem soils.

Pigeonpea

Present cultivar	Kywegyan Shewdigar and Ngasan Pe. Although these cultivars still lead in general cultivation, and are long-duration types; these also provide firewood. Pigeonpea is intercropped with sesamum, groundnut, and short-staple cotton.
New selections	Yezin 1 (1980), Yezin 2(BR-172) (1982). The cultivars ICPL 83074, **ICPL** 87, ICPI 7035, and ICPL 8324 were found promising, having the desirable characters of high yield, short duration, and dwarf stature. These traits are ideal in the cropping system after sesamum, mung bean, and rice.

Black gram

Present cultivar	P11-30 has now replaced an older late-maturing local cultivar. This Is early-maturing.
New selections	Cultivar P45-1 (Yezin 2) has been released. It is high-yielding, has large seed size and is good for export. U 19 (Yezin 1) is day length insensitive and early-maturing. It has been released. Under consideration for later release are PL 5-364 and BP 3, the latter being an early-maturing cultivar (80-90 days).

Mung bean

Present cultivar	Pedisein, a small-seeded cultivar is late-maturing but is still widely cultivated.
New selections	Yezin-Pedisein 1 released in 1980, Yezin-Pedisein 2 released in 1982, Yezin-Pedisein 3 released in 1988, Yezin-Pedisein 4 released in 1988, Myakyomon - 1 released in 1980,Myakyemon 2 (CES-87) released in 1982. Sample 1, a cultivar with only 60-65 days duration, is expected to replace sesamum in some locations. VK 76-1 is another new introduction that is suitable for the Upper Myanmar I Region.

Lima bean

Present cultivar The majority of the area is sown with

	an old cultivar released in the 1960s from the Mahlaing Experimental Farm. Two other cultivars; M 1 and M27/30, are also grown. These are all daylength-sensitive.
Newselections	PI 83-10, G 25192, PL 83-11, and PL 85-10.

Cowpea

Old cultivar	Bocate is still grown but it will be replaced by Yezin 1 (Pelun). Vita 4, a short and early-maturing vegetable type from IITA is resistant to both aphids and bruchid beetle.

Continuing activity on cultivar selection, and introduction of germplasm from various international agencies, is being carried out by the Agriculture Research Institute at Yezin, and at other locations and experimental farms. Preliminary and advanced tests on research stations and trials on farmers' fields have been carried out for adaptability and acceptability. Since 1986/87 a total of 560 variety trials have been conducted.

Agronomic Practices

A total of 449 trials have been carried out following cultural practices to maximize production. These included agronomic trials on optimum time of sowing, plant densities, and methods of fertilizer application. In total, 164 township field demonstrations have been carried outin cooperation with the Extension Division. Pilot-scale production blocks (100) of 200 ha and smaller blocks (68) of 40 ha were planted in various parts of the country.

Another major achievement of the food legume work has been the *Rhizobium* trials, and distribution of large quantity *of Rhizobium* packages. A total of 1205 rhizobia trials helped convince farmers of this new fertilizer alternative in 1987.

Other agronomic practices included and studied were for the semi-arid dry zone. Methods for breaking of hard pans by various small farm implements for the cultivation of food legumes have been introduced, but the transfer of these new technologies will have to be closely linked with the Extension Division in order that the cultivators become fully aware of them. Many improvements will still have to be made in these ongoing research programs.

Future Strategies

The present strategy for food legumes in Myanmar has focused on the improvement of cultivars, and this will continue. Substantial numbers of germplasm have been assembled with the help of several international research institutes and organizations (Table 3). A structure for varietal improvement has been formulated for various regions. Breeding for an increased number of better strains continues, at the Agriculture Research Institute and various experiment stations. It is expected that high-yielding cultivars from other sources will be identified for each region and season. With the present change in economic policy, food-legume improvement programs should include work on low-input cultivars and lay emphasis on high-yielding, high-input cultivars as well.

In compliance with the national program to increase food-legume production an immediate research program will be laid down to cover each of these areas of production and to study natural constraints in different regions, and to identify specific crops for specific zones. These may be grouped into four regions:

- the delta region for a second crop after rice;
- dry zone region, with emphasis on moisture stress;
- irrigated regions; and

Table 3. Germplasm of food legumes available at the Agricultural Research Institute, Yezin, Myanmar, 1989.

Crop	Types of germplasm: Landraces	Exotic	Total
Lima bean	85	194	279
Mung bean	47	46	93
Chickpea	26	506	532
Pigeonpea	3	222	225
Black gram	38	112	150
Soybean	3	164	167
Winged bean	2	18	20
Kidney bean	1	67	68
Lablab bean	10	2	12
Lentil	4	167	171
Total	219	1498	1717

Source: ARI (1989)

- highland regions — Shan and Kachin — for soybean *(Glycine max* (L.) Merr.) and other legumes.

The delta region

This region accounts for 10% of the total area and legume cultivation can be extended there. The southern delta area (Irrawaddy, Rangoon, Pegu, in Lower Myanmar) is characterized by heavy seasonal rainfall, but such food legumes as chickpea, black gram, mung bean, and soybean, which follow paddy crops, are raised in the dry part of the year. This area has favorable soil conditions and easy access to irrigation. The main problem is acidity of soils and high temperature that is not conducive to maximum production. The research thrust for this region will be for the breeding of cultivars that are tolerant to low soil pH and high temperature.

Upper Myanmar dry zone region

As the Agriculture Research Institute and most of the experimental stations are already in this region, there is a concentration on the research for food legumes but future strategy will be to strengthen the present research programs and staff. This area will need drought-resistant, daylength- and thermo-insensitive cultivars. For parts of this area under irrigation high-yielding cultivars that can utilize high inputs should be given priority in variety selection programs.

Irrigated regions

These are mostly in Upper Myanmar where irrigation is available and farmers cultivate pulses. Therefore, cultivars which respond to high inputs and irrigation and which can be rotated with rice are needed. Returns from pulses should be comparable to those from other high-yielding crops.

Highland regions

These are situated between 22°N and 26°N latitude, with an average altitude ranging from 500m to 2000m. This area has assured rainfall and the soil condition is well suited for soybeans, kidney beans *(Phaseolus vulgaris* L.), and chickpea. Because of low temperature in winter, most food-legume crops will have to be grown as early rainy-season crops, that is in May, and June or July or August. Identification of species and cultivars that will suit this area, and exploring the potential of this area is one of the thrust areas for research. Results from the ICRISAT research at Gwalior will be useful in the development of food grain crops in this region.

Conclusion

Food legumes occupy an important sector in the economy of Myanmar. These meet the domestic requirement and also generate foreign exchange. Nevertheless, the present export volume is much lower than in earlier years. During 1958 to 1967 Myanmar exported an average of 105 600 t, but in 1986/87 the export has gone down to 90 000 t. The decline may be due to many factors and one of them is the low quality of the produce. Improvement of quality and size of grains is one of the most important characters for all the cultivars that are to be released in the future. Thus postharvest technology should be taken into account. The research for *Helicoverpa* resistance or tolerance and other plant-protection measures will also be considered.

Six food-legume crops comprising chickpea, white lima bean, pigeonpea, black gram, mung bean, and cowpea were given priority in the present research program. With the expectation of expanding trade inclusion of soybeans, kidney bean, and other food legumes such as lentil *(Lens culinaris* (L.) Medic), should also be considered for further research programs. About 8% of food-grain crop production is handled mechanically. Traditional implements must be improved or increased use of tractors must be considered. The International Rice Research Institute (IRRI) Farming Systems Project is working on a new type of plow for zero tillage or minimum tillage after paddy for food-legume crops, which may be quite useful.

Discussion

D.G. Faris: Can you please explain how you transfer your technology through your 40-ha blocks - through ARI, ARD, extension ? How is the farmer involved in this process ?

Thaung Pe: Agriculture extension, research, distribution, and procurement of inputs are under our organization, which facilitates transfer of technology to the farmer. With the help of the administrative agency, high technology sites are selected. Improved seeds and inputs are supplied in these areas. The results are shown to other farmers during field days.

The involvement of the ARI is in the formulation of technology and supply of basic seeds. Formulation of technology is based on research funding in collaboration with extension package programs. The Applied Research Division multiplies the basic seeds obtained from ARI and tests the technology. Registered seed is supplied to the extension division.

J. Kumar: FAO records show that mean yield of chickpea in Myanmar in 1986/87 was 0.93 t ha^{-1}. The mean yields in your paper for 1985/86 are 0.43 t ha^{-1}. What is the actual position?

Thaung Pe: Mean yields of chickpea in Myanmar for 1986/87 were 0.88 t ha^{-1}. This is taken from the Burma Land Research final report. Myanmar produces the first survey report in October and the second survey in January. The annual report is published at the end of March. There can be discrepancies in figures depending on which report was referred to.

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Breeding Lentil for High Yield, Stability, and Adaptation[1]

R.S. Malhotra and W. Erskine
International Center for Agricultural Research in the Dry Areas,
(ICARDA), P.O. Box 5466, Aleppo, Syria

Abstract

Lentil (Lens culinaris *Medic.) is an important food legume in West Asia, the Indian subcontinent, Southern Europe, North Africa, Ethiopia, and North and South America. Mean lentil yields are low because of poor crop management and low yield potential of landraces. In South Asia and East Africa diseases are also major constraints to production. The breeding schemes followed at ICARDA for the Mediterranean countries, southern latitudes, and high-elevation areas are discussed. Strategies for breeding cultivars for earliness and wide adaptation, suitable for mechanical harvesting, resistant to diseases (wilt and root rot, rust, ascochyta blight, botrytis gray mold, and stemphylium blight), cold, and drought, have been discussed. Some joint efforts by ICARDA and Bangladesh food-legume scientists for improvement of lentil in Bangladesh are discussed.*

Introduction

Lentil *(Lens culinaris* Medic.) is an important food legume in West Asia, the Indian subcontinent, Southern Europe, North Africa, Ethiopia, and North and South America. The crop has a high nutritive value and is also used as an animal feed. Lentil fixes atmospheric nitrogen in association with *Rhizobium* sp and is thus very important in rotation with cereals in maintaining the nitrogen balance in the soil.

Lentil is cultivated as a winter crop in the Mediterranean region and the Indian subcontinent, and as a spring crop in the Central Anatolian Plateau in Turkey, North Europe, and the Americas. It is predominantly a rainfed crop.

Area and Production

The area, production, and productivity of lentils worldwide (FAO 1970, 1981) revealed that the production of lentil increased by 15% between 1961-1965 and 1979-81 and almost all of this increase (84%) came through an expansion in area. Between 1979-81 and 1985-87 lentil production increased by 88%, and 36% of this occurred through increased productivity (FAO 1987). However, mean lentil yields are still low because of poor crop management and the low yield potential of the landraces which are still being grown in most areas. In South Asia and East Africa diseases are also a major constraint to production. Accordingly, an integrated approach to lentil improvement needs to be followed which should involve both improvement in production technology and genetic stocks.

Breeding Objectives

Lentil is grown in a wide range of geographical areas with varied agroclimatic conditions. Thus the constraints to production also vary according to prevalent conditions. Yield remains the prime objective, and the importance of other attributes varies depending upon the environment.

For high-altitude areas in Afghanistan, parts of Iran, and the Central Anatolian Plateau in Turkey,

1. This paper was not presented at the workshop; however, the organizing committee accepted this for publication.

Citation: BARI (Bangladesh Agricultural Research Institute). 1991. Advances in Pulses Research in Bangladesh: proceedings of the Second National Workshop on Pulses, 6-8 Jun 1989, Joydebpur, Bangladesh. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

where the crop is currently spring-sown, the success of autumn sowing depends on the degree of winter-hardiness.

In Mediterranean environments at low to medium altitudes, where straw is also economically important in the farming systems, high biomass (seed + straw yield), wilt resistance, and drought tolerance are important attributes. Further, with the increasing labor cost for hand harvest, traits assisting the mechanization of lentil require special consideration.

For the Indian subcontinent the specific traits required in addition to high yield, are resistance to ascochyta blight, rust, and wilt.

Genetic Variation

The genetic variation existing in the crop and its wild relatives is the basic resource of any breeding program. The largest collection of both wild and cultivated lentil is maintained at the International Center for Agricultural Research in the Dry Areas (ICARDA) and labeled the International Legume Lentil (ILL), currently comprising 7000 cultivated accessions. About 4500 accessions from 52 countries have been evaluated for 17 descriptors and a Lentil Germplasm Catalog has been published (Erskine and Witcombe 1984). The ranges (minimum and maximum values) for some quantitative characters in this, germplasm collection are given in Table 1.

Breeding Methods

Lentil is a self-pollinated species. Very little cross pollination ($\leq 1.0\%$) has been observed in lentil. The breeding methods common for self-pollinated crops, viz., pure-line selection, pedigree method, bulk method, and back-cross method are all followed by lentil breeders, sometimes with modifications. Mutagenesis has also been used to improve existing cultivars for specific traits. The breeding scheme being followed at ICARDA is described below:

A total of about 350 crosses are made annually for the three major target regions according to the different regional objectives. These crosses are then handled as three streams within the breeding project with the material for each target region being of a different maturity type: southern latitudes, early-maturation stream; Mediterranean region, medium-maturation stream; and high-elevation areas, late-maturation stream.

The material for the three streams is handled together for the first few generations. A diagramatic representation of the scheme employed is given in Figure 1 (ICARDA 1986). All the crosses made at Tel Hadya are grown as F_1 generation in a high-elevation, off-season, summer nursery at Shawbak, Jordan, with irrigation. The F_2 generation is grown at Tel Hadya in winter and bulk harvested. Seeds from these bulks are used for the international F_3 nurseries, medium-maturity (large- and small-seeded LIF_3 N-L, LIF_3N-S), cold tolerance (LIF_3 N-CT), and early maturity (LIF_3 N-E). A

Table 1. Range for various descriptors in lentil germplasm, ICARDA, Syria.

Character	Minimum	Maximum	Mean	C.V.(%)
Days to flowering	100	162	132.8	9
Days to maturity	144	188	163.3	6
Plant height (cm)	10	45	25.8	18
Height of the lowest pod (cm)	3	30	13.6	31
Biological yield (t ha^{-1})	0.13	10.36	3.68	42
Seed yield (t ha^{-1})	0.05	3.26	1.14	45
Straw yield (t ha^{-1})	0.08	8.15	2.54	48
Harvest index	0.02	0.79	0.32	29
100-seed mass (g)	1.10	8.62	3.22	37
Seeds pod^{-1}	1.00	2.00	1.53	15
Protein content (%)	18.6	30.2	25.78	7

Source: Erskine and Witcombe (1984).

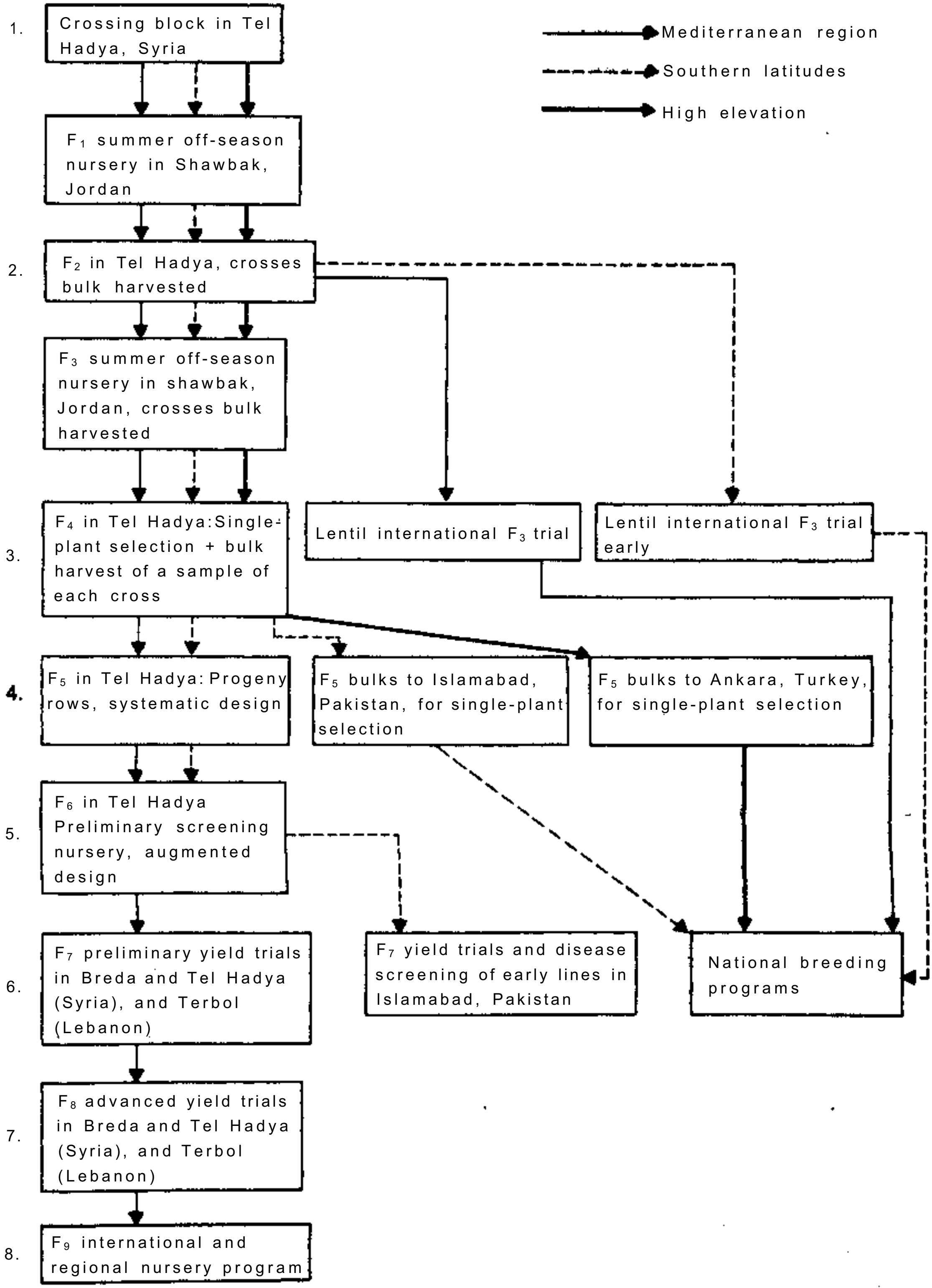

Figure 1. Lentil breeding scheme used at ICARDA

subsample is sent to the off-season nursery for generation advancement through the F_3 generation by the bulk method.

For the Mediterranean stream, single-plant selections are made at the F_4 generation on the basis of phenology, growth habit, and seed characters. The F_5 progeny rows are grown in a systematic design. The selected progenies are then grown in a Preliminary Screening Nursery (PSN) in F_6 in an augmented block design, then in replicated Preliminary Yield Trial (PYT) in F_7 at three sites with widely differing annual mean rainfall Tel Hadya, Syria (annual mean rainfall ca. 330 mm); Breda, Syria (ca. 280 mm); and Terbol, Lebanon (ca. 550 mm). Screening for fusarium-wilt resistance starts at F_7. The promising entries from PYTs are advanced to Advanced Yield Trials (AYT) which are again grown at the same three sites in larger plots and the material from these is sent to various national programs in the form of international nurseries.

Development of the early-stream material for southern latitudes has been carried out since the 1983/84 season in cooperation with the Pakistan National PulsesProgram, National Agricultural Research Centre (NARC), Islamabad. Segregating populations from early crosses in the F_5 generation are sent to Islamabad for single-plant selection. In addition, selections made for earliness at Tel Hadya are sent to Islamabad in yield trials for screening for ascochyta blight resistance.

For the high-elevation, late-maturity stream, material is developed in collaboration with the Turkish National Legume Program. The F_5 generation of crosses made with cold-tolerant parents is screened for winter hardiness at Haymana Research Station near Ankara at $\geq$1000m elevation. This collaborative arrangement with the two national programs has enabled more selections and tests for disease resistance and adaptation in the target regions.

Breeding Tall Types Suitable for Mechanical Harvesting

The increasing cost of harvest labor prevents some farmers in the Middle East and other countries from growing lentils. Further, traditional cultivars are lodging-susceptible, short, with semi-prostrate growth habit, and have pods which shatter and drop. Heritable differences in susceptibility to lodging have been found (Erskine and Goodrich 1988). Further, mechanical harvesting by cutting or pulling requires a clearance of about 15 cm between the soil surface and the lowest pods. Material with higher first-pod height is not suitable and is, in fact, more prone to lodging. Genetic variation in pod dehiscence has been found (Erskine 1985) and is being exploited at ICARDA.

Simultaneously, systems for mechanical harvesting of the crop have been developed. These include the lentil puller (for existing cultivars and production practices), mowers (for use on flattened seedbeds and nonlodging cultivars), and combine harvesters (for use on well prepared seedbeds sown with cultivars improved for mechanical harvesting).

Breeding for Resistance to Diseases

Lentils suffer relatively less damage from diseases than other legume crops. The most common lentil diseases include wilt, root rots, rust, ascochyta blight, botrytis gray mold, and stemphylium blight. Resistance to botrytis gray mold is available from the joint scoring done in Islamabad, Pakistan. But no sources of resistance to stemphylium blight are known. Some of the salient features of the important diseases are given below.

Wilt and root rots

Wilt and root rots in lentil are widespread. The most important disease is vascular wilt, caused by *Fusarium oxysporum* f.sp. *lentis.* Sources of resistance to this disease are known (Kanniyan and Nene 1978; Khare 1980). A simple, rapid, and reliable technique has been developed at ICARDA to screen lentil germplasm at the seedling stage for resistance to wilt (Bayaa and Erskine 1990). Using this technique, several lines have been identified with a useful degree of resistance, which are now being exploited in breeding for resistance. There is no published record of inheritance of resistance to wilt.

Rust (Uromyces fabae)

Rust is important, particularly in the Indian subcontinent (Khare 1980), Ethiopia, Morocco, and South America (Riva 1975). Several resistant genotypes have been identified by Pandya et al. (1980). Locations like Debre Zeit in Ethiopia and Pantnagar in India are useful hot spots for rust-resistance screening. Evaluation of breeding material in Ethiopia and Morocco for rust revealed several resistant sources, which are now being used in breeding for resistance. Rust resistance is conditioned by a single gene with resistance dominant to susceptibility (Sinha and Yadav 1989). National programs in Chile, Ecuador, Ethiopia, and Pakistan have released rust-resistant lines from ICARDA.

Ascochyta blight (Ascochyta lentis)

The disease is economically important in the Indian subcontinent (Khatri and Singh 1975) and Canada (Slinkard and Drew 1982). It is seedborne and attacks leaves, stems, fruits, and seeds. Screening against ascochyta blight is being done with the help of NARC Islamabad and the Agricultural University, Faislabad, Pakistan. Many resistant sources have been found and resistant breeding lines are in advanced stages of testing. There is no published record on inheritance of resistance to ascochyta blight.

Breeding for Resistance to Insect-pests

Among the insects which damage lentils, the weevils of the genus *Sitona,* pod borers *(Etiella lineatus),* bruchid *(Bruchus* sp and *Callosobruchus chinensis),* and aphids *(Aphis craccivora)* are of economic importance. Screening for host-plant resistance against *Sitona* has been done at ICARDA but was unsuccessful and abandoned due to lack of genetic variation.

Breeding for Cold Tolerance

Screening germplasm under severe winter conditions (temperatures down to - 26°C) has revealed cold tolerance in 238 of 3592 accessions tested (Erskine et al. 1981). Winter-hardy lines are being considered for release in Turkey for autumn sowing, where sowing is traditionally in spring.

Breeding for Drought Tolerance

In West Asia, lentil is cultivated mostly in the region between the rainfall isohyets of 275-400 mm year^{-1}. Although such areas are characterized by variable rainfall, the most commonly encountered drought and heat stress is during the reproductive period of growth. Drought tolerance is required to stabilize production in these areas, and possibly to enable production in lower-rainfall zones.

Drought tolerance is now being measured by manipulating the total seasonal moisture supply at one site with a normal date of sowing using a line-source sprinkler. Another approach is to select for drought avoidance through early maturity. The considerable variation among early flowering lentil accessions is being used. Further variability for response to drought stress may be found within *Lens culinaris* subsp *orientalis.*

Breeding for Earliness

Early maturing types are required in the lower-latitudes of the Indian subcontinent and in Ethiopia. While approximately 40% of the world lentil area is to be found in India, genetic diversity within Indian germplasm is very narrow and exclusively within the *pilosae* type (Barulina 1930).

Phenological problems associated with the introduction of Mediterranean germplasm into the Indian subcontinent led to the suggestion of the existence of a day length bottleneck, restricting the flow of germplasm into India (Erskine and Hawtin 1983). Recent data show this to be an over-simplification, because selection during the spread of the crop into India has been directed toward increased sensitivity to temperature and reduced sensitivity to photpperiod (Erskine et al. 1990). This emphasizes the role of selection of phenology in the evolutionary history of lentil and also the need to select for an appropriate phenology during plant introduction into southern latitudes in order to widen the genetic base available to local breeders. Early maturing, disease-resistant lines are now emerging from the program, but reconfirmation of their disease reaction is still required.

Breeding for Quality

There are no fixed quality standards for lentil seed or straw in most developing countries. Some standards based on local landraces must be set as a basis for comparison. The important characters for seed include size, color, protein and methionine concentration, ease of decortication, and cooking quality. Studies at ICARDA revealed that the time required for cooking was well predicted by the seed size with a genetic correlation of r = 0.92 (Erskine et al. 1985). There is genetic variability for all the above characters within the germplasm of cultivated lentil. The present aim of breeding with regard to quality is to monitor all these traits so that unacceptable levels in relation to the established standards are not found in newly developed cultivars.

Breeding for Wide Adaptation

The development of lentil germplasm which maintains a high level of performance over a wide range of environments within a target region is an important goal of the lentil improvement program. Elite lines and segregating populations of lentil are, therefore, developed at ICARDA and distributed each year as international nurseries and trials to the national programs for evaluation and use under local conditions.

Some entries having specific adaptation to particular environments have been identified from these materials and released for general cultivation by the national programs. For example, the lentil line Manserha 89 has been released for Northern Punjab and the North-West Frontier Province in Pakistan. In addition, a line FLIP 86-38L which has given high yields at Islamabad and was resistant to asocochyta blight in two seasons and has a good seed type.

The lentils of Bangladesh are among the earliest to flower in the world germplasm collection. Consequently, access to variability in a medium-season or late-season background is limited, because of problems with flowering synchrony in crossing. ICARDA is crossing the L 5 cuitivar from Bangladesh with different sources of resistance to rust and the F_2 generation is being grown in Bangladesh to incorporate rust resistance into an adapted background. Further crossing with other sources of early flowering lentil is being done at ICARDA to broaden the genetic base of

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Recommendations

Each workshop session was followed by group discussions, from which recommendations were evolved. Given below are the general proposals, followed by the recommendations made on specific aspects.

General proposals

Khesari (*Lathyrus sativus* L.), lentil *(Lens culinaris* Medic), chickpea (*Cicer arietinum* L.), black gram *(Vigna mungo* (L.) Hepper), and mung bean *(Vigna radiata* (L.) Wilczek) account for about 95% of the area under pulses in Bangladesh. Therefore, a major research thrust on these crops was proposed. A limited and localized research effort was suggested for pigeonpea *(Cajanus cajan* (L.) Millsp.), cowpea *(Vigna unguiculata* (L.) Walp.), and fieldpea *(Pisum sativum* subsp *arvense).* The working group also made the following general recommendations.

1. Procure more germplasm of khesari, lentil, black gram, mung bean, and minor pulses.
2. Strengthen field and laboratory screening for resistance to major biotic and abiotic stresses.
3. Expand facilities for pulses research in terms of staff, laboratories, and equipment, especially for mechanical seeding, interculture, harvesting, drying, seed handling, and storage.
4. Strengthen intra- and inter-institutional cooperation within the country.
5. Increase the opportunities for cooperation with some international organizations as International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Center for Agricultural Research in Dry Areas (ICARDA), Asian Vegetable Research and Development Center (AVRDC), and with neighboring countries, especially the National Bureau for Plant Genetic Resources (NBPGR) in India.
6. Create suitable facilities for large-scale seed production of high-yielding cultivars.

Breeding

Discussion Group Participants

M. Matiur Rahman (Leader)	M. Obaidul Islam
Ashutosh Sarker	Ali Newaj
A. Khaleque	P.N. Bahl
D.G. Faris	Jagdish Kumar

Major breeding efforts should be undertaken on khesari, lentil, chickpea, black gram, and mung bean in Bangladesh. Limited work should be done on pigeonpea, cowpea and fieldpea. Shortage of manpower precludes indepth studies on the latter three crops.

Future Strategy

The major problems have been identified and prioritized. Priority I problems should be undertaken immediately with the existing manpower and the rest should be taken up when more manpower and other resources are available.

Lentil

The main working strategy to be followed is to develop materials with a relatively larger seed size, disease resistance and higher harvest index. Consequently, the following research priorities have been set.

- Priority I: high-yielding, short-duration, rust- and stemphylium blight-resistant varieties.
- Priority II: varieties for late sowing.
- Priority II: varieties responsive to high inputs (irrigation and fertilizers).
- Priority III: varieties for nontraditional areas.

Chickpea

Research needs to be undertaken for the development of varieties with medium seed and higher harvest index. The following priorities have been set.

- Priority I: high-yielding, wilt-, botrytis-, and collar rot-resistant varieties.

- Priority II: high-yielding, botrytis gray mold and root rot-resistant varieties.
- Priority II: varieties suitable for *Barind* and *Tista* tracts.
- Priority II: varieties for late sowing.
- Priority II: kabuli-type varieties.
- Priority II: varieties for high-input conditions.

Khesari

The following research priorities have been set for the development of suitable materials.

- Priority I: high-yielding, low-toxin varieties.
- Priority II: downy mildew (DM) resistant varieties.
- Priority III: high-fodder varieties.

The strategy to be adopted involves

1. A hybridization program to raise the yield of low-toxin lines. Segregating populations should be handled by the single-seed descent (SSD) method. Individual plants should be selected from the F_6 generation on the basis of low toxin content and agronomic characters.
2. Testing of advanced lines in relay cropping with *aman* (rainy season) rice following farmers' practices.
3. Cross checking of p(N)-oxalylamino-L-alanine (BOAA) content of the advanced lines at different institutes.
4. Study of pollination behavior.

Black gram

Research is needed to develop materials according to the following priorities.

- Priority I: high-yielding, Yellow mosaic virus (YMV)- and Powdery mildew (PM)-resistant varieties having synchronous podding habit.
- Priority II: varieties suitable for zero-tillage conditions.

The following strategies are to be adopted:

1. Combining high yield with resistance to YMV and PM for Priority I
2. Testing promising lines under zero-tillage conditions for Priority II.

Mung bean

Research is needed to develop materials in the following priority areas.

- Priority I: high-yielding, YMV- and Cercospora leaf spot (CLS)-resistant/tolerant varieties with synchronous podding habit, suitable for January/February sowing in the t. *aman* rice-mung bean-aus (rainfed) rice cropping pattern.
- Priority II: high-yielding (high harvest index), short-duration (60-65 days) varieties with synchronous podding habit, YMV and CLS resistance/tolerance, waterlogging tolerance, and daylength insensitivity for August sowing in the *aus* rice/jute-mung bean-postrainy season (*rabi)* cropping pattern for northwestern Bangladesh.

The strategies to be adopted include:

1. Intensifying the hybridization program using available resistant/moderately resistant sources.
2. Advancing segregating populations at Ishurdi and Rahmatpur, specifically for each zone, in collaboration with Chittagong University.

Pigeonpea, cowpea, and fieldpea

The following steps should be taken:

- Collection of local germplasm.
- Evaluation of more germplasm from exotic sources such as ICRISAT and the International Institute for Tropical Agriculture (IITA).

General Breeding Principles and Policies

Principles

- Make pureline selections from within the local germplasm and landraces.
- Ensure maintenance of existing cultivars for each crop.

Policies

- Basic research should be emphasized at academic institutes.
- Test locations for each crop should be based on crop concentration and future potential.

- It should be ensured that breeders continue to work on a particular crop on a long-term basis.
- Sufficient manpower and physical facilities should be provided to ensure full operation of the breeding programs.
- Breeders' visits to farmers' fields and demonstration plots should be intensified.

Cultural Management

Discussion Group Participants

A.F.M. Maniruzzaman (Leader)	M.Z. Abedin
M. Shahidul Islam	M.S. Hoque
M. Motior Rahman	A. Ahad Miah
A. Sattar	Abu Mohd. Musa
A. Aziz	M.P. Bharati

Future Strategy

1. The existing cropping pattern needs to be adjusted so that pulses be sown on time and under proper soil-moisture conditions.
2. Alternative farming systems involving pulses need to be developed.
3. Identification of areas in nontraditional regions with potential for growing pulses should be undertaken.
4. Management practices for sole- and mixed-cropping situations should continue to be improved and tested in pulse-growing areas.
5. Efforts should continue to identify effective biofertilizers. A biofertilizer production center needs to be established, which should be responsible for producing effective inoculants.
6. Since most pulses are grown on residual soil moisture under rainfed conditions, development of drought-tolerant varieties should receive priority.
7. Morphological and physiological constraints to high yield need to be identified and used in varietal development programs.
8. Low-cost implements should be developed to make the best use of residual soil moisture.

Crop Protection

Discussion Group Participants

G.A. Fakir (Leader)	Hamiz Uddin Ahmed
M.A. Karim	A. Bakr
M. Mahbubur Rahman	M.V. Reddy

Future Research Needs

Plant pathology

Disease-management studies will be conducted according to the following crop and disease priorities.

- Crop priority :
  Lentil, chickpea, mung bean, black gram, khesari, and cowpea.
- Disease priority:
  Lentil: stemphylium blight, rust, foot rot.
  Chickpea: wilt, botrytis gray mold, collar rot.
  Mung bean: YMV, PM, CLS.
  Black gram: CLS, PM, YMV.
  Khesari: DM.
  Cowpea: Foot rot.
- Screening of germplasm against diseases
  1. Identification of pathogens/races of major diseases/pathogens and their use in screening tests.
  2. Standardization of screening methods.
  3. Screening of germplasm lines and cultivars, promising lines, and breeding materials of different pulses for resistance to major diseases under adequate disease pressure.
- Survey and monitoring of pulse diseases under different agroecological zones and under different cropping patterns.
- Estimation of yield losses due to major diseases, especially botrytis gray mold of chickpea and stemphylium blight and rust of lentil.
- Studies on cultural management of the major diseases of different pulses in collaboration with agronomists.
- Selection of seed dressing for foot rot of lentil, wilt and collar rot of chickpea, DM of khesari and foot rot of cowpea.
- Selection of foliar fungicides for stemphylium

blight and rust of lentil, botrytis gray mold of chickpea, and PM and CLS of mung bean and black gram.

- Development of integrated control measures.

Entomology

- The crop priority for research is as follows:

  Chickpea, mung bean, black gram, and cowpea, with emphasis on the field and storage problems of all important pulses.
- Research will be conducted on the following priority areas:

  1. Monitoring and surveillance of insect pest population/infestation levels in pulse crops under different agroecological conditions and different cropping patterns.
  2. Screening of germplasm against major insect pests of pulses.
  3. Bioecology, bionomics and life tables of major insect pests of chickpea, mung bean, black gram, and cowpea.
  4. Testing the efficacy of cultural methods for the management of major insect pests of pulses.
  5. Testing the efficacy of mechanical and physical methods for the management of the hairy caterpillar and pulse beetle.
  6. Evaluation of cheap and safe pesticides for their efficacy against the major insect pests of pulses.
  7. Determination of spraying threshold levels of major insect pests of pulses so as to minimize the number of applications of insecticides.
  8. Integration of effective control measures into a package for the control of the major pest complex of the pulses.
  9. Development of artificial rearing techniques for pod borer (*Helicoverpa armigera).*

Postharvest technology

The following research work will be undertaken, in order of priority:

- Survey and assessment of postharvest qualitative losses of different pulses.
- Evaluation of traditional and improved storage containers in controlling pests/molds and maintenance of seed viability.
- Further improvements of the fabricated pulse drier.
- Development of cheap and simple methods of:

1. Processing pulses into various products of high nutrient value.
2. Detoxification or reduction of BOAA content in khesari and antinutritional factors in other pulses.
3. Reducing cooking time of stored pulses.
4. Developing an inexpensive manually operable pulses thresher.

General Policies

1 Development of multilocational testing facilities for screening against diseases and insect pests of important pulses at different institutions/universities of the country.

2. Provision of greenhouse and cold-storage facilities for conducting pathological, entomological, and storage experiments under controlled conditions.
3. Procurement of laboratory equipment such as incubators, refrigerators, chromatographic equipment, dissecting microscopes, spectrophotometers, fermenters, seed magnifiers, and microphotographic equipment.

Seed Production, Extension, Marketing, and Nutrition

Discussion Group Participants

M.S. Ahmed (Leader)	Md. Hussain
S.M. Elias	Md. Mostafa Hussain
Bazlur Rahman	M. Ashraful Islam
K.F.G. Leferink	U. Thaung Pe
Umaid Singh	C.L.L. Gowda

Future Strategy

Seed Production

1. Targets should be defined and clear guidelines

set for the coordination of seed multiplication between breeders, the Bangladesh Agricultural Development Corporation (BADC), and the Department of Agricultural Extension (DAE) depending on the capabilities of each group. In view of the Crop Diversification Project (CDP) 500 kg breeders' seed should be produced by the breeders (250 kg for BADC and 250 kg for demonstration) in the first year of recommendation. In subsequent years BADC will supply seeds for demonstration. The National Seed Board (NSB) should indicate this minimum requirement of seed in their proforma.

2. Breeders should be responsible for the maintenance of breeders' seed, and they should liaise with DAE and BADC to popularize the variety through demonstrations.
3. Breeders' seed must be certified by breeders according to the seed rules.
4. Foundation and certified seed are to be certified before distribution by the seed-certification agency according to the seed rules.
5. To encourage the scientists responsible for the development of a particular variety, their institution should be given some royalty on the sale of certified seeds.
6. In view of pulses seed requirements of CDP the NSB may recommend some local improved varieties submitted by breeders and BADC.

Extension

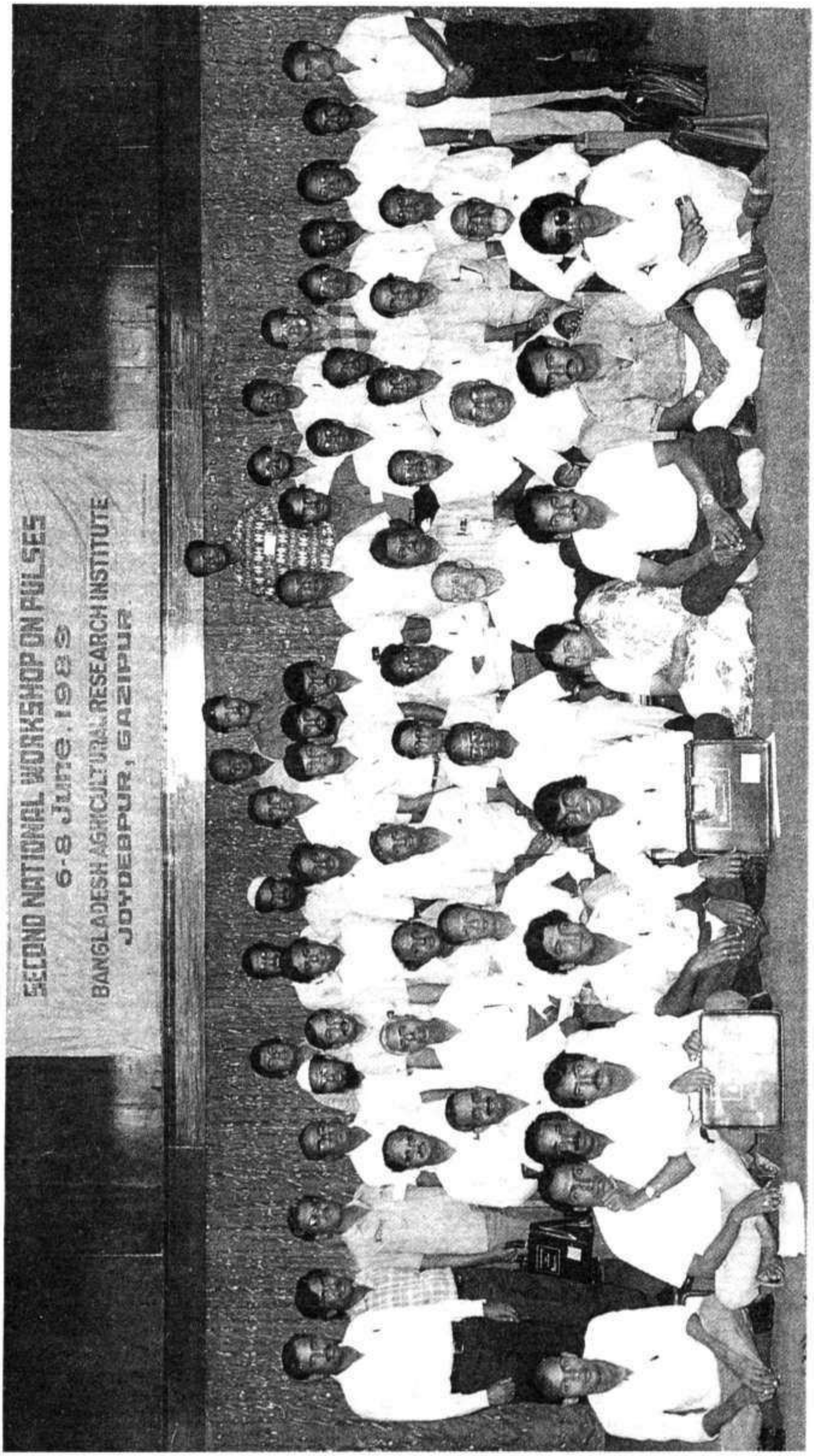
1. There should be intensive demonstrations in farmers' fields in pulse-growing areas by DAE in collaboration with scientists and BADC. Adequate funds should be provided to the DAE for. this purpose.
2. Before demonstration, seed multiplication officers (SMO), and block supervisors (BS) including BADC production personnel should be trained on the production technology of pulses by the institution responsible for developing the variety.

Marketing

1. Credit facilities should be provided for the production of seeds of improved pulse varieties.
2. Government procurement program of incentive price should be extended for pulses.
3. The Farmgate prices, as broadcast weekly, should accompany the consumer price and this information should be given by the marketing department.
4. Socioeconomic studies indicate a big gap between grower and consumer prices. Efforts should be made to narrow this gap.

Nutrition

1. Studies on nutritional, detailing, and cooking quality aspects of pulses need to be strengthened. Analytical facilities for such evaluation programs need to be established.
2. Antinutritional factors of pulses deserve special attention, particularly BOAA content in khesari. Screening lines for low antinutritional factors and their detoxification should be emphasized.
3. There is a need to devise a simple procedure for detoxification of the neurotoxin in khesari *dhal.*
4. The effect of environment, agronomic practices, and genotypes on nutritional quality of pulses should be studied.
5. The storage stability and quality of pulses should be studied.


SECOND NATIONAL WORKSHOP ON PULSES
6-8 June, 1989
BANGLADESH AGRICULTURAL RESEARCH INSTITUTE
JOYDEBPUR, GAZIPUR.

Participants

Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 15

Kazi M. Badruddoza	Former Executive Vice Chairman
M. Motlubor Rahman	Executive Vice Chairman
M. Siddique Ahmed	Scientist Emeritus
M.A. Razzak	Principal Scientific Officer

Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur

M.H. Mondal	Director General
M.A. Islam	Director of Research
M.A. Khaleque	Project Director Oil Seeds
S.M. Elias	Director Training
A.F.M. Maniruzzaman	Project Director Pulses
Awal Ahmed	Principal Scientific Officer

Agronomy Division

Kazi Reazul Haque	Principal Scientific Officer
M.A. Ahad Mian	Principal Scientific Officer (Agronomy)
M. Motior Rahman	Scientific Officer

Breeding Division

Helalul Islam	Principal Scientific Officer (Millets)
M.A. Wahaab	Principal Scientific Officer (Genetic Resources)
D. Sarwar	Senior Scientific Officer
M.A. Chowdhury	Scientific Officer
Fatima Khatun	Scientific Officer

Entomology Division

M.A. Karim	Chief Scientific Officer and Head
Mahbubur Rahman	Senior Scientific Officer

Pathology Division

H.U. Ahmed	Chief Scientific Officer and Head
Tapon Kumar Dey	Scientific Officer

On Farm Division

Z. Abedin	Chief Scientific Officer and Head
A. Hossain	Senior Scientific Officer
M.A. Rauf	Senior Scientific Officer

Post-harvest Technology Division

A. Zaman	Principal Scientific Officer
J.C. Shaha Chowdhury	Senior Scientific Officer

Soil Science Division

M.S. Islam	Chief Scientific Officer and Head
Maniur Rahman	Principal Scientific Officer

BARI, Regional Agricultural Research Station, Hathazari, Chittagong

S.K. Roy	Senior Scientific Officer

BARI, Regional Agricultural Research Station, Ishurdi, Pabna

M. Matiur Rahman	Principal Scientific Officer
M. Obaidul Islam	Principal Scientific Officer
A. Sarker	Senior Scientific Officer
Wahiduzzaman	Senior Scientific Officer
M.A. Karim	Senior Scientific Officer
A. Bakr	Senior Scientific Officer
A. Rahman	Scientific Officer
A. Aziz	Scientific Officer

Bari, Regional Agricultural Research Station, Jamalpur

H. Rahman	Chief Scientific Officer
A.F.M. Rahman	Senior Scientific Officer
M.A. Khaleque	Scientific Officer

BARI, Regional Agricultural Research Station, Jessore

M.A. Islam	Chief Scientific Officer
S. Rahman	Senior Scientific Officer
Z.I. Sarkar	Scientific Officer
R. Ali	Scientific Officer

BARI, Agricultural Research Station, *Barind*$_a$ Rajshahi

A. Musa	Senior Scientific Officer
N.K. Kar	Senior Scientific Officer
M. Kumar	Scientific Officer

BARI, Agricultural Research Station, Dinajpur

A.H. Talukder	Senior Scientific Officer

BARI, Patuakhali Krishi College, Dumki, Patuakhali

Enamul Haque	Principal

BARI, On Farm Research Division, Faridpur

Yousuf Ali	Scientific Officer

BARI, Wheat Research Centre, Noshipur, Dinajpur

M.A. Razzaque	Principal Scientific Officer

BARI, Agricultural Research Station, Rahmatpur

M. Rahman	Scientific Officer

Institute for Postgraduate Studies in Agriculture (IPSA), Salna, Gazipur

A. Hamid	Associate Professor
M.A. Khaleque	Associate Professor

Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh

M.A.Q. Shaikh	Chief Scientific Officer
Saiful Islam	Principal Scientific Officer
M.A. Satter	Senior Scientific Officer

Bangladesh Agricultural University (BAU), Mymensingh

Mohammed Hussain	Dean
G.A. Fakir	Professor
M.S. Hoque	Professor
Ali Newaz	Associate Professor

Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur

M.A. Mazid	Senior Scientific Officer Soil Science

Other Organizations in Bangladesh

T. Brulsema	Mennonite Central Committee (MCC), Noakhali, Dist Feni
M. Mustafa Hussain	Project Director, Pulses and Oil Seeds, BADC, Dilkusha, Dhaka
A.K.M. Anwarul Kibria	Director, Field Service Division (DAE), Khamarbari, Dhaka
A.K.M. Bozlur Rahman	Director, Marketing, Khamarbari, Dhaka
M.A. Rakib	Executive Director, Project Implementation Unit, Canadian International Development Agency (CIDA), Khamarbari, Dhaka
R.N. Mallick	Cheeky International, Steel House, Kawran Bazar, Dhaka
A.K.M. Habibullah	Coordinator, CDP, Canadian International Development Agency (CIDA), 9/7, Satmasjid Road, LalMatia, Dhaka

International Participation

National Programs

M.P. Bharati	Coordinator National Grain Legume Improvement Project (NGLIP), Kathmandu, Nepal
P.N. Bahl	Assistant Director General (Food Crops) Indian Council of Agricultural Research (ICAR), New Delhi 110 001, India
U. Thaung Pe	Deputy General Manager (Extension). Myanmar Agricultural Service (MAS), Rangoon, Myanmar

ICRISAT Center, Patancheru, A.P. 502 324, India

D.G. Faris	AGLN Coordinator
Umaid Singh	Biochemist
C.L.L. Gowda	Senior Plant Breeder
M. V. Reddy	Senior Plant Pathologist
Jagdish Kumar	Senior Plant Breeder

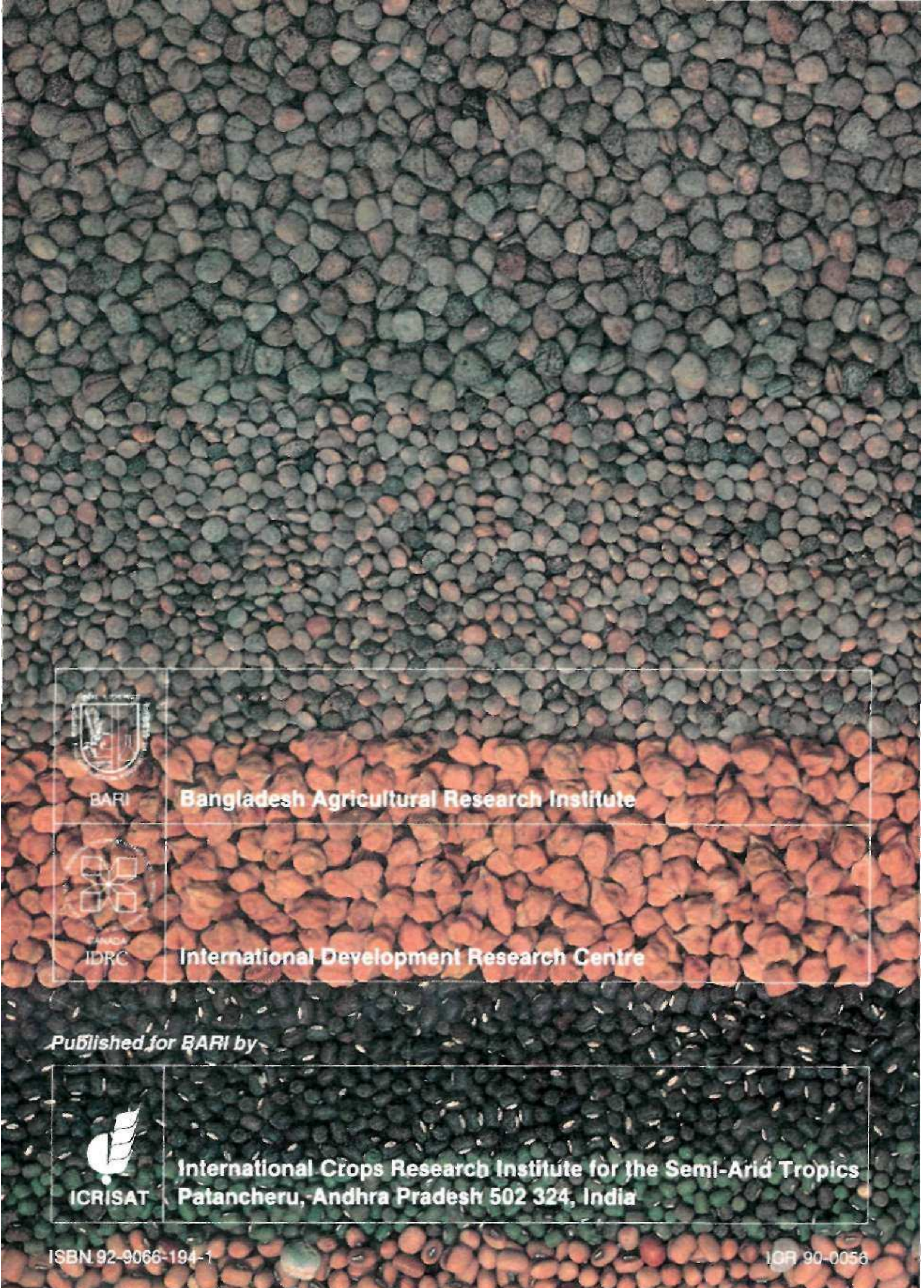
Synonyms, Acronyms and Abbreviations

Chickpea	:	Bengal gram, *boot, chhola*
Khesari	:	Lathyrus, grasspea
Mung bean	:	*Mung, moong,* green gram, *mugh*
Black gram	:	*Mash kalai, mash*
Lentil	:	*Masur*
Pigeonpea	:	*Tuar.Arhar*
Kharif-1	:	Early monsoon (March to May)
Kharif-2	:	Late monsoon (August to October)
Kharif	:	Rainy season (June to October)
Rabi		Postrainy season (October to March)
aus-rice	:	Rainfed paddy
boro-rice	:	Winter season, irrigated paddy
T.aman-rice	:	Transplanted, rainy-season paddy

Acronyms used

AGLN	:	Asian Grain Legumes Network
AVRDC		Asian Vegetable Research and Development Center
BADC	:	Bangladesh Agricultural Development Corporation
BARC	:	Bangladesh Agricultural Research Council
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BINA	:	Bangladesh Institute of Nuclear Agriculture
BOAA		ß-N-oxalyl aminoalanine
BRRI	:	Bangladesh Rice Research Institute
CDP	:	Crop Diversification Project
CIAT	:	Centro Internacional de Agriculture Tropical
CIDA	:	Canadian International Development Agency
CU	:	Chittagong University
DAE	:	Department of Agricultural Extension
ICAR	:	Indian Council of Agricultural Research
ICARDA	:	International Center for Agricultural Research in Dry Areas
ICRISAT	:	International Crops Research Institute for the Semi-Arid Tropics
IDRC	:	International Development Research Centre
IIT A	:	International Institute of Tropical Agriculture
IPSA	:	Institute of Postgraduate Studies in Agriculture
IRRI	:	International Rice Research Institute
MCC	:	Mennonite Central Committee
NBPGR	:	National Bureau of Plant Genetic Resources (India)
NGUP	:	National Grain Legume Improvement Program
ODAP	:	ß-N-oxalyl-L-α,ß-diaminopropionic acid

OFRD	:	On-Farm Research Division (BARI)
PIU	:	Project Implementation Unit
RARS	:	Regional Agricultural Research Station
Tk	:	*Taka,* local currency (In 1989 -1 US$ = Tk 32.85)
USAID	:	United States Agency for International Development



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Published for BARI by

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

ISBN 92-9066-194-1

ICR 90-0056