Managing AGLN Crops in Rice-based Cropping Systems

Myanma Agriculture Service
and
International Crops Research Institute for the Semi-Arid Tropics

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Managing AGLN Crops in Rice-based Cropping Systems

Summary Proceedings of the Myanmar-AGLN/ICRISAT Workshop and Monitoring Tour

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Edited by
D.G. Faris, C.L.L. Gowda, and Thein Han

Myanma Agriculture Service
Yangon, Myanmar

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

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Myanmar - AGLN / ICRISAT Workshop and Monitoring Tour

Objectives

Scientists from 11 AGLN countries, including Myanmar, and from ICRISAT, met in Yangon and Yezin and traveled through the dry zone and delta area of Myanmar in order to:

- Learn about and compare the management practices adopted for growing the AGLN crops, groundnut, chickpea, and pigeonpea, in rice-based cropping systems in Asia.
- Identify the constraints to the effective use of AGLN crops in these cropping systems.
- Observe the management practices used for AGLN crops in Myanmar and the constraints the farmers face when using them.
- Recommend ways to overcome these constraints in order to plan future AGLN activities.

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OPENING SESSION

Inaugural Address

H.E. Lt. Gen. Chit Swe

Minister for Agriculture and Forests, and for Livestock Breeding and Fisheries, Myanmar

I am deeply honoured for having been offered the opportunity to address this occasion, and at the same time have much pleasure in according a warm welcome to the members of ICRISAT and the participating scientists from Asian countries.

I would also like to convey my sincere thanks to ICRISAT for sponsoring the Workshop and providing the Ministry of Agriculture and Forests of Myanmar, an opportunity to co-host this important meeting.

Workshops and conferences are an invaluable medium to share scientific information; and it is laudable that ICRISAT, ever since its inception, has consistently engaged in a series of such exercises, embracing many important aspects related to the Semi-Arid Tropics (SAT).

The Semi-Arid Tropics cover over 20 million square kilometers, spanning two wide belts in Africa, and touching extensive areas in India, parts of Southeast Asia, West Asia, South America, Mexico, and Central America.

These areas are subject to severe climatic conditions, principally drought, soil degradation, erosion and desertification. The numerous obstacles to profitable agriculture have been more of a rule than an exception. Nevertheless, the SAT produce more than 50% of the world's sorghum *(Sorghum bicolor),* 80% of its pearl millet *(Pennisetum glaucum),* 90% of the chickpea *(Cicer arietinum),* 96% of the pigeonpea *(Cajanus cajan),* and 67% of the groundnut *(Arachis hypogaea).* The yields, however, have been disappointing. And the socioeconomic condition of the farm populace of these regions has continued to be dismal.

ICRISAT and the Asian Grain Legumes Network (AGLN) have, however, risen to meet these challenges. They have, in pursuance of their mandates, resolutely striven to:

- improve the yield and nutritional qualities of sorghum, pearl millet, pigeonpea, chickpea, and groundnut;
- develop appropriate farming systems so as to stabilize agricultural production;
- identify and alleviate socioeconomic and related constraints; and
- assist national and regional research programs.

They have contributed immeasurably to SAT agriculture, and their recent development of the world's first hybrid pigeonpea, ICPH 8, is a testimony to their efforts. This is the first time that a hybrid of a pulse crop has been developed, and it constitutes a milestone in

ICRISAT's brief history. We have great pleasure in congratulating the scientists at ICRISAT.

Rice *(Oryza sativa)* is the most important crop in the Asia and Pacific regions. This does not, however, imply that food legumes are of secondary significance. Pigeonpea and chickpea have a longstanding importance among pulse crops. Pigeonpea is a subsistence crop in many parts of the SAT, while chickpea is one of the most important crops in Asia. They constitute the main source of vegetable protein and play an important role in soil improvement through their symbiotic association with nitrogen-fixing bacteria. Similarly, groundnut is an important cash crop for farmers. The global hectarage under groundnut and pulses is about 67.5 m ha, and 50% of it is in Asia.

At present, the total area under various crops in Myanmar is about 10 m ha. Groundnut, chickpea, and pigeonpea together occupy about 0.82 m ha. They are grown either as sole rainy-season crops or as second crops after dryland crops or after rice. We have been collaborating extensively with ICRISAT and ICARDA (International Center for Agricultural Research in the Dry Areas) in research on these crops, and we are gratified that considerable improvements have taken place. However, there is no room for complacency, and the activities need to be continued vigorously.

While there is a need to encourage the wider cultivation of these crops, where appropriate, the quest for intensifying their association with the existing primary crops is also of great importance. Hence, we avidly welcome ICRISAT's thrust to further integrate groundnut, chickpea, and pigeonpea in Rice-based Cropping Systems (RBCS). The area under rice in Myanmar is over 5 m ha; but only about 0.3 m ha are double-cropped with pulses. I presume similar situations prevail in many other parts of Asia.

The Asian Cropping Systems Network has been carrying out research on cropping patterns in a number of rainfed and irrigated areas, involving, among others, groundnut and mung bean *(Vigna radiata)* in rice-based cropping systems. Accordingly, we consider the AGLN's engagement in these activities as highly appropriate. The continuing development of photoperiod-sensitive and short-duration rice varieties offers excellent scope for these measures. It will be necessary to consider agricultural problems in their totality so that cropping patterns can be tailored to the agroecological and socioeconomic conditions of different regions. Similarly, while opportunities are being sought to exploit land to its fullest, there will be a strong need to ensure that the inputs and practices in such farming systems do not hasten its degradation. At the same time, it remains significant that the research on cropping systems generates the greatest benefit to the multitude of small farmers.

Sorghum, groundnut, chickpea, and pigeonpea, together with other pulses and beans, constitute one of the most important dietary sources in the SAT. In certain countries, they are important to the national economy in generating foreign exchange. Their contribution to livestock breeding and thereby helping to meet the need for animal protein is also particularly important. The world's population continues to expand; and the Food and Agriculture Organization (FAO) has estimated that there will be a need to raise the world's production of pulses, from the current level of 50 m t to about 60-65 m t by the year 2000.

We have assembled here today to meet these challenges. The efforts of the participants at this forum, and their continued, dedicated research can have a far-reaching impact on the teeming millions of farmers in the SAT, and I wish them success in their endeavours.

Overview of Groundnut, Chickpea, and Pigeonpea Production in Myanmar

Tin Hlaing

Myanma Agriculture Service, Yangon

First of all, allow me to express my sincere gratitude to the Minister of Agriculture and Forests and for Livestock Breeding and Fisheries for his personal interest in this Workshop and for opening this session. My sincere appreciation is also due to ICRISAT in general, and AGLN Coordinator Dr D.G. Faris in particular, for organizing this meeting. The Minister's inaugural speech has pertinently addressed the role of food legumes production in general, and I shall confine myself to its situation in Myanmar.

Food legumes are an important component of Myanmar's agricultural system. About 1.64 m ha or nearly 17.7% of Myanmar's total cropped area of 9.23 m ha, are annually sown with legume crops including groundnut, to produce 1.16 m t of grains. Besides meeting the domestic demand, food legumes also sustain an export trade worth 63 m Kyats (about US$ 10 m) or 18.8% of Myanmar's agricultural commodity exports. Exports of pigeonpea and chickpea alone, valued at 17.7 m Kyats (about US$ 2.8 m), make up 5.2% of the total earnings through exports of grain legumes.

Food legumes are also important for their role as cheap and efficient sources of protein and for their agronomic contribution. The use of food legumes in general, and groundnut, chickpea, and pigeonpea in particular, in Myanmar agriculture can be classified broadly as follows:

- As catch crops in multiple cropping, in association with either rice or other crops.
- As contingency crops, when the main crop has either failed or cannot be sown due to the vagaries of nature.
- Components of monocropping systems of the dry zone, characterized by inadequate and/ or erratic rainfall.

An important feature unique to the legumes is their ability to improve soil fertility through their symbiotic association with nitrogen-fixing bacteria.

The cultivation of food legumes in Myanmar is characterized by the varied extent of cultivation, productivity, and profitability. Nevertheless, their contribution to the economics of subsistence farmers is substantial because of the low level of inputs and other resources involved.

Legume cultivation is predominant in upper and central Myanmar but its potential in the lower delta area has not been fully exploited. Of the 18 legume species cultivated, over 50% of the cultivated area is accounted for by groundnut, chickpea, and pigeonpea. Almost entirely dependent on rains, the cultivation and success of these crops are determined by conserved soil moisture and its depletion during the cropping season.

Pigeonpea is sown with the onset of rains. Chickpea is grown on conserved soil moisture during the late monsoon period. However, groundnut is sown during both the rainy season and the postrainy season if soil texture and moisture status are favourable for the crop. The Myanma farmer, in his intuitive wisdom, chooses his crops with growth habit, root system, and photosensitivity appropriate to seasonal conditions.

Groundnut has been cultivated as a major oil crop since the 18th century, and is grown throughout Myanmar. However, chickpea and pigeonpea attained popularity only in the 1960s and 1970s, and are distributed in upper and central Myanmar, particularly in Mandalay, Magway, Bago, and Sagaing divisions.

Organized research on food legumes began prior to the 1940s. In those days, research activities were not very intensive due to the lack of demand in the domestic and export markets. Moreover, concepts such as photoperiodism, soil-moisture conservation, and plant ideotype were unknown. Yet, better varieties such as the wilt-resistant chickpea variety *Karachi* were introduced.

Though the research and development of grain legumes have been given priority since the early 1960s, these efforts have not been commensurate with the importance of these crops in the agricultural economy.

Groundnut, chickpea, and pigeonpea are subjected to drought and irregular distribution of rainfall in Myanmar. The late monsoon crops rely on residual moisture. Further, instabilities in production rather than low productivity per se are the main constraints. The analysis of these constraints reveals that the low yield potential of genotype, the instability of productivity, meagre genetic resources, and limited inputs, are the main factors causing low productivity.

Both the Virginia runner and Spanish types of groundnut are cultivated in Myanmar. The runner types are predominant in the sole cropping systems of the dry zone. The Spanish types are used primarily for sequential cropping. The cropping pattern of rice followed by groundnut is predominant on light-textured soils.

On the other hand, chickpea is grown after rice, and on Vertisols that can conserve residual soil moisture. The major determinant for chickpea production, especially in lower Myanmar, seems to be the temperature regime.

Pigeonpea is mainly grown as a sole crop, or as a mixed crop with cotton *(Gossypium herbaceum),* sesamum *(Sesamum indicum),* etc. Pigeonpea varieties now grown are late-maturing ones and remain in the field for about 260 days. Hence, growing pigeonpea after rice is not a common practice in Myanmar.

The main thrust of the legume production program has been to increase cropping intensity and assure crop security. Thus, the strategy dictates a variety-based approach.

Varietal improvement programs have been carried out to keep pace with the present national demand. Low stability and low productivity still being the major constraints, genotypes possessing stable and moderate productivity deserve emphasis. Breeding of varieties adaptable to different agroclimatic conditions is being done at the Central Agricultural Research Institute (CARI) and several outreach stations. The national breeding programs have contributed by selecting six groundnut, three chickpea, and four pigeonpea improved high-yielding varieties.

The limited availability of inputs also indicates the need to exploit biological nitrogen fixation (BNF). The Myanma Agriculture Service (MAS) has been producing *Rhizobium* inoculum since 1984 using modest facilities. As a result, MAS was able to distribute inoculum for 52 277 ha of groundnut and for 34 525 ha of chickpea each year. These measures resulted in substantial increases in yield wherever moisture and extreme soil acidity were not major constraints. In addition, research related to the biological control of pests and diseases is also well underway.

Socioeconomic factors such as land policies, credit, input availability, and commercial trends are also important for the improvement of grain legume production. The decontrol of prices, freedom of trade in agricultural produce, access to prevailing market prices, and increased farm credit under the recently liberalized economic policies in Myanmar, have led to increased productivity and better responses to improved technologies. The participants at this session, presumably, will also be reviewing these aspects and we look forward to hearing their views.

In recent years, the area under legume cultivation has increased substantially through multiple cropping. It is estimated that the area under double-cropping with rice remains at about 0.13 m ha. Although the expansion of the area under groundnut and chickpea cultivation has faced some difficulties, the recent development of the extra-short-duration chickpea varieties opens new possibilities for sequential cropping after rice. Therefore, the trends indicate the need to further strengthen cropping systems research to increase agricultural productivity by increasing cropping intensity.

The prevailing management practices in groundnut, chickpea, and pigeonpea cultivation in Myanmar can be summarized as follows:

- Groundnut, chickpea, and pigeonpea production plays an important role in domestic consumption as well as in export.
- Research and development of these crops has progressed as anticipated.
- Introduction of new short- and medium-duration varieties has increased cropping intensity and productivity.
- Utilization of newly introduced adapted varieties requires further demonstration.
- Further research will have to be carried out in order to exploit the better-adapted cultivars appropriate for rice-based cropping patterns.

In addressing these issues, our national team will have to cooperate closely with international, regional, and national research centers. Our relationship with these institutions has been cordial, and their contributions to the development of Myanmar's agriculture have been invaluable. We will be grateful for their continued support.

Many of the scientists present here today represent or are closely associated with such organizations. I hope the discussion at this forum will address the problems of managing groundnut, chickpea, and pigeonpea crops in the RBCS of Asia. The Myanma Agriculture Service wishes to assure the meeting of its unstinted cooperation.

The AGLN and Rice-based Cropping Systems in Asia

D.G. Faris and C.L.L. Gowda

Legumes Program, ICRISAT

Introduction

On behalf of the Director General of ICRISAT and the members of the Asian Grain Legumes Network (AGLN) we welcome you to this workshop in Myanmar, on managing groundnut, chickpea, and pigeonpea in rice-based cropping systems. In the next nine days we plan to:

- Learn about and compare the management practices for growing AGLN crops in RBCS in Asia.
- Identify the constraints to the effective use of AGLN crops in these systems.
- Provide recommendations to overcome these constraints to use in planning future AGLN activities.

As some of you have not been directly involved in AGLN in the past, we would first tell you something about this network. Then we will say a few words about how we plan to achieve the goals set above.

AGLN

Objectives. The overall objective of AGLN is to assist in the coordination of technology exchange and collaborative research on groundnut, chickpea, and pigeonpea among scientists in Asian countries and at ICRISAT, in order to help farmers of the region increase legume production.

Members. All scientists and administrators in Asian countries and regional or international institutes interested in the improvement of AGLN crops and their cropping systems are invited to become members of the AGLN. A Directory of AGLN Cooperators is published periodically to provide information about each member's work. At present AGLN has 800 members.

The network is currently active in Bangladesh, the People's Republic of China, India, Indonesia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam and has contacts with other countries and regional and international institutes in Asia.

Structure. AGLN's structure consists of bilateral and multilateral elements. The bilateral element is founded on strong links between scientists at ICRISAT and in each of the

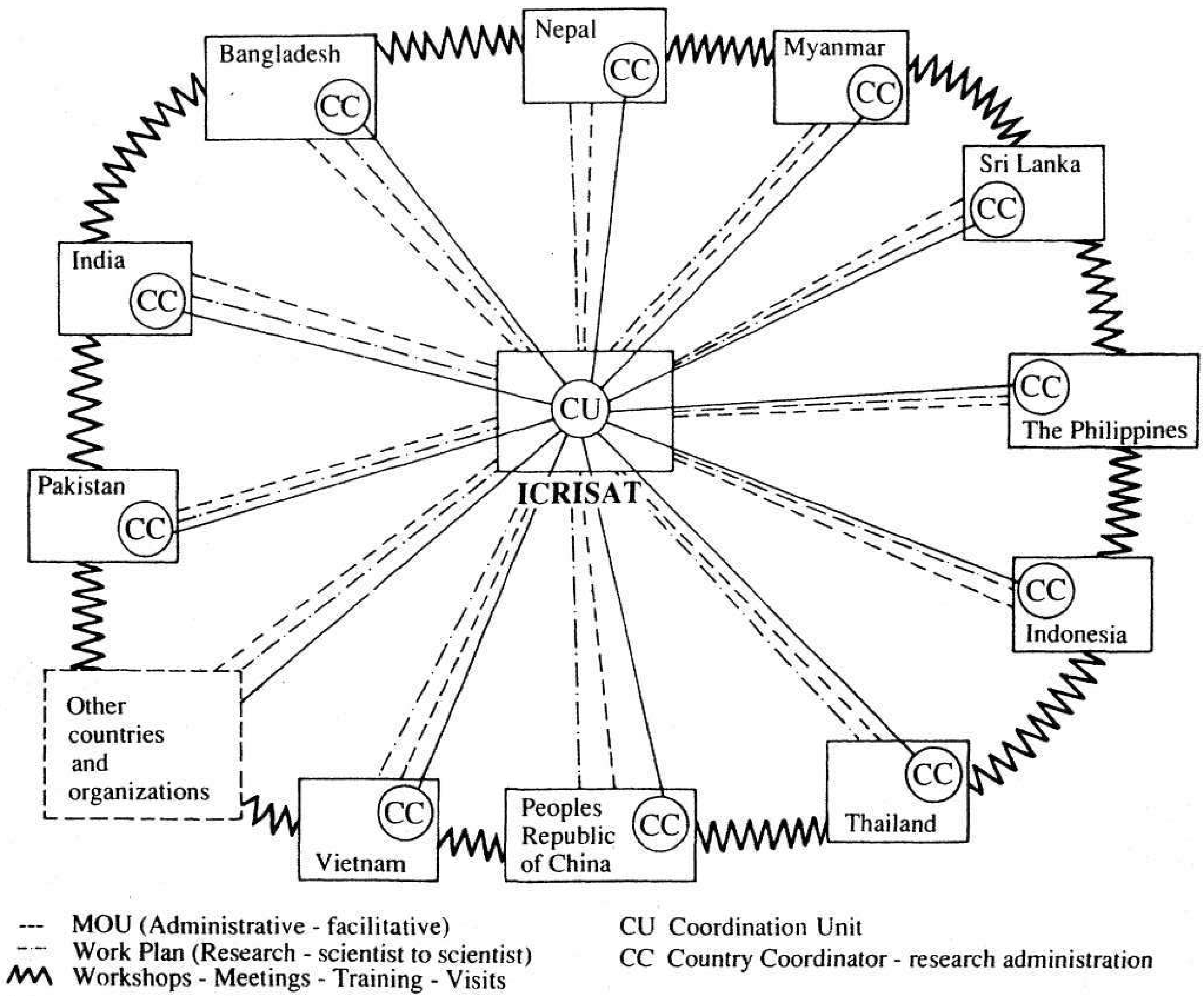

Figure 1. Diagram of the Asian Grain Legumes Network structure.

national programs, based on a formal Memorandum of Understanding (MOU) between ICRISAT and each AGLN country. These MOUs serve as broad umbrellas for collaborative research on ICRISAT's mandate crops, and facilitate administrative procedures (Fig.l).

Under the MOUs, collaborative work plans are prepared with each country based on the needs and interests of that country's programs. The work plans contain details of administrative procedures, germplasm exchange, trials, nurseries, joint monitoring tours, surveys, meetings, etc., and identify the commitment and responsibility to carry out these activities.

The multilateral element in AGLN's structure involves activities that link all the network members together. These activities include network coordinators' meetings, workshops such as this one, scientists' meetings, monitoring tours, working groups, and training courses involving participants from several countries.

The structure of AGLN also includes interaction with donors, and other regional, international, and mentor institutions. Association with such groups has helped AGLN strengthen its basic backup research.

Coordination. The AGLN Coordination Unit (CU), which facilitates and integrates the activities of the network, is located at ICRISAT Center, India.

For effective coordination and smooth functioning of collaborative activities, each country appoints a Country-AGLN Coordinator. The Country-Coordinator (CC) is the main administrative link between the CU and the country. The CC is responsible for activities such as clearing germplasm, material and equipment, and distributing it to the scientists concerned; monitoring and coordinating research activities; compiling results; preparing reports for AGLN review meetings; and organizing meetings and workshops related to AGLN crops in each country. Thus there are 11 subnetworks in the AGLN, each with a National Agricultural Research System (NARS) and an ICRISAT component.

Meetings of AGLN Country Coordinators and an Advisory Committee at ICRISAT guide the CU's activities within the network.

Activities. The AGLN structure supports many diverse activities and also permits easy initiation of new ones. These activities include:

- Information from ICRISAT for AGLN cooperators through ICRISAT's Information Services; Library; International Arachis, Chickpea, and Pigeonpea Newsletters; the Joint CABI (Commonwealth Agricultural Bureaux International)-ICRISAT Prompts for Chickpea-Pigeonpea, and for Groundnut; AGLN Cooperators' Report; and the Geographical Information System (GIS).
- A major contribution of ICRISAT to AGLN is the world germplasm collections and genetically improved material of chickpea, pigeonpea, and groundnut. These materials are shared directly by ICRISAT's Genetic Resources Unit (GRU), and Legumes Program scientists with the NARS through international nurseries and trials. AGLN assists in testing, evaluating, and using these materials in the country programs.
- The CU facilitates the training of network members by identifying training needs and supporting trainees from Asia; organizing special-topic training courses; arranging in-

country training programs; and organizing meetings and workshops to meet the specific needs of the Asian region.

- Several specialized working groups or subnetworks have been established to conduct research on specific high-priority regional constraints. These working groups consist of specialists from the national programs, regional and mentor institutes, and ICRISAT. Examples are: Asia-Pacific Working Group on Groundnut Viruses, bacterial wilt *(Pseudomonas solanacearum)* of groundnut (with Australian Centre for International Agricultural Research (ACIAR)), botrytis gray mold *(Botrytis cinerea)* of chickpea; Integrated Pest Management and Insecticide Resistance Management; ascochyta blight *(Ascochyta rabiei)* of chickpea (with ICARDA); and acid soil tolerance (with Peanut-CRSP (Collaborative Research Support Program)).
- AGLN is involved in specially funded country projects to strengthen in-country backup and on-farm research. E.g.: the Sri Lanka-ICRISAT-ADB (Asian Development Bank) Pigeonpea Production Project to enhance the production and utilization of pigeonpea to replace imported lentil *dhal (Lens culinaris);* and the UNDP (United Nations Development Programme)-FAO project on Asian Grain Legumes On-farm Research (AGLOR) in Indonesia, Nepal, Sri Lanka, and Vietnam.

Resources. Most of the support for the network's activities comes from the scientists in AGLN countries who use their available facilities and resources to carry out collaborative research. ICRISAT provides support to the CU and its scientists, and trains national-program scientists. Additional external funding comes from donors such as the ADB, which is helping to support this workshop, UNDP, FAO, the International Development Research Centre (IDRC), the Australian International Development Assistance Bureau (AIDAB), and Peanut-CRSP.

Outcome. The major strength of the AGLN structure is its flexibility to adjust to the priorities of each member country and the region. This flexibility is enhanced by the direct scientist-to-scientist contact facilitated by the network.

Another strength of AGLN is its wide range of activities ranging from germplasm exchange, to basic research, to applied on-farm research, to exchange of information. The working groups have been successful in providing solutions to high-priority regional problems.

AGLN's impact can be gauged by the release of several varieties of AGLN crops in Asia, the strengthening of research on AGLN crops in each country, the solutions to problems provided by working groups, the provision of appropriate technology to farmers, and the enthusiasm of its members.

About this Workshop

To learn about AGLN crops and compare their uses in rice-based cropping systems, we have a paper from each country giving its practices and problems, the importance of AGLN crops, how they fit into their cropping systems, how farmers choose which ones to grow, the constraints they face, the research being done to overcome these constraints, and what the future holds for these crops and systems. ICRISAT scientists will describe material and technology available for AGLN crops and ICRISAT's experience on legumes in rice-based cropping systems. Comparisons can be further clarified during discussions and during the five days we will spend on research stations and farmers' fields in Myanmar.

The recommendations emerging from this Workshop hold much importance. Some questions that require your attention are:

- What role do AGLN crops play in rice-based cropping systems?
- What are the major problems to be addressed?
- How can the existing technology answer these problems?
- What further information and research is needed?
- What actions should be taken?
- Who will carry out the actions?

Answers to these questions should form the basis for recommendations. Your recommendations can play an important role in guiding the future course of the AGLN, including its integration into the new Cereals and Legumes Asia Network (CLAN). So the better your ideas are the more everyone will gain.

Acknowledgements

We wish to thank the Myanma Cabinet for approving this Workshop, the Minister of Agriculture, and the Managing Director of the Myanma Agriculture Service and their staff for their unceasing effort in organizing and providing the means to hold this Workshop, and to ICRISAT and ADB for providing the funding and support. We look forward to working with all of you.

Managing AGLN Crops in Rice-based Cropping Systems in Bangladesh

A.F.M. Maniruzzaman and M.A. Razzaque

Bangladesh Agricultural Research Institute, Joydebpur and Crop Diversification Programme, Dhaka

Introduction

Bangladesh lies in the northeastern part of South Asia. Except for the hilly and undulating regions in the north-northeast, the northwest, and the southeast, the country is a flat alluvial plain. A network of rivers and their tributaries, about 20 000 km long, covers the country and flows into the Bay of Bengal

Bangladesh's agricultural economy accounts for about 46% of the Gross Domestic Product (GDP) and employs 61% of the labour force. Of the total land area of 14.4 m ha, about 8.16 m ha are cultivated with a cropping intensity of 160%. Crops account for over 78% of the agricultural production. Rice, jute *(Corchorus* spp.), sugarcane *(Saccharum officinarum),* tea *(Camellia* spp.), oilseeds, pulses, and potatoes *(Solatium tuberosum)* are the principal crops. Rice occupies 76% of the total cropped area, the remaining 24% being used for about 50 different crops. Wheat *(Triticum aestivum),* the other principal cereal, occupies only 4% of the cultivated area. Pulses account for 5% and oilseeds 4% of the total cropped area.

Bangladesh, with its humid subtropical monsoon climate, grows a wide variety of crops in three cropping seasons. The premonsoon season (late Mar-May) is characterized by thunderstorms and high temperatures. The southwest monsoon rainy season (Jun-Sep) is hot and humid when more than 80% of the total annual rainfall occurs. The postrainy winter period from Oct to early Mar with high solar radiation, is suitable for growing cool-season crops. *Aus* rice is grown during the premonsoon, *Aman* rice during the rainy season, and *Boro* rice during the postrainy season. *Aman* rice leads in terms of the area under cultivation and production, followed by *Aus* rice and *Boro* rice.

The annual production of pulses, which include lathyrus *(Lathyrus sativus),* lentil, chickpea, black gram *(Vigna mungo),* mung bean, cowpea *(Vigna unguiculata),* and pigeonpea is 0.52 m t, less than a third of the estimated requirement of 1.80 m t. Ground-nut, the third most important oilseed crop after rape seed *(Brassica napus),* mustard

Table 1. Area and production of AGLN crops in Bangladesh, 1989-90.

	Total for all cropping systems		Total in RBCS	
Crop	Area ('000 ha)	Production ('000 t)	Area ('000 ha)	Production ('000 t)
Groundnut	38.6	41.1	3.5	3.4
Chickpea	102.8	70.0	102.8	70.0
Pigeonpea	5.3	3.0		
All legumes	784.9	562.1	749.6	524.4

Source: Bangladesh Bureau of Statistics, 1991

(Brassica juncea), and sesame, has a production of 41 000 t. However, most of the groundnut is consumed in the form of roasted nuts and in confectionery products. The area and production of AGLN crops is given in Table 1.

Chickpea is next to lathyrus and lentil in importance, providing 14.5% of the total pulse production. It is grown during the postrainy season on residual soil moisture. Pigeonpea accounts for less than 1% of the total area and production, which comes mostly from cultivars that take about 300 days to mature. These crops are mainly confined to the flood plains of the river Ganges in the central and western parts of the country. In addition, the pigeonpea area extends northwards in the Active Tista Floodplain and the Tista Meander Floodplain. Pulse crops are grown in marginal areas under a low level of management which accounts for their very low yields.

Groundnut is produced mainly in the postrainy season on residual soil moisture but is also grown during the rainy season, primarily for seed production. Most groundnut-growing areas lie in the central and northeastern parts of Bangladesh.

Cropping Systems

Crop production in Bangladesh revolves around rice and RBCS. Although legume crops improve soil fertility and organic matter content, many farmers prefer to grow rice after rice because of the need to produce enough food grains. This is particularly noticeable in areas under irrigated crop production. However, green-manuring legume crops are now being incorporated in many areas without affecting the main rice crop *(Aman),* while reducing the need for urea fertilizer by about 50%. Due consideration is also being given to crop diversification to increase the production of pulses and oilseeds. These efforts have opened up possibilities of expanding pulse cultivation into nontraditional areas.

Chickpea is grown in the postrainy season in two sequential cropping patterns: *Aus* rice orjute (Apr-Aug) -fallow -chickpea (Nov-Apr): and *Aman* rice (Jul-Dec) -chickpea (Dec-Apr) -fallow (Apr-Jun). The Nov-Apr period is optimal for chickpea production, so about 60% of the chickpea is grown in the first pattern. Pigeonpea, being a long-duration crop, does not fit into any of these cropping sequences. Therefore, it is sown in May-Jun as a hedge crop, on field-bunds, and sometimes mixed with upland rice or finger millet (£/e-*usine coracana).* Medium-duration pigeonpea could be introduced as a rainy-season crop in the hilly areas of the southeastern part of the country. Short- or medium-duration pigeonpea could be intercropped with black gram or mung bean in the well-drained soils in the northern or northwestern region.

Groundnut is cultivated during both the rainy and postrainy seasons. Postrainy-season groundnut is the major crop grown mostly in the *char* lands (new river deposits) as a sole crop during Oct/Nov-Mar when land is relatively free from floods. Thus no crop precedes or succeeds groundnut in *char* lands. For the rainy-season groundnut grown for seeds in the highlands, the cropping pattern is: local broadcast *Aus* rice (Mar-May) followed by groundnut (June-Sep).

Choice Factors

As the farmers' needs, options, abilities, socioeconomic, and agroecological situations greatly influence their choice of crops and varieties, the adoption of new crops in traditional cropping patterns will largely depend on costs and benefits. A short-duration crop may be squeezed in between two major crops, provided no additional costs are involved and the major crop is not affected. The possible benefits could be reduced cost of inputs, a ready market for the produce, additional fuel and fodder, tolerance to weather hazards, and generation of employment.

Constraints to Production

The production of oilseeds (including groundnut) and pulses (including chickpea and pigeonpea) in Bangladesh has not been given enough attention by policymakers and researchers. As these crops are mainly rain-fed, they have been labelled minor crops and gradually pushed to marginal and submarginal lands. The low yield potential of the existing cultivars, their susceptibility to biotic and abiotic stresses, the absence of proper management practices, the lack of enthusiasm for good management practices, and poor marketing are some of the factors limiting production.

Research Progress

A coordinated multidisciplinary approach to research and development in pulses and oilseeds in order to overcome production constraints in Bangladesh has been financially supported by IDRC and the Canadian International Development Agency (CIDA). In chickpea, breeding is being done to develop high harvest index lines resistant to fusarium **wilt *{Fusarium oxysporum* f.sp. *ciceri)* and collar rot *(Sclerotium rolfsii)*. In cooperation** with ICRISAT our breeders are screening short- and medium-duration lines. As a result, scientists from the Bangladesh Agricultural Research Institute (BARI) have released a chickpea cultivar called Nabin which matures 10-15 days earlier while yielding substantially more than the local cultivar Sabur 4. Agronomists have established the importance of timely sowing in order to exploit the residual soil moisture and optimize yield. Mixed and intercropping practices have established the advantages of the optimum seeding ratios of chickpea when mixed with wheat and linseed *(Linum usitatissimum),* and intercropped with maize *(Zea mays),* or sugarcane. Studies on agronomic practices for late-sown chickpea, *Rhizobium* inoculation, and plant protection are in progress.

In pigeonpea, studies have been limited to the testing of medium- and short-duration lines obtained from ICRISAT and the United States Department of Agriculture (USDA). Line 76012 yields about 1.3 t ha^{-1} within 125-135 days. This line will be submitted for release to the National Seed Board (NSB).

Four varieties of groundnut have been recommended by the NSB. These are: Dhaka-1, a local selection susceptible to late leaf spot *(Phaeoisariopsis personata)* and rust *(Puccinia arachidis);* DG 2 or Basanti Badam, introduced in Bangladesh which has some tolerance to late leaf spot and rust; DM 1 or Tridana Badam, a short-duration dwarf variety suitable for intercropping with sugarcane, maize, cotton, and banana *(Musa paradisiaca);* and Acc-12 or Jhinga Badam, the highest yielding of the four. The present program is aimed at breeding varieties with short dormancy (20-30 days) at harvest, earlier maturity (120-130 days), high yield potential and high oil content, and tolerance to prevalent diseases and insect pests. Studies have established an optimum sowing time and plant spacing for these varieties. Postharvest studies have sought to determine the best method of seed storage under farmers' conditions so that the seeds remain viable until the next growing season.

Research Needs and Future Strategy

While research is underway to overcome the current constraints to production, future research will delve into issues likely to pose problems in the future. The varietal improvement program should focus on developing short-duration varieties which are easy to fit into cropping patterns and also incorporate characters to withstand both excess and limiting soil moisture. Since chickpea and pigeonpea have to compete with high-yielding cereals, physiological and morphological constraints need to be identified and the required resistances incorporated in the new varieties. Until it is understood why pulses do not respond to inputs like irrigation and fertilizer, they will continue to be grown under residual soil moisture situations. Research is needed to devise implements that enable farmers to sow crops so as to make the best use of residual soil moisture. New areas will be sought to expand cultivation of chickpea and pigeonpea. The Barind tract is one such area where chickpea cultivation following transplanted *Aman* rice holds promise. At present the land remains fallow after the *Aman* harvest (Dec onwards). The expansion of pigeonpea cultivation is possible if extra-short (80-90 days) and short-duration (100-120 days) varieties are developed for mixed cropping or intercropping with black gram in the *Aus* rice-black gram-fallow cropping pattern. For this, crop varieties tolerant to temperatures of less than 15* C and resistant to pod borer *(Helicoverpa armigera)* are needed. Management of long-duration pigeonpea for high biomass and as a hedge crop is another issue which requires attention.

Groundnut has the potential to become the most important oilseed crop after mustard and rape seed. For its cultivation in northern Bangladesh, cold-tolerant varieties responsive to high inputs are needed to compete with the other crops. In the southern regions, varieties with 120-day duration are necessary.

Chickpea, pigeonpea, and groundnut require special policy support by the government relating to the use of irrigation water and marketing. Currently, the price of irrigation water is based on the area covered and not on the volume. Although the prices of pulses have increased, the grower's share is negligible. The slow diffusion of technology is another hindrance. The flow of information from scientists to extension agents and finally to farmers, must be speeded up. Also, a supportive credit system and timely delivery of inputs must be ensured. The Crop Diversification Programme financed by CIDA has been recently started to provide these necessary thrusts. We hope that the AGLN crops and other legumes will play a vital role in RBCS and in crop diversification in Bangladesh.

Managing AGLN Crops in Rice-based Cropping Systems in China

Xiao Nenghuang

Oil Crops Research Institute,
Chinese Academy of Agricultural Sciences, Wuhan.

Introduction

Rice-based cropping systems are very important in Chinese agriculture with 32 m ha under rice producing 171 m t. Rice accounts for 29% of the area under cereals and 43% of the cereal production. About 92% of the area and production of rice is in southern China. Thus, rice production, to a large extent, determines food supply in the country, especially in southern China.

The main edible legumes in China are soybean *(Glycine max),* groundnut, broad bean *(Vicia faba),* pea *(Pisum sativum),* and mung bean, and to a small extent chickpea and pigeonpea (Table 1).

Legumes are important sources of edible oil and protein whereas rice and other cereals have low oil and protein contents. Groundnut and other legumes sown in RBCS use a reasonable amount of labor, water, sunlight, and other resources. They also improve soil fertility and promote a stable high yield of all crops.

Table 1. Area and production of groundnut and legumes in China in total and in RBCS during 1990.

	Total for all cropping systems		RBCS	
	Area	Production	Area	Production
Crop	m ha	m t	m ha	m t
Groundnut	3	5.7	0.38	0.87
All legumes	13.7	20.3	1.30	2.30

Choice Factors

In southern China most of the fields are continuously sown to rice. Tests show that such continuous cultivation causes secondary gleization of the soil and the deterioration of its physico-chemical properties. Some of the consequences are: worsening structure; increased unit weight; reduced porosity and permeability; lower temperatures in early spring; poorer oxidation-reduction state; less effective nutrient status; reduced presence of favorable microorganisms; increased disease, insect, and weed buildup; and lower yields. Using groundnut and other legumes as part of the RBCS and turning in their straw improves the soil and helps control diseases, insects, and weeds.

There are some rice-producing areas in China where there is insufficient water for continuous cropping of rice. Since rice uses about 80% more water than groundnut or legumes, farmers in these areas can get a better crop by sowing groundnut or some other upland crop. Besides effectively using the available water, these crops allow the effective use of labor and reduce fertilizer requirement.

In early spring, soil temperatures remain very low in the rice fields of the mountains if the field is left submerged. Rice transplanted in these fields grows slowly and produces a low yield. If the water in these fields is drained away during the winter and groundnut is sown in spring, it usually grows well and produces high yields.

Cropping Patterns

The main cropping patterns involving groundnut in RBCS in China are as follows:

- Double-cropping in central China
  - Groundnut-rice
  - Rice-groundnut
  - Groundnut-wheat or rape seed: second year: soybean-rice
- Triple-cropping in southern China
  - Groundnut-rice-soybean, rape seed, broad bean, pea or sweet potato *(Ipomoea batatas)*
  - Rice-rice-groundnut
  - Rice-groundnut-wheat or sweet potato
  - Soybean-rice seedling-groundnut

Practices

The average yield of groundnut in China is moderate (1.92 t ha^{-1}) and variable (0.7540.00 t ha^{-1}). Studies conducted in recent years have identified some effective practices to increase groundnut yields. These include:

Popularizing excellent varieties. Yueyou 116, Yueyou 551, Heyou 77, Zhonghua 17, and Ehua 3 are high-yielding groundnut varieties with resistance to bacterial wilt and rust and/ or leaf spots *(Cercospora arachidicola* and *Phaeoisariopsis personata).*

Improved seed quality. To improve groundnut seed quality, farmers in China usually harvest and dry the seeds on time, store them in cool and dry conditions, select healthy seeds, and expose the nut-in-shell to the sun once or twice before sowing. They also use other traditional methods. Scientists, technicians, and farmers in southern China emphasize the use of autumn groundnut seeds for sowing in spring instead of sowing spring seeds the following spring. Autumn groundnut sown in the spring has greater vigor, earlier emergence (2-4 days), higher emergence rate, and gives 15-25% higher yields than other seeds.

Appropriate fertilizer application. Soils in China are generally deficient in nitrogen (N), phosphorus (P), and potassium (K). There is little nitrogen fixation in groundnut in the first month after sowing. Under these conditions, groundnut seedlings grow slowly and their leaves appear yellow. This first nitrogen starvation results in insufficient vegetative mass to produce good yields. The second nitrogen starvation is at the full seed stage when too many nutrients are lost from the functional leaves to allow proper filling of the seeds. It also leads to poor nitrogen fixation and absorption of mineral nutrients from the soil, and early senescence and low yield. For better growth and high yield, it is necessary to supplement manure with fertilizers. Commonly, application rates are 75-150 kg ha^{-1} of urea, 300-600 kg ha^{-1} of calcium phosphate, 150-225 kg ha^{-1} of potassium chloride, and 450-750 kg ha^{-1} of lime before sowing, followed by foliar spray with 1% urea and 1% calcium phosphate 2-3 times at the full seed stage.

Early sowing under plastic film. Groundnut in China is mostly sown in spring and is of a growth duration of 120-130 days. In order to grow well and produce a high yield, it is necessary to prevent the groundnut seedling from emerging at a temperature less than 15℃ and peg and pod at temperatures greater than 30°C. Early sowing encourages high yields as it produces extended growth and avoids high temperatures at the later stages. But temperatures are low and variable in early spring and groundnut seeds sown in cold soil germinate poorly and decay. Tests show that covering the soil with a plastic film (0.012-0.020 mm thickness) raises its temperature (1-5℃) and allows the sowing to take place 10-15 days earlier. By adopting this method, groundnut seeds germinate and emerge 3-8 days earlier, the soil retains its moisture and nutrients, leading to accelerated growth and high yields.

Other practices. Plant population is an important factor in determining the yield in groundnut. At the yield level of 3-4 t ha^{-1}, usually a plant density of 300 000-360 000 plants ha^{-1}, and at 4.5-6 t ha^{-1}, 240 000-270 000 plants ha^{-1} is required. Other practices are irrigation and timely control of diseases, insects, and weeds.

Constraints

The main constraints to using groundnut in RBGS in southern China are as follows:

Economy. Most of the agricultural land must be used to cultivate rice in order to meet the food needs of the large population in southern China. Groundnut yield is low at low plant densities (150 000-210 000 plants ha^{-1}) when little, if any, fertilizer is used, if varieties and seed quality are poor, and if disease is not controlled in time.

Nature. Some regions of southern and central China are drought-prone, the temperatures are low in early spring and high in summer, the soil has low fertility and acidic pH (<5.5), and diseases like bacterial wilt, rust, and leaf spots are common.

Research

Though groundnut is an important crop in China, it has low and variable yields. A research effort is needed to overcome these constraints. This must include programs like screening germplasm and breeding material for high yield, resistance to rust, bacterial wilt, and leaf spots; tolerance to drought and acid soils; reasonable patterns of RBCS; better practices; and technical development of groundnut for low-yielding regions.

The Future of AGLN Crops in RBCS

In RBCS, groundnut is necessary to cater to the market needs and to improve the soil. In recent years, rice production in China has exceeded the demand. Therefore, more area can now be made available for groundnut cultivation, especially in fields unfit for rice, or where there is water scarcity, poor soil fertility, sandy soil, low temperature in early spring, serious diseases, and weed buildup with continuous rice cultivation. Under these conditions, groundnut might be more advantageous than rice.

Chickpea and pigeonpea can only be produced on a small scale.

Suggestion

Soybean contains rich protein with a complete amino acid profile and oil. It is an excellent protein resource for developing countries which have a scarcity of meat, egg, and milk.

Soybean is widely sown but gives low and variable yields in Asia. If soybean were included in AGLN, the network could help encourage increased soybean production in Asia.

Managing AGLN Crops in Rice-based Cropping Systems in India

Masood Ali and M.S. Basu

Directorate of Pulses Research, Kanpur and National Research Centre for Groundnut, Junagadh

Introduction

Rice is the most important cereal crop in India. It is grown over an area of 42 m ha and adds about 74 m t annually to the food basket of the country. It is cultivated on all types of terrain, soil, and climate: in the hilly regions and at sea level; on rainfed uplands and deep water; on acidic as well as alkaline soils; and in tropical to temperate climate. Apart from monocropping, it is grown in many different cropping systems, the predominant ones being rice-wheat (in northern and parts of central India), rice-rice (in the eastern and coastal peninsular regions), rice-chickpea (in the northeastern plains), rice-groundnut (in the eastern and southeastern region), and rice-urd bean *(Vigna mungo)/mung* bean (in the low-lying areas of the southeastern coastal region).

In India, the importance of grain legumes in cereal-based cropping systems has long been recognized for their role in sustaining crop production and meeting the growing demand for dietary protein. Groundnut, chickpea, pigeonpea, lentil, mung bean, lathyrus, and urd bean are the major grain legumes grown in RBCS in India. In the lowland rainfed areas of eastern India, lentil and lathyrus have been grown for centuries in relay cropping with medium-duration rice cultivars. In the traditional rice fallows of the coastal peninsular regions, urd bean and mung bean have been successfully introduced, both in relay and sequential cropping systems.

Among AGLN crops, chickpea, which occupies an area of 1.29 m ha (Table 1) is the most important in RBCS. It is also becoming popular in the rainfed areas of the northeastern plains and also in the irrigated areas of the northwestern plains. Pigeonpea and groundnut are next in importance in RBCS. Traditionally, long-duration pigeonpea cultivars are intercropped with upland rice in the states of Bihar and eastern Uttar Pradesh. In the low-lying areas of West Bengal, eastern Madhya Pradesh, and Orissa states, pigeonpea is generally grown on rice bunds. In RBCS, groundnut is a unique crop grown either

Table 1. Area and production of AGLN crops in RBCS in India, 1989/90.

Crop	Total for all cropping systems		Total in RBCS	
	Area (m ha)	Production (m t)	Area (m ha)	Production (m t)
Groundnut	8.71	8.09	0.60	1.08
Chickpea	6.50	4.23	1.29	1.19
Pigeonpea	3.58	2.72	0.10	0.15
Total	18.79	15.04	1.99	2.42

completely on residual moisture or with minimal irrigation in the states of Orissa, coastal Andhra Pradesh, and West Bengal. In the eastern and northeastern hill regions, upland rice and groundnut intercropping (3:1) is becoming popular because it gives a higher net monetary return than a sole rice crop. The area under groundnut in the postrainy season in RBCS may go up to 1 m ha within a short span of time once quality seeds of suitable varieties become available.

Cropping Systems and their Management

The RBCS involving AGLN crops being practised in India are: rice-chickpea, rice + pigeonpea, rice-groundnut cropped sequentially, and pigeonpea on rice bunds. Rice-pigeonpea in relay cropping and rice-groundnut cropped sequentially may gain favour with farmers in some nontraditional areas if appropriate genotypes of the legume crops are developed.

Rice-chickpea. The advent of chickpea genotypes amenable to late sowing has popularized rice-chickpea sequential cropping in the rainfed areas of the northeastern plains and in the irrigated areas of the northwestern plains where water is limited. The major states with this cropping system are Uttar Pradesh, Bihar, Madhya Pradesh, West Bengal, Punjab, and Haryana. All India Coordinated Pulses Improvement Project (AICPIP) studies have shown that rice-chickpea was more profitable than rice-wheat sequential cropping. The inclusion of chickpea in sequence with rice economizes on nitrogen (20-30 kg ha^{-1}), improves the physical condition of the soil, and helps in eradicating obnoxious weeds like wild oat *(Avetta fatua)* and Canary grass *(Phalaris minor).* This system is generally followed on heavy soils. Rice genotypes of 120-150 days duration are either direct-seeded or transplanted. The chickpea genotypes recommended are Radhey, Pant G 114, and BG 261. The sowing of chickpea in this system is often delayed until late Nov or early Dec either due to a late rice harvest or excess moisture in the field. Chickpea receives either a small amount of fertilizer (10 kg N ha^{-1} plus 15 kg P ha^{-1}) or none at all. On heavy soils, chickpea is cultivated as a rainfed crop but on light soils one irrigation is given. *Helicoverpa* pod borer is the major pest but few control measures are taken. Botrytis gray mold is a serious disease but lately Stemphylium blight *(Stemphylium* sp.) has also been reported from Bihar.

Rice + pigeonpea. This system of intercropping is practised in the rainfed uplands of eastern Uttar Pradesh and southern Bihar. The monsoon rains are received from the end of June to mid October and some winter rains may also occur. The soil is, by and large, light textured. The seeds of short-duration rice (90-100 days) and long-duration pigeonpea (250-280 days) cultivars are generally mixed and broadcast. A full population of both crops is maintained. AICPIP studies have shown that a 4:1 row ratio of intercropped rice and pigeonpea is most productive. At sowing, 40-50 kg N ha^{-1} and 20 kg P ha^{-1} are applied by broadcasting. After the rice harvest the pigeonpea crop does not receive any inputs or plant-protection measures. Thus the yield is generally low. Pod fly *(Melanagromyza obtusa)* and pod borer *(Helicoverpa armigera)* are the major pests. Wilt *(Fusarium udum),* sterility mosaic, and phytophthora stem blight *(Phytophthora drechsleri* f.sp. *cajani)* are the major diseases.

Pigeonpea on rice bunds. This system is followed in the low-lying areas of West Bengal and Orissa where water stagnation does not permit the cultivation of pigeonpea in the fields. Rains are often heavy and extended. Two-three rows of long-duration pigeonpea varieties (250-270 days) are sown on rice bunds after the rice is transplanted. The pigeonpea does not receive any fertilizer or plant protection. No attempt has yet been made to identify suitable genotypes and develop technology to enhance the productivity of this system.

Rice-groundnut. Groundnut is grown in the postrainy season on about 1.5 m ha, of which more than 50% is under RBCS. Orissa is the major state where groundnut is grown under residual moisture. In the states of Andhra Pradesh, Tamil Nadu, Karnataka, and West Bengal groundnut is grown with minimal irrigation. The majority of the soils in RBCS are acidic and require liming. The average productivity of groundnut in RBCS is twice that of the rainy-season crop and the production is stable. Owing to the relatively low incidence of diseases and pests and the high and stable yield, the groundnut area in RBCS has increased by many times in recent years. Short-duration Spanish bunch varieties are widely grown during the postrainy season. Improved varieties released recently for RBCS are RSHY 1, ICGS 11, TG 3, and VRI 3. Some low-cost technologies to increase the production of groundnut in RBCS are:

- Release of efficient *Rhizobium* strains i.e., IGR 6 and IGR 40.
- Development of varieties resistant to bud necrosis disease (bud necrosis virus).
- Development of a simple method of drying and storing pods to retain seed viability.

In the state of Kerala groundnut is also grown as a catch crop between two rice crops. Extra-early varieties are preferred in such situations.

Rice-pigeonpea relay cropping. In the rice fallows of coastal peninsular India, pigeonpea may find a place using extra-early (90 days), high-yielding, and photo- and thermo-insensitive varieties. Similarly, pigeonpea is sometimes grown as a spring crop (Mar-May) in the irrigated areas of the northern plains in the rice-mustard/potato/peas cropping pattern, if suitable genotypes are available.

Production Constraints

The major constraints limiting the productivity and popularity of AGLN crops in RBCS are:

- Lack of early-maturing, fast-growing, and cold-tolerant genotypes of chickpea and groundnut to fit into RBCS.
- Nonavailability of genotypes tolerant to pod borer in chickpea and leaf-miner ***(Aproaerema modicella)*** **and leaf feeders** ***(Spodoptera*** **spp and** ***Helicoverpa*** **spp) in** groundnut.
- Late sowing of chickpea after rice due to excessive moisture in field or late harvest of rice.
- Nonavailability of high-yielding, foliar disease-resistant groundnut varieties; and sterility mosaic-resistant, long-duration pigeonpea varieties for intercropping with rice.
- Lack of appropriate technology to cultivate pigeonpea on rice bunds.
- Lack of extra-early, high-yielding, and photo- and thermo-insensitive varieties of pigeonpea and groundnut for rice fallows in the central and peninsular regions, and for spring crops in the northern plains.
- Terminal drought in rainfed conditions.
- Heavy rains at pod maturity in some areas resulting in *in situ* germination in groundnut.
- Poor plant stand and a low level of management with little or no use of plant-protection measures.
- Soil salinity, acidity, poor drainage, and a high water table in the eastern regions.

Research Activities and Needs

Comprehensive and systematic research is being done on chickpea and pigeonpea in the different agroecological regions under the AICPIP and at the Directorate of Pulses Research, Kanpur, and on groundnut at the Directorate of Oilseeds Research, Hyderabad, the National Research Centre for Groundnut, Junagadh, and under the All India Coordinated Research Project on Oilseeds (AICORPO), to overcome the management constraints and to develop genotypes matching different cropping systems including the RBCS.

Sufficient information on the management of rice-chickpea, rice-groundnut, rice + pigeonpea, and rice + groundnut cropping systems has been generated. However, high-yielding, early-maturing varieties resistant to biotic and abiotic constraints have yet to be developed in chickpea, pigeonpea, and groundnut to further promote these cropping systems.

Varietal development and standardization of technology for pigeonpea on rice bunds have yet to be covered under the AICPIP. Similarly, pigeonpea genotypes for rice fallows and spring cultivation have yet to be developed. AICPIP has initiated a program but it needs to be strengthened.

Research under the AICORPO on groundnut has been started to develop cold- tolerant, early-maturing varieties with fresh-seed dormancy to bring more area under groundnut in spring. Similarly, screening for tolerance to aluminium toxicity, iron chlorosis, aflatoxin *(Aspergillus flavus),* and other biotic and abiotic stresses has been initiated to strengthen the varietal improvement program. The quick loss of seed viability of postrainy-season groundnut is the major problem limiting the spread of groundnut in RBCS.

The Future of AGLN Crops in RBCS

The increasing awareness of the importance of grain legumes in cropping systems, the spurt in grain legume prices, and the pressing need to enhance the production of pulses and oilseeds, will result in chickpea, pigeonpea, and groundnut receiving greater emphasis. Chickpea and groundnut will occupy the premier position in RBCS and their area will gradually increase. The area of pigeonpea in RBCS is likely to be stable, but may increase when spring cultivation of pigeonpea becomes remunerative.

Managing AGLN Crops in Rice-based Cropping Systems in Indonesia

T. Adisarwanto

Malang Research Institute for Food Crops, Malang

Introduction

Soybean, mung bean, groundnut, cowpea, and pigeonpea are the important grain legumes grown in Indonesia. These crops, cultivated since the beginning of the seventeenth century, were probably introduced by Chinese immigrants and Portuguese traders. It is likely that pigeonpea was brought from India in the seventh century. Cultivation of grain legumes was once confined to Java and Bali, but since the early 1920s, has spread to Sulawesi, Sumatra, Kalimantan, and the eastern parts of the Indonesian archipelago.

Importance of Grain Legumes in Food Crop Production

The three major grain legumes in Indonesia are soybean (1.2 m ha), groundnut (0.6 m ha), and mung bean (0.3 m ha). Pigeonpea and cowpea are less important crops. Eastern and central Java are the major groundnut-producing regions, accounting for 43% of the area and production in Indonesia. Western Java accounts for about another 15% and Sulawesi about 12%.

Utilization

Most of the groundnut grown in Indonesia is consumed after being roasted, boiled, or made into groundnut chips *(Rempeyek).* Waste from pressed groundnut is used as livestock feed or made into flour, nut curd *(Oncom),* and *Tempeh* for human consumption. Only a little groundnut is used for making oil or peanut butter. Most pigeonpea is consumed as a vegetable (young pods) or as dry seed.

Groundnut

Sixty-six percent of the groundnut produced is rainfed, and only about 34% is irrigated in RBCS in Indonesia,

On wetland, groundnut is cultivated either after the first or second rice crop, or after soybean, during the dry season. Cropping systems depend on such factors as rainfall, the production characteristics of the land, and labor and other socioeconomic factors. In RBCS in Indonesia, groundnut fits into the following cropping sequences:

- Rice - rice - groundnut.
- Rice - groundnut - groundnut.
- Rice - soybean - groundnut or groundnut + maize.

Cultural Practices

Variety. Twelve groundnut varieties have been released since 1983. They range in yield from about 1.2 t to 3.0 t ha^{-1}, mature in 90-110 days, and have seed size of 35-57 g 100 $kernels^{-1}$.

Land preparation. Trials have shown that the method and amount of land preparation used before a rice crop and before the groundnut crop succeeding it can affect the yield of the latter. In some areas, especially with light soils, groundnut is normally sown without tillage. The crop is normally hilled at the first weeding. Sowing on broadbeds has increased yields by 25% over sowing on flat beds.

Sowing dates, seeding rate, plant density, and spacing. On irrigated wetland, groundnut is sown in Mar-Apr as a second crop after rice and in Jul-Aug as a third crop after rice. An appropriate sowing date is important in order to utilize the available soil moisture and rainfall.

Like other legumes, groundnut is sown manually using a dibbling stick, hand hoe, or an animal-drawn plow. Using the plow, the seed is dropped into the plow-track and covered with soil. This method is quicker but the seed position and depth is not even. The recommended spacing is 40 cm x 10 cm. However, the seeding rate depends on the sowing method and the seed size. For a small-seeded variety, dibbling requires 50-60 kg ha^{-1}, while sowing with a plow requires 80-90 kg ha^{-1}.

Fertilizer. The recommended fertilizer rates, similar for all areas, consist of 25-50 kg N ha^{-1}, 30-50 kg P_2O_5 ha^{-1}, and 20-50 kg K_2O ha^{-1}. On a light- textured soil, 10 t ha^{-1} of cattle manure did not increase groundnut yield significantly.

Weeds. Weeds can reduce groundnut yields by as much as 45% if weeding is not done. Broad-leaf weeds and sedges are common on wetland and dryland. Farmers hand weed their groundnut, seldom using herbicides.

Water management. Groundnut sown on wetland after the first rice crop will suffer waterlogging if drainage is not provided. On the other hand, stress occurs in groundnut sown in the dry season and such crops can benefit from four to five irrigations if water is available.

Pests and diseases. Pest incidence is less prevalent on groundnut than on other grain legumes but occasionally leaf roller *(Aproaerema modicella),* leaf feeders *(Spodoptera litura* and *Helicoverpa armigera),* aphids *(Aphis craccivora),* and thrips *(Scirtothrips dor-salts* and *Frankliniella schultzei)* attack the crop.

The most common diseases are late leaf spot, rust, and peanut stripe virus. Research indicates that pod yield increases by more than 50% if rust and late leaf spot are controlled. However, despite this fact, farmers rarely take any measures to control these diseases. In some areas disease is such a serious problem that farmers prefer to switch over to crops like mung bean or cowpea.

Harvesting and drying. Harvest is done by pulling the plants manually after about 85-95 days after sowing. The pods are picked by hand and then dried for about 6-7 days. This reduces their moisture content from 40-50% down to 20-25%. Sorting is done after drying. Groundnut is stored in the shell for seed as well as for consumption.

Constraints and Research Needs

The main constraints to groundnut production in RBCS in Indonesia are:

- Poor drainage.
- Drought stress when sown in the dry season.
- Diseases, especially late leaf spot, rust, and peanut stripe virus.
- Damage by rats.

The following research topics need to be given priority:

- Improving crop establishment in the early dry season.
- Increasing drought tolerance in the late dry season.
- Improving crop management using such techniques as broadbeds, hilling, double rows, and other sowing systems.
- Developing technology for wetland agroecosystems.

Pigeonpea

Pigeonpea, not an important grain legume in Indonesia, is mostly grown in Java, southern Sulawesi, Bali, Lombok, and in the islands east of Lombok up to Timor.

Variety. Pigeonpea varieties introduced from Australia and ICRISAT are capable of producing 3 t ha^{-1} of dry grain and mature in about 105 days when sown as a sole crop with good crop management and insect protection. As this crop is very susceptible to pests, it often fails to produce yields over 1 t ha^{-1}.

Mulching. The yield of pigeonpea, used as a second crop after rice, increased when mulched with rice straw.

The Future of AGLN Crops in RBCS

Groundnut has considerable potential in RBCS in Indonesia. New high-yielding, stress-tolerant varieties may help stabilize yields. Pigeonpea may find more use in RBCS for sowing on bunds. Its expansion can be expected in the dry eastern islands of Indonesia.

Managing AGLN Crops in Rice-based Cropping Systems in Myanmar

Thein Han, Tun Saing, Aung Thaung, and Myat Twe

Central Agricultural Research Institute, Yezin
and Myanma Agriculture Service, Yangon

Introduction

The diverse agroecological conditions in Myanmar have permitted the cultivation of over 60 different crops. Rice production is common in 289 townships out of 314 and covers 4.88 m ha or about 61% of Myanmar's cultivated area. Rice production is distributed 55% in the delta, 14% in the coastal strip, 13% in the central semi-arid zone, and 18% in the northern upland area. Since the average landholding per farm family is less than 4 ha (and this is on the decline), farmers find it increasingly difficult to meet their annual expenditures with only one crop a year. Thus there is a need to increase cropping intensity.

Sequential cropping is common in rice-growing areas where double- and triple-cropping is carried out to suit agroclimatic conditions. Double-cropping is most common in rainfed lowland rice areas. The availability of short-duration, high-yielding rice cultivars has made it possible to fit in another crop like cotton, sesamum, jute, and food legumes before and/or after rice.

Grain legumes are an important source of foreign exchange and a good source of protein. Groundnut contributes more than any other crop to the country's supply of cooking oil. The unique properties of legume crops such as their nitrogen-fixing ability increase their agronomic significance in rice-based and upland crop-based farming systems.

Myanmar farmers have intuitively chosen legume crops with a growth habit to suit the seasonal soil moisture status. Thus, chickpea is mainly grown as a relay or sequential crop in the lowland rice areas where day and night temperatures are mild in winter. It follows the rice crop in central Myanmar and the delta region where the soil texture, moisture-holding capacity, and fertility are relatively favorable to the crop's growth and development.

Pigeonpea is not yet widely used in RBCS due to its long duration and other physiological constraints.

Production

AGLN crops are an important component of Myanmar's agricultural system (Table 1). Season-to-season distribution of these crops varies greatly, their cultivation primarily determined by the availability of soil moisture. Groundnut and chickpea are commonly grown as second crops wherever biophysical factors are favorable to their growth and development.

Table 1. The cultivated area and production of AGLN crops in total and in RBCS in Myanmar, 1990/91.

	Total		In RBCS	
Crop	Area ('000 ha)	Production ('000 t)	Area ('000 ha)	Production ('000 t)
Groundnut	554	472	86	93
Chickpea	170	104	55	32
Pigeonpea	71	42	0.02	0.006

Cropping Patterns

Sequential cropping is common in the rice-growing areas of Myanmar. Groundnut is used extensively as a succeeding crop. It is primarily grown on ligh-textured soil after rice. Since the soil moisture gets depleted quickly in these soils, the crop often suffers from drought stress during its later growth stages. The transplanted rice-groundnut cropping pattern is popular in the delta area where precipitation is relatively heavy. The lighter alluvial soil in this region is particularly suitable for the growth, development, and easy harvest of groundnut.

Chickpea after rice is a potential cropping pattern in upper and central Myanmar wherever winter temperatures are relatively mild. Since these areas have a low annual rainfall, chickpea is commonly grown on the heavier soils in which the residual moisture depletes slowly. Heavy-textured soils such as Vertisol are difficult to prepare for proper crop establishment. As a result, relay cropping is commonly practiced for the rice-chickpea cropping pattern.

In Myanmar, rice-pigeonpea cropping patterns are not common. The existing pigeonpea varieties are photoperiod-sensitive, and stay in the field for 150-180 days. The recent development of extra-short-duration pigeonpea cultivars that mature in less than 100 days can fit into a rice-pigeonpea cropping sequence. Research is essential to exploit the appropriate technology for using this pattern.

Major Determinants in RBCS

The following are the biotic and abiotic stresses which cause low and unstable productivity of groundnut, chickpea, and pigeonpea in Myanmar.

- The unimodal precipitation pattern between May and Nov results in drought stress during the early growth stage of the crops preceding rice, and moisture deficit during the later growth stage of the crops succeeding rice.
- Heavy-textured soil, which is favorable for the growth and development of groundnut because of its slow rate of soil-moisture depletion, makes harvest of groundnut difficult. Although chickpea can be grown with the residual moisture in the heavy-textured soils after rice, it cannot be extended into areas where the temperature during the growing season is too high.
- Extensive infestation by early and late leaf spot and collar rot *(Aspergillus niger* and *Diplodia* sp) reduce groundnut production by as much as 10% annually. Fusarium wilt, root rots *(Rhizoctonia bataticola, R. solani,* and *Fusarium solani)* and pod borer cause substantial yield losses in chickpea. Pigeonpea pod borer and pod fly limit productivity and area expansion.
- Shortage of inputs, such as chemical fertilizers and pesticides, lead to yield instability and low productivity in leguminous crops.
- Medium-duration groundnut cultivars (120-140 days) encounter late-season drought stress resulting in severe yield reduction. Despite their high yield potential, improved groundnut varieties are not popular with farmers because of their low oil content. Currently available kabuli and desi chickpea varieties are not able to give high yields

because of the warm temperatures during the growing season in the delta area. Medium- and long-duration pigeonpea cultivars (150-280 days) do not fit into rice-based sequential cropping patterns.

- The delta area where the rice-groundnut cropping pattern would benefit farmers cannot effectively produce and store groundnut seed because of its high precipitation and relative humidity. The high cost of transportation of groundnut seeds from drier areas makes them too expensive for most farmers.
- Labor shortages and high wages during critical periods result in low monetary returns for succeeding leguminous crops.

Research

- Breeding programs have been initiated to develop early-maturing chickpea, pigeonpea, and groundnut varieties to withstand drought stress.
- Selection of pest- and disease-resistant groundnut and chickpea varieties has been carried out in collaboration with ICRISAT since 1985. The international chickpea root rots and wilt nursery and the pigeonpea sterility mosaic, wilt, and canker disease screening nurseries have been evaluated in Myanmar to select resistant types.
- The varietal improvement program is also designed to improve yield, grain quality, and maturity.
- Germplasm collection and characterization of local groundnut, chickpea, pigeonpea, sorghum, and millet landraces is well underway.
- Agronomic trials are conducted at CARI and the cooperating regional research stations.
- Studies on the effectiveness of biological nitrogen fixation (BNF) have led to the commercial production of *Rhizobium* inoculum since 1977. Farmers are convinced that inoculating chickpea and groundnut with *Rhizobium* is advantageous.

The Future of AGLN Crops in RBCS

Production of groundnut, chickpea, and pigeonpea in Myanmar can be increased by a two-dimensional approach: (1) the improvement of yield per unit area through varietal improvements; and (2) area expansion accomplished by sequential cropping after rice in lower Myanmar and the delta region.

The exploitation of adapted varieties is of prime importance. The varietal improvement program calls for collaboration between Myanmar and international research centers because the staff in Myanmar is insufficient to initiate a hybridization program by itself. Early-maturing and high-yielding rice as well as the other crops in RBCS are needed urgently to increase cropping intensity, and consequently increase the productivity of AGLN crops in the delta area.

Intensive research on cropping systems is essential to exploit the full potential of cropping patterns. Currently, a considerable portion of the lowland rice area is left fallow after rice. If appropriate component technologies for both rice and the succeeding crops can be generated, the production of AGLN crops in Myanmar will increase rapidly.

Managing AGLN Crops in Rice-based Cropping Systems in Nepal

G.P. Koirala and G. Chaudhary

National Oilseed Research Program, Sarlahi and National Rice Research Program, Parwanipur

Introduction

Nepal lies between 26°20'N and 30°30'N and rises from 100 m to 8848 m above sea level. In Nepal, 93% of the population depends on agriculture. Rice, the country's major crop, is cultivated over an area of 1.4 m ha, that is, 10.7 % of the total land or 62.5% of the cropped land, yielding a total production of about 3.4 m t. The average yield is 2.37 t ha^{-1}.

Grain legumes rank fourth in area and fifth in production. Of the AGLN crops, both chickpea and pigeonpea are grown as sole, mixed, and intercrops. Chickpea is also relay cropped in RBCS, and pigeonpea is grown on rice bunds in eastern Nepal. Groundnut is not grown as part of RBCS in Nepal. It is grown in the dry (summer) season as a sole crop if irrigation is available, or intercropped with maize and pigeonpea in the rainy season. Groundnut cultivation in the dry season (Feb sowing) is on the increase.

AGLN Crops in Nepal

Chickpea. Chickpea is a major grain legume in the *Terai,* and Inner *Terai* regions of Nepal. It is sown in the rainfed areas after rice and maize over 28 100 ha (Table 1) with an average yield of 0.59 t ha^{-1}. Recent prices of grain legumes including chickpea have been very encouraging compared to those of cereals, and are expected to help increase the productivity of chickpea mainly in western Nepal.

Pigeonpea. Pigeonpea, also an important pulse crop in Nepal, is grown in a variety of ways in different cropping systems in the *Terai,* Inner *Terai,* and the lower valleys up to the 800-m level. It occupies 18 800 ha or 7.5% of the total area under pulses (Table 1).

Groundnut. Groundnut is grown as a rainfed crop mainly in the *Terai,* Inner *Terai,* and Mid-hill regions of Nepal. The interest in groundnut as an oil crop has been a factor in the establishment of ten vegetable ghee and oil industries in Nepal.

Prior to 1982, farmers cultivated groundnut in small pockets. In 1983, groundnut production was organized in 8 districts but the expected increase in production has not been achieved. While in 1971/72 the area under groundnut cultivation was about 4080 ha, in 1981/82 it was about 4310 ha (Table 1). The 1991 census of agriculture is expected to give more reliable figures of the present area.

Table 1. The cultivated area and production of AGLN crops and their use in RBCS in Nepal during 1981/82.

Crop	Total: Area ('000 ha)	Total: Production ('000 t)	Total in RBCS: Area ('000 ha)	Total in RBCS: Production ('000 t)
Groundnut	4.3	4.3		
Chickpea	28.1	16.6	28.1	16.6
Pigeonpea	18.8	13.2		
All legumes	252.8	167.5	196.9	118.8

Cropping Sequences

There are many cropping sequences in Nepal involving AGLN crops or ones in which they might fit. Some of these are:

- Rice-chickpea or lentil-fallow.
- Rice-lentil/lathyrus-early rice.
- Rice-wheat-mung bean.
- Pigeonpea + maize, cotton, or finger millet-fallow.
- Pigeonpea + sesame-spring maize.
- Sesame-toria + chickpea/lentil.
- Maize-pigeonpea + groundnut-fallow.
- Groundnut (sole or with maize)-wheat *(Terai* and Mid hills).
- Groundnut + pigeonpea-fallow.
- Rice-fallow-groundnut (spring sowing).
- Groundnut - fallow (Mid hills).

Constraints

The major constraints limiting the production of AGLN crops in Nepal are:

- Relegation of these crops to marginal, infertile, and rainfed lands.
- Inability of farmers with small holdings to invest in inputs.
- Nonavailability of high-yielding varieties suited to the range of agroclimatic conditions in Nepal.
- Varieties with insufficient resistance to insect-pests and diseases including wilt, collar rot, and botrytis gray mold in chickpea, and sterility mosaic, pod borer, and pod fly in pigeonpea.
- Lack of adequate services to ensure timely availability of inputs to farmers.
- Inadequate supply of quality seeds.
- Nonavailability of equipment such as bed makers, groundnut diggers, and shelters.
- Inadequate plant populations and fertilizer use.
- Inadequate use of plant-protection measures.
- Serious damage by birds and rats.

- Poor weed control.
- inadequate use of good postharvest technology.
- Lack of irrigation facilities for spring groundnut crops.
- Inability of farmers to grow a winter crop after late-maturing groundnut.
- Farmers have a limited ability to absorb new technology because of their inability to read information bulletins and their limited interest in consulting agricultural workers.
- Poor coordination among groups providing technology to farmers.

Research

To increase the production and productivity of groundnut in Nepal, it is necessary to plan research to solve the farmers' problems. Some progress has been made to overcome some of the constraints.

Groundnut. Several strategies have been used including:

- Crop improvement
  - ICGS 36, an early-maturing variety (115-120 days), allows farmers to grow winter crops after groundnut
  - Janak, a high-yielding variety, has been developed
- Production technology
  - Alachlor effectively controls weeds as a pre-emergence herbicide
  - Application of 20 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 20 kg K_2O ha^{-1} has produced profitable yields
  - Lime application has also increased yields
  - Plant-protection measures increase groundnut yields substantially

Chickpea and pigeonpea. Research activities have included the following:

- A multidisciplinary legumes research program started in early 1972 for chickpea and in 1977 for pigeonpea.
- Intensive and widespread testing of new technology at research stations and in farmers' fields.
- Release of chickpea varieties Dhanush, Trishul, Radha, Sita, Kosheli, and Kalika.
- Release of long-duration pigeonpea cultivar Bageswari (PR 5174) and medium-duration cultivar Rampur Rhar 1 (Rampur local).

The Future of AGLN Crops in RBCS

Groundnut. Nepal is a net importer of oilseeds including groundnut. The demand for oil will increase with the rise in population. Ten vegetable ghee and oil processing plants have already been established to meet this increase in demand. Since groundnut is one of their major raw materials, there is ample reason for increasing its production in Nepal.

There has been little, if any, increase in groundnut production in Nepal for many years. Groundnut production can be increased by changing the balance of rainy season and spring season groundnut, intercropping groundnut with maize, and reducing the gap between yields obtained by farmers and potential yields. Appropriate technology to maximize the yield should be developed and an effective handling and marketing system should be established.

ICRISAT's Contribution to AGLN Crops in Nepal

- Since the early 1980s, ICRISAT has supplied chickpea, pigeonpea, and groundnut germplasm and breeding lines to Nepal through AGLN.
- Scientists and technicians of the National Oilseed Research Program (NORP) and the National Grain Legumes Research Program (NGLRP) have been trained at ICRISAT to facilitate better implementation of chickpea, pigeonpea, and groundnut improvement activities.
- ICRISAT publications help Nepalese scientists to update their knowledge on chickpea, pigeonpea, and groundnut technology.
- Workshops organized by ICRISAT have involved participation by Nepalese researchers.
- Monitoring tours conducted jointly by NARS and ICRISAT have effectively identified field-level problems.
- Review and planning meetings have been held and Nepalese scientists have provided the inputs essential for the success of Nepal-AGLN work plans.
- ICRISAT, through the AGLN/ADB grant, has provided equipment to meet important research needs.
- ICRISAT/AGLN/AGLOR support has permitted increased mobility for Nepalese staff to visit research stations and farmers' fields to identify constraints and monitor trials.

ICRISAT's contribution to chickpea, pigeonpea, and groundnut improvement in Nepal through AGLN/AGLOR has been highly appreciated and NORP and NGLRP look forward to the continuation of this collaboration.

Managing AGLN Crops in Rice-based Cropping Systems in Pakistan

B. A. Malik

National Agricultural Research Centre, Islamabad

Introduction

Pakistan grows rice over an area of 2.04 m ha and produces 3.29 m t. The Punjab province contributes about 58% of the area under the crop and 44% of the production, and Sindh 34% of the area and 45% of the production. Rice is the major agricultural export commodity after cotton. The area and production of food legumes grown in all cropping systems and in RBCS in Pakistan are given in Table 1. Rice grown under canal irrigation leaves sufficient residual moisture for succeeding crops like chickpea and lathyrus, whereas wheat needs supplemental irrigation.

Chickpea is the only important AGLN crop which fits into the RBCS of Sindh and Baluchistan provinces. The rice areas in Punjab could also support the rice-chickpea system provided early-maturing, ascochyta blight-resistant varieties of chickpea, and better agronomic management are available. Groundnut and pigeonpea are grown in the same season as rice, hence they are of little importance in RBCS.

The other important grain legumes grown under RBCS include lathyrus and lentil. Lathyrus is grown exclusively in the provinces of Sindh and Baluchistan and is cultivated in RBCS to provide green fodder (60%) for livestock and as dry grain (40%) for both animal feed and human consumption.

Table 1. Area and production of food legumes in all cropping systems and in RBCS in Pakistan during 1989/90.

	All cropping systems		In RBCS	
Crop	Area ('000 ha)	Production ('000 t)	Area ('000 ha)	Production ('000 t)
Groundnut	80	82		
Chickpea	1035	562	96	71
Pigeonpea				
All legumes	1576	850	262	156

Source: Agricultural Statistics of Pakistan, 1990

Lentil is grown on a limited scale after rice in Punjab. One of the major production constraints is the nonavailability of rust-resistant varieties with orange cotyledons.

Cropping Sequences

The main cropping sequences in the provinces of Sindh and Baluchistan in order of importance are:

1. Rice-wheat-rice.
2. Rice-chickpea-rice.
3. Rice-lathyrus-rice.
4. Rice-flax-coriander/peas-rice.

The following cropping sequences are common in Punjab:

1. Rice-wheat-rice.
2. Rice-lentil-rice.
3. Rice-Egyptian clover-rice.
4. Rice-sunflower-rice.
5. Rice-peas-rice.
6. Rice-chickpea-rice.

Choice Factors

Farmers are interested in deriving more income from their land. The legumes which fetch a monetary return comparable to the rice-wheat-rice system in Sindh and Baluchistan include chickpea and lathyrus. The cost of cultivating chickpea is lower than that of wheat, but the selling price of chickpea is more than double that of wheat. Chickpea is the major *dhal* used in Sindh and Baluchistan, hence virtually every farmer grows it after rice.

Rice farmers in Punjab are reluctant to grow chickpea due to the damage caused by ascochyta blight. Therefore, ascochyta blight-resistant varieties combined with better sowing methods for better plant stand establishment and efficient pod borer control are essential. Pod borer damage, poor stand establishment, and salinity are responsible for low chickpea yields in the rice areas of Sindh and Baluchistan.

Constraints

The average yield of chickpea in Pakistan is about 0.5 t ha^{-1}. While yields in the RBCS in Sindh and Baluchistan are about 0.8 t ha^{-1}, they are far below those at experimental stations, demonstration plots, and farmer-managed and researcher-supervised on-farm trials. This wide productivity gap gives scope for major productivity gains. Higher yields can be achieved in RBCS by overcoming a number of production constraints:

General Constraints

- Waterlogging and salinity.
- Expensive power supply for tubewells.
- High cost of fertilizers, chemical pesticides, farm machinery, and fuel.
- Reluctance of small farmers to get loans.
- Need for adapted high-yielding varieties resistant to major biotic and abiotic stresses.
- Need for suitable sowing and threshing machinery.
- Need for genotypes with early vigour and rapid canopy cover.
- Need for better herbicides to control weeds.
- Need for more effective *Rhizobium* strains for RBCS.

On-Going Research on Chickpea

Research on chickpea in Pakistan has provided the following:

- Reliable screening techniques against ascochyta blight and wilt.
- Multi-stress screening at the National Agricultural Research Centre (NARC) has identified a few promising multiple-resistance genotypes.
- Chickpea varieties resistant to ascochyta blight and with better plant type and bold seeds.
- By using pheromone traps, critical periods for controlling pod borer with minimum chemical use have been established.

Research Needs

Research is needed on the following aspects for an improved management of AGLN crops in RBCS:

- Development of kabuli chickpea varieties with seed quality and high yield potential in order to utilize the ample moisture available in RBCS.
- Development of location-specific genotypes of AGLN crops with improved yield.
- Study mineral nutrition in RBCS for a better understanding of the value of the rice-chickpea cropping sequence to sustain production.
- Screen germplasm to identify lines with good germinability and vegetative growth at low temperatures for the rice-producing areas of Punjab.
- Pay close attention to research on integrated disease management.
- Identify and evaluate herbicides for use on farmers' fields.
- Evaluate zero-tillage seed drills for chickpea in RBCS.

The Future of AGLN Crops in RBCS

Chickpea is predominantly grown in the rice areas of Sindh and Baluchistan. The yield varies from 800 kg to 1000 kg ha^{-1} in RBCS because there is sufficient residual moisture after rice. In rainfed areas, chickpea only yields 300-400 kg ha^{-1}. Chickpea in RBCS competes in terms of monetary return with two other major systems, rice-wheat and rice-lathyrus. Chickpea production in these areas will be even more profitable when short-duration and high-yielding, disease-resistant varieties are easily available. Control of weeds and pod borer, and suitable sowing and threshing machinery will further improve the economics of growing chickpea in RBCS.

In future chickpea is expected to find a place in the rice areas of Punjab where multilocational on-farm trial plots using ascochyta blight-tolerant varieties have given yields of up to 3.5 t ha^{-1}.

Increased food-crop production is required to meet the needs of Pakistan's annual population growth of 3.1%.

The following agenda has been drawn up for bringing more areas under chickpea in RBCS:

- Transfer of improved production technology and improved seed to farmers through research/extension collaboration.
- Improve the system of production and distribution of improved seeds of location-specific cultivars.
- Use the governmental support price policy for timely procurement of produce from farmers.
- Establish processing mills in production zones to minimize the role of middlemen in the movement of the produce from the farmer to the mill and the market.
- Strengthen verification and validation of applied research results through operational research in different agroecological conditions and production systems.
- Seek ICRISAT's help through AGLN for increased scientist-to-scientist contact for training, germplasm exchange, research planning meetings, and visit by scientists.

Managing AGLN Crops in Rice-based Cropping Systems in the Philippines

Ester L. Lopez

Philippine Council for Agriculture, Forestry and Natural Resources Research and Development, Los Banos

Introduction

Rice is the staple food of over 80% of 62 m Filipinos. While the country's population has increased at the average rate of 2.3% per year, the area under rice cultivation has remained stable for the past 25 years. The yield per unit area has been increased by using high-yielding varieties and intensifying land use. Rice is cultivated over 3.5 m ha (about 23% of the country's total agricultural land) of which 52% is irrigated, 44% rainfed-lowland, and 4% upland.

Rice production in 1987 was about 8.9 m t. In terms of value of production, rice consistently tops other agricultural commodities, averaging about 25% of the total agricultural production.

Rice cultivation is central to the lives of 18 m Filipinos and is the most important activity in the Philippine rural economy. Hence, the significance of RBCS cannot be overemphasized.

Cropping Sequence

In the dominant rice-based cropping patterns in the country, legumes are among those crops most commonly preferred by farmers for rainfed conditions. This can be attributed to the special features of leguminous crops such as drought tolerance, short life cycle, ability to fix nitrogen, varied utility, nutritive value, and marketability.

The area under legumes is about 110 000 ha and groundnut is grown on 54 620 ha. Groundnut is grown after rice or maize, or intercropped with upland rice or maize. It is mainly grown on upland rainfed areas, with about 30% area under RBCS.

Decision Factors

Based on the experience of the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), farmers generally consider the following factors in their choice of leguminous crops to fit into their cropping pattern:

Crop duration. Farmers give priority to their main rice crop and so will not alter their calendar of activities for rice. Thus, they prefer short-maturing supplementary crops that will not affect their established schedules.

Cash inputs. Rice farmers have very little cash to invest in another crop; so they prefer crops which require few cash inputs. Hence they prefer crops with a high degree of resistance to major insect pests and diseases in order to save on pest-control expenses.

Seed availability. Lack of seeds is a major reason for farmers keeping their lands fallow after rice.

Marketability and high profit. A farmer practising sequential cropping involving other legumes like mung bean or cowpea will shift to an AGLN crop like groundnut only if he is assured of a market and higher profit.

Risk. The farmer knows his farm and his environment and has a good idea of the risk of crop failure, which is mainly due to the lack of water during the dry season. Thus, he prefers crops that can withstand drought stress. Some farmers know that the period after rice is risky and would be satisfied if the crop met their fodder needs (since it is scarce) even if it does not yield seed.

Constraints and Possible Solutions

For more widespread use of AGLN crops in RBCS in the Philippines, the following constraints must be overcome:

Dependence on residual moisture by crops sown after rice. To reduce the risks associated with dependence on residual moisture, PCARRD and the Department of Science and Technology (DOST) have been trying to establish small farm reservoirs. Breeding programs are also screening germplasm to develop drought-tolerant varieties.

Susceptibility to pests and diseases. Since farmers cannot afford expensive pesticides, pest-resistant crops are needed to assure them of a yield.

High weed population. The labor cost to control this pressing problem is high. Crops with rapid seedling establishment and early vegetative growth are needed to compete better with the weeds.

Lack of quality seeds. This is a problem particularly in groundnut; farmers have to forego sowing if quality seeds are not available. A seed support system for legumes is being planned by PCARRD.

Groundnut import. This depresses local prices, discouraging farmers from cultivating groundnut. Adjusting government import policies can help.

Lack of technical knowhow and operating capital. A survey of farmers identified these constraints. As a result, a technology-transfer program under the PCARRD-DOST peanut commercialization program is currently underway, which includes technical and credit-assistance components.

Acid soils in the uplands. Trials have shown that acid soils decrease groundnut yields by 30%. Extensive areas where groundnut is sown after rice have a pH of < 5.5. Screening groundnut for acid soil tolerance is going on.

Potential for AGLN Crops

Among the three AGLN crops, groundnut is the most important in the Philippines and has the greatest potential as a cash crop.

With demand expanding rapidly, imports of groundnut have been increasing (3700 t in 1985, 8400 t in 1986, and 17 300 t in 1987). The national average yield is only about 0.8 t ha^{-1} but the potential does exist to increase yield in areas under groundnut (some of them rice-based). Another possibility of increasing groundnut production is to convince farmers who fallow their land after rice to grow groundnut instead.

Pigeonpea, a potential source of protein, is an integral part of the farming systems in some regions of the Philippines. Its importance in the nutrition of subsistence farmers in the uplands of central and western Visayas has been documented.

Chickpea is a relatively new crop, not widely known in the country. Only a small amount is imported for use in special meat and vegetable dishes. Its potential performance under Philippine conditions is being evaluated.

Managing AGLN Crops in Rice-based Cropping Systems in Sri Lanka

N. Senanayake

Regional Agricultural Research Centre, Angunukolapelessa

Introduction

Sri Lanka is divided into three major agroclimatic zones: wet, dry, and intermediate. These are subdivided into agroecological regions on the basis of rainfall, soil, and vegetation. The wet and intermediate zones range from <300 m above sea level (low country) to 300-900 m (mid-country) and > 900 m (up-country). The low country is flat or undulating and includes major irrigation schemes, while the mid- and up-country varies from undulating through rolling, hilly and steeply dissected mountainous terrain. On the basis of rainfall there are two well-defined seasons: *Maha* (Oct-Mar), under the influence of the northeast monsoon, and *Yala* (Apr-Sep), under the influence of the southwest monsoon.

Rice is grown mainly in the low country dry zone under supplementary irrigation during the *Maha* season and only under irrigation during the *Yala* season. The total area under rice is 85 600 ha and the production is around 253 000 t with an average yield of 3.26 t ha^{-1}.

The major constraint in the irrigated rice tracts is inadequate irrigation water during *Yala.* In the rainfed uplands there is a water shortage during both the seasons. Sometimes,

Table 1. AGLN crops under cultivated area and under production in Sri Lanka, 1990.

	All cropping systems		In RBCS	
Crop	Area ('000 ha)	Production ('000 t)	Area ('000 ha)	Production ('000 t)
Groundnut	11.0	11.1	(Not estimated)	
Chickpea	Recent introduction		None	
Pigeonpea	0.4	0.5	None	
All legumes	91.5	82.2	(Not estimated)	

Source: Division of Technology Transfer, Department of Agriculture, Sri Lanka, 1990.

however, there is excess water during the *Maha* season. These conditions have created an RBCS in which rice is grown during *Maha* and a crop requiring little moisture in *Yala.* Legume crops are thus the obvious choices. Among the AGLN crops, chickpea has a limited potential in RBCS because the temperature in Sri Lanka is too high except in a small area in the up-country. The other two AGLN crops, groundnut and pigeonpea, have more potential.

Legume Production

Legume crops are grown mainly in the rainfed highlands during the *Maha* season in all the agroclimatic zones. There is only a limited cultivation of these crops under irrigation. The production statistics of legumes in Sri Lanka, are given in Table 1.

Status of Legumes Crops

Legumes are major food crops in Sri Lanka and they require little input. They are grown mostly as rainfed sole crops during the *Maha* season. They are usually components of the subsistence *chena* (shifting cultivation) system. The major legumes in Sri Lanka are mung bean (38 000 ha), cowpea (28 000 ha), black gram (18 000 ha), groundnut (10 000 ha), and soybean (6000 ha). Two attempts to increase pigeonpea production in Sri Lanka, by introducing perennial varieties in the early 50s, and the early dwarf variety MI 10 in the 70s, failed because of the high incidence of pod borers and blister beetle *(Mylabris* sp), and the nonavailability of processing facilities. Thus the area under pigeonpea decreased from 1136 ha in 1970 to 270 ha in 1975, and 69 ha in 1976. Today it is mainly a backyard crop grown in isolated pockets around the country. However, short-duration pigeonpea varieties have again been introduced. Research is in progress along with field demonstrations which appear to be having some success. The potential for chickpea in Sri Lanka appears very limited since the required area with the low temperature and low humidity is very small.

Rice-based Cropping Systems

Research on RBCS was initiated in the Walagambahuwa Project in the dry zone under minor tank irrigation in the 1970s. The rainfall in this area is bimodal with little rainfall during *Yala.* This research evolved three possible cropping patterns instead of the traditional single rice crop:

- One *Maha* rice crop (90 days) from Oct to Jan, followed by a vegetable crop (60 days), then some other field crop (OFC) during *Yala.*
- Two rice crops (90 days each) from Oct to Jan during *Maha* and Mar to May during *Yala.*
- One rice crop during *Maha* (90 days) followed by a pulse or OFC.

Research on RBCS started at Katupotha in the intermediate zone under totally rainfed conditions, in the late 1970s. Except for valley bottoms and in very wet years the rice crop during *Yala* was a failure. However, research proved that a legume crop could be successfully cultivated following a *Maha* rice crop.

RBCS research was initiated in System H of the Mahaweli Major Irrigation Scheme in the dry zone, in the early 1980s. Results indicated that several cropping patterns are possible:

- Rice-OFC.
- Rice - legume - OFC.
- Rice - legume.

Constraints to AGLN Crops in RBCS

In almost all irrigation schemes, a stable lowland rice crop during *Yala* is only partially successful. High evaporation demand and high infiltration rates in the middle and upper slopes aggravate the situation. Under these constraints farmers are convinced that they should grow short-duration field crops in the rice fallow.

In order to make AGLN crops popular in RBCS, research should concentrate on providing:

- High-yielding, short-duration varieties.
- Drought-tolerant varieties.
- Insect pest and disease control.
- Network of marketing facilities.
- Processing of pigeonpea.

Research is already underway to identify high-yielding, short-duration AGLN crop varieties. Research conducted at different regional research centers in Sri Lanka has identified several potential introductions of groundnut (Angunukolapelessa) and pigeonpea

(Maha Illuppallama). Chickpea introductions (Bandarawela) do not appear to be well adapted.

Several diseases have been identified in groundnut: early and late leaf spot, rust, bud necrosis, and stem rot *(Sclerotium rolfsii).* Among pests, aphids, thrips, and white grubs *(Lachnosterna* sp) are important. The major insect pests on pigeonpea are the pod borers, blister beetle, and bruchids *(Callosobruchus* spp.) for which resistant or tolerant varieties have yet to be identified. Pod borer is an important pest in chickpea.

Water shortage during *Yala* means that drought-tolerant varieties of AGLN crops will have an advantage in RBCS in Sri Lanka. The absence of processing facilities for pigeonpea has been a constraint to its acceptance in Sri Lanka, but now the technology is available, so all that is required is for this technology to be passed on to the farmers.

Large-scale cultivation of AGLN crops in RBCS must also overcome the constraint of underdeveloped market facilities.

Future Research Needs

Further research on AGLN crops should focus on breeding or screening introductions to select high-yielding, short-duration, pest- and disease- resistant varieties for local conditions. Knowledge of the best sowing time to obtain high yields and avoid peak pest and disease buildup is also required to incorporate these crops into RBCS. The future of chickpea in Sri Lanka, however, is very limited.

Future of AGLN Crops in RBCS

In Sri Lanka, RBCS is a viable concept especially in irrigation schemes where there is a water shortage for rice cultivation during the *Yala* season. Here, short-duration AGLN crops which can grow under low moisture conditions have a great potential for incorporation into RBCS under irrigation. Pigeonpea has the greatest potential because of its deep roots and drought tolerance. It is also necessary to identify cultivars with pest and disease resistance. Chickpea has little potential in RBCS in Sri Lanka unless high-yielding cultivars are identified to grow during the *Yala* season in the up-country intermediate zone.

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Managing AGLN Crops in Rice-based Cropping Systems in Thailand

C. Smitobol

Farming Systems Research Institute, Bangkok

Introduction

Thailand has long been one of the world's major rice-producing countries. In 1990, about 10 m ha were harvested producing over 20 m t. The sown area for rice during the dry season was only slightly under 1 m ha, although the total irrigable land at the end of 1989 was over 4 m ha. Over 3 m ha of irrigable land was not sown to rice because of insufficient reserve water. Since other field crops require much less water than rice, this land has great potential for growing crops other than rice. However, only about 0.8 m ha of irrigated rice land was reported to be under field crops and vegetables in the dry season. Furthermore, in most rainfed areas, the length of the growing period is estimated to be six months or more annually, which should leave enough time to grow a second crop, before or after rice.

In Thailand as well as other Asian countries, soil fertility can decline rapidly. High temperatures coupled with high rainfall bring about conditions favorable for soil microorganism activity, causing a rapid decomposition of organic matter and undesirable physical and chemical soil properties. Growing legumes in the crop sequence not only provides a source of protein but also reduces the C/N ratio, thus increasing soil fertility.

Production

Among the AGLN crops, chickpea and pigeonpea are not grown commercially in Thailand. A few local varieties of vegetable pigeonpea are grown in the backyards for their green pods. Perennial varieties of pigeonpea are sometimes used as a plant host for lac production. Groundnut, on the other hand, is a popular legume grown in the country.

In the future, legumes will play a much more important role in RBCS in Thailand. Most farmers, noticing the deterioration in soil fertility, understand that legumes could improve the fertility of rice soil. More importantly, there is a great demand for legumes such as soybean, mung bean, and groundnut in both domestic and foreign markets.

Many of the figures for the area and production of AGLN crops in Thailand can only be estimated (Table 1). For example, the figure for pigeonpea is an estimate as is the area of legumes in RBCS. The best estimate for groundnut cultivation in RBCS is 30% of the total area while chickpea and pigeonpea are not grown in RBCS. The area of all legumes in RBCS including mung bean, soybean, and groundnut is estimated to be about 35-40% of the total area.

Table 1. Area and production of AGLN crops in Thailand in 1990[1].

Crop	All cropping systems		In RBCS	
	Area ('000 ha)	Production ('000 t)	Area ('000 ha)	Production ('000 t)
Groundnut	122	161	32	45
Pigeonpea	1	-[2]		
Mung bean + soya + groundnut	1148	1190	400	500

1 Some of these figures are estimates.
2 Data not available.
Source: Agricultural Statistics of Thailand, 1989/90

Cropping Sequences

The cropping sequence in RBCS is governed by various factors such as rainfall patterns, crop behavior, and soil properties. The rains start by about mid April with light showers and become heavier under the influence of the northeast monsoon during Aug-Oct. During Apr-Jul, most rice fields do not accumulate rain water on the surface and soil aeration is suitable for field crops, especially in well-drained soils. Sesame, mung bean, groundnut, soybean, jute, and kenaf *(Hibiscus cannabinus)* are popular crops for growing before rice. After the rice harvest, crops like mung bean, black gram and groundnut can be grown using the soil moisture left from the rainy season. In irrigated areas, however, rice is always grown at the onset of the rainy season. In the dry season, soybean, mung bean, groundnut and vegetable crops as well as rice are grown under irrigation.

Choice Factors and Constraints

Market demand and a reasonable selling price (preferably at the village level) are prime considerations in choosing a crop. Farmers are satisfied if they earn a net profit of about 6000 Baht ha^{-1} (about US$ 240) from their crop. However, small farmers grow food crops for family consumption regardless of their monetary return. It is for these reasons that chickpea and pigeonpea are not popular choices.

Cropping patterns adopted must fit the moisture status of the area. Under rainfed conditions, the combined growing period of AGLN crops and rice must not exceed the total length of the growing period. Also, the crop grown before rice must be harvested before the heavy rains in Aug. The crop after rice must be early-maturing so as to escape drought.

Labor requirement is a factor that helps determine the kind of AGLN crops that can be grown in RBCS. Groundnut is labor intensive compared to other crops. Should this constraint be overcome, the groundnut-growing area might increase greatly.

Insect damage and disease infestation are sometimes the reasons why farmers avoid growing chickpea and pigeonpea. In some areas, farmers do not grow groundnut before rice in order to avoid the aflatoxin-producing fungi that infect groundnut pods harvested in the middle of the rainy season. Breeding for resistant varieties is a good strategy to overcome these biotic constraints.

Research

Breeding of groundnut has been actively conducted in Thailand in cooperation with international organizations such as ICRISAT. In this program, varieties of groundnut have been tested for their resistance to insect and disease pests such as subterranean ants, aspergillus crown rot *(Aspergillus niger),* sclerotium stem rot, rust, leaf spot, and aflatoxin-producing fungi. Early-maturing varieties of groundnut have been bred to fit before and after rice cultivation. Khon Kaen 60-3 was released recently as a high-yielding variety for northeastern Thailand. Attempts have been made to provide small machinery for soil ridging, harvesting, and pod shelling in order to solve the labor problem. Nutrient requirements of legume crops have been investigated in various soils. Deficiency and excess of microelements such as iron, molybdenum, boron, and manganese have also been studied.

The Future

Among AGLN crops, chickpea and pigeonpea have no great potential in Thailand. Developing insect- and disease-resistant varieties of these crops would be easier than developing a domestic market for them.

Groundnut cultivation has the potential to develop further. In rainfed areas, groundnut before rice would be more popular if varieties resistant to aflatoxin-producing fungi were available. Development of early-maturing and/or drought-tolerant varieties should enhance cultivation of groundnut after rice. In irrigated areas, further acceptance of dry-season groundnut cultivation will depend on the success of small machinery for ridging and harvesting.

Managing AGLN Crops in Rice-based Cropping Systems in Vietnam

Tran Nghia and Nguyen Quang Pho

Vietnam Agricultural Science Institute, Hanoi and Agricultural University No.II, Hue

Introduction

Vietnam is a tropical country with a humid monsoon climate (Table 1).

Table 1. Climatic conditions in northern, central, and southern Vietnam.

Meteorological factors	Hanoi 21°0 N	Hue 16°5 N	Ho Chi Minh City 10°5 N
Total T/year (℃)	8 660	7 908	10 000
Radiation (Kcal cm^{-3})	85.8	130	112.2
Mean T/year (°C)	23.4	25.2	27.6
No. months T >25℃	5	7	12
Mean T of coldest month (℃)	16.6	19.9	26.2
Mean T of hottest month (℃)	28.8	29.8	28.8
Annual rainfall (mm)	1 600	2 744	1 984
Wet season	May - Oct	Sep - Nov	May - Oct

Production

The main aim of the Vietnam government is to make the country self-sufficient in food. During 1981-1990, because farmers were given direct responsibility for their farms and investment in agriculture was increased, rice production rose from 7.6 m t to 19.2 m t and yield from 2.1 t ha^{-1} to 3.2 t ha^{-1}.

During the same period, legume crops have also played an important role, particularly groundnut and soybean. Production of both crops has increased, particularly during 1981-1985 (Table 2). Yields have also increased.

The main constraints to further increasing groundnut production are:

- Most groundnut is grown on rainfed exhausted soil.
- Fertilizer, insecticide, and high-yielding varieties are unavailable.
- New technology has not been applied on a large scale.
- Inappropriate rotations such as continuous groundnut, which favors buildup of insect pests and diseases, are being used.

During 1990, about 100 000 ha of groundnut were rotated with rice.

Table 2. Area, yield, and production of groundnut and soybean in Vietnam in 1980, 1985, and 1990.

	Groundnut			Soybean		
Year	Area ('000 ha)	Production ('000 t)	Yield (t ha^{-1})	Area ('000 ha)	Production ('000 t)	Yield (t ha^{-1})
1980	106.1	95.1	0.896	48.8	32.1	0.657
1985	212.7	202.1	0.950	102.0	75.6	0.740
1990	201.4	213.5	1.060	110.0	86.9	0.790

Research

Ngoo Nham Go-operative in Ha Bac province has a poor soil As a result of research during 1968-1973, the cooperative introduced the following technical improvements to their soil:

- Built an irrigation system.
- Used plows which increased the depth of the cultivated layer from about 10 cm to 16 cm.
- Used phosphatic fertilizer (500 kg ha^{-1}) and lime (300-500 kg ha^{-1}) for 3 years for their summer rice crops.
- Rotated summer rice with groundnut on 15-20% of the cultivated land.
- Buried the groundnut haulm 7-15 days before transplanting summer rice. This resulted in a yield increase of about 15%.
- Applied other progressive technology for growing groundnut and rice.

As a result, rice yield increased from 2.5 t ha^{-1} in 1968 to 6.2 t ha^{-1} in 1973 and groundnut yield increased from 1 t ha^{-1} in 1968 to 1.9 t ha^{-1} in 1991. Profits were further increased by adding a winter crop such as sweet potato to the rotation.

Groundnut

Constraints. The main constraints to the groundnut crop when grown in rotation with rice are as follows:

- Under highland rainfed conditions:
  - little cash to purchase inputs;
  - buildup of diseases such as damping-off, early and late leaf spot, rust, pod rot *(Fusarium* spp, *Macrophomina phaseolina,* and *Rhizoctonia solani),* and bacterial wilt;
  - nonavailability of high-yielding varieties with fresh seed dormancy and resistance to leaf spot and drought; and
  - failure to apply technologies such as fertilizers, insecticides, and fungicides.
- On the exhausted soils:

The normal practice of growing a spring and a summer rice crop and a sweet potato winter crop results in poor soil with little organic matter and low income to farmers. However, the farmers are unwilling to replace spring rice with groundnut even though they know it will improve their soil and profits, unless they have the technology and the inputs to do so.

- On improved soils:

Rice yields 3.5-4 t. ha^{-1} per season. Groundnut crops need to yield 2.5-3 t ha^{-1} to compensate for the replaced rice crop even though using it improves soil fertility.

- In south Vietnam:

In south Vietnam, groundnut yields are high (1.3-3 t ha^{-1}) due to the favourable weather and the use of intensive technology. The main constraints to higher groundnut production are:

- excess spraying of insecticides;
- disease due to excessive plant density;

- use of groundnut varieties with low yield potential;
- use of poor quality seed and mixed varieties; and
- nonuse of fungicides to control foliar diseases.

Pigeonpea

Pigeonpea is essentially a wild plant in Vietnam scattered throughout the country. It could have economic importance in the midlands and the highlands along with maize.

Short-duration pigeonpea was introduced into Vietnam from ICRISAT in 1989, first at Hanoi and later in different ecological regions including the plains and midlands of Bac bo, coastal Trung bo, and eastern Nam bo. Initial results indicate that pigeonpea can yield very well in central Vietnam. In addition, it can grow under drought conditions where other crops cannot. A technology needs to be developed and adopted in Vietnam to ensure high and stable pigeonpea yields.

Constraints. The constraints to high pigeonpea yields include the following:

- Damping-off diseases.
- Scattered pods on the plant and an extended harvest making harvesting difficult.
- Nonfamiliarity of the farmers with the uses of the crop.

Future Research on AGLN Crops in RBCS

The following aspects need to be researched:

- Collect, evaluate, and conserve legume germplasm.
- Breed high-yielding, good-quality varieties, resistant to drought, insect pests, and diseases.
- Determine appropriate technology for growing legumes in RBCS.
- Test this technology on-farm and extend it to farmers.

Contribution of ICRISAT's Legumes Program to Scientists and Farmers in AGLN Countries

Onkar Singh, D.H. Smith, and D. McDonald

Legumes Program, ICRISAT, India

Introduction

The International Crops Research Institute for the Semi-Arid Tropics has a global mandate for the improvement of groundnut, chickpea, pigeonpea, sorghum, and pearl millet. Groundnut, chickpea, and pigeonpea are cultivated mainly in the rainfed areas of AGLN countries by resource-poor farmers.

Production and Utilization

Groundnut is produced in Asia under rainfed conditions. In Asia, groundnut is largely used for oil, in confectionery, and as boiled vegetable. Elsewhere it is used primarily in confectionery.

Chickpea is largely a crop of South Asia, where desi types with small brown seeds are produced. Kabuli chickpeas with large white seed are mainly produced in West Asia and the Mediterranean region. Chickpea is usually grown on residual moisture with low inputs. It is mainly consumed as *dhal* or *besan* (flour), although green or dry seeds are also used in a variety of recipes.

Pigeonpea is produced mainly in India. However, it is grown extensively in the rest of South Asia, eastern Africa, and the Caribbean region. Longer-duration pigeonpea, commonly cultivated in mixed or intercropping systems, accounts for most of the production. However, short-duration pigeonpea as a monocrop has become popular in recent years. Pigeonpea is mostly consumed as *dhal* or as a vegetable cooked from green pods/shelled peas. Its stems are used as fuel wood or building materials, and its leaves as fodder.

ICRISAT Legumes Research

Research in ICRISAT's Legumes Program is directed toward strengthening capabilities of national agricultural research programs to increase the productivity of groundnut, chickpea, and pigeonpea. Much of ICRISAT research is conducted at ICRISAT Center near Hyderabad, India, but ICRISAT scientists are also located at five other regional centers in West Asia and Africa. Much collaborative research is done with national programs at their locations.

The major biotic and abiotic constraints to the production of groundnut, chickpea, and pigeonpea have been characterized by ICRISAT scientists. Legume breeding programs at ICRISAT are aimed at incorporating resistances to these constraints as referred to below, to raise and stabilize the yield in specific environments, and to develop cultivars with wide adaptation.

Biotic Constraints

Groundnut. At ICRISAT Center, field screening of groundnut germplasm and wild *Arachis* species has revealed sources of resistance to late leaf spot and rust. The resistant sources have been used as parents in the groundnut-breeding program. Two varieties, ICGV 87160 and ICGV 86590 with partial resistance to late leaf spot and rust have been released by the Indian national program for cultivation in peninsular India. Since early leaf spot reaches epidemic proportions every year in Malawi, screening for resistance is done in that country. Screening for groundnut rosette disease (Groundnut rosette virus) resistance is also done in Malawi.

Aspergillus flavus invades groundnuts and the subsequent production of aflatoxins is a serious problem in many rainfed production areas. Several genotypes with resistance to pre- and post-harvest invasion of seed by *A. flavus* have been identified and are used by groundnut breeders at ICRISAT. Use of resistant cultivars and appropriate integrated crop management practices may substantially reduce the risk of aflatoxin contamination.

ICRISAT diagnostic methods for peanut mottle (Peanut mottle virus), peanut stripe (Peanut stripe virus), clump (Peanut clump virus), and groundnut rosette viruses can now be used to determine the distribution and incidence of these groundnut viral diseases. Sources of resistance to groundnut mottle and groundnut rosette have been identified and these sources are now used in breeding programs.

Aphis craccivora and various thrips species are important because they damage plants and vector viruses. Research is being conducted so that integrated pest management systems can be developed for these pests. Leaf feeder and leaf miner are important defoliators of groundnut plants. In Africa, termites *(Microtermes* sp and *Odontotermes* spp) contribute to pod losses of more than 30% and to aflatoxin contamination.

Chickpea and pigeonpea. Fusarium wilt of chickpea is the major soilborne disease of that crop, but wilt-resistant varieties are now available. Dry root rot *(Rhizoctonia bataticola)* and collar rot are problems in some areas. Resistance to dry root rot is available but sources of resistance to collar rot have yet to be identified. Chickpea stunt is a problem in some areas, and the etiology is currently being studied at ICRISAT, Sources of resistance identified from field screening are being used in the breeding program. Ascochyta blight and botrytis gray mold are important diseases of chickpea in areas outside the tropics. While screening for resistance to botrytis gray mold is in progress, strong and stable sources of resistance have not yet been found in the case of ascochyta blight. However, varieties that give fair protection to the crop have been developed. This has made winter sowing possible in West Asia.

Fusarium wilt of pigeonpea is a widely distributed disease. Sources of resistance to this disease have been identified in the ICRISAT germplasm collection. Phytophthora blight attacks short-duration pigeonpea where the soil is extremely wet. Disease-resistant cultivars are not available for phytophthora blight, but partial disease management can be achieved with a combination of good field drainage and foliar sprays of metalaxyl (Ridomil®). Sterility mosaic is a serious disease of pigeonpea. The causal agent is unknown but the vector of the pathogen has been identified. Host-plant resistance has been incorporated into high-yielding lines.

Pod borer is a destructive insect pest of chickpea and pigeonpea. Control of this insect is very difficult. Screening for host-plant resistance has revealed less susceptible genotypes which are being used in breeding programs. Pod fly is an important pest of pigeonpea in subtropical regions. Sources of resistance to pod fly are now used in breeding programs. Leaf miner *(Liriomyza cicerina)* is a serious insect pest of chickpea in West Asia and the Mediterranean region. Host-plant resistance to leaf miner has been identified.

Abiotic Constraints

Groundnut. Mid-season and terminal drought stress are important for groundnut cultivation. Drought-resistant genotypes were identified and are used in breeding programs. Calcium deficiency and aflatoxin contamination are also involved in drought stress.

Photoperiod research at ICRISAT has shown that partitioning of vegetative and reproductive plant parts is influenced by photoperiod. These studies have demonstrated that the adaptation of groundnut in different environments may have a significant effect on cultivar performance.

Nitrogen fixation is probably not a serious yield-limiting factor for groundnut. However, studies on phosphorous, iron, and calcium nutrition are being conducted.

Chickpea. Terminal drought stress is a major constraint to chickpea in most environments. Extra-short-duration cultivars that escape terminal drought have been identified and made available to farmers. In other maturity groups, genotypes that can avoid drought by developing a more extensive root system are being used in the breeding program. Low temperatures delay pod set of chickpea. Genotypes that can initiate pod set at 5°C have been identified. This may result in the development of varieties that can escape terminal drought and heat stress, avoid excessive vegetative growth and lodging, and escape foliar diseases and *Helicoverpa* damage. At ICARDA a combination of cold tolerance in the early vegetative growth stage of chickpea and resistance to ascochyta blight has been identified. This has enabled the sowing of chickpea in winter, which has resulted in high yields and lower terminal drought stress than in spring-sown chickpea.

Multiplication and inoculation methods for chickpea rhizobia have been improved in tropical environments. Genotypic differences in nitrogen fixation of chickpea have been observed Nonnodulating chickpea genotypes are now available.

Studies at ICRISAT have shown that chickpea root acid exudates solubilize calcium-bound soil phosphorous. This is the main form of phosphorous in Vertisols.

Pigeonpea. Medium-duration pigeonpea is screened for terminal drought stress at ICRISAT Center. Genotypic differences for reproductive growth under receding soil moisture have been observed. Similarly, large differences in drought response among short-duration pigeonpea genotypes have been found when screened under the line-source sprinkler irrigation tests. Similar differences in tolerance to waterlogging have been observed.

Pigeonpea genotypes do not differ in their response to salinity, but some related wild *Cajanus* spp were tolerant to salinity.

Symbiosis with native *Rhizobium* supplies enough nitrogen (40 kg N ha^{-1}) for satisfactory plant growth of pigeonpea. In soils with a high clay content, nodule development is limited and larvae of *Rivellia angulata* damage nodules.

Pigeonpea root exudates contain substances that solubilize iron-bound soil phosphorous. This may explain why pigeonpea grows well on soils with a high iron content but low available phosphorous.

ICRISAT's Contribution

The world germplasm collection of groundnut, chickpea, and pigeonpea and their wild relatives is collected, characterized, evaluated, and maintained at ICRISAT by its Genetic Resources Unit (GRU). This collection stands at 12 841 groundnut, 16 346 chickpea, and 11 637 pigeonpea accessions as of Dec 1991. Seed samples and related information from this collection can be obtained by anyone on request. The evaluation data of chickpea and pigeonpea germplasm held at ICRISAT have been computerized and published as catalogs. A catalog on groundnut is being compiled.

Improved cultivars, elite lines, and segregating breeding material of the three legumes developed by ICRISAT are also made available to the national programs in the collaborating countries on request. Multilocational testing of advanced material is carried out by the national programs and they decide on their release or otherwise.

The International Crops Research Institute for the Semi-Arid Tropics coordinates the International Trials/Nurseries of groundnut, chickpea, and pigeonpea for Asia from its center in India. National programs are encouraged to contribute entries to such trials/nurseries. A list of these trials and segregating breeding materials is circulated to all cooperators every year so that they can choose material of interest to them.

Legumes Program scientists collaborate with those in the Resource Management Program at ICRISAT in order to merge genetic and management innovations. Such efforts have resulted in the development of improved cropping packages to suit Indian conditions. Examples are: summer groundnut, irrigated chickpea in peninsular India, and short-duration pigeonpea in rotation with winter crops in northern India or for multiple harvests in central and southern India. These packages have been successfully demonstrated in India and may be extended to similar environments elsewhere.

Literature can be provided to AGLN members. Some examples are the International *Arachis* Chickpea, and Pigeonpea Newsletters. Publications by ICRISAT are included in the ICRISAT publication catalog. Literature searches are available free from the Semi-Arid Tropical Crops Information Service (SATCRIS) by contacting the librarian at ICRISAT. Keywords should be provided to access literature citations for specific needs.

Various training opportunities at ICRISAT include in-service fellowships for 1 to 6 months, Research Fellowships for 1 to 12 months, and Research Scholarships for preparing a thesis for a degree, and in-service training for 6 months.

Workshops are designed to provide participants with the latest information about a mandate crop. Research plans and technology exchange ideas can be shared among delegates from different countries.

Meetings usually have specific and limited objectives for reviewing progress and planning future research. Collaborative research projects are useful for enhancing communication among scientists with common interests. Special projects could be suggested by a national scientist or agency. The project should involve a subject of interest to a donor organization. If possible the project should involve collaboration with a scientist from the donor country. Examples of special projects are the Peanut Stripe Virus Working Group involving scientists from the U.S. and a Pigeonpea Production Project in Sri Lanka.

ICRISAT can provide personnel for participating in tours to monitor field trials, in surveys of yield-limiting constraints, in training courses on disease diagnosis, and in management strategy planning.

Germplasm collection trips can be organized by ICRISAT in conjunction with NARSs. Careful advance planning is needed to ensure the success of such trips.

Successful NARS/ICRISAT collaborative on-farm trials have been carried out in several countries to overcome specific constraints of AGLN crops. AGLN is considering expanding this activity which can be useful to share appropriate technology with farmers in AGLN countries.

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Rice-based Cropping Systems - ICRISAT's Experience

A. Ramakrishna, M.M. Anders, and D.J. Flower

Resource Management Program, ICRISAT

Introduction

Rice is the most important staple food crop in Asia, where about 90% of the world's rice production is located. Rice covers 81 m ha in South and Southeast Asia, where approximately 30% of the cropped land is irrigated and double-cropped throughout the year. With the increase in population and a continuous decline in the average farm size (0.5-2.0 ha), there is a growing need to put the existing land base to better use. The prevailing practice of monocropping rice and then leaving the fields fallow after the harvest, could prove disastrous because of its inability to meet the increasing demand for rice and grain legumes.

Grain legumes are a major source of protein and can enrich the rice land. Further, with the rising cost of nitrogenous fertilizer, their importance in sustainable rice farming systems will increase. Grain legumes are important in RBCS.

Cropping-systems research at ICRISAT is focused on developing economically and ecologically sound and sustainable cropping systems for the rainfed areas in the SAT, which include agroecological zones where upland rice is grown.

Legumes with Upland Rice

Upland rice is the primary subsistence crop of very poor farmers in the tropics. Upland ecosystems present a difficult challenge to sustainability. Productivity of upland rice has remained low (about 0.6 t ha^{-1}) largely because of climatic stresses, of which rainfall is the most variable and least predictable. Recently-developed early-maturing upland rice cultivars (75-100 days) with fertilizer responsiveness have increased the prospects for crop diversification in upland areas. Crop diversification through intercropping can assist in stabilizing productivity in such systems. The most important criterion for intercropping upland rice is to maintain the rice yield while obtaining additional yield from grain legumes.

At ICRISAT, research was initiated on the grain legume-upland rice intercropping system with the focus on improved resource use and higher productivity by improving N availability to rice and associated crops, reducing late drought stress on rice, and increasing protein availability and cash income to farm families.

Intercropping consists of growing two crops on the same land at the same time. It can stabilize the yield from season to season; which is an important criteria in subsistence or near-subsistence agriculture. Another advantage of intercropping can be increased productivity of complementary component crops. Well-designed intercropping combines component crops that use available resources better than would single crops. While one crop is harvested early, the second continues to grow after the first is harvested, making full use of the residual resources, primarily moisture. The overall advantage of such a system is the complementary use of resources by component crops.

Given the long growing period in upland rice systems, there is a choice of two types of intercropping: temporal and spatial.

Temporal intercropping. Rice/pigeonpea intercropping is an example of the temporal system in which rice grows fast and pigeonpea slowly. Following the rice harvest at about 100 days, the pigeonpea continues to grow for an additional 50 to 80 days making the best use of the residual moisture and light. In studies conducted at ICRISAT using an upland rice/pigeonpea intercrop, rice gave 85-90% of the sole crop yield with pigeonpea producing 70-80% of the sole crop yield. This resulted in a land equivalent ratio (LER) between 1.54 and 1.74. In this study, intercropping was 54-74% more productive than monocropping.

Spatial intercropping. The spatial system of intercropping involves growing two crops which have similar maturity but dissimilar canopy height in the same area. Rice/cowpea and rice/extra-short-duration pigeonpea systems are examples of this system. Mixtures of short-duration and short-statured determinate legumes were found to be more appropriate for intercropping with upland rice. Intercropping increased the total intercepted radiation due to the faster canopy cover i.e., spatial complementarity. An intercropping advantage was achieved with a small reduction in rice yield and a substantial increase from the legume.

Intercropping experiments. A series of agronomic experiments were initiated at ICRISAT with the objective of identifying pigeonpea cultivars with growth habits compatible with upland rice and testing these genotypes for their sensitivity to intercropping competition (e.g., crop ratios). Productivity of each intercrop component and its respective sole crop was determined in terms of Crop Performance Ratio (CPR). Extra-short-duration pigeonpea recorded the largest partial CPR for grain (2.89) followed by early (2.39) and medium (1.21) pigeonpea genotypes. Spreading genotypes had a larger partial CPR than semi-compact types. However, the CPR of intercropped rice was less (0.65-0.69) with spreading pigeonpeas and greater than 1 with compact types. Pigeonpea canopy appeared to be more important than differences in phenology. A wide range of light transmission coefficients (K)(0.45 to 0.78) were recorded in pigeonpea. Another factor which appears to determine competitive ability is the relative height of intercropped pigeonpea and upland rice. Rice appears to be very sensitive to low light and shading during its reproductive phase.

Legumes Following Irrigated Rice

Partially irrigated areas i.e., lands irrigated only during the rainy season contribute 70% of Asia's total rice production. In these areas the fields are usually kept fallow following the rice harvest. In the areas growing a second crop under residual moisture after rice, the crop could add to the farmers' income.

Cropping-systems research at ICRISAT has concentrated on increasing cropping intensity in rainfed rice areas and rice fallows by using early-maturing, photoperiod-insensitive, drought-tolerant, and high-yielding legume genotypes. Experiments have been conducted to identify better techniques in crop establishment that will result in an improved plant stand and reduce the time between crops.

The main rainy-season cereal crop in Vertisol areas is rice followed by a grain legume. Two varieties of rice (120-day and 100-day genotype) were used as the main rice crop. Postrainy-season crops of pigeonpea, chickpea, groundnut, and sorghum were raised on residual moisture at ICRISAT Center, Patancheru, Andhra Pradesh, India and with irrigation at the Directorate of Rice Research, Rajendranagar, Andhra Pradesh, India. In these experiments, efforts were made to optimise production in the first and second crops and maximize efficiency of water and fertilizer use.

At Rajendranagar, 2.5 t ha^{-1} of groundnut or sorghum were harvested with irrigation whereas at ICRISAT Center the groundnut yield was very poor under residual moisture conditions (about 0.4 t ha^{-1}). Sorghum and pigeonpea yielded about 1.0-1.2 t ha^{-1}. Our experience indicates that groundnut yields were lower after rice and that acceptable yields were possible only when irrigation was available. The two primary factors for reduced yields, particularly for ICRISAT Center, were the absence of a fine seedbed and drought stress for the legumes. However, sorghum and pigeonpea were able to withstand both stresses and gave reasonably good yields. On the other hand, at Rajendranagar where irrigation was applied to all legume crops so that seedbed preparation could be better, legume yields were acceptable.

Delayed seedbed preparation and sowing of upland crops after the rice crop cause serious reduction in yield. By selecting early-maturing rice cultivars and by reducing the turnaround time, good plant stands of groundnut, pigeonpea, chickpea, and sorghum could be obtained. This system has reduced the need for irrigation water and fertilizers, and is more restorative of soil fertility. It is also more remunerative as the price of grain legumes is about 2-3 times that of rice. These studies indicate that through better soil management and use of improved varieties of grain legumes the farmer should be able to diversify RBCS.

Problems Affecting the Efficiency of RBCS

Growing legumes after rice offers more challenges than any other cropping system. After the rice harvest the soil becomes hard and compact resulting in poor drainage. The ability of a seed to germinate and establish when the top soil is drying is a major constraint on residual soil moisture. Change from the submerged soil condition to upland condition brings significant changes in soil reaction and nutrient availability, particularly of phosphate, iron, manganese, and zinc. Hence fertilizer application is essential for obtaining good yields of upland crops.

Factors to be Considered when Developing a Suitable Technology for RBCS

Varietal development. Varietal requirements of grain legumes in RBCS are early maturity, multiple disease and insect resistance, and drought tolerance.

Tillage. Zero or reduced tillage provides yield comparable to conventional tillage. Zero-tillage soils usually have high surface soil moisture at sowing time and soil exposure to evaporation is minimized.

Plant establishment. Deep sowing is an obvious way to reduce the affect of early moisture deficiency but seedling emergence and its subsequent vigour is dependent on seed size and genotype. One 'come-up' irrigation can make a significant difference in yield since the profile may be fully charged while the surface soil is dry.

Seed quality and seed rate. Under limited-moisture conditions, low plant density may be beneficial but under adequate-moisture conditions, optimum or slightly higher density improves yields. Poor seed viability and low seed rates lead to a low population density and poor yields.

Inoculation and fertilizer application. Use of proper *Rhizobium* inoculation following lowland rice often improves the yield of grain legumes. The addition of 30-50 kg P_2O_5 ha^{-1} has also been shown to increase yields. Band placement of fertilizer is generally more efficient particularly when only a small amount is being applied. Deep placement of nutrients is beneficial especially when the surface layers become dry.

Conclusion

Researchers have developed photoperiod-insensitive, high-yielding, and short-duration legume varieties which can fit in rice-based systems as a sequential, intercrop, or alley crop. Careful selection of species, genotype, and efficient management will lead to the most beneficial system. Crops requiring little water and fertilizer should be introduced to minimize inputs and improve efficiency. Crop diversification is desirable for the economy of the system along with a rational utilization of resources to maintain soil health.

RECOMMENDATIONS

The following recommendations were developed by five groups which participated in the monitoring tours of upper and lower Myanmar and discussion/recommendation sessions at Yezin. These groups were: Pests, Diseases, Agronomy/Physiology, and Socioeconomic groups in upper Myanmar and a lower Myanmar group looking at RBCS. The recommendations represent the overall consensus of the groups; so they appear under general topics. They are mainly suggestions for research and policy thrusts to strengthen the production of AGLN crops in Asia in general, and Myanmar in particular.

Breeding

Groundnut

- Breed early-maturing, high-yielding, acid-soil-tolerant varieties resistant to major diseases and pests and also with maturities ranging from 90 to 120 days for conditions in lower Myanmar.

Chickpea

- Start a breeding program to develop early-maturing, high-yielding, high-temperature-tolerant varieties with resistance or tolerance to wilt, root rot, and pod borer with special emphasis on extra-early maturity for lower Myanmar.

Pigeonpea

- Identify medium- to long-duration, photoperiod-sensitive, high-yielding, and pod borer-tolerant cultivars with high biomass production suitable for intercropping.
- Evaluate and screen for lower Myanmar pigeonpeas of different maturity for use as a postrainy-season crop and long-season cultivars for use on bunds.

Agronomy/Physiology

- Conduct research on integrated nutrient management including bio-fertilizers to exploit the yield potential of groundnut, chickpea, and pigeonpea in rice-based cropping systems.
- Study the long-term effects of different cropping systems on productivity, soil fertility, and pest and disease buildup.
- Undertake soil tests and crop-response studies to identify appropriate crops and cropping patterns based on soil moisture and nutrient status.
- Develop appropriate moisture-conservation techniques including breaking of the hardpan, contour planting and *in situ* moisture conservation.
- Encourage cereal-legume cropping systems wherever possible including relay cropping of chickpea in rice and sequential cropping of groundnut with rice.

- Identify rice cultivars which fit in the rice-chickpea sequential cropping so as to reduce terminal stress to chickpea,
- Improve the management of low pH wetland soils in lower Myanmar.

Integrated Pest Management

- Survey yield losses due to pests *(Helicoverpa,* pod fly, white grub, leaf miner) and diseases (late leaf spot, fusarium wilt, and stunt). Include studies on the role of parasites and predators.
- Strengthen the monitoring of pests and diseases using light and pheromone traps for insects and spore traps for foliar diseases.
- Screen resistant or tolerant germplasm and breeding lines from ICRISAT and other AGLN countries against the major pests and diseases in Myanmar.
- Adopt immediately fungicide and pesticide seed treatment to reduce seedling mortality. The seed treatments recommended should be tested for compatibility with *Rhizobium.*
- Expand the range of pesticides available to avoid pesticide resistance buildup in insects and disease organisms. Backup with research and education of extension workers and farmers.
- Evaluate plant-based pesticides and biocontrol agents for managing pests and diseases.
- Consider immediately an integrated eradication program by MAS for 'Koyaung' weed *(Euphorbia* sp).

On-Farm Research

- Work with farmers to understand, and if necessary, modify existing farming practices. This approach can lead to rapid improvement and adoption of technology.
- Expand on-farm testing and demonstration of improved production technologies and encourage feedback to research workers.
- Encourage farmers to retain traditional crops such as pigeonpea known to provide stability and to maintain a mixture of crops rather than switch to a single high-paying crop. This approach should help cope with the crop failure expected in one in three years in upland areas.
- Continue MAS's Contact Farmer Program and explore the possibility of providing more incentives to farmer-participants.
- Use on-farm demonstrations to emphasize to farmers the value of integrated management for control of pests and diseases.

Seed

- Make farmers aware of the value of quality seeds as a way of strengthening MAS's program of providing quality seeds to farmers.

- Increase the availability of quality groundnut seed for timely sowing, particularly in lower Myanmar by improving storage and postharvest technology and by increasing groundnut area in high-elevation areas during the rainy season.
- Activate and utilize existing cold storage facilities and where necessary develop effective, low-cost seed storage technologies for AGLN crops (particularly groundnut) at the village level; explore the possibility of organized purchase and distribution of seed; and encourage private sector involvement to ensure seed availability at an appropriate price.
- Re-evaluate MAS's existing certified seed price policy and consider instead ensuring premium prices for certified seeds. Continue the policy of supplying seeds of new crops with a high price potential.

Rhizobium

- Establish an efficient facility for large-scale production of high-quality *Rhizobium* inoculum in Myanmar.

Farm Implements

- Encourage timely field operations by developing and demonstrating appropriate farm implements including implements to work the heavy-textured soils of lower Myanmar, strengthen custom hiring, and provide implements to help meet labor shortages in areas where cropping intensities are increasing.
- Popularize multiseed planters particularly for groundnut.
- Consider policies to encourage availability in the market of mechanized farm implements such as power tillers and tractors needed for efficient crop production.

Training

- Continue to provide training opportunities on AGLN crops at ICRISAT and in Myanmar for innovative farmers, technicians, and scientists to benefit the production of AGLN crops in Myanmar.
- Organize through AGLN training to upgrade the knowledge of plant protection personnel.

Networking

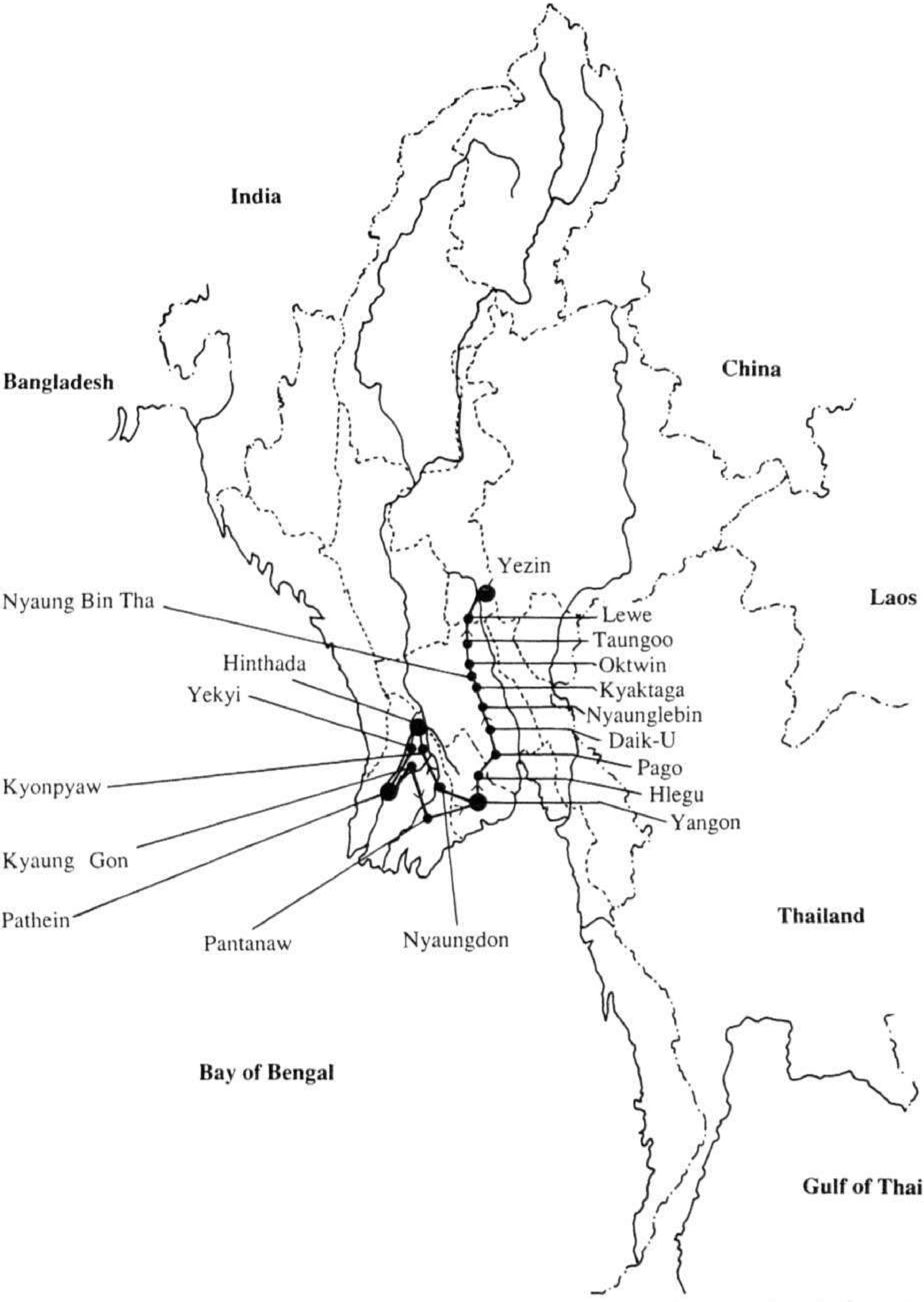
- Organize through AGLN/ICRISAT the exchange of germplasm and technology among AGLN countries.

Prices

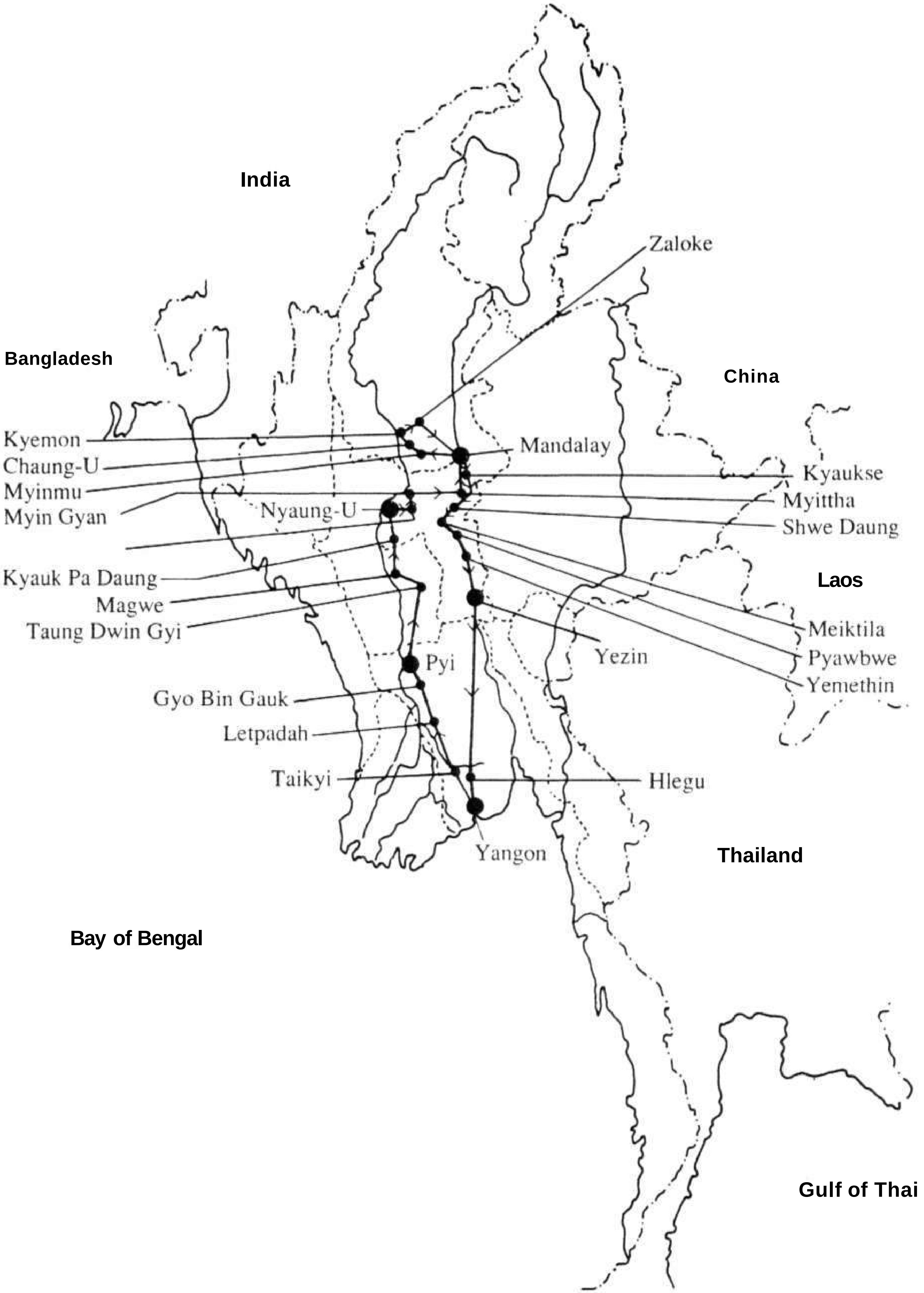
- Use the price fluctuations experienced by farmers trying new crops to help them understand the costs and benefits of these new crops and, when necessary, encourage them to consider alternative ways of using the new crops.
- Investigate the cause of chickpea price reductions and if necessary re-evaluate the marketing policy for this crop.
- Use the large expected increase in pigeonpea production as an opportunity to:
  - study the effects of price on farmers' decisions; its results can help form future policy directions;
  - investigate whether expected price reductions in pigeonpea will result in an equivalent reduction in area sown;
  - encourage farmers to use mixed-cropping such as intercrops of groundnut with pigeonpea to stabilize returns; and
  - monitor the benefits seen by farmers for growing pigeonpea.
- Encourage indigenous use of pigeonpea so that its production will not be so dependent on the volatile export market. For doing this, examine methods of cooking and ways of eating pigeonpea used in areas where the crop is now popular to see if these can be transferred to new areas; and investigate alternative uses for pigeonpea.
- Examine ways to retain experienced labor on experimental farms so as to maintain the efficiency of the research program.

Workshop and Monitoring Tour Program

- The monitoring tour and workshop were excellent and the group commended the organizers highly and expressed their deep appreciation.
- The tour program provided an ideal opportunity to see the wide range of agroecological systems and cropping patterns in Myanmar.
- Future meetings might build on this good start by providing in the workshop more time for presentation and discussion of AGLN country reports. Reducing travel time on tours and increasing time in the field with researchers, extension workers, and farmers would be ideal.
- Consideration should also be given to providing more 'unscheduled' stops to check out specific situations. This could provide more opportunities to understand the circumstances of smaller farmers not specifically associated with government programs and examine fields where crops appear to be failing.
- A tour earlier in the season might be more appropriate in order to see all three AGLN crops in the field.
- Similar workshops and monitoring tours should be held in future by AGLN (or CLAN) at regular intervals to help exchange information among countries and buildup a strong network database.



Lower Myanmar Monitoring Tour Map



Upper Myanmar Monitoring Tour Map

Committees

Organizing Committee

Myanmar

Tin Hlaing Chair
Aung Thaung
Myat Twe
Maung Ko
Aye Kyaw
Tun Saing
Thein Han Secretary

ICRISAT

D.G. Paris
C.L.L. Gowda

Secretarial Assistance

Myanmar

Myat Twe Chair
Chit Ko Ko
John Ba Maw
Sein Win
Mejit Swe
Saw Ler Wah

ICRISAT

G. Shinde
G. Bajpai

Monitoring Tour and Recommendations Groups

Pests

C.S. Pawar Chair
Mya Thwin Secretary
G.P. Koirala
Tin Soe
Than Aung
Tran Nghia

Diseases

D.H. Smith Chair
M.S. Basu Secretary
B.A. Malik
Aung Shwe
Hla Than
Toe Aung

Physiology

Thein Han Chair
A. Ramakrishna Secretary
Han Ngunt
A.F.M. Maniruzzaman
Ohn Kyaw
Nguyen Quang Pho
N. Senanayake
C. Smitobol

Socioeconomics

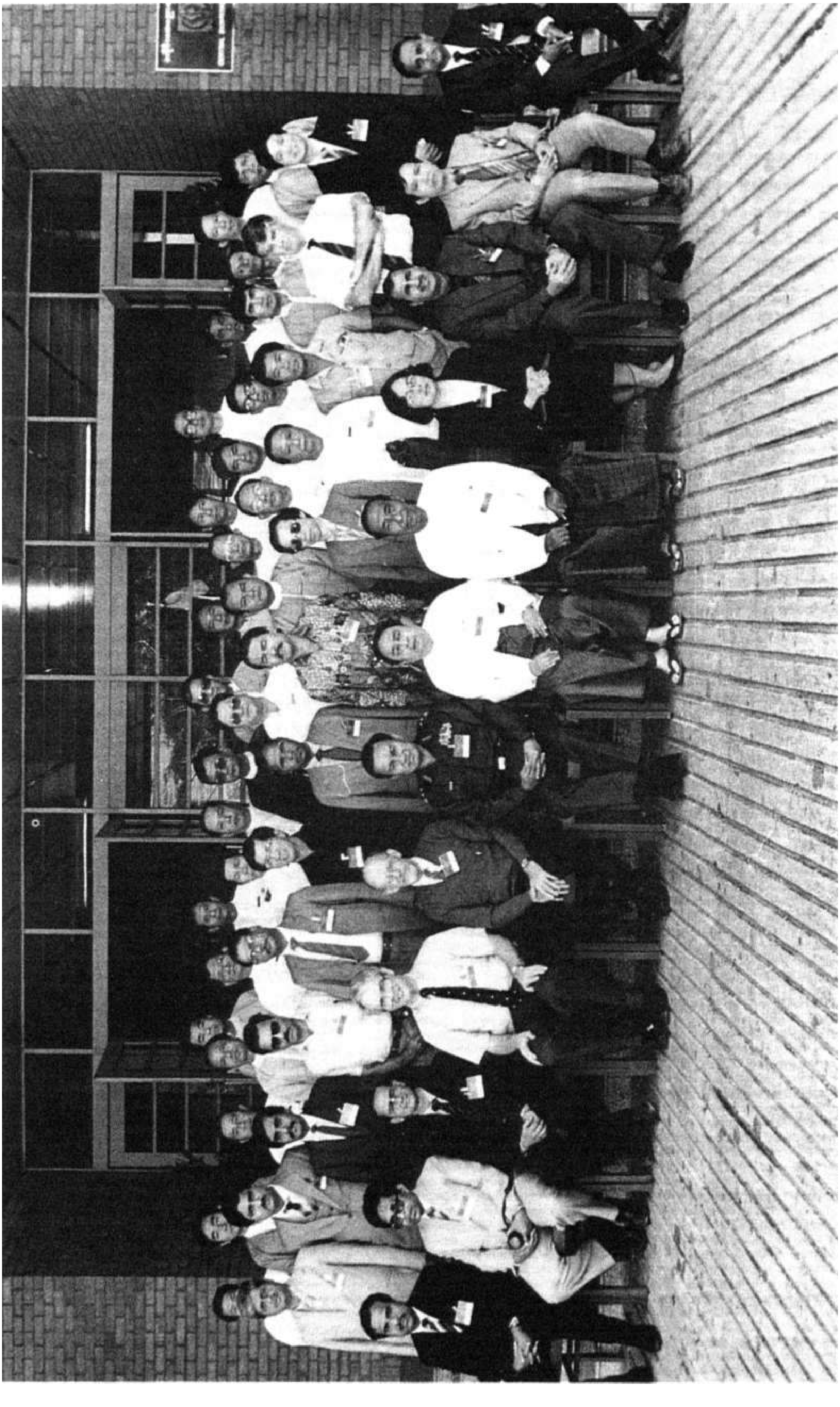
Ester Lopez Chair
Nyi Nyi Secretary
T. Adisarwanto
D.G. Faris
Kyaw Shin
Kyi Win
San Thein
Xiao Nenghuang
Tin Hla

Lower Myanmar

Tun Saing Chair
Masood Ali Secretary
G. Chaudhary
M.A. Razzaque
Maung Mar
Onkar Singh
R.K. Palis
Thein Htay
Hla Shwe

Recommendations Committee

Formed from the Chair and
Secretary of each group



Participants

Bangladesh

A.F.M. Maniruzzaman
Director (Research)
Bangladesh Agricultural
Research Institute
Joydebpur
Gazipur 1701

M. A. Razzaque
Farming Systems Specialist
CIDA/CDP
Khamarbari
Middle Building, 6th Floor
Farmgate
Dhaka 1215

China

Xiao Nenghuang
Deputy Director
Oil Crops Research Institute
Chinese Academy of
Agricultural Sciences
Wuhan City
Hubei Province 430062

India

Masood Ali
Principal Investigator (Agronomy)
Directorate of Pulses Research
Kalyanpur P.O.
Kanpur 208 024
Uttar Pradesh

M.S. Basu
Project Coordinator (Groundnut)
National Research Centre
for Groundnut
Timbawadi P.O.
Junagadh 362 015
Gujarat

Indonesia

Titis Adisarwanto
Malang Research Institute for
Food Crops (MARIF)
Jalan Raya Kendalpayak
P.O. Box No.66
Malang 65101
East Java

Nepal

G. Chaudhary
Assistant Agronomist
National Rice Research Program
Parwanipur

G.P. Koirala
Deputy Oilseeds Agronomist
National Oilseed Research Program
Nawalpur, Sarlahi
Janakpur Zone

Pakistan

Bashir Ahmed Malik
National Coordinator (Pulses)
National Agricultural Research
Centre
P.O. National Institute of Health
National Park Road
Islamabad

Philippines

Ester L. Lopez
Assistant Director
Crops Research Division
Philippine Council for Agriculture,
Forestry and Natural Resources
Research and Development (PCARRD)
Los Banos
Laguna

Sri Lanka

N. Senanayake
Deputy Director (Research)
Regional Agricultural Research Centre
Angunukolapelessa

Thailand

Chirtchart Smitobol
Farming Systems Research Institute
Department of Agriculture
Bangkhen
Bangkok 10900

Vietnam

Nguyen Quang Pho
Pigeonpea Physiologist
Agricultural University No.II
Hue
Hue-Thua Thien

Tran Nghia
Groundnut Breeder
Vietnam Agricultural Science Institute
Hanoi

Myanmar

Myanma Agriculture Service
72-74, Shwedagon Pagoda Road
Yangon

Tin Hlaing
Managing Director

Aung Thaung
General Manager
Extension and Education Division

Maung Ko
General Manager
Administration Division

Aye Kyaw
General Manager
Accounts Division

Myat Twe
General Manager
Project Planning, Management and Evaluation Division

Ohn Kyaw
General Manager
Seed Division

Maung Maung Tin
Deputy General Manager
Plant Protection Section

Kyi Win
Deputy General Manager
Project Planning, Management and Evaluation Division

Nyi Nyi
Deputy General Manager
Land Use Division

Mya Maung
Project Director
Plant Protection Section

Central Agricultural Research Institute
Yezin, Pyinmana

Tim Saing
General Manager

Maung Mar
Deputy General Manager
Agronomy Section

Hla Than
Deputy General Manager
Plant Pathology Section

Thein Han
Manager
Food Legumes Section

Tin Soe
Manager
Oil Crops Section

Kyaw Shin
Manager
Regional Research Section

Tin Hla
Project Manager
Extension and Education Division

Toe Aung
Manager
Maize and Other Cereals Section

Aung Shwe
Deputy Supervisor
Food Legumes Section

R.K.Palis
IRRI Representative to Myanmar

Institute of Agriculture
Yezin, Pyinmana

Thang Aun
Deputy Professor

Han Nyunt
Associate Professor

San Thein
Lecturer

ICRISAT

D.G. Faris
Principal Coordinator
AGLN

C.S. Pawar
Entomologist II (Legumes)

A. Ramakrishna
Agronomist

Onkar Singh
Senior Chickpea Breeder

D.H. Smith
Principal Plant Pathologist

Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank (Philippines)
AGLN	Asian Grain Legumes Network (ICRISAT)
AGLOR	Asian Grain Legumes On-farm Research (ICRISAT)
AICORPO	All India Coordinated Research Project on Oilseeds
AICPIP	All India Coordinated Pulses Improvement Project
AIDAB	Australian International Development Assistance Bureau
BARI	Bangladesh Agricultural Research Institute
BNF	biological nitrogen fixation
CABI	Commonwealth Agricultural Bureaux International (UK)
CARI	Central Agricultural Research Institute (Myanmar)
CC	Country Coordinator (AGLN)
CIDA	Canadian International Development Agency
CLAN	Cereals and Legumes Asia Network (ICRISAT)
CPR	crop performance ratio
CRSP	Collaborative Research Support Program (USAID)
CU	Coordination Unit (AGLN)
DOST	Department of Science and Technology (Philippines)
FAO	Food and Agriculture Organization, United Nations (Italy)
GDP	gross domestic product
GIS	geographic information system
GRU	Genetic Resources Unit
ICARDA	International Center for Agricultural Research in the Dry Areas (Syria)
ICGV	ICRISAT groundnut variety
ICPH	ICRISAT pigeonpea hybrid
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (India)
IDRC	International Development Research Centre (Canada)
K	light transmission coefficient
LER	land equivalent ratio
MAS	Myanma Agriculture Service
MOU	memorandum of understanding
NARC	National Agricultural Research Centre (Pakistan)
NARS	national agricultural research system
NGLRP	National Grain Legumes Research Program (Nepal)
NORP	National Oilseed Research Program (Nepal)
NSB	National Seed Board (Bangladesh)
OFC	other field crops
PCARRD	Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
Peanut CRSP	Peanut Collaborative Research Support Program (USA)
RBCS	rice-based cropping systems
SAT	semi-arid tropics

SATCRIS	Semi-Arid Tropical Crops Information Service (ICRISAT)
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture

Crop Names

Only common names are used in this report.	Their Latin binomials are as follows:
Banana	*Musa paradisiaca*
Black gram, urd bean	*Vigna mungo*
Chickpea	*Cicer arietinum*
Coriander	*Coriandrum sativum*
Cotton	*Gossypium herbaceum*
Cowpea	*Vigna unguiculata*
Egyptian clover	*Trifolium alexandrinum*
Finger millet	*Eleuscine coracana*
Flax, linseed	*Linum usitatissimum*
Green gram, mung bean	*Vigna radiata*
Groundnut	*Arachis hypogaea*
Jute	*Corchorus* spp.
Kenaf	*Hibiscus cannabis*
Lathyrus	*Lathyrus sativus*
Lentil	*Lens culinaris*
Maize	*Zea mays*
Millet, pearl millet	*Pennisetum glaucum*
Mung bean, green gram	*Vigna radiata*
Mustard	*Brassica juncea*
Pea	*Pisum sativum*
Pearl millet, millet	*Pennisetum glaucum*
Pigeonpea	*Cajanus cajan*
Potato	*Solanum tuberosum*
Rice	*Oryza sativa*
Sesamum	*Sesamum indicum*
Sorghum	*Sorghum bicolor*
Soybean	*Glycine max*
Sugarcane	*Saccharum officinarum*
Sunflower	*Helianthus annuus*
Sweet potato	*Ipomoea batatas*
Tea	*Camellia sinensis*
Toria, rape seed	*Brassica campestris* var. *sarson* and *Brassica campestris* var. *toria*
Urd bean, black gram	*Vigna mungo*
Wheat	*Triticum aestivum*

Diseases and Pests

Diseases and insects are referred to in the text by their common names. The following listing by crop gives the Latin binomials of pests mentioned in this report.

Common name or abbreviation	Latin binomials or full name

Diseases

Chickpea

Ascochyta blight	*Ascochyta rabiei*
Botrytis gray mold	*Botrytis cinerea*
Collar rot	*Sclerotium rolfsii*
Dry root rot/root rots	*Rhizoctonia bataticola, R. solani,* and *Fusarium solani*
Stemphylium blight	*Stemphylium* sp
Stunt	Viruses (to be identified)
Wilt (fusarium wilt)	*Fusarium oxysporum* f.sp *ciceri*

Pigeonpea

Phytophthora blight	*Phytophthora drechsleri* f.sp *cajani*
Sterility mosaic	Not known
Wilt (fusarium wilt)	*Fusarium udum*

Groundnut

Aflatoxin producing fungus	*Aspergillus flavus*
Aspergillus crown rot	*Aspergillus niger*
Bacterial wilt	*Pseudomonas solanacearum*
Bud necrosis (BNV)	Bud necrosis virus
Clump	Peanut clump virus
Collar rot	*Aspergillus niger,* and *Diplodia* sp
Crown rot	*Aspergillus niger*
Early leaf spot	*Cercospora arachidicola*
Groundnut rosette	Groundnut rosette virus
Late leaf spot	*Phaeoisariopsis personata*
Peanut mottle (PMV)	Peanut mottle virus
Peanut stripe (PStV)	Peanut stripe virus
Pod rots	*Fusarium* spp, *Macrophomina phaseolina,* and *Rhizoctonia solani*
Rust	*Puccinia arachidis*
Stem and pod rot	*Sclerotium rolfsii*

Insects

Chickpea

Pod borers	*Helicoverpa armigera*
Leaf miner	*Liriomyza cicerina*

Pigeonpea

Blister beetle	*Mylabris* sp and *Coryna* sp
Bruchids	*Callosobruchus analis,* C. *chinensis,* and *C. maculatus*
Pod borers	*Helicoverpa armigera* and *Maruca testulalis*
Pod fly	*Melanagromyza obtusa*

Groundnut

Aphids	*Aphis craccivora*
Bruchid	*Caryedon serratus*
Leaf feeders	*Spodoptera litura* and *Helicoverpa armigera*
Leaf miner	*Aproaerema modicella*
Leaf roller	*Aproaerema modicella*
Pod borers	*Helicoverpa armigera*
Termites	*Microtermes* sp and *Odontotermes* spp
Thrips	*Scirtothrips dorsalis* and *Frankliniella schultzei*
White grubs	*Lachnosterna* sp (= *Holotrichia* sp)

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ICRISAT

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

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