Legumes in Rice and Wheat Cropping Systems of the Indo-Gangetic Plain

Constraints and Opportunities

International Crops Research Institute for the Semi-Arid Tropics

Cornell University

Citation: Johansen, C, Duxburv, J.M., Virmani, S.M., Gowda, C.L.L., Pande, S., and Joshi, P.K. (eds.) 2000. Legumes in rice and wheat cropping systems of the Indo-Gangetic Plain - Constraints and opportunities. Patancheru 502 324, Andhra Pradesh, India: International Crops Research institute for the Semi-Arid Tropics; and Ithaca, New York, USA: Cornell University. 230 pp. ISBN 92-9066-418-5. Order code: BOE 028.

Abstract

Cultivation of legumes for grain, forage, and green manure purposes has been a traditional practice in the Indo-Gangetic Plain (IGP) region of South Asia. However, this practice has declined in recent decades as the production of the major cereal crops, rice and wheat, has increased since the advent of the "green revolution". Consequences of decreased legume cultivation in the region include reduced opportunities for ameliorative effects of legumes on cropping system sustainability and decreased local accessibility of grain legumes as a nutritious dietary component, particularly for poorer sections of the community. This book updates knowledge of area, production, and yields of legumes grown in the countries of the IGP, Bangladesh, India (northern), Nepal, and Pakistan, making use of geographic information systems (CIS) technology to display and analyze the output. Biotic, abiotic, and socioeconomic constraints facing cultivation of legumes are examined and opportunities for their increased production in the region assessed.

Time trend data do indeed reveal declining trends for most major legumes in each country. However, there are some exceptions to this (e.g., lentil in Nepal, mung bean in Pakistan, etc.) and reasons for optimism that many of the declining trends can be reversed. A fundamental problem to overcome in significantly increasing legumes production is to change the prevailing perceptions of their status as subsistence crops and have them considered as commercial crops. This will require aggressive on-farm demonstration of the many seemingly viable technical options, mainly developed on research stations, to alleviate the major biotic and abiotic production constraints. This involves dissemination of improved varieties and of improved, low-cost, and environmentally friendly crop husbandry techniques. There is also a need for changes in government policy considerations with respect to legumes as existing policies overwhelmingly favor cereal cultivation at the expense of legumes. There is continuing need for focussed strategic research efforts to more effectively tackle some of the more intractable biotic and abiotic constraints. To move towards commercialization of legume cultivation in the IGP, a more holistic and integrated approach by the relevant public sector research and extension agencies, non-government organizations, and the private sector is recommended.

Resume

Les legumineuses dans les systemes de culture de riz et de ble: contraintes et possibilites. Traditionnellement, les legumineuses etaient cultivees dans la plaine indo-gangetique (en Asie du sud) pour les graines, le fourrage et le fumier vert. Mais, avec l'accroissement de la production des cereales principales, notamment le riz et le ble, a la suite de la Revolution Verte, la culture des legumineuses se pratique de moins en moins. Par consequent, les systemes de culture ne peuvent plus beneficier des eftets positifs qu'elles ont sur leur durabilite et, la communaute locale, surtout les sections defavorisees, n'a plus acces sur place a un aliment nutritif. Cet ouvrage presente une etude menee dans les pays de la plaine indo-gangetiques (le Bangladesh, l'Inde du Nord, le Nepal et le Pakistan) grace a la technologie des systemes d 'information geographique et met a jour les donnees concernant la culture, la production ainsi que le rendement des legumineuses. Les contraintes biotiques, abiotiques et socio-economiques entravant la culture des legumineuses sont egalement examinees et les possibilites d'augmenter leur production dans cette region sont eValuees.

Les donnees revelent bien que la culture des legumineuses est en baisse de maniere g6nerale avec quelques exceptions (les lentiiles au Nepal, le mungo au Pakistan...). Il est possible d'inverser cette tendance a la baisse. La plus grande contrainte pour une augmentation importante de la production est la perception des legumineuses comme des cultures vivrieres. Il est donc tout d'abord necessaire de les faire considerer comme des cultures commerciales. Pour cela, il faut un programme agressif de demonstrations en milieu reel des options techniques viables mises au point en laboratoire pour faire face aux stress biotiques et abiotiques. Ce programme consisterait a rendre disponibles des varietes ameliorees par l'apport des techniques de culture qui soient plus adaptees, moins couteuses et plus respectueuses de l'environnement. Il est egalement necessaire de changer les politiques du gouvernement qui favorisent la culture des cereales au detriment des legumineuses. De plus, il faut developper des recherches plus concentrees sur les contraintes biotiques et abiotiques qui echappent encore a toute solution. Enfin, pour parvenir a une commercialisation de la culture des legumineuses dans la plaine indo-gangetique, il faut une approche complete et integree de la part des agences de recherche et de vulgarisation du secteur public concerne, des organisation non-gouvernementales, ainsi que du secteur prive.

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2000

Acknowledgments

The authors and editors are particularly indebted to the ICRISAT CIS technicians who developed all the maps and most of the graphics of this publication. These are K S Prasad and M Ashok Reddy of Agroclimatology, under the supervision of S M Virmani, and M Irshad Ahmed and M Moinuddin of the GIS Laboratory, under the supervision of F T Bantilan. Although many contributed to word processing of original manuscripts and subsequent corrections, the coordinating role played by J Nalini is particularly appreciated. All contributors to this volume are appreciative of the competent technical editing of V K Sheila to enhance the final output. The coordination of the production process by T R Kapoor is gratefully acknowledged.

The research activities reported and cost of publication of this book were partly supported by the Asian Development Bank.

Contents

Preface

ICRISAT began research on its mandate legumes, chickpea *(Cicer arietinum* L.), pigeonpea (*Cajanus cajan* (L.) Millsp.), and groundnut *(Arachis hypogaea* L.) in the 1970s, focusing on genetic improvement efforts to alleviate the major biotic and abiotic stresses facing these crops in the harsh environments where they are normally grown. With the advent of on-farm evaluation of the products of these breeding programs in the 1980s, it became increasingly evident that better targeting of genetic materials to defined environments was needed to improve the efficiency of the breeding process. With this in mind, crop improvement and resource management scientists of ICRISAT and national agricultural research systems (NARS) of several Asian countries combined to produce a publication on "Agroclimatology of Asian grain legumes (chickpea, pigeonpea, and groundnut)". This exercise was done ten years ago and involved hand drawing of legume distribution maps, along with maps depicting the major biotic and abiotic constraints in the major legume producing countries of Asia. This publication has since served as a valuable "guidebook" to the status and distribution of ICRISAT's mandate legumes in Asia and the constraints they face. However, it is by now outdated.

With the ever increasing need to increase production of the staple cereal crops, rice and wheat, in Asia to match needs of the expanding population, it is apparent that grain legume cultivation is being relegated to less favorable environments. This is despite the long acknowledged role of legumes contributing to the long-term sustainability of cropping systems where cereals dominate. It has also resulted in less local availability, and consequent relative price rises, of grain legumes in areas predominantly devoted to cereal cultivation. Thus the supplemental nutritive inputs to the diet afforded by grain legumes has been eroded in these areas. This has particularly impacted poorer sections of the community with limited access to alternative sources of protein, vitamins, and minerals that grain legumes provide. There are also increasing concerns about the sustainability of cropping systems with cereals in continuous rotation. Such concerns have spawned eco-regional initiatives, such as the Rice-Wheat Consortium for the Indo-Gangetic Plains (RWC), to specifically address such system sustainability issues.

During the 1990s, ICRISAT developed "systems" projects aimed at better focusing genetic improvement and resource management research and development efforts on defined agroecosystems, to enhance prospects of impact. One such project, "Legume-based technologies for rice and wheat production systems of South and Southeast Asia", focused on the better endowed cereal growing regions to examine current status and recent trends of legume production and to introduce interventions that would lead to increased legume production. This book is the outcome of efforts to characterize the legume situation and examine future prospects for legumes in the densely populated and major rice and wheat producing region of the Indo-Gangetic Plain (IGP). It thus moves forward from the "agroclimatology" bulletin of a decade earlier by updating the legume database, utilizing geographic information systems (GIS) technology for cropping systems analysis and interpreting possible future scenarios.

The book is the result of a considerable collective effort, of scientists from the NARS of Bangladesh, India, Nepal, and Pakistan, and from the international centers and advanced institutes, ICRISAT, Asian Vegetable Research and Development Center (AVRDC), and Cornell University. The exercise has had inputs into the RWC by examining options for legumes in improving the production and sustainability of rice-wheat rotations in the IGP. The relevant data on legume distribution and production for each of the four countries are presented as attractive and easy to interpret GIS maps. This information is used to critically examine constraints to legume production and assess prospects for their increased production in cereal-dominated cropping systems. The output should be of value to agricultural scientists and extension personnel with interests in the IGP region, and also beyond. The GIS database developed for the immediate purpose of this legumes analysis can also be used for other purposes in agricultural systems analysis. The book should be of particular value to research managers and policy makers as it prioritizes options for research and development with respect to legumes and suggests appropriate roles and potential for legumes in intensive input cereal-based production systems.

The Editors

1. Introduction and Background

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The Context

There is increasing concern about the sustainability of high input, intensively cropped, cereal-dominated crop rotations in Asia. A particular example is the continuous rice *(Oryza sativa* L.)-wheat *(Triticum aestivum* L.) rotation practiced in the subtropics of South Asia. There is evidence of system productivity stagnation, nutrient and water imbalance, and increased pest and disease incidence. The ameliorative effect of including legumes in such continuous cereal cropping and cereal dominated systems has long been known but, over time, legume crops have generally declined in importance with crop intensification. This is a consequence of low yield potential of legumes, as compared with cereals (e.g., rice or wheat), and their susceptibility to many abiotic and biotic stresses. Consequently, legumes are perceived as risky crops, especially by resource-poor farmers. However, recent advances in genetic improvement and management techniques for legumes do raise the feasibility of their greater use in cereal dominated systems, so as to increase crop diversification and contribute to system sustainability.

The study presented in this book results from the project "Legume-based technologies for rice and wheat production systems in South and Southeast Asia" being implemented by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India and national agricultural research systems (NARS) of several collaborating countries. The overall objectives of this project are to:

- Quantify the scope for greater inclusion of legumes in rice-wheat cropping systems (RWCS).
- Develop technological options (genetic and management) for reducing the major biotic and abiotic constraints to adoption of legumes in RWCS.
- Evaluate improved technologies on farmers' fields to catalyze adoption and elicit feedback on further research needs and adoption constraints.
- Assess adoption and quantify the impact of improved legume-based technologies for RWCS.

The project addresses sustainability issues of cereal dominated agricultural production systems in South and Southeast Asia, specifically in examining options for greater use of legumes in improving system productivity, quality of output of agricultural products, and long-term sustainability of the production system. It focuses on two broad classifications of production systems: (1) the Indo-Gangetic Plain (IGP) region of South Asia, where both rice and wheat are grown, often in rotation, as the region is in subtropical latitudes; and (2) tropical rice-based cropping systems of peninsular India, Sri Lanka, Vietnam, and Indonesia, which are unsuitable for wheat cultivation.

This study focuses on the rice- and wheat-growing areas of the IGP of Bangladesh, India, Nepal, and Pakistan. It links to the Rice-Wheat Consortium for the Indo-Gangetic Plains (RWC), an ecoregional initiative addressing sustainability issues of rice-wheat rotations in the IGP. The project attempts to contribute to the goals of RWC by exploring options for including legumes in rice-wheat rotations. However, the project has wider scope than this in that it covers areas where rice or wheat are grown separately, and even where legumes are grown in rotation with crops other than these two major cereals.

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Also linked to the RWC is a project managed by the Cornell University entitled "Sustainability of post-green revolution agriculture: the rice-wheat cropping system of South Asia", funded by the United States Agency for International Development (USAID) through the Soil Management Collaborative Research Support Program (SMCRSP). This project is studying a range of factors influencing sustainability of rice-wheat systems but has a particular interest in examining the role of green manure and fodder legumes. Therefore, the Cornell University and ICRISAT projects have linked in this study of constraints and opportunities for legumes in the 1GP region.

Objectives of the Study

A fundamental need of both the Cornell University and ICRISAT projects, as well as of the RWC, was to have an updated database of crops grown in the target region and an analysis of this information to understand the current situation, recent trends and factors influencing those trends. Such knowledge is fundamental to designing a relevant research and development program and for providing a baseline against which to measure technology adoption and assess impact. Although elements of the required databases exist, they are widely dispersed and need assembly and focusing on the problem at hand. Recent developments in computerized database techniques and in geographic information systems (GIS) make this task more feasible and open opportunities for a more comprehensive analysis of existing databases than hitherto possible. Therefore, the objectives of the study presented in this book were to:

- Update the database on area, production, and yields of the major legumes, including grain, oilseed, green manure, and fodder grown in the IGP.
- Use GIS technology to relate area and yields of these legumes, and their trends over time, to influence of factors of the physical environment, biotic stresses, alternative cropping options, and socioeconomic considerations.
- Interpret these data in terms of prospects for increased use and production of these legumes in rice- and/or wheat-based cropping systems of the IGP.
- Present the resultant information and recommendations in attractive hardcopy and in an electronic format to facilitate easier access and utilization by scientists and policy makers.

The Procedure Followed

This study builds on earlier attempts along the lines indicated above, by utilizing recent advances in GIS and computer database technologies. The first attempt by ICRISAT in cropping systems analysis for its mandate legume crops was published as a research bulletin (Virmani et al. 1991). All maps were hand prepared, a laborious and error-prone task. Data plotted referred to the mid- to late 1980s. Nevertheless, through the 1990s this publication has proved to be a valuable guide to the status, problems, and prospects of the ICRISAT mandate legumes in Asia.

With the advent of GIS, ICRISAT and the International Center for Agricultural Research in the Dry Areas (ICARDA), Syria attempted an agroclimatic analysis of their joint mandate crop, chickpea *(Cicer arietinum* L.). GIS was used to prepare colored maps which were published in a book (Saxena et al. 1996). This volume provided fresh insights into chickpea in the target region for scientists and policy makers, due to its simple and attractive layout. We thus intended to further evolve this approach, now targeting legumes in the IGP. However, we wanted to further exploit GIS to be more analytical, interpretive, and explorative for opportunities for legumes in existing and novel cropping systems.

Solicitation of interest of NARS scientists in such an endeavor began in mid-1995, and the preparation of country papers began soon thereafter. At that time, it was apparent that many institutes, national and international, were embarking on use of G1S related to agricultural research but that efforts were largely independent and using different base maps and databases. In conjunction with the RWC and some other international institutes associated with it, it was thought worthwhile to first conduct a GIS harmonization workshop to update on GIS software options, discuss database requirements, availability, storage, exchange and output options, and develop recommendations for optimizing interaction in the use of GIS for cropping systems analysis in the Asia region. The workshop was conducted in 1997 and the proceedings were published (Pande et al. 1999).

Associated with the GIS Harmonization Workshop, and with the preparation of country chapters, training was provided at ICRISAT for NARS scientists in use of GIS for cropping systems analysis, with the hope that the techniques available would ultimately be adopted for regular use within NARS—an additional objective of this exercise.

A workshop on the topic of this book was held at ICRISAT, Patancheru during 15-17 Oct 1997. Here, the country papers were presented and discussed in detail with regard to further data and presentation requirements. Regional overview presentations were made and participants formulated future research and development requirements to promote legumes production in the IGP region. The outcome is the subject of this book.

At the workshop, protocols for data presentation were finalized. For Bangladesh, Nepal, and Pakistan, legumes data for the entire country were presented. For India, data for the states of Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal were presented, as these states covered most of the IGP area in India. Data for all major legumes (>5% total legumes area) would be considered, irrespective of cropping system; whether grown in rice-wheat rotations, with rice or wheat only, or with neither of these cereals (i.e., as upland crops). The legumes considered in this study are listed in Table 1.1. Indeed, a question to be addressed was whether legumes can and should fit into intensive cropping systems (e.g., rice-wheat rotations) in "favorable" environments or they should be relegated to marginal environments unsuitable for rice or wheat cultivation.

Subsequent to the workshop, there was still much work to be done in terms of standardization of GIS maps and presentation, filling of data gaps, and completion of overviews. Some potentially valuable data, such as for green manure and forage legumes, were not available. It was noted that for several countries, data currently available in a uniform manner across all administrative divisions referred to several years previously. Thus up-to-date area distribution maps could not always be prepared. Questions also arose about relative reliability of available data, particularly those indicating biotic stresses, and it was considered necessary to indicate degree of data reliability in the final output. Nevertheless, despite the hurdles encountered, the editors hope that this book will provide a current view of the legume situation in the IGP and a basis for designing appropriate research and development efforts that would optimize use of legumes into the future.

Table 1.1. Legumes grown in the Indo-Gangetic Plain of South Asia, and their climatic adaptation and relative importance.

Common name	Botanical name
Grain legumes	
Warm season	
Major	
Black gram, urd bean	*Vigna mungo* (L.) Hepper
Cowpea	*Vigna unguiculata* (L.) Walp.
Groundnut, peanut	*Arachis hypogaea* L.
Mung bean, green gram	*Vigna radiata* (L.) Wilczek
Pigeonpea	*Cajanus cajan* (L.) Millsp.
Minor	
Common bean	*Phaseolus vulgaris* (L.)
Horse gram	*Macrotyloma uniflorum* (Lam.) Verdc.
Lablab bean	*Lablab purpureus* (L.) Sweet
Moth bean	*Vigna aconitifolia* (Jacq.) Marechal
Soybean	*Glycine max* (L.) Merr.
Cool season	
Major	
Chickpea	*Cicer arietinum* L,
Khesari, grass pea, lathyrus	*Lathyrus sativus L.*
Lentil	*Lens culinaris* Medic.
Minor	
Faba bean, broad bean	*Vicia faba* L.
Pea	*Pisum sativum* L.
Forage and green manure legumes	
Warm season	
Cluster bean, guar	*Cyamopsis tetragonoloba* (L.) Taub.
Sesbania, dhaincha	*Sesbania cannabina* (Retz.) Pers.
	S. aculeata Pers.
	S. rostrata Bremek & Oberm
Sunn hemp	*Crotalaria juncea* L.
Cool season	
Berseem clover, Egyptian clover	*Trifolium alexandrinum* L.
White clover	*Trifolium repens* L.

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2. Legumes in Bangladesh

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Abstract

Food legume crops occupy about 5% of cropped area of Bangladesh but play a significant role in rainfed agriculture. About a dozen legume crops are grown in Bangladesh of which khesari (lathyrus), lentil, chickpea, black gram, mung bean are the major pulses, and groundnut is an oilseed crop. Their cultivation is mainly concentrated in the Gangetic floodplain area. The productivity of these crops is much lower compared to the cereals, and compared to the potential productivity of these legumes, due to various biotic, abiotic, and socioeconomic constraints. Among the biotic stresses, diseases, pests, seed dormancy, and weeds cause significant yield losses. The major diseases are botrytis gray mold, fusarium wilt, and collar rot in chickpea; foot rot, stemphylium blight, and rust in lentil; powdery mildew and downy mildew in khesari (lathyrus); yellow mosaic, cercospora leaf spot, and powdery mildew in black gram and mung bean: and leaf spot, rust, foot rot, and root rot in groundnut. Among the insect pests, Helicoverpa armigera *is a major pest of chickpea and black gram;* Diacrisia obliqua *is a major pest of black gram, mung bean, and groundnut; aphids are common in lentil, khesari (lathyrus), and mung bean;* Euchrysops cnejus, Monolepta signata, *and* Bemisia tabaci *are the major pests of mung bean and black gram. Among the storage pests* Callosobruchus chinensis *infests all pulses except black gram, which is attacked only by C.* maculatus. *Lack of seed dormancy is a major constraint in groundnut and mung bean cultivation. Weeds are a very common problem in all legume crops and in all growing zones. Among the abiotic constraints, drought causes severe yield reduction in some years. Sometimes excess rain and high humidity encourage vegetative growth, in turn leading to high disease and pest incidence and resultant yield loss. Terminal heat stress and rainfall also cause substantial yield loss. In some areas, micronutrient deficiency and soil acidity limit legume cultivation. Among the socioeconomic constraints, low profit, instability of yield, and lack of support price influence the farmers to follow the traditional practices for legume cultivation which inevitably result in poor yields. The area and production of these legume crops are generally declining. The government has consequently launched a Pilot Production Program on lentil, black gram, and mung bean to halt the declining trend. Details of the constraints and the opportunities to fit the legumes in new and diversified cropping systems in Bangladesh are discussed in this chapter.*

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Introduction

Food legumes, particularly pulses, play a significant role in rainfed agriculture and in Bangladeshi diets. They occupy the second largest cropped area after rice *(Oryza sativa* L.) in the country (5.2% of the total cropped area) (BBS 1993; 1994). The major pulses grown are khesari *(Lathyrus sativus* L.; lathyrus; grass pea), lentil *(Lens culinaris* Medic), chickpea *(Cicer arietinum* L.), black gram *(Vigna mungo* (L.) Hepper), mung bean *(Vigna radiata* (L.) Wilczek), and cowpea *(Vigna unguiculata* (L.) Walp.) and they contribute to more than 95% of total pulses production in the country. Groundnut *(Arachis hypogaea* L.) is the second most important oilseed crop after rapeseed mustard *(Brassica* sp) in Bangladesh, although it is consumed almost entirely as a confectionery product (roasted nut). Other food legumes are also grown in the country but are of minor importance and will not be further discussed here. These include pigeonpea *(Cajanus cajan* (L.) Millsp.), pea *(Pisum sativum* L), faba bean *(Vicia faba* L.), lablab bean *(Lablab purpureus* (L.) Sweet), and soybean *(Glycine max* (L.) Merr.).

Food legumes have traditionally been cultivated under rainfed conditions, usually without any monetary inputs. The productivity of these c rops is low compared to wheat (*Triticum aestivum* L.) and rice. Farmers consider that food legumes do not respond to high inputs of irrigation and fertilizer in the same way as cereals do. Their inherently low yield potential, susceptibility to diseases and pests, and sensitivity to microclimatic changes, contribute to their yield instability. Farmers generally pay little attention to cultivation of pulses, particularly to good quality seed, timely sowing, adequate land preparation, fertilization, weeding, and plant protection. This normally results in very low yields. Since Bangladesh has an acute shortage of food grain production, cereal cultivation receives top priority. With the expansion of irrigation facilities farmers prefer rice-rice or rice-wheat cropping systems and legumes are continuously being relegated to marginal lands. The area and production of some legumes such as lentil, chickpea, and mung bean have decreased over the past decade.

Although some legumes, such as *Sesbania* spp, are cultivated as green manures, there is little quantitative information on these and so they will not be discussed in this chapter.

The objectives of research on legumes in Bangladesh have been to develop improved varieties and new technology packages, and to explore new avenues for these crops in the existing cropping systems so as to halt the declining trend in area and production. In this chapter, the current situation for grain legumes in Bangladesh and the recent trends in area, production, and yield are presented. This information is combined with available physical, biological, and economic databases to explore constraints and opportunities for legumes in the country.

Area, Production, and Yield of Grain Legumes

Distribution of the major grain legumes in Bangladesh is indicated in Figures 2.1-2.6. Cowpea is grown after rainy season rice in Chittagong

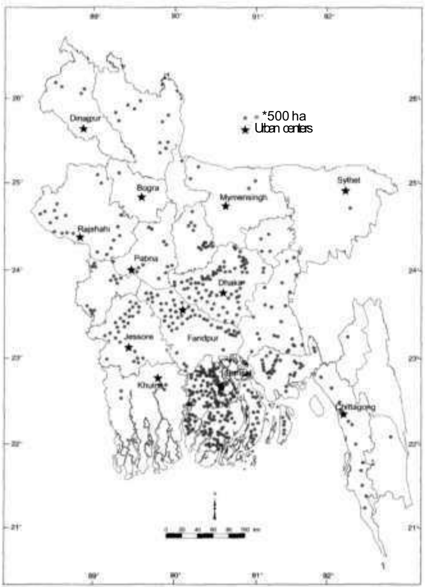

Figure 2.1. Area distribution of khesari (lathyrus) in Bangladesh, 1993-96 (Source: Various issues of Yearbook of Agricultural Statistics of Bangladesh).

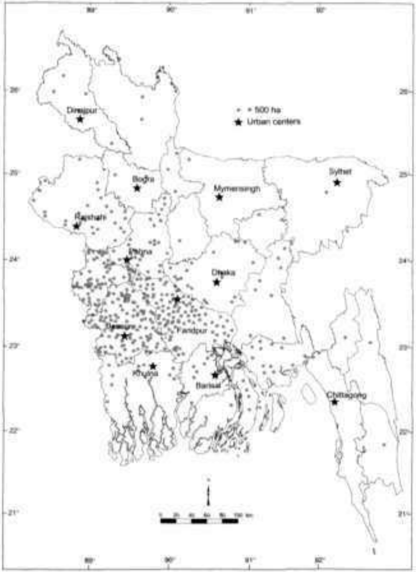

Figure 2.2. Area distribution of lentil in Bangladesh, 1993-96 (Source: Various issues of Yearbook of Agricultural Statistics of Bangladesh).

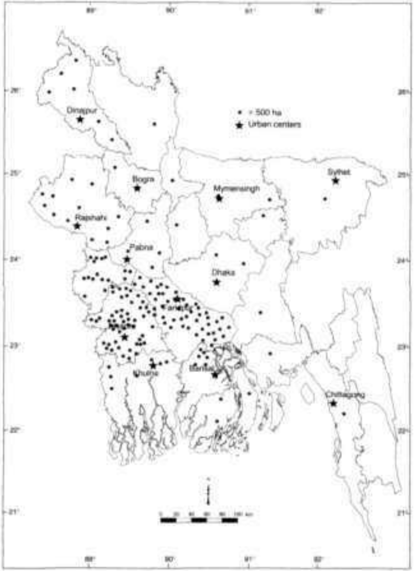

Figure 2.3. Area distribution of chickpea in Bangladesh, 1993-96 (Source: Various issues of Yearbook of Agricultural Statistics of Bangladesh).

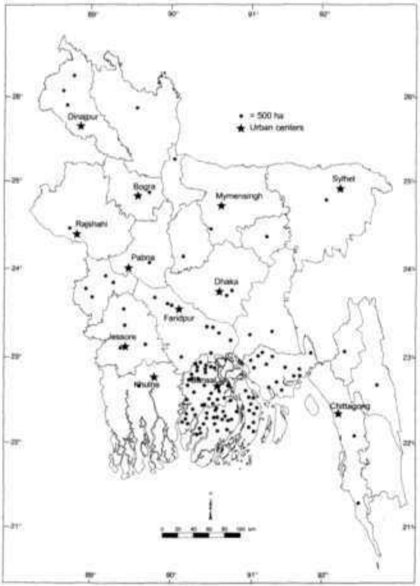

Figure 2.4. Area distribution of mung bean in Bangladesh, 1993-96 (Source: Various issues of Yearbook of Agricultural Statistics of Bangladesh).

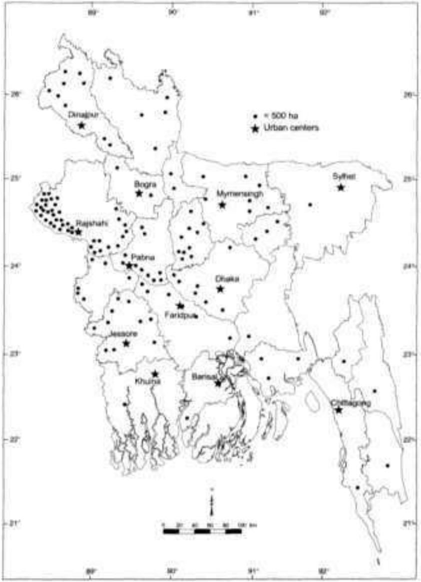

Figure 2.5. Area distribution of black gram in Bangladesh, 1993-96 (Source: Various issues of Yearbook of Agricultural Statistics of Bangladesh).

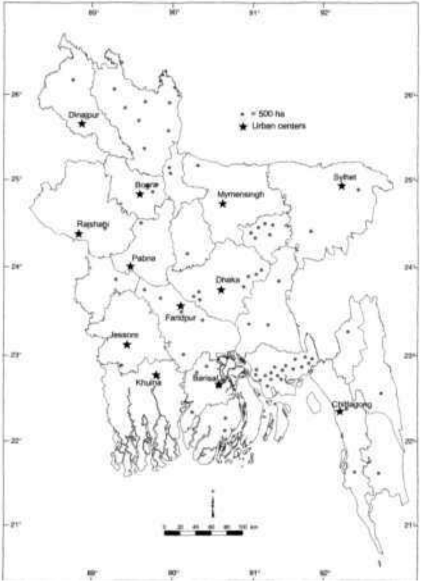

Figure 2.6. Area distribution of groundnut in Bangladesh, 1993 96 (Source: Various issues of Yearbook of Agricultural Statistics of Bangladesh).

Division only. Data have been compiled from various issues of the Year Book of Agricultural Statistics of Bangladesh, published by the Bangladesh Bureau of Agricultural Statistics. For Figures 2.1-2.6, old district boundaries (applicable prior to 1985) are used in area allocation for each crop.

Khesari (lathyrus), lentil, and chickpea are cultivated during winter (rabi or postrainy season; Nov-Mar), and contribute more than 75% of total pulses production. Black gram is grown during rainy season to early winter (Aug-Dec), while mung bean is grown during the rainy season in the northern parts of the country and during late winter (Jan-Apr) in the southern parts. Cultivation of grain legumes is mainly concentrated within the Gangetic floodplains in the northern districts and in some southern districts. Groundnut is produced mainly in winter on residual soil moisture, but is also grown on a small scale on highlands during the rainy season, primarily for seed production. Groundnut cultivation was mainly limited to the central and southern parts of the country but recently its cultivation has been extended to the northern parts.

Trends in area, production, and yield of the principal grain legumes in Bangladesh during 1983/84 to 1995/96 indicate that the area of most crops, in general, has declined or remained static (Fig. 2.7). Yield has similarly remained static, except for lentil where increasing yields have compensated area declines to maintain production levels (Table 2.1).

Agroclimatic Factors Impacting Legume Production

The agroclimatic divisions of Bangladesh are indicated in Figure 2.8 and the soil types in Figure 2.9. Most of the pulses are concentrated in the Gangetic floodplain. Lentil, black gram, and mung bean are grown mainly on high and medium highlands and moderately well to poorly

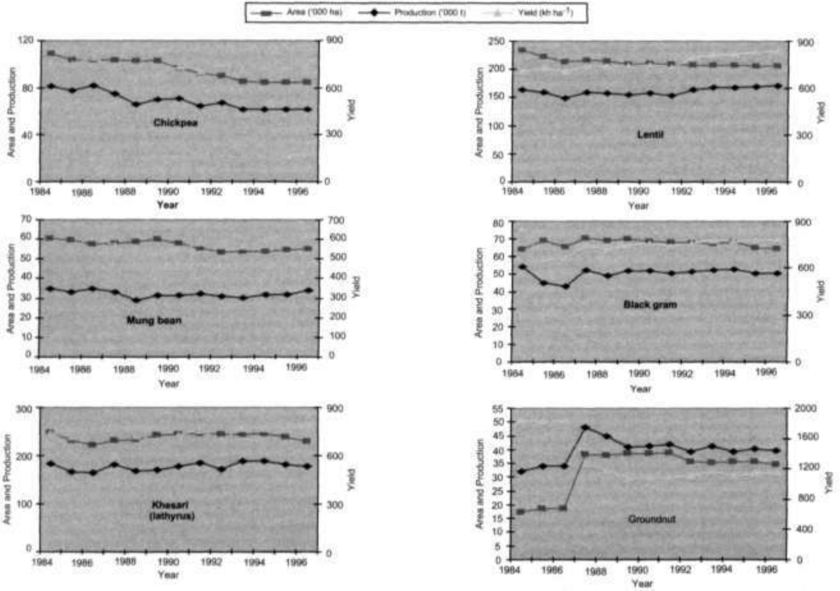

Figure 2.7. Trends in area, production, and yields of the major legumes in Bangladesh during 1983/84 to 1995/96 (Source: Various issues of Yearbook of Agricultural Statistics of Bangladesh).

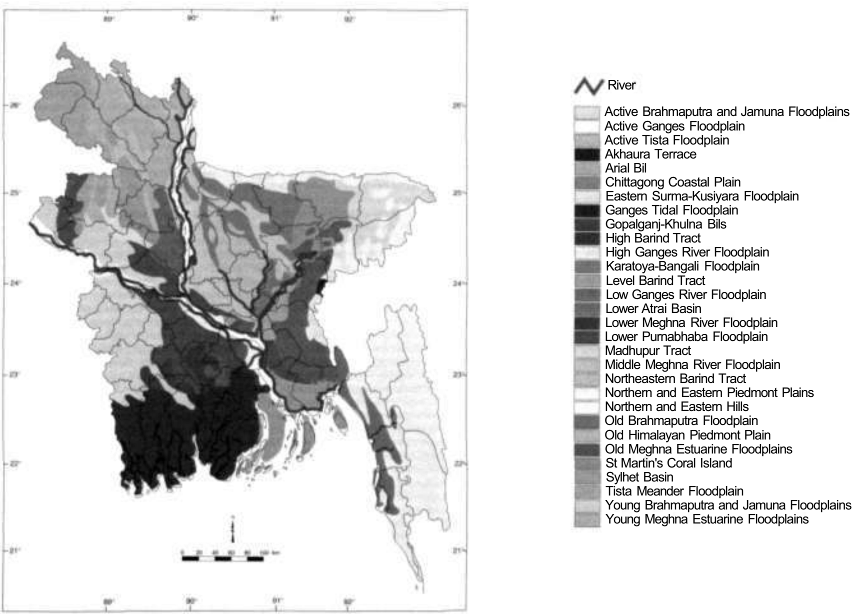

Figure 2.8. Generalized agroecological regions of Bangladesh (Source: FAO 1988).

Table 2.1. Mean area, production, and yield of different grain legumes commonly grown in Bangladesh.

	Period 1: 1983/84-1989/90			Period II: 1990/91- 1995/96			Change (%)		
Legume	Area ('000 ha)	Production ('000 t)	Yield (t ha^{-1})	Area ('000 ha)	Production ('000 t)	Yield (t ha^{1})	Area	Production	Yield
Khesari (lathyrus)	233.9	166.0	0.71	243.2	183.0	0.75	4.1	10.2	5.9
Lentil	221.4	157.4	0.71	207.3	163.9	0.79	-6.4	4.1	11.2
Chickpea	107.1	76.9	0.72	91.0	65.6	0.72	-15.1	-14.7	0.5
Pea	20.9	14.0	0.67	18.4	13.8	0.75	-11.7	-0.8	12.1
Mung hean	59.1	32.9	0.56	55.6	31.5	0.57	-5.9	-4.2	1.9
Black gram	71.9	50.4	0.70	67.4	51.6	0.77	-6.2	2.4	9.4
Pigeonpea	6.1	4.2	0.69	5.9	2.9	0.50	-3.6	-30.4	-27.0
Groundnut	33.6	38.0	1.13	36.7	40.6	1.11	9.2	7.0	-1.8

Source: Government of Bangladesh(1995).

drained light-textured soils. Chickpea and khesari (lathyrus) are grown mainly on medium high to low lands and poorly drained heavy-textured soils. Soils of these areas are calcareous and range from loamy to clayey. The available soil moisture ranges from 160 to 282 mm at I m depth (Jashua and Rahman 1983) and pH ranges from 6.5 to 8.0. Availability of phosphorus and calcium are relatively high. Most of the pulses area is located within the K_4, K_5,and K_6, kharif (rainy season) and rabi-growing period zones; but some area lies within K_1, K_2, and K_3 zones (Fig. 2.10; FAO 1988). The length of rabi-growing period in these regions ranges from 105 to 145 days and begins during 12-21 October. These regions receive relatively low annual rainfall of about 1500-2000 mm (Fig. 2.11), with 60-100 mm winter rainfall (Fig. 2.12). They belong to T_3, T_4, and T_5 thermal zones (Fig. 2.13). The cool period (minimum temperature < 15°C) lasts for 50-110 days and normally begins during 20 Nov-6 Dec. Typical seasonal patterns of rainfall, temperature, and humidity in the major pulses growing region are given in Figure 2.14.

Groundnut is cultivated in pockets throughout the country. In the north, duration of the crop is 130-140 days and in the warmer south it is 120-130 days. Groundnut growth and development is inhibited at temperatures below 20°C, and the crop is, therefore, mainly distributed in regions with milder winter temperature (Fig. 2.13).

Constraints to Production of Grain Legumes

Biotic Constraints

Diseases and insect pests (including stored grain pests) are the major biotic constraints to grain legume production in Bangladesh. Weeds and lack of seed dormancy also limit the productivity of some legumes. To date some 93 diseases and 30 insect pests of the six major legumes have been recorded in Bangladesh (Gowda and Kaul 1982; Rahman et al. 1982; Bakr 1994). The important diseases and pests are listed in order of importance in Tables 2.2 and 2.3, respectively. Biotic stresses of the major legumes are briefly discussed.

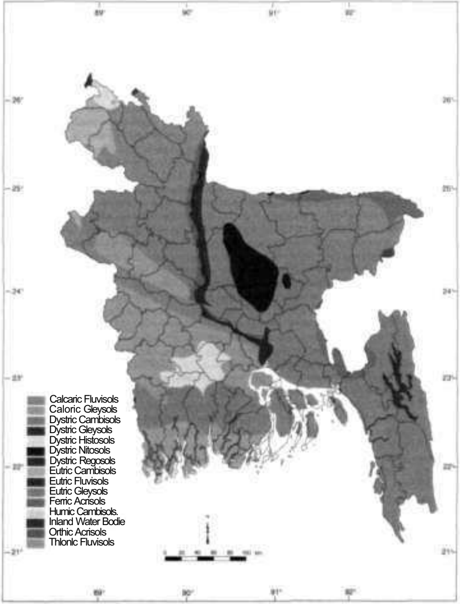

Figure 2.9. Generalized soil types of Bangladesh (Source: FAO 1988).

Diseases

Chickpea. Out of 13 diseases recorded so Far, four diseases, viz., botrytis gray mold (BGM), wilt, dry root rot, and collar rot, are the major ones. BGM and collar rot may cause up to 90% and 84% yield loss respectively (Bakr and Ahmed 1992). All the diseases are widespread over the chickpea-growing zones, but BGM Incidence is low in the Barind tract (Fig. 2.15).

Lentil. Out of 16 diseases, two diseases, viz., stemphylium blight (up to 80% yield loss; Bakr and Ahmed 1993) and rust are the most serious ones. Collar rot and vascular wilt also cause considerable yield loss. Their distribution is almost uniform throughout the country.

Mung bean and black gram. Sixteen diseases in mung bean and 21 in black gram have been recorded. Of these, yellow mosaic, cercospora leaf spot, and powdery mildew are the major ones in both the crops. Recently, sclerotinia blight has also appeared as a major disease. These diseases are evenly distributed throughout the growing zones. Yellow mosaic causes up to 63% yield loss in mung bean (BARI 1984) while powdery mildew causes up to 42% yield loss in black gram (BARI 1987a).

Khesari (lathyrus). Out of 11 diseases recorded, downy mildew and powdery mildew are the major ones. Downy mildew causes up to 12% yield loss while powdery mildew causes up to 23% loss (BARI 1986). Both diseases are evenly distributed across areas where khesari (lathyrus) is grown.

Groundnut. Of the 18 diseases reported, late leaf spot, rust, and sclerotium stem and root rot are considered as major diseases. Late leaf spot causes 30-40% yield loss and rust causes 20-30% yield loss (Ahmed and Ahmed 1994). These diseases are widely distributed throughout the country.

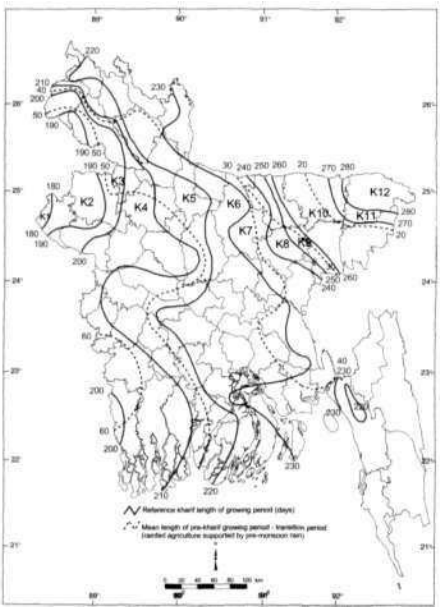

Figure 2.10. Length of growing period map for Bangladesh (Source: FAO 1988).

Generalized moisture characteristics of kharif growing period zones

	Kharif Growing Period		Kharif Humid Period			Rabi Growing Period	
Zone	Days	Period	Days	Period	Excess rainfall (mm)	Days	Period
K1	170-180	27 May 18 Nov	105 115	22 Jun- 12 Oct	600-750	105 -115	12 Oct- 30 Jan
K2	180-190	24 May 25 Nov	115- 130	13Jun- 05 Oct	650-800	11 5125	15 Oct- 12 Feb
K3	190-200	21 May- 02 Dec	115--135	10Jun- 05 Oct	700-1200	115- 135	15 Oct- 17 Feb
K4	200-210	18 May- 09 Dec	125 •145	01 Jun- 05 Oct	700-1200	115- 135	15 Oct- 1 7 Feb
K5	210-220	09 May- 10 Dec	130-160	20 May- 05 Oct	700-1500	120- 140	1 5 Oct- 22 Feb
K6	220-230	03 May- 14 Dec	140-170	17 May- 21 Oct	800-2000[1]	120--145	21 Oct- 02 Mar
K7	230-240	27 Apr- 18 Dec	155 175	10 May- 24 Oct	1200-2500	120-145	24 Oct- 05 Mar
K8	240-250	24 Apr- 25 Dec	165- 175	05 May- 24 Oct	1400-2500	135–150	24 Oct- 15 Mar
K9	250-260	18 Apr- 29 Dec	165- 180	05 May- 27 Oct	1600-2800	135–150	27 Oct- 18 Mar
K10	260-270	12 Apr- 02 Jan	170-190	27 Apr- 27 Oct	1800-4000	135–150	27 Oct- 1 8 Mar
K11	270-280	03 Apr 03 Jan	185- 195	20 Apr- 01 Nov	2500-4000	135- 150	01 Nov- 22 Mar
K12	280-290	27 Mar Of. Jan	195-210	10 Apr- 03 Nov	3000-4500	135 150	03 Nov- 25 Mar

1. Excess moisture of Humid Moisture Period in K6 zone for areas of coastal Chittagong, Sandwip, and Hatiya is in the range 2000- 3000 mm.
2. Rabi periods in K6 zone lor areas of coastal Chittagong, Sandwip, and Hatiya end 10-15 days earlier than elsewhere in the zone.

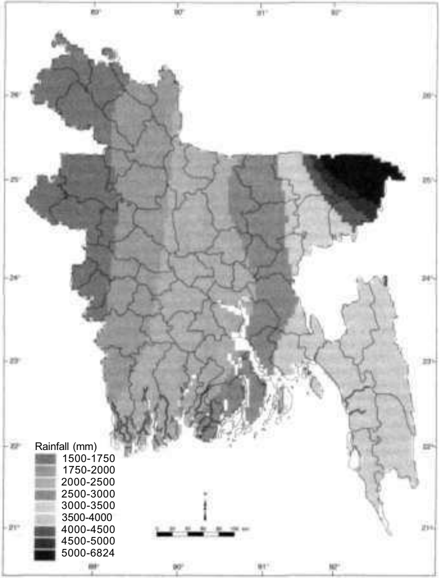

Figure 2.11. Mean annual rainfall for Bangladesh (Source: International Water Management Institute, Colombo, Sri Lanka).

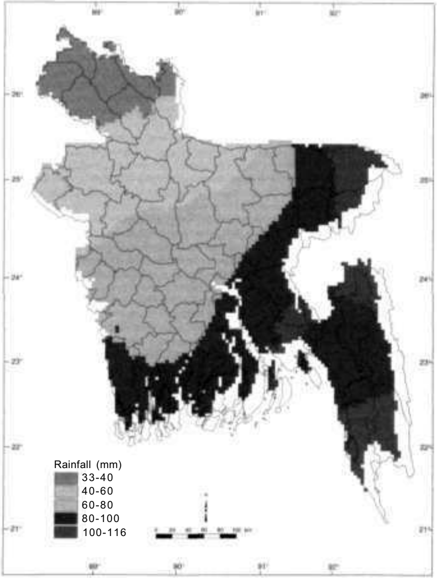

Figure 2.12. Mean winter (Nov-Feb) rainfall in Bangladesh (Source: International Water Management Institute, Colombo, Sri Lanka).

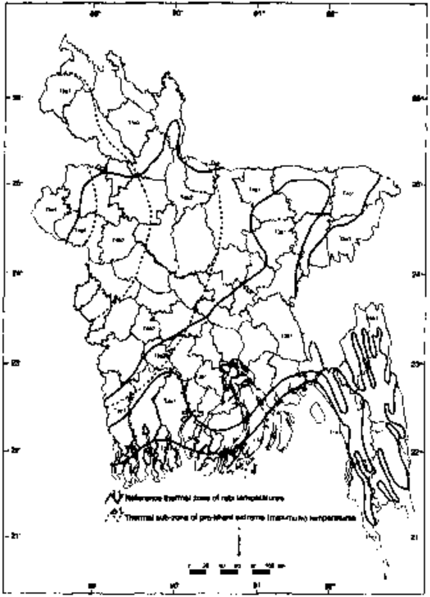

Figure 2.13. Generalized map of thermal resources of Bangladesh (Source: FAO 1988).

Generalized mean temperature characteristics of thermal (T) zones[1]

Thermal zone	Begin period	SD (days)	End period	SD (days)	Length period	SD (days)
			Mean temperatures < 17.5°C			
T1	-	-	-	-	-	-
T2	31 Dec	1	3 Jan	3	4	4
T3	30 Dec	5	4 Jan	5	6	7
T4	26 Dec	6	7 Jan	7	12	10
T5	23 Dec	6	14 Jan	12	22	12
			Mean temperatures <20.0°C			
Tl	23 Dec	7	12 Jan	11	20	14
T2	17 Dec	8	14 Jan	10	28	15
T3	14 Dec	8	23 Jan	13	40	15
T4	9 Dec	8	3 Feb	6	56	15
T5	3 Dec	9	11 Feb	15	70	19
			Mean temperature <22.5°C			
Tl	1 Dec	7	14 Feb	13	76	19
T2	25 Nov	8	9 Feb	13	77	18
T3	24 Nov	9	18 Feb	9	87	12
T4	19 Nov	8	27 Feb	6	101	15
T5	9 Nov	10	5 Mar	11	117	15

1. Mean of stations occurring in the individual zones.

Generalized maximum temperature characteristics of extreme temperature (e) sub-zones[1]

Extreme temperature zone	Occurrence of maximum temperatures					
	<35°C		> 35°C		>37.5°C	>40°C
	days	**SD**	days	SD	**days**	days
el	353	9	12	9	2	0.1
e2	325	20	40	20	16	2
e3	321	17	44	17	22	6
e4	308	19	57	19	30	10

1. Mean of stations occurring in the individual zones.

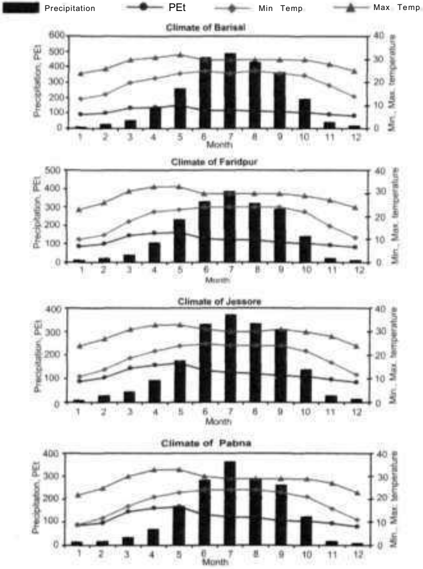

Figure 2.14. Mean monthly precipitation, potential evapotranspiration (PEt), and maximum and minimum temperature in Barisal, Faridpur, Jessore, and Pabna in Bangladesh.

Insect pests

Among the 30 insects recorded many are common pests for several of the legumes (Table 2.3). Aphids are common for lentil, khesari (lathyrus), and mung bean, where they can be a major pest, and for groundnut. *Helicoverpa armigera* Hiibner (pod borer) is a major pest on chickpea and black gram, and can cause up to 90% pod damage in chickpea (Rahman 1989). *Spilosoma (Diacrisia) obliqua* Walker (hairy caterpillar) is a major post of black gram, mung bean, and groundnut. *Euchrysops cnejus* Fab. (hair-streak blue butterfly pod borer), *Monolepla signata* Ol. (monolepta beetle), and *Bemisia tabaci* (whitefly) are the major pests of mung bean and black gram. *Agrotis ipsilon* Hufnagel (cutworm) is a common, major pest of chickpea; and it also attacks lentil and black gram (Karim and Rahman 1991). Thrips are also a major pest in mung bean. Infestation of these pests varies over space and time, depending on weather conditions.

Storage problems

Fungal and insect pest infestations are major constraints in storage and can damage the seed causing loss of seed viability. A total of 15 fungal species were recorded from different pulses. Fungi such as *Aspergillus* spp, *Penicillium* spp, and *Rhizopus spp* are more common in stored grain and increase in severity with an increase in storage period. *Aspergillus flavus* produces aflatoxin, which is the most serious Storage problem of groundnut. Pulses seeds are severely damaged bv bruchids. Two species of this pest, *Callosobruchus chinensis* L. and C. *maculatus* Fab. have been reported to infest all pulses, except black gram which is attacked only by C. *maculatus* (Rahman 1991a).

Seed dormancy

Lack of seed dormancy in the existing cultivars of groundnut, except Virginia types, is a major constraint to groundnut growers. Spanish and

Table 2.2. Recorded diseases of major legumes with casual organisms and their status in Bangladesh.

Crop/Disease	Causal organism	Status
Chickpea		
Botrytis gray mold	*Botrytis cinerea*	Major
Wilt'	*Fusarium oxysporum* f. sp *ciceris*	Major
Collar rot	*Sclerotium rolfsii*	Major
Dry root rot	*Macrophomina phaseolina* (sclerotial state *Rhizoctonia bataticola)*	Major
Alternaria blight	*Alternaria alternata*	Minor
Stunt	Bean (pea) leaf roll virus	Minor
Rust	*Uromyces ciceris-arietini*	Minor
Root-knot	*Meloidogyne javanica, M, incognita, Belonolaimus* sp	Minor
Lentil		
Stemphylium blight	*Stemphylium* sp	Major
Rust	*Uromyces viciae-fabae*	Major
Collar rot	*Sclerotium rolfsii*	Major
Vascular wilt	*Fusarium oxysporum* f. sp *lentis*	Major
Damping-off	*Pythium* sp	Minor
Cercospora leaf spot	*Pseudocercospora cruenta*	Minor
Root-knot	*Meloidogyne javanica; M. incognita*	Minor
Mung bean		
Yellow mosaic	Mung bean yellow mosaic virus	Major
Cercospora leaf spot	*Pseudocercospora cruenta*	Major
Powdery mildew	*Oidium* sp; *Erysiphe polygoni*	Major
Anthracnose	*Colletotrichum lindemuthianum*	Minor
Sderotinia blight	*Sclerotinia sclerotiorum*	Major
Leaf blight	*Leptosphaerulina trifolii; Phoma* sp.	Minor
Nematode disease	*Helicotylenchus* sp; *Hoplolaimus indicus*	Minor
Black gram		
Powdery mildew	*Erysiphe polygoni; Oidium* sp	Major
Cercospora leaf spot	*Pseudocercospora cruenta*	Major
Yellow mosaic	Mung bean yellow mosaic virus	Major
Anthracnose	*Colletotrichum caulicola*	Minor

continued

Table 2.2 *continued*

Crop/Disease	Causal organism	Status
Seed rot and seedling blight	*Macrophomina phaseolina*	Minor
Root-knot	*M. javanica;* M. *incognita; Aphelenchoides* sp	Minor
Target spot	*Corynespora cassicola*	Minor
Leaf crinkle	Leaf crinkle virus	Minor
Leaf blight	*Leptosphaerulina trifolii*	Minor
Khesari (lathyrus)		
Downv mildew	*Peronospora viciae*	Major
Powdery mildew	*Oidium* sp	Major
Leptosphaerulina blight	*Leptosphaerulina trifolii*	Minor
Leaf curl	Leaf curl virus	Minor
Groundnut		
Late leaf spot	*Phaeoisariopsis personata*	Major
Rust	*Puccinia arachidis*	Major
Crown rot	*Aspergillus niger*	Major
Sclerotium stem and root rot	*Sclerotium rolfsii*	Major
Early leaf spot	*Cercospora arachidicola*	Minor
Sclerotinia blight	*Sclerotinia sclerotiorum*	Minor
Rhizoctonia leaf blight/seedling rot	*Rhizoctonia solani*	Minor
Seed rot	*Aspergillus flavus*	Minor

Valencia types arc preferred by farmers because of their short-duration compared to Virginia types. Generally, the main season (rabi or postrainy season) groundnut is harvested during Apr-May, when there is a chance of heavy rain. During this time mature seeds can germinate in the field due to lack of seed dormancy causing a considerable yield loss. This can also be a problem in rainy season groundnut used for seed production. Groundnut seed stored under ambient conditions loses

Table 2.3. Insect pests on major legumes with their nature of damage and importance in Bangladesh.

Insect pest	Nature of damage	Status
Chickpea		
Helicoverpa armigera Hiibner	Bore into pods and feed on seeds and foliage	Major
Agrotis ipsilon Hufnagel	Cut the young plants	Major
Callosobruchus chinensis L.; C. *tnaculatus* Fab.	Damage seed in storage	Major
Alcidodes collaris Pascoe	Bore into pods and feed on seeds	Minor
Aphis craccivora Koch.	Suck sap from foliar parts	Minor
Pachynerus chinensis	Bore into pods and feed on seeds	Minor
Lentil		
Callosobruchus chinensis L.; C. *tnaculatus* Fab.	Damage seed in storage	Major
Aphis craccivora Koch.	Suck sap from shoots and pods	Minor
Spodoptera exigua Hiibner	Cut the plant or plant parts	Minor
Helicoverpa armigera Hiibner	Bore into pods and feed on seeds and shoots	Minor
Nezara viridula L	Suck sap from shoots and pods	Minor
Black gram		
Spilosorna (Diacrisia) obliqua Walker	Feed on leaves	Major
Helicoverpa armigera Hiibner	Bore into pods and feed on seeds, young stems, and leaves	Major
Agromyza phaseoli	Bore into stem	Major
Callosobruchus tnaculatus Fab.	Damage stored seeds	Major
Monolepta signata Ol.	Feed on leaves	Major
Euchrysops cnejus Fab.	Bore into pods and feed on seeds	Major
Aphis craccivora Koch.; *A. medicagenis*	Suck sap and transmit virus	Minor
Maruca testulalis Gever	Bore into pods and feed on seeds	Minor
Bemisia tabaci Genn.	Suck sap and transmit virus	Minor

continued

Table 2.3 *continued*

Insect pest	Nature of damage	Status
Mung bean		
Bemisia tabaci Genn.	Suck sap and transmit virus	Major
Euchrysops cnejus Fab.	Bore into pods and feed on seeds	Major
Agromyza phaseoli	Bore into stems and feed on internal tissue	Major
Aphis craccivora Koch.	Suck sap and transmit virus	Major
Spilosotna (Diacrisia) obliqua Walker	Feed on leaves	Major
Nezara viridula L	Suck cell sap	Minor
Monolepta signata Ol.	Feed on leaves	Major
Callosobruchus chinensis L.; C. *tnaculatus* Fab.	Damage stored seeds	Major
Megalurothrips distalis Karny	Cause flower drop	Major
Khesari (lathyrus)		
Aphis craccivora Koch.	Suck sap from leaves, twigs, and branches	Major
Groundnut		
Spilosoma (Diacrisia) obliqua Walker	Feed on leaves	Major
Odontotermis sp	Feed on pods and underground plant parts	Major
Empoasca kerri Pruthi	Suck sap from foliage of plants	Minor
Scirtothrips dorsalis Hood.	Scrape leaf surface, suck sap; cause leaf curl and stunting of plants	Minor
Anarsia ephippias	Roll young leaves and feed inside	Minor

viability after three months of storage, with complete loss of viability before the next sowing time. Storage techniques have been developed which can help retain 100% viability up to 9-10 months. Well dried seed (7-8% moisture content) preserved in a polythene bag or metal container can retain viability to a satisfactory level (Table 2.4).

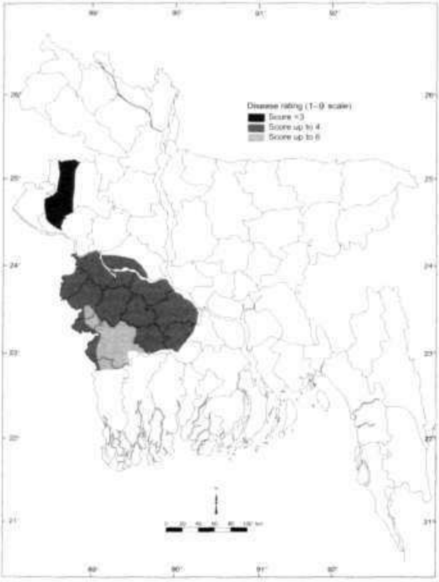

Figure 2.15. Distribution and severity of botrytis gray mold of chickpea in Bangladesh Mean disease severity on a rating scale of 1 9 where 1 is least disease and 9 is most severe.

Table 2.4. Moisture content (%) and germination (%) of groundnut seed of rabi (winter) and kharif (summer) crops stored in different containers for 8 months, Joydebpur, Bangladesh.

	Winter (rabi) season				Summer (kharif) season			
	Moisture content		Germination		Moisture content		Germination	
Treatment	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Earthen pitcher	9.]	11.7	100	0	9.2	9.9	100	89
Tin container	9.1	9.7	100	96	9.2	9.8	100	100
Polythene bag	9.1	10.0	100	99	9.2	9.7	100	100
Gunny bag (jute bag)	9.1	11.8	100	0	9.2	9.9	100	90

Source: Bhuiyan and Quasem (1983).

Seed of the mung bean cultivars used also does not have dormancy and consequently the seed sprouts within the pods if rain occurs at the maturity stage. However, this is not a regular phenomenon.

Weeds

Farmers consider legumes as minor crops and they do not normally weed their legume crops. Hence, weeds compete with legumes and can cause substantial yield losses. Little research has been done in this area. Gowda and Kaul (1982) reported that one hand weeding of a mung bean crop at 20 days is essential otherwise yield reductions will occur. Aziz (1993) reported that grain yield loss due to unrestricted weed growth in a lentil crop was around 25% and the critical period of weed competition ranged from 20 to 30 days after emergence. Several common weeds of legumes are found in farmers' fields in Bangladesh (Table 2.5). These weeds are more or less evenly distributed throughout the growing zones of Bangladesh.

Table 2.5. Common weeds of legume crops in Bangladesh.

Local name	Scientific name	Lentil	Chickpea	Khesari (lathyrus)	Black gram	Mung bean	Groundnut
Mutha	*Cyperus rotundas* L.	Major	Major	-	Major	Major	Major (summer)
Bathua	*Chenopodium album L.*	Major	Major	Major	-	-	Major (winter)
Durba	*Cynodon dactylon* (L.) Pers.	Major	Major	Major	Major	Major	Major
Bindi	*Canvolindus arvensis* L.	Major	Minor	-	-	-	Minor
Dondokalos	*Leucas aspera* Spreng.	Major	Major		-	-	Major
Fashka begun	*Physalis heterophylla* Nees.	Minor	Major	Major	Major	Major	Major
Boon moshure	*Vicia sativa* L	Major	Minor	Minor		-	Minor (winter)
Moshure chana	*Vicia hirsuta* (L) S.F. Grav	Major	Major	Major		_	Minor
Phulkaghash	*Panicum paludosum* Roxb.	-	Minor	Major	-		-
Green foxtail	*Setaria viridis* Beauv.	-	-	Major	Minor	Minor	-
Chhotoshama	*Echinochloa colonum* Link	-	Minor	Major	Minor	Minor	Minor
Chapra	*lileusine indica* Gaertn.	-		Minor	Major	Major	-
Thistle	*Sonchus oleraceus* L.	Major	Major	Minor	-	-	-
Kontanotae	*Amaranthus spinosus* L.	Minor	-	-	Major	Major	Major

Source; M.A Aziz, BARI, personal mmmiiniiation

Abiotic Constraints

A range of climatic and soil factors limit the productivity of both winter and summer food legumes grown in Bangladesh. Among these drought, excess moisture, and adverse temperature and soil conditions are important. As most pulse production occurs in the postrainy season (>80%), the water-holding capacity of the soils is a major factor determining the onset of drought stress.

Drought

The climatic conditions in Bangladesh are variable, particularly during the postrainy (winter) season. In some years very little rainfall occurs during winter and the major legumes [lentil, khesari (lathyrus), chickpea, and groundnut] that are grown on conserved soil moisture suffer from drought stress. Dried-out surface soil hampers proper germination and emergence, especially in case of late-sown lentil and chickpea. Consequently, optimum plant stand cannot be established and thus yields are low (Ahad Miah et al. 1991). The crops can suffer from drought stress during vegetative as well as reproductive phases. This leads to abortion of flowers and young pods and prevents seed filling (Saxena et al. 1994).

Excess soil moisture and humidity

In some years excessive rainfall can occur during winter and this can cause substantial yield loss. If it occurs at an early stage it will encourage excessive vegetative growth leading to lodging, and also encourage development of various leaf and root diseases. If rainfall occurs at the reproductive stage it will not only physically damage the flowers and developing pods/seeds, but also encourage foliar diseases such as BGM in chickpea, rust and stemphylium blight in lentil, downy mildew in khesari (lathyrus), and late leaf spot in groundnut. Some of these diseases can cause complete yield loss in these crops. High rainfall coupled with high humidity also encourages insect pest infestation. In some years when rainfall occurs at the time of crop maturity for rabi crops (Mar-Apr), it affects crop yields due to pod-shedding, seed rotting, and hampering of harvesting and threshing.

Black gram and some mung bean are sown in the late rainy (kharif-II) season (Aug-Dec). The peak months for rainfall are Aug and Sep and so land preparation is difficult during this period and heavy infestation of weeds occurs. Crops may be seriously damaged due to waterlogging, and infestation of insect pests which cannot be controlled effectively through insecticide sprays applied in rainy weather.

Temperature extremes

Low temperatures encountered during Dec-Feb especially towards the north and west of the country (Fig. 2.13), can minimize vegetative growth of both cool and warm season legumes and may delay or reduce podding in crops such as chickpea (Saxena et al. 1988b). A sudden rise in temperature in late Feb in some years severely reduces vegetative growth and pod formation and development of rabi crops, especially of late-sown lentil and chickpea grown in e2T3, e2T4, e3T4, and e4T4 isothermal zones (Fig 2.13). This phenomenon also occurs in other parts of the world (Saxena et al. 1988a; Nene and Reed 1994;Slinkard et al. 1994).

Soil factors

Pulse crops have been traditionally grown in Ganges floodplain soil, although chickpea cultivation is now increasing in the Barind tract, and mung bean in the young Meghna estuarine floodplain (Fig. 2.8). The Ganges floodplain soils are calcareous and alkaline, but older soils are decalcified to a variable depth. Moderately well to poorly drained, loamy to clayey, pale brown soils occur on raised areas. Basin areas have poorly drained, mainly clayey soils with gray to dark gray color. The soils of the Barind tract are mainly imperfectly to poorly drained, brown to gray, loamy to clayey soils. The surface soil is acidic. Young Meghna estuarine floodplain soils are mainly gray and loamy on the raised areas and gray to dark gray loamy to clayey in the basin areas. Soils here are neutral to slightly acidic in reaction. In soils of higher clay content, plow pan formation impedes root development of crops following rice, and thus the ability of those crops to access soil moisture and nutrients.

The organic matter content in the floodplain soils usually ranges from 0.5% to 2.5%, lower in the raised soils and relatively higher in the basin soils. In the Barind tract, it ranges from 0.3% to 1.8% (Idris 1995). Soil analyses conducted by the Soil Resources Development Institute (SRDI 1990-97) suggest that potassium (K), calcium (Ca), and magnesium (Mg) deficiencies are not likely to limit yield of grain legumes in Bangladesh. Phosphorus (P) levels may be marginal and sulfur (S) deficiency would be likely in western and northwestern regions but not in floodplain soils. By contrast to S, soils appear more deficient in zinc (Zn) in the floodplain than in uplifted areas in the northwest. In the Tista floodplain area of northern Bangladesh (Rangpur and Dinajpur), there are increasing reports of boron (B) deficiency limiting yields of lentil and chickpea (BARI 1987b, 1993; Miah 1995).

Socioeconomic Constraints

In Bangladesh, farmer and government priority is given to production of cereals such as rice and wheat, or to cash crops. Farmers consider that legumes are very sensitive to microclimatic variation and to diseases and pests, and thus high and stable yields cannot be ensured.

Therefore, they consider them as risky crops, even if they are potentially remunerative, and give low priority to their optimum husbandry. The major socioeconomic constraints related to legume production in Bangladesh are discussed.

Low profit and high risk

Lack of high-yielding varieties of legumes, analogous to those for rice or wheat, is an important consideration to the farmers. Traditional landraces continue to be used and it is thus not surprising that yields have generally not increased over time (Fig. 2.7). Although market price of grain legumes is generally increasing relative to other grains, the benefitxost ratio is low and ranges from 1.03 to 3.38 on full cost basis (Hossain 1993).

Input use

Farmers have experienced that use of irrigation and fertilizers encourages excessive vegetative growth of legume crops, which ultimately results in poor pod set and low yield. Therefore, they do not use inputs, conduct plant protection measures, or practice weeding. The prices of fertilizers, insecticides, and fungicides are relatively high and increasing which discourage their use for risky crops like legumes.

Lack of cash and credit

Most of the farmers do not have enough cash on hand to buy quality seeds or inputs, even if they intended to. Credit facilities are not available for legume crops in the same way that they are for other crops such as rice, cotton (*Gossypium* sp), and sugarcane (*Saccharum officinarum* L.) (Hossain 1993).

Lack of support price and marketing

Pulses are generally more susceptible than other crops to stored grain pests. As a result farmers cannot store their produce for long and hence they sell it immediately after harvest. There is neither a definite marketing channel nor a government support price for legumes. The traders buy the grains from the farmers at a low price. About 74% share of the profit goes to traders and only 26% to the farmers (Elias 1991).

Traditional cultivation practices

Farmers follow traditional cultivation practices for legumes in Bangladesh, because improved methods of cultivation (such as line sowing and use of inputs) cannot assure them of a high yield. Although prices of legumes are much higher than other competing crops, profitability seems to have little influence on production decisions. On the contrary, production with minimum cash inputs seems to be the aim (Elias 1991). So, unless improved technologies can be demonstrated on farmers' fields to ensure high and stable yields, it will be extremely difficult to change traditional cultivation practices for legume crops.

Consumer preference

All the pulses are not equally liked by the consumers all over Bangladesh. Hence the price is determined by the consumers' preference as well as total production. The present ranking of pulses on the basis of price is as follows: mung bean > lentil > chickpea > black gram > khesari (lathyrus). Some pulses are regionally preferred; for example, black gram is preferred by most of the people of northwestern Bangladesh and hence it is not widely grown in other parts of the country. The price of groundnut is more or less stable throughout the year. Its marketing is also channelized in the same way as pulses.

Role of Legumes in Cropping Systems

As irrigation facilities become available, farmers shift to predominantly rice-rice or rice-wheat cropping systems (RWCS). However, there is increasing concern about the long-term sustainability of cereal monocropping systems. It is generally considered undesirable to indefinitely continue with these systems. Legumes are considered as ameliorative crops from the point of view of sustainability to break continuous cropping with cereals. Soil aggregation, soil structure, permeability, fertility, and infiltration rate are reported to improve with the inclusion of pulses in the cropping system (Yadav et al. 1997). Grain legumes can add 20-60 kg ha^{-1} residual nitrogen (N) to the succeeding crop (Kumar Rao et al. 1998). Therefore, legumes in general can play a vital role in sustainability of agroecosy stems.

In Bangladesh, pulses are grown in different cropping systems. The major ones are presented in Table 2.6 and discussed below.

Lathyrus

Khesari (lathyrus) is cultivated as a relay crop with main season rice (*aman* rice) in the medium-low and lowlands. It is broadcast on the saturated soils by the end of Oct to mid-Nov, about 15-20 days before the rice harvest. It is the hardiest crop among pulses and can thrive under both excess moisture and extreme drought conditions. It has no major disease or insect problems, stable yields, and negligible input cost. It is difficult to replace khesari (lathyrus) by any other crop under the situation in which it is presently cultivated. Most of the land planted to this crop would have remained fallow after rice had there been no khesari (lathyrus). However, it is reported that if it is consumed as a staple food (one-third of the daily calorie intake) continuously for 2-3 months, it may cause lathyrism, a paralytic disease of the limbs of humans.

Lentil

Lentil is mostly grown in the upland rice (aus)/jute (*Corchorus capsularis* L.)-fallow-lentil cropping pattern, and is usually sown by mid-Nov. But some lentil is also grown in the broadcast *aman* rice-lentil cropping pattern, where it is sown during the later part of Nov and is considered as a late-sown crop. Apart from these patterns, lentil is commonly cultivated as a mixed crop with mustard (*Brassica* sp) and as an intercrop with sugarcane in the northern part of the country where it is sown during early Nov.

Chickpea

Chickpea is grown on relatively heavier soils under the *aus* rice/jute-fallow-chickpea cropping pattern, where it is sown in Nov and covers about 60% chickpea area. About 35-40% chickpea is grown in the *aman* rice-chickpea cropping pattern, where it is sown in Dec (Rahman and Mallick 1988) as a late-sown crop. Apart from these systems, chickpea is cultivated as a mixed crop with linseed (*Linum usitatissimum* L.), barley *(Hordeum vulgare* L), and mustard and as an intercrop with sugarcane.

Black Gram

Black gram is a relatively hardy pulse crop. It is generally sown in Aug-Sep on well-drained medium-high or highlands after harvest of *aus*

Table 2.6. Major cropping patterns of grain legumes in Bangladesh.			
Crop	Cropping pattern[1]	Land type	Remarks
Khesari (lathyrus)	B. *aman* rice-khesari relay (Apr-mid-Nov) (Nov-mid-Mar)	Medium lowland, clay loam, clay soil	Broadcast khesari seeds before rice harvest
	T. *aman* rice-khesari relay (Apr/May-Aug) (mid-Nov-Mar)	Medium, high-medium, lowland, clay loam, clay	Broadcast khesari seeds before rice harvest
Lentil	*Aus* rice/jute-fallow-lentil (Apr/May-Aug) (Aug-Oct) (Nov-Feb)	Highlands, loamy soil	Optimum sowing; major pattern
	B. *aman* rice-lentil (May-Nov) (late Nov-mid-Dec)	Medium highland, clay loam/loam soils	Late sowing
	Sugarcane + lentil (Oct/Nov) (Nov-Feb)	Hlighlands, loamy soil	Companion crop, sown along with sugarcane
Chickpea	*Aus* rice/jute-fallow-chickpea (Apr/May-Aug) (Aug-Oct) (Nov-Apr)	Highlands, clay loam soil	Optimum sowing; major pattern
	Aus rice + B, *aman* rice-chickpea (May-Nov) (Dec-rnid-Apr)	Medium highlands, clay loam to clay soils	Late sowing
	T. *aman* rice-chickpea (Jul-Nov) (Dec-mid-Apr)	Medium lowlands, clay soil	Late sowing
Black grain	*Aus* rice/jute-black gram (Apr/May-Aug) (late Aug-Dec)	Highlands/medium highlands, river basin (after flood), sandy loam, silty	Major pattern
	Aus rice-black gram-mustard/wheat/lentil/sugarcane (Apr-Aug) (Aug-Nov) (Nov-Mar)	Highlands sandy loam to clay loam	Short-duration black gram
Mung bean	*Aus* rice-*T. aman* rice-mung bean (Apr-Jul) (Aug-Dec) (Jan-Apr)	Silty loam to clay loam	Southern belt (65%) mung bean
	Winter crops-mnng bean-*T. aman* rice/vegetabie.s (Nov-Mar) (Mar-Jun) (Jul-Dec)	High/medium highlands, sandy to silty loam	Northwestern Bangladesh (5%)
	Aus rice/jute-mung bean-winter crops (Apr-Aug) (Aug-Nov) (Nov-Mar)	Well drained highlands, sandy to loam soil	Green-seeded, short-duration mung bean
	Aus rice/jute-mung bean-fallow (Apr-Aug) (Sep-Dec) (Jan-Feb)	High-medium highlands, sandy loam to clay loam soil	Golden-seeded, long-duration mung bean
Groundnut	*Aus* rice/jute-fallow-groundnut (Apr-Aug) (Aug-Oct) (Nov-Apr)	High-medium highlands, sandy loam to silty loam	Major pattern
	Groundnut-fallow-winter crops (Apr-Aug) (Sep-Oct) (Nov-Apr)	High-medium highlands, sandy loam to silty loam	Minor pattern

1. B - Broadcast; T = Transplanted.

rice in the *aus* rice-black gram-fallow cropping pattern. Short-duration black gram (small seeded called *thakrikalai*) is cultivated in the *aus* rice-black gram-rabi crops cropping pattern where sowing is completed within Aug. The Bangladesh Agricultural Research Institute (BARI), Joydebpur, Bangladesh has released one variety, Barimash, for this cropping pattern and a few more are in the pipeline.

Mung Bean

About 65-70% of the mung bean crop is grown in the *aman* rice-mung bean-aws rice cropping pattern in the southern part of Bangladesh. In these areas the crop is sown in Jan/Feb and harvested in Mar-Apr. About 5% of the mung bean crop is grown in the northwestern part of the country in the winter crops-mung *bean-aman* rice cropping pattern. This crop is sown in Mar and harvested in Jun. The remaining 20-25% of mung bean is cultivated in the central part of the country in the *aus* rice/jute-mung bean cropping pattern. Varieties for this pattern are photoperiod-sensitive and golden seeded (*sonamung);* they are planted in Aug and harvested in Dec. This pattern, however, is gradually being replaced by rabi crops such as wheat, mustard, and potato *(Solatium tuberosum* L.).

Groundnut

Groundnut is mostly grown in the *aus* rice-groundnut cropping pattern or as a monocrop in the riverbed areas (*chaur).* It is sown in Oct-Nov and harvested in Mar-Apr. A small portion of groundnut (mostly for seed purpose) is sown in Apr-May and harvested in Aug-Sep in the groundnut-winter crop cropping pattern.

National Policies and Emphasis on Legumes Production

The population of Bangladesh, as per the World Bank projection, will cross 132 million by the year 2000, 153 million by 2010, and 173 million by 2020 (BARC 1995). The current production of pulses is 0.532 million t (BBS 1997). If the present rate of per capita consumption of about 12 g day^{-1} (which itself is only one-third of the world average) is to be maintained in the year 2010, the demand for pulses is expected to be 0.672 million t. This means the total production of pulses needs to be increased by about 28% by 2010 over the present production, with an average annual growth rate of 2.19%.

The Government has given priority for pulses production policy. It launched the Crop Diversification Programme (CDP) with the assistance of the Canadian International Development Agency (CIDA) in 1990 to augment pulses, oilseeds, and tuber crops production in the country. This program is expected to continue up to the year 2000. The themes of the CDP are: (1) increase area and production through utilization of fallow lands or periods; (2) introduction of new cropping patterns with increased cropping intensity, through introduction of new varieties and technologies; and (3) increase consumption and marketing. To achieve these goals the CDP has supported several components such as:

- Strengthening research for development of suitable high-yield technology packages.
- Seed production of improved varieties through the Bangladesh Agricultural Development Corporation (BADC).

- Strengthening of extension services through training and demonstration programs to familiarize farmers with the latest production technology.

The CDP has strengthened linkages among the research institutes [BARI and Bangladesh Institute of Nuclear Agriculture (BINA)], Department of Agricultural Extension (DAE), and BADC to achieve their common goals. In addition, the Government launched a special project called "Pilot Production Project on Lentil, Black gram and Mung bean" in 1996-97 which will continue up to 2000. The main objectives of this project are to extend improved varieties and production technologies of these crops among the farmers to increase their area and production. BARI is implementing the project in collaboration with BINA, BADC, DAE, and the Institute of Postgraduate Studies in Agriculture (IPSA).

Prospects for Increased Production and Use of Legumes

There are good prospects for increased legume production in Bangladesh. The additional production can be achieved by. (1) increased productivity through adoption of improved varieties and cultural practices; and (2) increased area through utilization of fallow lands and introduction of new cropping patterns. The list of the newly released varieties of the major grain legumes is given in Table 2.7. These varieties produced higher yields compared to the existing varieties at research stations and farmers' field demonstrations.

Some of the potential technologies and new cropping patterns incorporating legumes for additional production are discussed.

Table 2.7. Pulses varieties recommended or released in Bangladesh.

Crop	Variety	Year of release/registration
Lentil	Barimasur 1 (Uthfala)	Released in 1991
	Baritnasur 2	Released in 1993
	Barimasur 3 (BLX-8405-36)	Registered in 1996
	Barimasur 4	Registered in 1996
Chickpea	Hyprosola	Released in 1981
	Nabin	Released in 1987
	Barirhola 2	Released in 1993
	Barichola 3[1]	Released in 1993
	Binachola 2	Released in 1994
	Binachola 4 (ICCL 85222)	Registered in 1996
	Binachola 5 (RBH 228)	Registered in 1996
	Binachola 6 (ICCL 83149)	Registered in 1996
Khesari (lathyrus)	Barikhesari 1	Registered in 1995
	Barikhesari 2 (No. 8603)	Registered in 1996
Black gram	Barimash	Released in 1990
	Barimash 1	Released in 1994
	Barimash 2 (BMAX-90233)	Registered in 1996
	Barimash 3 (BMAX-90235)	Registered in 1996
Mung bean	Mubarik	Released in 1982
	Kanti	Released in 1987
	Binamung 1[2]	Released in 1992
	Binamung 2[2]	Released in 1994
	Binamung 3 (BMX-842243)	Registered in 1996
	Binamung 4 (BMX-841121)	Registered in 1996
	Binamung 5 (NM-92)	Registered in 1997
Cowpea	Barifaion 1	Released in 1993
	Barifalon	Registered in 1996
Groundnut	Dhaka 1	Recommended
	DC 2	Recommended
	Jhinga badam	Recommended
	DM 1	Recommended
	ICGS(E) 55	Released in 1995

1 For Rarind only.
2. For Kharif-1.
Source: S e e d Certilualum A , G.MJW, BannUlrsh

Lentil

Most of the local cultivars suffer from rust and stemphylium blight especially under late planting conditions. The loss caused by these diseases may be minimized by early planting (first week of Nov). Yield of lentil may be increased significantly by early planting with a higher seed rate to achieve a plant stand of 333.3 plants m^{-2} (Ahlawat et al. 1982, 1983; Saxena et al. 1983).

Chickpea

Most of the traditional chickpea area is concentrated within the Gangetic floodplains. Yield stability is very low due to sporadic yield losses caused by various diseases, mainly BGM. On the other hand most of the 0.8 million ha land of the high Barind area in northwestern Bangladesh remains fallow in the winter months after harvest of local transplanted *aman* rice (Raisuddin and Nur-E-Elahi 1984). Experiments indicate that yields of more than 1 t ha^{-1} can be harvested if chickpea is planted by early November (Table 2.8a, b). In this case, the local long-duration rice cultivars need to be replaced by short-duration varieties such as BR 1, BR 14, and IR 50. The relatively less humid climate in the Barind area is not favorable for BGM infestation, which is a major threat to chickpea in the traditional areas. If only 10% of the Barind could be brought under chickpea cultivation, it may double the chickpea production in the country (Kumar et al. 1994). Similarly, lands remain fallow after harvest of transplanted *aman* rice in some parts of eastern Bogra, Rangpur, and Dinajpur districts. The soils are silty loam with high soil moisture-holding capacity. Chickpea grows vigorously on these soils but sets fewer pods. On-station studies indicate that chickpea yield of more than 1 t ha^{-1} can be obtained by applying 0.5 kg B ha^{-1} (Table 2.9). If parts of these areas are brought under chickpea cultivation, total area and production of this pulse crop could be greatly increased (Fig. 2.16).

Table 2.8a. Grain yields of modern rice varieties and following rabi (postrainy season) crops in Barind, Bangladesh.

Rice variety	Rice date	Grain yield (t ha^{-1}) 1988	1989	Mean	Rabi crops	Grain yield (t ha^{-1}) 1988/89'	1988/90	Mean
BR 14	23 Oct-7 Nov	4.58	4.21	4.39	Chickpea	0.77	0.81	0.79
					Lentil	0.21	0.45	0.33
					Mustard	0.46	0.76	0.61
					Linseed	0.38	0.70	0.54
BR 1	11-25 Oct	4.17	2.93	3.55	Chickpea	0.66	1.04	0.85
					Lentil	0.31	0.30	0.31
					Mustard	0.55	0.50	0.53
					Linseed	0.31	0.44	0.38
BR 11	7-23 Nov	5.00	4.71	4.85	Chickpea	0.30	0.30	0.30
					Lentil	0.14	0.43	0.29
					Mustard	0.22	0.32	0.27
					Linseed	0.21	0.52	0.37

Table 2.8b. Grain yield of kabuli and desi chickpea lines planted after rice harvest in Barind, Bangladesh.

Line	Grain yield (t ha^{-1}) 1988/89	1989/90	Mean
ICCL 83007 (kabuli)	2.07	1.63	1.85
1CCL 83008 (kabuli)		1.65	
Rajshahi Local (desi)	1.61	1.98	1.60
Nabin (desi)	2.16	1.82	1.99

Source: OFRD (1989. 1990).

Black Gram

One of the major upland cropping patterns of the northern districts is *aus* rice-fallow (Aug-Oct)-winter crops. If this fallow period of 80-90 days could be utilized to grow short-duration pulses such as mung

Table 2.9. Effect of boron on the yield and other characteristics of chickpea at Rangpur, Bangladesh in 1992/93.

Boron applied (kg ha^{-1})	Plant height (cm)	No. of pods $plant^{1}$	No. of seeds pod^{-1}	100 seed weight (g)	Grain yield (kg ha^{-1})
0	44.3	1.0	0.7	9.7	11
0.5	44.8	32.9	1.3	12.8	1025
1.0	46.0	33.5	1.3	12.8	1157
1.5	46.2	35.4	1.3	12.9	1213
2.0	44.2	35.3	1.3	12.9	1188

Source: BARI (1993).

bean or black gram, a large area could come under pulses without disturbing the existing cropping pattern. BARI has released a short-duration (60 days) black gram variety, Barimash, which is tolerant to yellow mosaic and fits well into this pattern provided sowing is completed by the end of Aug (Table 2.10). The major cropping pattern with black gram is *aus* rice-black gram-fallow. In this pattern farmers cannot grow winter crops after black gram due to lack of moisture for sowing of the winter crops. However, short-medium-duration pigeonpea can be grown as a mixed crop or intercrop. Black gram is harvested in Dec when pigeonpea attains a height of about 60 cm and begins to flower. Thus pigeonpea does not affect the black gram yield. However, insect pest damage is the major constraint to pigeonpea, which can be managed by careful need-based insecticide sprays. If this cropping system is extended, a large area can be brought under pigeonpea, which otherwise would remain fallow.

Mung Bean

About 30% of the country's mung bean is cultivated during Aug-Dec in the *aus* rice-mung bean cropping pattern. These are golden-seeded mung bean [*sonamung*] having long-duration (about 90 days) and low productivity. The area under this pattern is being replaced by other winter crops such as wheat and mustard. If the long-duration mung cultivars are replaced by short-duration varieties, e.g., Kanti, it will be possible to grow winter crops after mung. The major upland cropping pattern of the northern districts, i.e., *aus* rice-fallow-rabi crops can be replaced by aus rice-mung bean-rabi crops. (Table 2.10). Thus, it would be possible to bring a large area under mung bean cultivation, which otherwise remains fallow.

BARI also tried to introduce mung bean in early summer in the winter crop-mung bean (May-Jun)-aman rice cropping pattern. This pattern is feasible under irrigated conditions when sowing must be completed by Feb/mid-Mar (Rahman 1991b). In these patterns if mung bean plants are plowed down after the harvest of pods, considerable organic matter and fixed N will be added to the soils.

Table 2.10. Yield increase, net return increase, and cost-benefit ratio of the *aus* rice-mung bean/black gram-winter crops pattern over the existing *aus* rice-fallow-winter crops pattern in Bangladesh.

	Yield increase (%)		Net return increase (%)		Cost-benefit ratio	
Cropping pattern	1987	1988	1987	1988	1987	1988
Aus rice-mung bean-wheat	15	17	62	131	1.04	1.05
Aus rice-mung bean-mustard	36	34	101	139	1.15	1.16
Aus rice-mung bean-lentil	32	30	63	78	1.64	1.91
Aus rice-black gram-wheat	19	19	90	123	1.16	1.01
Aus rice-black gram-mustard	46	44	133	145	1.33	1.19
Aus rice-black gram-lentil	37	29	74	53	1.79	1.90

Source: Aziz and Rahman (1991)

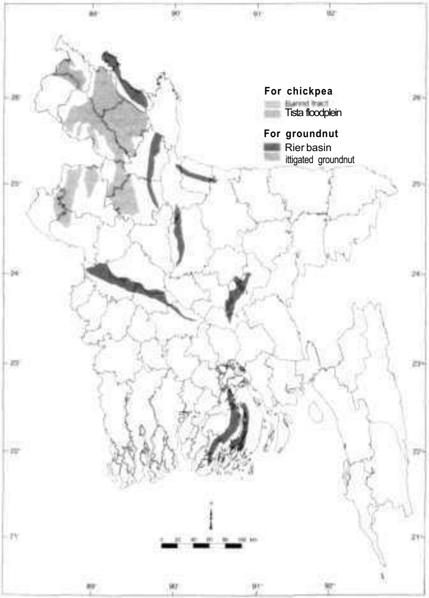

Figure 2.16. Potential area for expansion of chickpea and groundnut in Bangladesh.

Groundnut

Groundnut is facing considerable competition from other crops in the existing cropping patterns due to its long-duration and low productivity. However, there is potential for expansion of the postrainy season (main season) groundnut in *chaur* (river basin) lands without much competition from other crops. These areas are found in Lalmonirhat, Gaibandha, Sirajganj, Jamalpur, Tangail, Kustia, Faridpur, Dhaka, Narayanganj, Munshiganj, Narsingdi, Noakhali, Potuakhali, and Bhola districts. Parts of Thakurgaon, Panchagahar, and Nilphamari districts, in the northwest region of the country, are suitable for irrigated groundnut cultivation during winter and rainfed cultivation during summer (Fig. 2.16).

Conclusion

The productivity of legume crops in Bangladesh is low and unstable due to various biotic and abiotic constraints and as such their area and production are declining due to low profitability compared to other crops such as rice, wheat, and sugarcane. However, there is some scope of increasing the area and production of these crops if the appropriate technologies are followed for their cultivation and also if they are fitted in various niches of rice, wheat, and sugarcane cropping systems, as discussed above. Better linking of research and extension efforts is needed to achieve this.

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3. Legumes in the Indo-Gangetic Plain of India

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Abstract

Cropping in the Indo-Gangetic Plain of India covering 44 million ha is predominantly cereal based. Rice-wheat and rice-based cropping systems are the most important systems, with rice-wheat rotations covering about 10 million ha. Legumes account for about 5 million ha, which amounts to about 14% of the total area in the country. This region has large spatial variation in rainfall pattern (268 mm in the extreme north to 1600 mm in the extreme east), and is largely dominated by Inceptisol soils. There is large variation in other agroclimatic characteristics such as temperature regime, length of growing season, and evapotranspiration. Despite this large variation chickpea, lentil, and pigeonpea are cultivated as major legumes across the region. Their production in this diverse part of the country is severely constrained by a number of diseases, insect pests, and abiotic stresses. Socioeconomic constraints are also important in discouraging their production. The Government of India increased research outlay to develop improved technologies for increasing legumes production in the country. The results of Government investment were promising, and a number of improved cultivars and technology options were developed to alleviate biotic and abiotic constraints. The Government also initiated several policy measures to alleviate socioeconomic constraints for increasing legumes production. The available trends show that in some parts, legumes area is gradually increasing. The region shows huge potential for legumes production (either as a catch crop, summer crop, or sole crop in different cropping systems), provided appropriate cultivars/ technologies reach farmers' fields.

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Introduction

The Indo-Gangetic Plain (IGP) of India, covering about 44 million ha, is the most important food producing domain in South Asia. It extends from 21°31' to 32°20'N and 73°16' to 89°52' E and is spread over the states of Punjab, Haryana, Delhi (Union Territory), Uttar Pradesh, Bihar, and West Bengal, and small parts of Jammu and Kashmir, Himachal Pradesh, and Rajasthan (Fig. 3.1)

There is a large spatial variation in physiographic, climatic, edaphic, and socioeconomic production features of IGP. The western part of IGP (Punjab, Haryana, Delhi, and western Uttar Pradesh) has a semi-arid climate with annual rainfall of 500-800 mm, whereas the eastern part (eastern Uttar Pradesh, Bihar, and West Bengal) experiences a humid climate with annual rainfall of 1000-2000 mm (Fig. 3.2). The summer and winter temperatures are extreme in the western IGP whereas in the eastern part they are moderate. In moving from west to east, the soil texture becomes heavier and drainage is impeded (Fig. 3.2). Agricultural productivity and farm returns also show a declining trend from the western to eastern IGP

The Indian IGP is dominated by cereals, contributing to half of the country's cereals production. The IGP includes about 40% of the cereals area in the country. Although area has almost stabilized around 40 million ha, the production has marginally increased from 97.7 million t in 1988/89 to 113.3 million t in 1994/95 (Table 3.1). Legumes in the IGP share 13.6% of the total area in the country, and account for 15.8% of the total production. The issue for concern is that both area and production of legumes are declining.

The important crops grown in the Indian IGP are rice [*Oryza sativa* L.), maize [*Zea mays* L.), pearl millet [*Pennisetum glaucum* (L.) R. Br.), wheat (*Triticum aestivum* L.), barley [*Hordeum vulgare* L.), and sorghum [*Sorghum bicolor* (L.) Moench) among cereals; chickpea

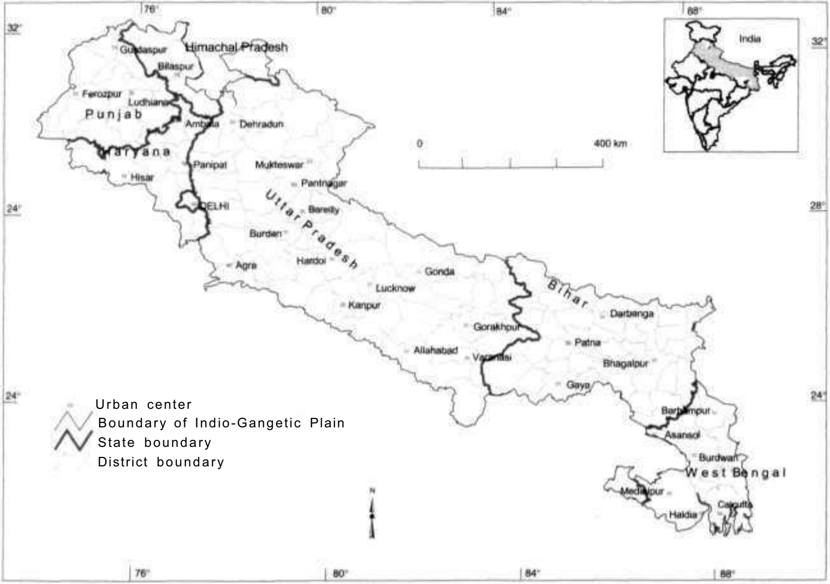

Figure 3.1. Administrative divisions and major urban centers in the Indo-Gangetic Plain of India (includes all districts, irrespective of state, considered to be located in the Indo-Gangetic Plain).

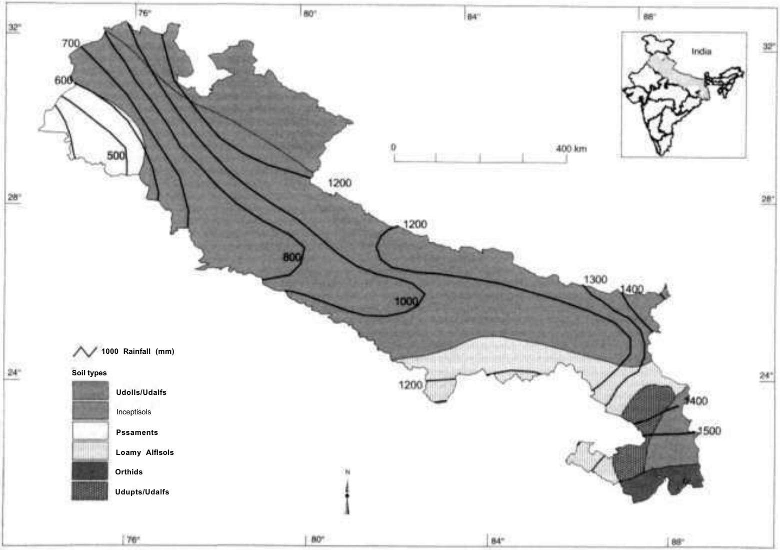

Figure 3.2. Annual rainfall distribution and major soil types in the Indian Indo-Gangetic Plain of India (Source: India Meteorological Bureau and National Bureau of Soil Survey and Land Use Planning).

Table 3.1. Area and production of cereals and legumes in the Indo-Gangetic Plain of India. 1988/89 to 1994/95.

	Cereals		Legumes[1]		Cereals		Legumes[1]	
Year	Area (million ha)	Production (million t)	Area (million ha)	Production (million t)	Area contribution[2] (%)	Production contribution (%)	Area contribution[2] (%)	Production contribution[2] (%)
1988/89	40.6	97.7	5.4	4.6	38.8	51.0	16.3	18.5
1989/90	40.6	98.8	5.5	4.2	39.3	50.7	16.0	18.4
1990/91	40.8	101.3	5.6	4.7	39.5	50.8	15.8	19.2
1991/92	39.8	101.2	4.9	4.0	40.1	52.2	14.2	18.7
1992/93	40.0	101.0	4.9	4.0	39.7	49.7	14.3	16.2
1993/94	40.6	110.0	4.9	4.1	40.4	52.1	14.1	16.0
1994/95	40.6	113.3	4.8	4.1	40.4	52.0	13.6	15.8

1. Includes pulses, groundnut, and soybean.
2 Contribution to area and production in India.
Source: Directorate of Economics and Statistics, Government of India, compiled from various issues (1989 to 1995) of Agricultural Situation in India.

(*Cicer arietinum* L.), lentil (*Lens culinaris* Medic), pigeonpea (*Cajanus cajan* (L.) Millsp.), black gram *(Vigna mungo* (L.) Hepper), mung bean *(Vigna radiata* (L.) Wilczek), and pea *(Pisum sativum* L.) among pulses; rape (*Brassica napus* L.), mustard (*Brassica* sp), sunflower (*Helianthus annuus* L.), groundnut (*Arachis hypogaea* L.), soybean (*Glycine max* (L.) Merr.), and linseed (*Linum usitatissimum* L.) among oilseeds; and cotton (*Gossypium* sp), sugarcane (*Saccharum officinarum* L.), and potato (*Solarium tuberosum* L.) among cash crops. The major cropping systems in western 1GP are rice-wheat, sorghum-wheat, cotton-wheat, pearl millet-rape and mustard, maize-wheat, sugarcane-wheat, pigeonpea-wheat, groundnut-wheat, rice-chickpea, rice-mustard/potato-black gram/mung bean. In the eastern IGP, rice-wheat, rice-lentil/chickpea, rice-rice, maize-wheat, sugarcane-wheat, rice-mustard, rice-groundnut, rice-mustard-black gram/mung bean, and groundnut-wheat are the important cropping systems. However, rice-wheat is the predominant cropping system, occupying about 10 million ha.

Agroecological Features

According to the national classification (Ghosh 1991), the agroecological subregions (AESRs) of the Indian IGP are depicted in Figure 3.3. A brief description of the major ones, in terms of area, location, rainfall, length of growing period, and soil characteristics is given.

AESR 2.3 (Hot, Typic Arid)

The subregion covers the central Ferozpur, Mukhtesar, Bhatinda, and south Faridkot in Punjab, and Bhiwani, Hisar, and west Mahendragarh in Haryana, with a total area of 0.28 million ha. The mean annual rainfall is 400 mm and the length of growing period is 60-90 days. Soils are deep, well drained, calcareous, and moderately alkaline (pH 8.2), with sandy to loamy sand surface. The soils of this region belong to Ustic Torripsamment and Ustochreptic Camborthids.

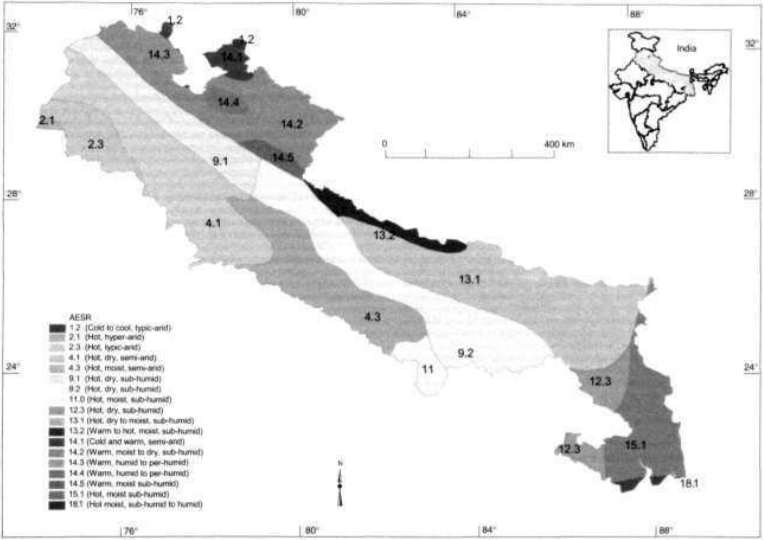

Figure 3.3. Agroecological subregions (AESR) of the Indo-Gangetic Plain of India (Source: 1998 map produced by National Bureau of Soil Survey and Land Use Planning).

AESR 4.1 (Hot, Dry, Semi-arid)

The subregion is spread in northern Punjab, and Ganga-Yamuna Doab in Haryana, excepting western districts, with a total area of 7.6 million ha. The mean annual rainfall is 714 mm and length of growing period is 90-120 days. Soils are deep, loamy, moderately to strongly alkaline [electrical conductivity (EC) up to 6 dS m^{-1}; pH 8.0 to 10.3, exchangeable sodium percentage (ESP) 83-96%], surface sandy loam to clay loam. They comprise Ustochrepts, Typic Atrustalf, and Aquic Natrustalf.

AESR 4.3 (Hot, Moist, Semi-arid)

The subregion occupies 5.7 million ha area spreading in Ganga-Yamuna Doab, Rohilkhand, and Avadh Plains in the state of Uttar Pradesh. The mean annual rainfall is 879 mm and length of growing period is 120-150 days. Soils are fine silty to fine loamy, deep, well to imperfectly drained, neutral to very strongly alkaline (pH 6.7 to 10.4, ESP up to 96%) with sandy loam to silty loam surface. They are Udic Ustochrepts, Aerie Haplaquepts, and Typic Naturstalfs.

AESR 9.1 (Hot, Dry, Sub-humid)

The subregion covers northeastern Punjab and Rohilkhand Plains and Ambala and Yamunanagar in Haryana, with a total area of 3.6 million ha. The mean annual rainfall is 704 mm and length of growing period is 120-150 days. Soils are sandy to loamy, deep, excessively to imperfectly drained, moderate to strongly alkaline with sandy to loamy surface. They comprise Aquic Ustochrepts, Typic Ustochrepts, Typic Ustipsamments, and Udic Ustochrepts.

AESR 9.2 (Hot, Dry, Sub-humid)

The subregion is spread in Rohilkhand and Avadh in Uttar Pradesh, and south Bihar Plains, with a total area of 6.1 million ha. The mean annual rainfall is 1200 mm and length of growing period is 150-180 days. The soils are fine loamy to clay, deep, moderately well drained to poorly drained, neutral to very strongly alkaline (pH 6.6 to 9.3), with sandy loam to silty clay loam surface. The soils are Typic Ustochrepts, Aerie Ochraqualfs, Fluventic Ustochrepts, and Natric Ustochrepts.

AESR 13.1 (Hot, Dry to Moist, Sub-humid)

The subregion occupies 8.8 million ha area spreading in north Bihar and Avadh Plains of Uttar Pradesh. The mean annual rainfall is 1115 mm and length of growing period is 180-210 days. The soils are fine loamy to sandy, deep, imperfectly drained to well drained, strongly alkaline (pH 9.1 to 9.3) with silty loam to loam surface. They comprise Typic Ustifluvents and Fluventic Ustochrepts.

AESR 13.2 (Warm to Hot, Moist, Sub-humid)

The subregion is spread in the foothills of the central Himalayas, with a total area of 1.4 million ha. The mean annual rainfall is 1355 mm and length of growing period is 180-210 days. The soils are loamy, deep, moderately well drained slightly acidic to neutral (pH 6.5 to 7.3) with sandy loam to silty clay loam surface. The soils are Typic Hapludolls, Typic Haplaquallos, Typic Udifluvents, and Typic Fluvaquents.

AESR 15.1 (Hot, Moist, Sub-humid)

The subregion occupies 5.9 million ha area spreading in the Bengal basin of West Bengal. The mean annual rainfall is 1586 mm and length of growing period is 210-240 days. The soils are fine loamy to clay, deep, poorly to moderately drained, slightly acidic to neutral (pH 4.7 to 7.0), with loamy to clay surface. They are Typic Ustifluvents, Typic Fluvaquents, Vertic Endoaquepts, Typic Ustochrepts, and Typic Endoaqualfs.

In view of the crop production pattern, the Indian IGP can also be divided into two major zones: (1) the western part, comprising Haryana, Punjab, and parts of Uttar Pradesh (northern, central, and western), which is largely dominated by rice-wheat cropping systems (RWCS); and (2) the eastern part, comprising eastern Uttar Pradesh, Bihar, and West Bengal, which is largely dominated by rice-based cropping systems. Mean monthly values for rainfall, evaporation, and maximum and minimum temperature for representative locations across the Indian IGP are given in Figure 3.4.

Spatial Distribution and Temporal Changes in Legumes

Grain legumes were grown on <5 million ha in 1994/95 in the IGP of India. This is nearly 65% of the total grain legumes area in all four countries (Bangladesh, India, Nepal, and Pakistan) covered under the IGP About 1 million ha grain legumes has been substituted by other crops (largely rice and wheat) during the past 15 years in the Indian IGP. The decline in area has been largely attributed to relatively higher profitability of rice and wheat in comparison to legumes (Malik 1994). The spatial distribution and temporal changes of important legumes in the Indian IGP are discussed.

Chickpea

Chickpea is the most important legume in the Indian IGP. It covered about 1.6 million ha in 1992/93 (latest period for which data are available in all IGP districts). Its share in total grain legumes is largest (about 30%). Chickpea area has declined by more than 1 million ha during the past 15 years (Table 3.2). In 1994/95, it occupied 24% of total chickpea area in India, and shared about 28% of production. About 60% of the chickpea area in IGP is spread in Uttar Pradesh followed by Haryana (25%) (Fig. 3.5). In general chickpea production has fallen in all the states of the Indian IGP due to a rapid decline in its area (particularly noticeable in Haryana and Punjab), although yields have substantially risen (Table 3.3). Average chickpea yields in IGP have increased from 700 kg ha^{-1} in 1980/81 to 970 kg ha^{-1} in 1994/95 with maximum of 1100 kg ha^{-1} in Haryana and minimum of 890 kg ha^{-1} in West Bengal.

Lentil

Lentil is the second most important grain legume in the Indian IGP which covered about 0.7 million ha in 1992/93. The area under lentil has increased from about 0.6 million ha in the triennial average for 1981-83 (Table 3.2). The Indian IGP alone contributes more than 70% of total lentil production in the IGP countries. A close perusal of Figure 3.6 indicates that about 90% of lentil area is distributed in Uttar Pradesh and Bihar. In both the states, lentil area has increased during the past 15 years, while in other states its area has declined (Table 3.2). Lentil yields show markedly increasing trends (Table 3.3).

Pigeonpea

Pigeonpea is the third most important legume in the Indian IGP, and covered about 0.66 million ha in 1992/93 (Table 3.2). More than 95% of pigeonpea area in the total IGP is grown in the Indian IGP. The IGP contributes about 28% of the pigeonpea production of India. Among

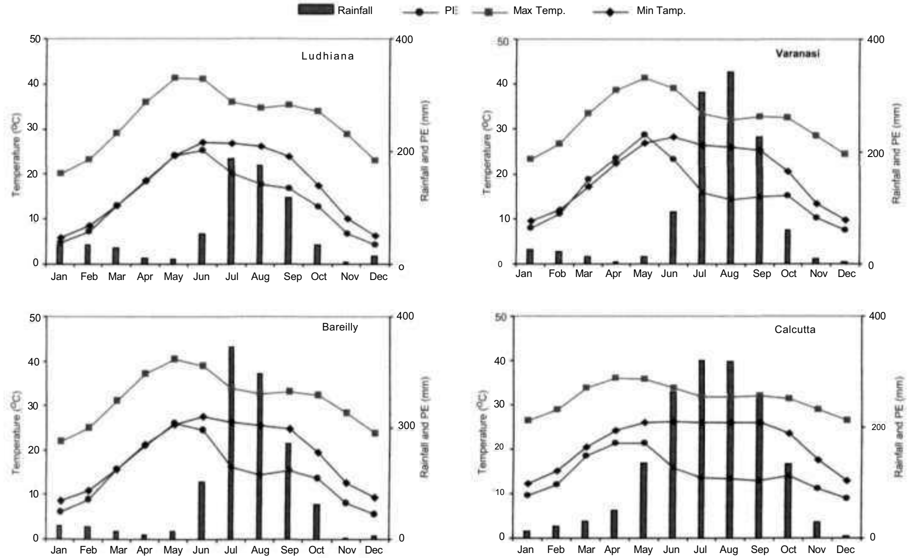

Figure 3.4. Mean monthly rainfall, potential evaporation (PE), and maximum and minimum temperature for representative locations in the Indo-Gangetic Plain of India (Source: India Meteorological Bureau).

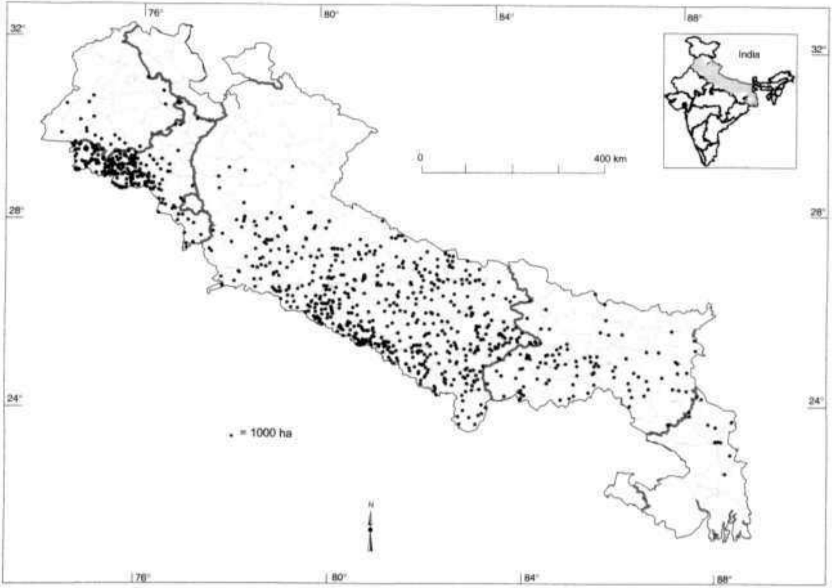

Figure 3.5. Area under chickpea in the indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

Table 3.2. Triennial average area ('000 ha) of principal grain legumes in the states of the Indo-Gangetic plain of India.

Crop	Year	Punjab	Haryana	Uttar Pradesh	Bihar	West Bengal
Chickpea	1981-83	208	764	1524	187	78
	1985-87	96	523	1482	187	68
	1993-95	22	398	1022	130	61
Pigeonpea	1981-83	16	8	506	88	25
	1985-87	33	32	515	78	10
	1993-95	11	47	523	71	5
Black gram	1981-83	18	10	205	119	129
	1985-87	11	3	222	101	93
	1993-95	6	2	318	85	121
Mung bean	1981-83	20	5	148	161	22
	1985-87	45	7	139	191	31
	1993-95	52	9	102	198	13
Lentil	1981-83	18	24	331	173	81
	1985-87	12	22	449	168	86
	1993-95	6	11	501	175	50
Peas and beans[1]	1981-83	4	8	243	32	4
	1985-87	4	7	269	35	6
	1993-95	4	2	411	31	8
Horse gram	1981-83	0	0	0	87	4
	1985-87	0	0	0	80	8
	1993-95	0	0	0	28	8
Khesari (lathyrus)	1981-83	0	0	0	398	91
	1985-87	0	0	0	361	75
	1993-95	0	0	0	206	34
Groundnut	1981-83	84	7	250	6	2
	1985-87	40	6	121	5	13
	1993-95	10	2	131	5	19
Soybean	1981-83	Neg.[2]	Neg.	145	Neg.	Neg.
	1985-87	Neg.	Neg.	127	Neg.	Neg.
	1993-95	Neg.	Neg.	33	Neg.	1
All pulses	1981-83	373	830	3355	1279	442
	1985-87	242	601	3331	1210	392
	1993-95	112	472	3036	987	282

1. Separate dats for pea and common bean are not available.
2. Negligible
Source; Directorate of Economics and Statistics. Government of India; compiled from various issues (1981to 19%) of Agricultural Situation in India

IGP states, about 78% of the total pigeonpea area is in Uttar Pradesh (mostly central and eastern part), followed by 10% in Bihar and 8% in Haryana (Fig. 3.7). Although pigeonpea area in the Indian IGP has stagnated during the past 15 years, there has been a differential pattern in changes in its area in different states. Pigeonpea area has substantially increased in Haryana (from 8,000 ha in the triennial average for 1981-83 to 47,000 ha in the triennial average for 1993-95), and stagnated in Uttar Pradesh (around 0.5 million ha). Its area has declined in Bihar, Punjab, and West Bengal (Table 3.2). Yields of pigeonpea are generally high in the IGP, compared to other pulses or pigeonpea elsewhere in India, at around 1 t ha^{-1} (Table 3.3). There has been no noticeable change in yields over time.

Black Gram

The crop covers about 0.5 million ha in the Indian IGP; about 75% is sown in the rainy season. More than 75% of the total black gram in the entire IGP is grown in the Indian IGP. The crop is mainly confined to Uttar Pradesh (0.3 million ha) followed by West Bengal (0.12 million ha) and Bihar (85 thousand ha) in 1992/93 (Table 3.2). A close examination of Figure 3.8 shows that black gram is more prevalent in the eastern part of the Indian IGP. Its area has increased in Uttar Pradesh and West Bengal from 1985 onwards, while in other states it has declined (Table 3.2). This part of the country contributes about 17% of the total black gram production in India. Yields of black gram are low, at around 0.5 t ha ', but with gradually increasing trends over time (Table 3.3).

Peas and Beans

Separate statewise data for the postrainy season legumes pea and common bean (*Phaseolus vulgaris* L.; French bean) are not available.

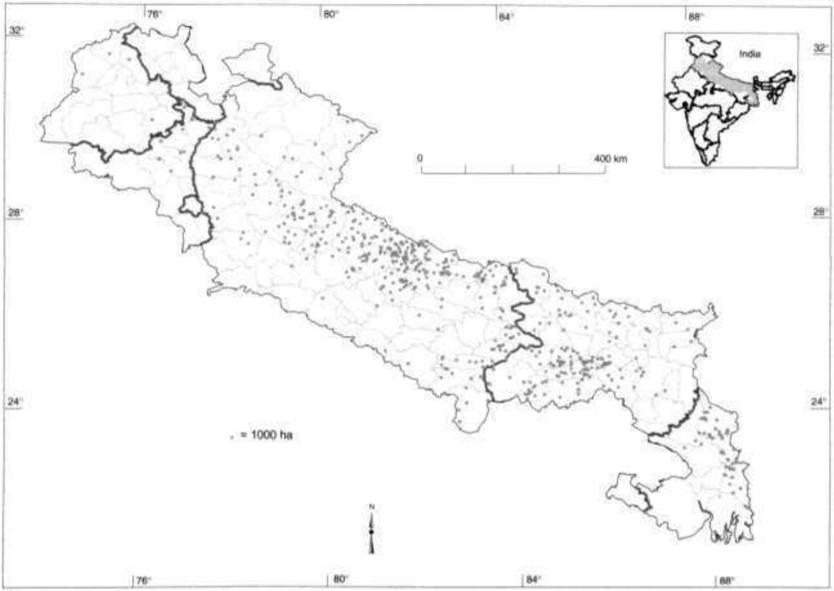

Figure 3.6. Area under lentil in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

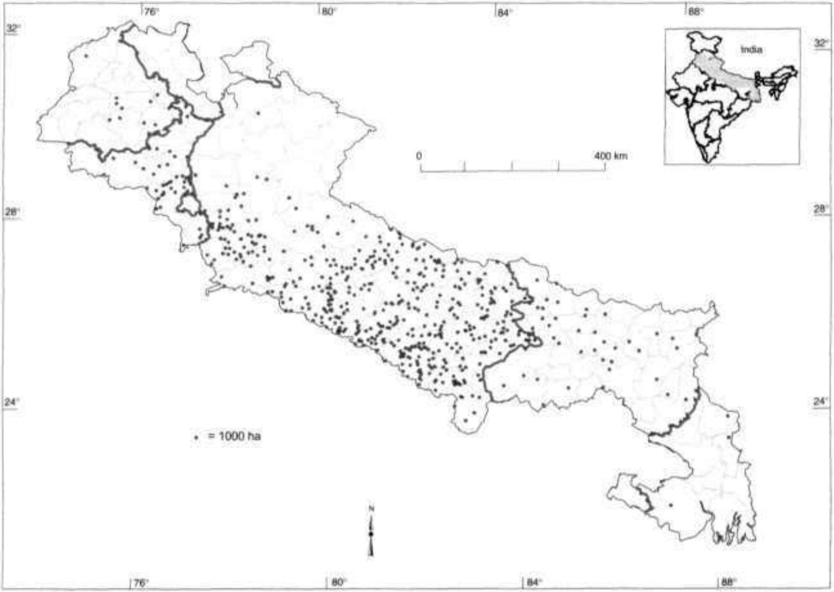

Figure 3.7. Area under pigeonpea in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

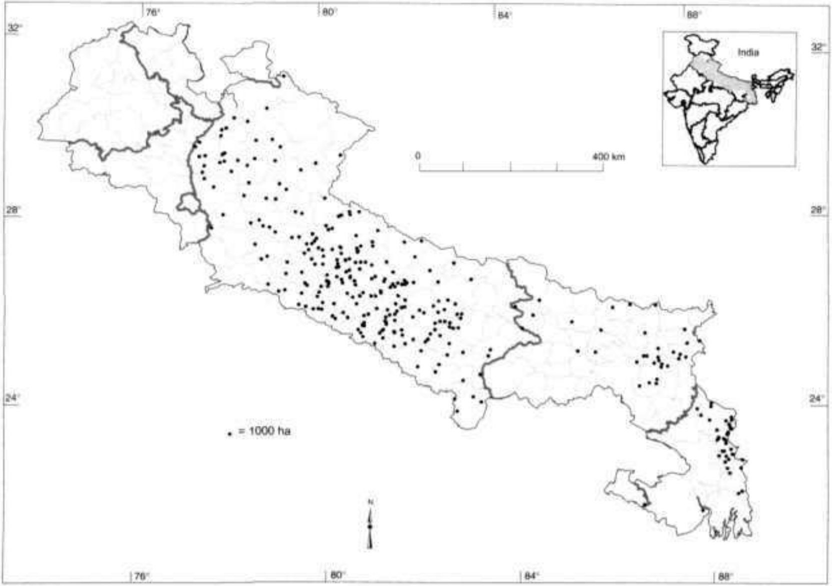

Figure 3.8. Area under black gram in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

Table 3.3. Triennial average yield (kg ha^{-1}) of principal grain legumes in the states of the Indo-Gangetic Plain of India.

Crop	Year	Punjab	1 laryana	Uttar Pradesh	Bihar	West Bengal
Chickpea	1981-83	518	493	821	724	645
	1985-87	690	609	816	801	734
	1993-95	826	921	907	1001	854
Pigeonpea	1981-83	955	-	1280	1038	848
	1985-87	980	1021	1306	1183	1020
	1993-95	-	1014	1032	1007	-
Black gram	1981-83	918	-	282	458	455
	1985-87	591	-	287	476	502
	1993-95	-	-	408	481	597
Mung bean	1981-83	761	-	406	432	567
	1985-87	847	-	336	504	513
	1993-95	825	-	507	549	-
Lentil	1981-83	-	483	584	628	397
	1985-87	-	535	701	747	620
	1993-95	-	-	746	881	607
Peas and beans[2]	1981-83	-	-	958	569	-
	1985-87	-	-	1107	679	-
	1993-95	-		1144	596	-
Horse gram	1981-83	-	-	-	442	-
	1985-87	-	-	-	491	-
	1993-95	-	-	-	436	-
Khesari (lathyrus)	1981-83	-	-	-	604	451
	1985-87	-	-	-	723	603
	1993-95	-	-	-	894	1001
Groundnut	1981-83	1013	973	765	-	-
	1985-87	886	933	799	-	1216
	1993-95	997	-	923	-	1174
Soybean	1981-83	-	-	697	-	-
	1985-87	-	-	881	-	-
	1993-95	-	-	1110		-
All pulses	1981-83	558	501	826	604	505
	1985-87	775	645	906	694	606
	1993-95	801	918	866	777	662

1. Data not available.
2. Separate data for pea and common bean are not available.
Source: Directorate of Economics and Statisties, Government of India, compiled from various issues (1981 to 1996) of Agricultural Situation in India.

These legumes are together cultivated in about 0.45 million ha in the triennial average for 1993-95 in the Indian IGP (Table 3.2). Their area has increased from <0.3 million ha in the triennial average ending 1992/93. More than half of the peas and beans (common bean) in IGP are grown in the Indian IGP. These crops are largely concentrated in Uttar Pradesh, accounting for about 90% of their total area in the Indian IGP (Table 3.2). During 1985-95, area of peas and beans in Uttar Pradesh has increased, while it almost stagnated in Bihar and Punjab, and declined in Haryana and West Bengal. This part of India contributes more than 80% of the production of total peas and beans in the country. Average yields of peas and beans have shown increasing trends in Uttar Pradesh, whereas they have been stagnant or declining in Bihar (Table 3.3).

Mung Bean

Mung bean is a minor legume in the Indian IGP and occupies only about 8% of the total legumes area. Its area has fallen from 0.41 million ha in the triennial average for 1985-87 to 0.37 million ha in the triennial average for 1993-95 (Table 3.2). About 80% of the mung bean is sown in the postrainy season. About 90% of total mung bean area in the whole IGP is confined to the Indian IGP. In the Indian IGP, 60% of mung bean is grown in Bihar (largely the northern part), and more than 25% in Uttar Pradesh (mostly in the western part) (Fig. 3.9). These two states of India contribute about 17% of total mung bean production in India. Mung bean area in Bihar, Haryana, and Punjab has risen during the past 15 years, while it has fallen in Uttar Pradesh and West Bengal (Table 3.2). Yield of mung bean has increased in all states of the Indian IGP, with exception of West Bengal (Table 3.3). Yield levels are much higher in Punjab in the Indian IGP than in other states.

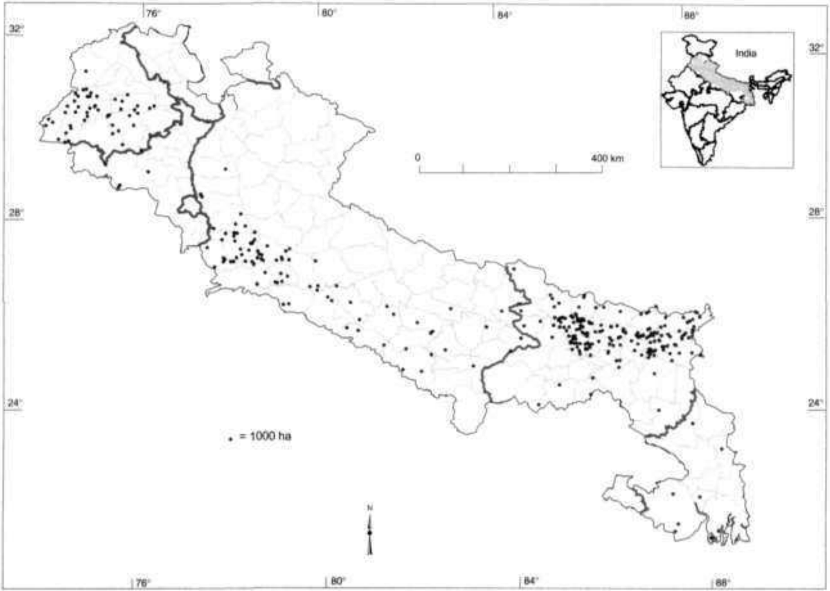

Figure 3.9. Area under mung bean in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

Khesari (Lathyrus)

The crop covered about 0.24 million ha in the Indian IGP in the triennial average for 1993-95. This accounts for 26% of the total khesari (lathyrus) area, and produces 39% of total production in the country. The crop finds its niches only in some parts of Bihar and West Bengal during the postrainy season. The area under this crop has declined rapidly during the past two decades (Table 3.2). Interestingly, yield of khesari (lathyrus) has been increasing over time (Table 3.3).

Horse Gram

Horse gram is a minor legume, which covered 36 thousand ha in the triennial average for 1993-95 (Table 3.2). The crop in the Indian IGP accounts for only 3% of the total horse gram area in India. The crop is largely grown in Bihar (80% area) during the rainy season, and West Bengal (20%) during the postrainy season (Fig. 310). The area under this crop is rapidly declining in Bihar (Table 3.2) and yields are low (<0.5 t ha^{-1}) and static or declining (Table 3.3).

Groundnut

Groundnut is not a major legume in the Indian IGP, and was grown in about 0.17 million ha in the triennial average for 1993-95 (Table 3.2). The crop has been traditionally grown in the rainy season; however, it is gaining importance in the postrainy season in West Bengal. The area under groundnut in the Indian IGP has fallen considerably in traditional areas (Table 3.2). The crop is still largely confined (~70%) in central Uttar Pradesh (Fig. 3.10) but groundnut area is rapidly increasing in West Bengal. Yields are increasing with time only in Uttar Pradesh but they are highest, at around 1.2 t ha^{-1}, in West Bengal (Table 3.3).

Soybean

Although 60% (34 thousand ha) soybean of the total IGP is sown in the Indian IGP alone, it is not an important legume in this part of the country (Table 3.2). Its cultivation in the Indian IGP has been declining over time and now it contributes only < 1 % of total area and production of soybean in the country. The crop is largely confined to district Nainital of Uttar Pradesh (Fig. 3.10). Yields have been rising rapidly here, now reaching well over 1 t ha^{-1} (Table 3.3),

Constraints to Legumes Production

The important biotic, abiotic, and socioeconomic constraints of the major legumes cultivated in the Indian IGP are summarized as follows.

Biotic Constraints

Potential yield of grain legumes usually far exceeds that realized in farmers' fields especially when cultivated in the RWCS (Asthana and Ali 1997). The unpredictable nature of several biotic stresses affecting these legumes discourages their cultivation (Table 3.4). An attempt has been made to summarize the current knowledge on the main biotic constraints facing each of the important legumes in the major producing areas of western and eastern IGP of India. The discussion covers severity and losses caused by each biotic constraint (Table 3.4) and suggests alternative options to alleviate the stress. However, much of the information, especially on the relative importance and yield

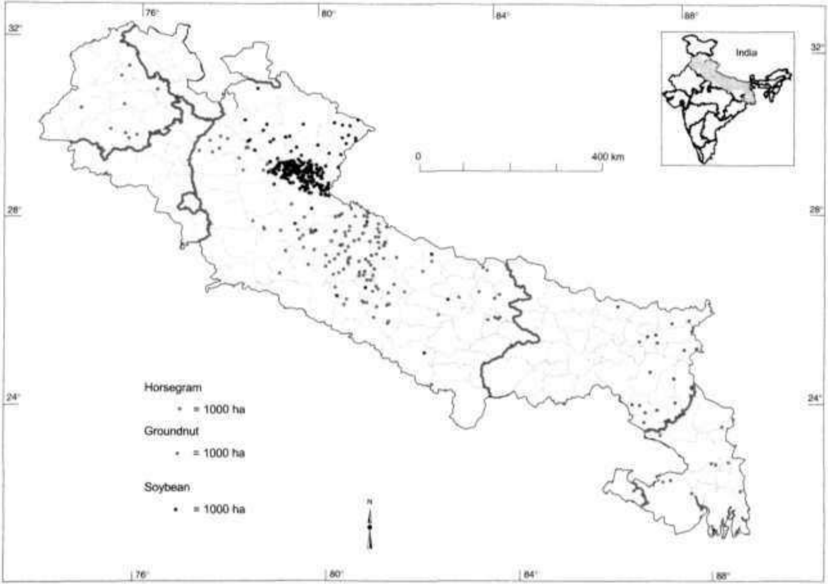

Figure 3.10. Area under groundnut, soybean, and horse gram in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

Table 3.4. Estimated crop losses (%) caused by diseases, nematodes, insect pests, and weeds affecting legumes production in the Indo-Gangetic Plain of India[1].

Crop	Diseases	Nematodes	Insect pests	Weeds
Chickpea	10-70	2 5	5-50	10-35
Lentil	10-35	-[2]	5-20	5-20
Pea	5-15	-	2-5	5-20
Pigeonpea	5-45	3-5	3-44	10-40
Vigna pulses[3]	5-40	5-15	5-25	10-25
Groundnut	5-50	3-5	5-10	10-25
Soybean	10-15	3-5	5-15	10-25
Others[4]	5-10	-	5-10	-

1. Crop loss estimates are based on the athors' observations of experimental plots and results ot pest surveys.
2. Not known or not available.
3. Black (gram, mung bean, and cowpea.
4. Primarily khesari (lathyrus), faba bean, and horse gram.

losses, is incomplete. We have referred to published data where available, but in many instances we have had to rely on unpublished survey information and personal experiences. The important diseases, insect pests, and nematodes affecting production of legumes are listed in Tables 3.5 and 3.6.

Chickpea

A major constraint to chickpea yield in western and eastern IGP is posed by the foliar diseases, Ascochyta blight (*Ascochyta rabiei*), botrytis gray mold (BGM) (*Botrytis cinerea*), stemphylium blight *(Stemphylium* sp), and rust *(Uromyces ciceris-arietini).* These diseases are widespread almost throughout the IGP but ascochyta blight is the main threat in the western IGP and BGM is the main problem in the eastern IGP. Despite intensive screening efforts, it has been difficult to find substantial levels of host plant resistance, especially across biotypes of the pathogens (Nene and Reddy 1987). Some progress in

Table 3.5. Major diseases of grain legumes in the Indo-Gangetic Plain of India.

Crop	Western region	Eastern region
Chickpea	Ascochyta blight Fusarium wilt Wet root rot	Fusarium wilt Botrytis gray mold Wet root rot Stemphylium blight
Groundnut	Early leaf spot Late leaf spot Rust	Early leaf spot Late leaf spot Rust Sclerotium stem, pod, and root rot Aflatoxin contamination
Lentil	Rust Fusarium wilt	Rust Stemphylium blight Fusarium wilt
ft.	Powdery mildew Rhizoctonia seedling rot	Powdery mildew Rhizoctonia seedling rot
Pigeonpea	Fusarium wilt Sterility mosaic	Fusarium wilt Phytophthora blight Sterility mosaic Alternaria blight
Soybean	Fusarium root rot Rhizoctonia root rot Anthracnose Rust	Fusarium root rot Rhizoctonia root rot Anthracnose Rust
Vigna pulses[1]	Yellow mosaic Cercospora leaf spots	Yellow mosaic Cercospora leaf spots Powdery mildew

1. Includes black gram, mung bean, and cowpea.

Table 3.6. Key insect pests and nematode constraints of grain legumes in the Indo-Gangetic Plain of India.

Crop	Insect pest	Nematode
Chickpea	Pod borer (*Helicoverpa armigera*) Semilooper (*Autographa nigrisignn*) Bruchids (*Callsobruchus* spp)	Root-knot (*Meloidogyne* spp)
Groundnut	White grubs (*Lachtosterna* sp) Termites *(Microtermes* spp, *Odontotermes* spp*)* Tobacco caterpillar *(Spodoptera litura)*	Root-knot *(Meloidogyne* spp)
Lentil	Aphid *(Aphis craccivora)* Pod borer (*Etiella zinckenella*) Bruchids (*Callosobruchus chinensis, C. maculatus*)	Root-knot *(Meloidogyne* spp)
Pea	Leaf miner (*Phytomyza atricornis)* Stem fly (*Ophiomyia phaseoli*)	Root-knot *(Meloidogyne* spp) Cyst (*Heterodera goettingiana)*
Pigeonpea	Pod borer (*Hclicoverpa armigera)* Podfly (*Melanagromyza obtusa)* Legume pod borer (*Maruca testulalis*) Blister beetle *(Mylabris pustulata*)	Cyst *(Heterodera cajani*) Lesion *(Pratylenchus* spp) Root-knot *(Meloidogyne* spp)
Soybean	Leaf folder *(Lamprosema (Omiodes*) *indicata*) Girdle beetle (*Oberopsis brevis*) Blister beetle (*Mylabris* sp)	Cyst *(Heterodera glycines)* Root-knot *(Meloidogyne* spp) Reniform (*Rotylenchulus reniformis)*
Vigna pulses'	Ilairy caterpillar (*Spilosoma* (*Diacrisia*) *obliqua)* Thrips (*Megalurothrips distalis*) Whitefly (*Bemisia tabaci)* Aphid (*Aphis craccivora*)	Root-knot *(Meloidogyne* spp) Cyst *(Heterodera* spp)

1. Includes black gram, mung dean, and cowpca.

genetic enhancement of host plant resistance to ascochyta blight and BGM has been made using wild species of *Cicer* (Singh et al. 1991, 1998). Lines derived from these crosses need more refinement before they can be used agronomically. However, the severity of these foliar diseases can be minimized by using agronomic and cultural practices (Ali et al. 1998). Additionally, these foliar diseases can be controlled by fungicide application, but its widespread use is not a viable option.

Among the soilborne diseases that infect the chickpea root system and stem base, fusarium wilt (*Fusarium oxysporum* f. sp *ciceris)* and collar rot (*Sclerotium rolfsii*) are endemic diseases in the Indian IGP (Pande and Joshi 1995). In general, fusarium wilt assumes greater importance at locations in the IGP where sufficient soil moisture is not available during crop establishment. Good sources of resistance to fusarium wilt have been identified and bred (Ali 1998). Collar rot is a disease of potential importance and it causes substantial losses even in well managed chickpea crops. The pathogen S. *rolfsii* grows on crop residues in humid environments provided by a dense crop stand. However, these soilborne diseases to some extent can be minimized by management options, such as appropriate crop rotation to reduce soilborne inoculum level and seed dressing with fungicides. Wet root rot caused by *Rhizoctonia solani* is also an important disease in the region.

A large number of nematode species are associated with chickpea (Ali 1994b). The most important species are *Meloidogyne incognita,* M. *javanica, Pratylenchus* spp, *Tylenchorynchus* spp, and *Rotylenchulus reniformis,* which cause 12-15% yield losses in chickpea in the IGP Information on host plant resistance and other effective options to manage nematode diseases, such as application of nematicides, is available. However, the prohibitive cost of nematicides as well as the cumbersome method of their application results in their negligible use in practice in the management of nematodes (Ali 1.994b).

A wide variety of insect pests infest the chickpea crop (Ali 1998). The insect pests that cause economic losses to chickpea are pod borer *(Helicoverpa armigera* Hubner), semilooper (*Autographa nigrisigna* Walker) and cut worms (*Agrotis ipsilon* Hufnagel) (Table 3.6). Although these insect pests cause damage to chickpea throughout the IGP, their intensity varies from location to location and annual losses caused by them ranges from 15% to 40% (Ali 1998). Intensive screening and field evaluation studies against *H. armigera* has resulted in identification of some promising lines with moderate levels of host plant resistance (Ali 1998). It is expected that these lines will be used as an important component of integrated pest management strategies to minimize the losses caused by pod borers in chickpea. In addition, pod borer can be controlled by need-based spraying of insecticides but in subsistence farming their use may not be practical or economical.

Weeds such as *Chenopodium album* L. (lamb's quarters), *Cyperus rotundus* L. (nut grass), and *Cynadon daclylon* (L.) Pers. (Bermuda grass) pose serious threats to the chickpea crop especially where soil conditions remain moist during early growth stages. Thus, in the IGP, weeds compete with chickpea for nutrients and moisture and can cause up to 42% yield loss (Ali et al. 1998). Among various control measures, pre-emergence application of pendimethalin at 1.0 to 1.5 kg ha^{-1} was found to be effective in controlling weeds of chickpea (Ali et al. 1998). However, one hand weeding after 20-25 days of sowing was found equally effective as the herbicide application. However, the use of herbicides in the management of weeds in chickpea is neither economical nor popular.

Lentil

The most important biotic constraints facing lentil appear to be foliar diseases such as ascochyta blight (*Ascochyta fabae* f. sp *lentis*), BGM (*Botrytis cinerea*), rust (*Uromyces viciae-fabae*), powdery mildew (*Erysiphc poiygoni*), and stemphylium blight (*Stemphylium* spp). These diseases either together or alone can cause considerable damage to the lentil crop depending upon the prevailing environmental conditions (Table 3.4). In addition to foliar diseases, vascular wilt (*Fusarium oxysporum f.* sp *lentis*) is the most important root disease of lentil in both the western and eastern IGP of India. Moderate levels of host plant resistance to rust and wilt diseases of lentil are available (Ali 1998), but are rarely used in breeding programs. A combination of host plant resistance and fungicides has been only either suggested or experimentally employed. There appears to be greater opportunities for using host plant resistance to control foliar and root diseases of lentil (Khare et al. 1993).

Species of root-knot nematodes (*Meloidogyne incognita* and *M. javanica)* were found associated with lentil crops and can cause 12-15% yield losses (Ali 1998). Host plant resistance to these nematodes is available but is not used in breeding programs. In general, there is no information on the distribution and importance of nematodes in the lentil crop grown in rice-based cropping systems of the IGP

Among insect pests, aphids (*Aphis craccivora* Koch.) and lima bean pod borer (*Etiella zinckenella* Treitschke) are the major field pests of lentil. Together they can cause an estimated crop loss of about 15% (Ali 1998). A perusal of literature reveals that systematic studies have never been conducted on the pest biology and ecology, forecasting and monitoring, host plant resistance, and control measures of insect pests of lentil. Normally, aphid and pod borer can be controlled by commonly used insecticides such as endosulfan. Lentil seeds are also attractive to seed storage pests such as bruchids *(Callosobruchus chinenis* L *and* C. *maculatus Fab.);* thus precautions in storage are necessary.

Lentil is a poor competitor with weed flora due to its slow growth and development in the cold winters of the IGP. Like chickpea, one hand weeding (mainly to remove weeds like *Chenopodium album* and *Cyperus rotundus)* after 20-25 days of sowing was found effective to control weeds.

Pigeonpea

Of the 60 pathogens reported to attack pigeonpea (Nene et al. 1984), fusarium wilt (*Fusarium udum*), sterility mosaic (a virus (?) transmitted by the eriophyid mite *Aceria cajani* Channabasavanna), phytophthora blight (*Phytophthora drechsleri* f. sp *cajani),* and alternaria blight (*Alternaria alternata*) are widely distributed in the Indian IGP (Pande and Joshi 1995). Wilt and sterility mosaic can cause yield losses of 30% (Ali 1998). Resistance to wilt and sterility mosaic is available both in germplasm and pigeonpea cultivars bred for the IGP. Some of these cultivars have been extensively deployed in the farmers' fields to effectively combat these diseases.

Cyst (*Heterodera cajani*), reniform *(Rotylenchus reniformis),* and root-knot *[Meloidogyne incognita)* nematodes are frequently observed on pigeonpea in the 1GP (Ali 1994b). However, the cyst nematode is the most important causing substantial yield loss (18-19%). Management options to control these nematode species are few and generally impractical (e.g., soil solarization) (Ali 1994b).

Among insect pests that attack pigeonpea, pod borer (*Helicoverpa arrnigera*)*,* legume pod borer (*Maruca testulalis* Geyer), blue butterfly *[Lampides boeticus* L.), podfly (*Melanagrotnyza obtusa* Malloch), and blister beetle (*Mylabris pustulala* Thunberg) are the most important insect pests in the Indian IGP. The annual losses in pigeonpea yield due to these pests are of the order of 20% (Ali 1998). Systematic studies on identification of host plant resistance indicated that moderate levels of resistance are only available against podfly (Sachan and Lal 1997). However, the damage caused by these pests can be minimized by other control measures such as combining available levels of host plant resistance with application of insecticide.

Pigeonpea is susceptible to weed competition only in the early growth stages, but it effectively suppresses the weeds when the crop reaches about 50 cm in height (Ali 1991).

Black gram, mung bean, and cowpea

Yellow mosaic (mung bean yellow mosaic virus), cercospora leaf spot (*Pseudocercospora cruenta),* and powdery mildew (*Erysiphe polygoni)* are considered as the most important diseases attacking both black gram and mung bean in the IGP, while cercospora leaf spot (*Cercospora canescens* and *P. cruenta),* and fusarium wilt caused by *Fusarium oxysporum* f. sp *tracheiphilim* are the most important seed- and soilborne diseases of cowpea (*Vigna unguiculata* (L.) Walp.). The distribution, importance, and control measures of these diseases are not well documented for the IGP. However, host plant resistance to yellow mosaic (mung bean yellow mosaic virus) in mung bean and black gram, and powdery mildew in black gram is available in agronomically elite lines of these legumes, but it needs thorough testing across environments (Ali 1998).

Meloidogyne incognita and *M. javanica* are the two important species of root-knot nematodes associated with black gram, mung bean, and cowpea (Ali 1994b). In addition, *Heterodera cajani* has been found infecting mung bean and cowpea crops in the IGP. Host plant resistance in a few lines of mung bean and black gram is available but is not being used to breed nematode resistant cultivars (Ali 1994b).

Among the insect pests whitefly (*Bemesia tabaci* Genn.), jassids (*Empaasca kerri* Pruthi; leafhopper), and thrips (*Megalurothrips distalis* Karny) are commonly found causing damage to black gram and mung bean crops in the IGP. Host plant resistance in good agronomic backgrounds is not available for the IGP. However, soil application of granular insecticides such as aldicarb, phorate, and carbofuran @ 1.0 kg ha^{-1} have proved to be highly effective against whitefly and other sucking pests.

Very little is known about weeds causing yield losses in mung bean, black gram, and cowpea grown in the IGP. However, as a general principle, two hand weedings during the first 35 days of sowing provides effective control of weeds.

Pea

Powdery mildew *(Erysiphe pisi)* and rust (*Uromyces viciae-fabae*) are the two most important and widely spread foliar diseases of pea throughout the Indian IGP. Field resistance to powdery mildew is available in a range of pea cultivars. Powdery mildew control is further enhanced by combining resistance with reduced and modified foliage characteristics (S. Pande, ICRISAT, India, personal observation, 1996). Such progress is not apparent in rust of pea. Among the root diseases, rhizoctonia seedling rot (*Rhizoctonia solani)* and fusarium wilt *(Fusarium* spp) are of minor importance in the IGP.

The two species of root-knot nematodes, M. *incognita* and M. *javanica,* and the reniform nematode *R. reniformis* have been observed to cause sporadic infections and reduce yields of pea (Ali 1994b). However, not much is known and documented about nematode diseases of pea.

Insect pests are rated as relatively minor yield reducers in pea. Bean fly or stem fly (*Ophiomyia phaseoli* Tryo.) and leaf miner (*Phytomyza atricornis* Meig) have been frequently observed causing some damage to pea crops.

As pea is normally grown in moist environments, weed problems can be severe at early growth stages. Commonly occurring weeds such as *Chenopodium* sp and *Cyperus* sp infest pea cultivation in the IGP These weeds can be managed by adopting the weed management practices followed for chickpea and lentil crops.

Soybean

Little appears to be recorded about the biotic constraints of soybean when grown in rice lands or in RWCS of the IGP in India, as it is a relatively minor crop in this environment. The important diseases of soybean in the region are fusarium root rot *(Fusarium* spp), rhizoctonia root rot *(Rhizoctonia solani),* anthracnose (*Colletotrichum truncatum*)*,* and rust (*Phakopxora pachyrhizi).*

Groundnut

Important biotic stresses of groundnut in the IGP region include early leaf spot *(Cercospora arachidicola*) and late leaf spot *(Phaeoisariopsis personata*)*,* bud necrosis (bud necrosis virus), rust (*Puccinia arachidis),* sclerotium stem, pod, and root rot *(Sclerotium rolfsii),* aflatoxin contamination *(Aspergillus* spp), white grubs *(Lachnosterma* sp), thrips, jassids, and aphids *(Aphis craccivora* Koch.) (Reddy 1988; Reddy et al. 1992; Middleton et al. 1994).

Khesari (lathyrus)

Khesari (lathyrus) is one of the more robust legumes normally grown in marginal lands which are considered unsuitable for cultivation of other legumes. The crop seems to be able to withstand several biotic stresses much better than the other legumes discussed here, even under late or early sown conditions. In the Indian IGP, precise studies on diseases, insect pests, and other biotic stresses of khesari (lathyrus) are not available. However, diseases such as downy mildew *(Peronospora viciae*) and powdery mildew *(Erysiphe* spp) have been observed on khesari (lathyrus). Similarly, aphids (*Aphis craccivora*) are the major pests of khesari (lathyrus). Two species of nematodes (*M. incognita* and R. *reniformis*) are associated with the khesari (lathyrus) crop. Khesari (lathyrus) can effectively smother weeds and even use more erect species to support its vining habit.

Horse gram

Horse gram is essentially the "poorest of the poor" farmers' crop in the Indian IGP, and is often broadcast into the rice fallows in Bihar and West Bengal. It is grown on those lands that are not suitable for any other legume, except perhaps khesari (lathyrus). Although two improved cultivars have been released, negligible information is available on the biotic constraints of this legume. However, yellow mosaic, caused by a gemini virus, has been observed in a few farmers' fields in the IGP (Pande and Joshi 1995).

Abiotic Constraints

Drought, waterlogging, temperature extremes, wind or hail (causing lodging), alkaline and saline soils, acid soils, and deficiencies or toxicities of various mineral nutrients are the common abiotic stresses that limit legume production in the Indian IGP.

Drought

Among abiotic stresses, drought is the major yield reducer of several legumes (especially chickpea, lentil, mung bean, black gram, and pigeonpea) because these crops are either grown in a receding soil moisture environment or need to complete their reproductive phase under soil moisture deficit conditions. Thus the crops are exposed to terminal drought stress. To overcome such a situation in chickpea, some genetic options for making substantial improvements through use of short-duration cultivars to escape the end of season soil moisture deficit, and exploiting drought resistance traits such as prolific rooting ability are available (Saxena et al. 1993). Recently, chickpea cultivars such as K 850, Avrodhi, and Pusa 256 were reported to be relatively less prone to drought stress due to their earliness (Yadav et al. 1998). Also, management techniques to better conserve soil moisture and maximize crop transpiration over soil evaporation, provide scope to reduce drought effects in legumes. On the other hand, in the IGP, good soil conditions near soil field capacity can induce excessive vegetative growth with consequent lodging and attack of foliar diseases (e.g., BGM in chickpea and lentil).

As in chickpea, lentil production is also predominantly rainfed. Therefore, drought stress is the most important abiotic stress of lentil in all parts of the IGP. Appropriate matching of crop duration to probable soil moisture availability pattern offers the best scope for yield improvement in this context. This also requires matching of photoperiod response to target environments (Webb and Hawtin 1981). Khesari (lathyrus) has good drought resistance and produces a more reliable crop than other legumes when sown on drought-prone upland soils.

Temperature

'lerminal drought stress in chickpea and lentil is normally accompanied by high temperatures (>30"C) towards maturity, which may cause poor pod filling. Low temperatures cause either frost injury or mortality or delayed podding (especially in chickpea and lentil) in some parts of IGP Genetic options are available to better adapt chickpea to unfavorable temperature regions. This is yet to be exploited in the case of high temperature stress but tolerance to low temperatures has been found (Singh 1987; Saxena et al. 1988). Pea is particularly sensitive to drought and high temperature. In some years, cold stress (frost damage) can be a problem in pea at certain locations in the IGP.

Waterlogging

Khesari (lathyrus) and horse gram can establish well in waterlogged soils, even when relay-sown into rice, and can grow until maturity in waterlogged soils. Sometimes pea faces waterlogging damage in submontane soils of western IGP.

Micronutrient deficiencies

There are several reports of nutrient deficiencies adversely affecting chickpea, lentil, and other legumes but, other than phosphorus (P) deficiency, effects seem to be location specific. A more thorough diagnosis of such problems is needed in the IGP. Further, nutrient imbalances may become more apparent when major yield reducers such as biotic stresses and drought are corrected.

Nitrogen fixation

In traditional chickpea and lentil growing areas of the IGP, *Rhizobium* spp normally already present in the soil usually ensure effective nodulation, provided other environmental conditions are conducive. However, when chickpea and lentil are introduced to new areas, their host-specific *Rhizobium* also needs to be introduced through inoculation. In the IGP, khesari (lathyrus) nodulates prolifically in Bihar (S. Pande, ICRISAT, India, personal observation, 1996), presumably satisfying its own nitrogen (N) needs and also contributing fixed N_2 to the cropping system as a whole.

Legumes are particularly sensitive to alkaline, saline, and acidic soil conditions, and such soils are usually avoided for their cultivation. Increasing incidence of saline and alkaline conditions in irrigated areas would further limit options for growing legumes.

Socioeconomic Constraints

There are several important socioeconomic constraints to legumes production in the Indian IGP

Yield and profitability

Crop yield and profitability are the most important determinants in deciding the crops to be grown and cropping patterns. Legumes generally are considered as subsidiary crops to major crops such as cereals or cash crops (Sharma and Jodha 1982). Legumes are often relegated to marginal environments as irrigated and fertile lands are preferred for rice and wheat cultivation, where both technology-based growth in productivity and a favorable policy environment make these crops more profitable (Acharya 1993).

A study based on primary data from 70 farmers in Karnal district of Haryana state revealed that legumes are less profitable than rice and wheat (Joshi et al., in this volume). It is noted that despite a substantially lower cost of cultivation of legumes in comparison to rice and wheat, the net profit obtained with different legumes was not competitive with rice and wheat. However, berseem (*Trifolium alexandrinum* L.) is more profitable than wheat but it is grown only for fodder purpose, and its area expansion is restricted due to market considerations.

Lower net profit of legumes in comparison to rice and wheat is mainly due to their poor yield performance. However, output prices per unit of grain of all legumes are much higher than those of rice and wheat. Yields of legumes are so low that higher output prices cannot make them more profitable than rice and wheat (Joshi et al., in this volume). While the output prices of pigeonpea are just double those of rice, yield of rice is four times higher than that of pigeonpea. Similarly, chickpea prices are almost double those of wheat prices, but wheat yields are 60% higher than chickpea yields.

Markets and prices

Another most important constraint in legumes production in the RWCS is the lack of adequate output markets. It has been reported that markets for legumes are thin and fragmented in comparison to rice and wheat which have assured markets (Byerlee and White 1997). Although the Government of India regularly announces procurement prices for legumes, their procurement is not as effective as for rice and wheat. There are reports that farmers often do not actually receive the minimum prices announced by the government.

The benefits of a sharp rise in retail prices of legume grains are generally not shared by farmers due to lack of an appropriate market mechanism. A large share of market margin goes to middlemen. Several studies reported that the price spread (or the market margin) for legumes is much higher than those of rice and wheat due to higher postharvest costs, including the profit of middlemen (Joshi and Pande 1996; Joshi 1998).

Farmers' accumulation of fixed resources

Commercialization and specialization of agriculture in the RWCS encourages farmers to mechanize so as to more effectively realize the potential benefits of high-yielding varieties of rice and wheat. Some examples are tractor and puddler for land preparation, and harvester, thresher, and combine for harvesting and threshing of rice and wheat. Possession of such fixed resources tends to institutionalize continued cultivation of rice and wheat. However, these fixed resources can be adapted to legume cultivation provided other factors favored movement from rice or wheat (Joshi et al., in this volume).

Risk

Production of legumes is relatively more risky than that of rice and wheat (Joshi and Pande 1996). High temporal fluctuation in yield (due to biotic and abiotic stresses) and prices (due to variation in supply) of legumes in comparison to rice and wheat results in instability in farmers' income. There is very low instability in yield of rice and wheat, and their output prices are almost assured. Therefore, risk-averse farmers prefer to cultivate rice and wheat rather than legumes. Since there is no functioning policy to cover crop failure, farmers invariably prefer to avoid risks associated with legutne cultivation even if there is potential for greater profitability over the cereals.

Lack of knowledge about improved technology

Farmers generally lack knowledge about the recently developed and released improved varieties and production technologies of legumes (especially chickpea, pigeonpea, and lentil). In a survey conducted in northern India, it was observed that farmers know little about the improved varieties of short-, and extra-short-duration pigeonpea (Pande and Joshi 1995).

Role of Legumes in Cropping Systems

Legumes have been known for their soil ameliorative effects since time immemorial. They trap atmospheric N in the root nodules of their deep root system and add substantial amounts of protein-rich biomass to the soil surface and rhizosphere and thus keep the soil productive and healthy. By including legumes in cropping systems, the heavy N needs of modern intensive cereal-based cropping systems such as rice-rice, rice-wheat, and maize-wheat, can at least be partly met, and the physical and chemical characteristics of the soil generally improved (Kumar Rao et al. 1998).

Legumes in rotation with cereals not only improve cereal productivity but also economize on N use. Studies conducted at the Directorate of Pulses Research, Kanpur during 1984 and 1985 (Meena and Ali 1984) showed that chickpea increased productivity of succeeding rice by 1 t ha^{-1} at 40 kg N ha^{-1} as compared to wheat (Table 3.7). At a higher level of N application (120 kg ha^{-1}), the effect was narrowed down (0.79 t ha^{-1}). Comprehensive studies under the All India Coordinated Pulses Improvement Project have clearly shown that legumes in rotation with cereals economize N to the extent of 30-40 kg ha^{-1} (Ali 1994a).

Nutrient recycling in legumes cropping system could be partial or complete. An example of partial recycling in the existing cropping systems is growing of short-duration legumes such as mung bean, black gram, or cowpea as a catch crop during spring/summer or intercropping with cereals (e.g., maize, sorghum, and pearl millet), oilseeds (sunflower), and commercial crops (e.g., cotton and sugarcane). This system not only provides a bonus yield of legumes but also benefits the succeeding or companion crop. Ali (1992) reported that cultivation of cowpea during summer enhanced productivity of succeeding rice by 0.33 t ha^{-1}. Studies on intercropping of short-duration legumes with spring-planted sugarcane at Lucknow revealed that black gram and mung bean had synergistic effects on cane yield and also provided 0.4-0.5 t ha^{-1} bonus yield of pulse grains (Yadav 1980) (Table 3.8). Soybean, on the other hand, adversely affected cane production.

Complete recycling of N can be achieved by green manuring of dhaincha (*Sesbania cannabina* (Retz.) Pers.), sunn hemp (*Crotalaria juncea* L.), and cowpea in rice-wheat rotations. Comprehensive studies under the All India Coordinated Agronomic Research Project conducted during the 1980s showed that green manuring with *Sesbania* sp over a period of 3-4 years improved productivity of rice-wheat system by 3 t ha^{-1} on the light-textured, loamy sand soils of

Table 3.7. Grain yield of rice as influenced by nitrogen levels and preceding winter crop at Kanpur, India, 1984.

		Rice grain yield (t ha^{-1})				
		Nitrogen level (kg ha^{-1})				
winter crop	yield (t ha^{-1})	0	40	80	120	Mean
Chickpea	1.96	4.31	5.64	5.98	6.67	5.65
Lentil	2.11	4.64	5.25	6.02	6.26	5.54
	2.87	3.82	4.81	5.54	5.90	5.02
Wheat	5.48	3.35	4.63	5.31	5.88	4.79

Source: Meena and Ali (1984).

Table 3.8. Effect of legume intercropping on yield of sugarcane and legumes at Lucknow, India.

	Yield (t ha^{-1})	
Treatment	Sugarcane	Legume
Sugarcane alone	109.4	
Sugarcane + mung bean	113.3	0.4
Sugarcane + black gram	128.8	0.5
Sugarcane + soybean	102.5	1.2
Sugarcane + cowpea	106.3	0.5

Source: Yadav (1980).

Ludhiana, Punjab (Table 3.9). On medium-textured (sandy loam to loam) soils of Kanpur, Uttar Pradesh, the effect was marginal (0.55 t ha^{-1}). The effect of *Sesbania* green manuring was also observed in a pearl millet-wheat system at Bichpuri near Agra, Uttar Pradesh.

Incorporation of loppings of leguminous trees such as *Gliricidia* sp or *Leucaena* sp in rice fields also helps in partial recycling of plant nutrients. At the Indian Agricultural Research Institute, New Delhi, incorporation *of Leucaena* loppings over a period of 3 years (1991-94) increased yield of rice by 0.48 t ha^{-1} and of wheat by 0.73 t ha^{-1} (Prasad 1998).

Several long-term fertility trials have shown that legumes in cropping systems improved fertility status of soil. Meelu et al. (1992) working at Ludhiana reported that green manuring with *Sesbania* sp increased organic carbon of soil from 0.29% to 0.45% over a period of 6 years under rice-wheat systems. At Pantnagar, comprehensive studies on sustainability of rice-wheat sequential cropping through inclusion of legumes was made during 1986/87 to 1990/91 on sandy loam soil. It was observed that after 5 years, the organic carbon and total N decreased under a rice-wheat rotation whereas with inclusion of *Sesbania* sp as a green manure crop, the organic carbon (OC), total N, and available P increased by 0.01%, 15.0 kg ha^{-1}, and 13.8 kg ha^{-1}, respectively (Table 3.10). Increase in OC and available P was also observed under rice-lentil and pigeonpea-wheat sequential cropping. The effect of increased fertility status was reflected on grain yield of rice and wheat as well. Additional examples of residual effects of legumes in the 1GP of India are mentioned in Kumar Rao et al. (1998).

Table 3.9. Effect of green manuring on productivity of different cropping systems at some locations in the Indo-Gangetic Plain of India.

Location/Crop sequence	Grain yield[1] (t ha^{-1}) Rainy season	Postrainy season	Total
Kanpur, Uttar Pradesh			
Rice-wheat	3.63	3.58	7.21
Rice-wheat-Sesbania[2]	3.96	3.80	7.76
Ludhiana, Punjab			
Rice-wheat	5.81	3.82	9.63
Rice-wheat-*Sesbania*	6.72	4.88	11.60
Bichpuri (Agra), Uttar Pradesh			
Pearl millet-wheat	2.01	4.15	6.16
Pearl millet-wheat-Sesbania	2.14	4.33	6.47

1. Mean of 3 or 4 years.
2. *Sesbania* sp used as a green manure crop before rice or pearl millet.
Sourcr: Hegde (1992).

Prospects of Increasing Production of Legumes

The Indian IGP offers a vast scope for enhancing legumes production both under irrigated and rainfed agroecosystems. Some of the

Table 3.10. Grain yield and change in fertility status of soil under different crop sequences over a period of 5 years from 1986/87 to 1990/91 at Pantnagar, Uttar Pradesh, India.

Crop sequence	Grain yield (t ha^{-1}) Rainy season	Winter	Change in fertility status of soil[1] Organic carbon (%)	Total N (kg ha^{-1})	Available P (kg ha^{-1})
Rice-wheat	4.42	4.51	-0.004	-8.0	1.4
Rice-lentil	4.55	1.40	0.006	10.0	4.8
Pigeonpea-wheat	1.33	5.22	0.006	9.0	8.8
Rice-wheat-GM[2]	4.95	5.06	0.010	15.0	13.8

1. N= nitrogen; P= phosphorus.
2. Green manuring of *Sesbania cannabina*

production systems where legumes could be successfully introduced are discussed separately for western and eastern IGP

Western IGP

Mung bean as a catch crop in rice-wheat rotations

The development of short-duration (60-65 days), high-yielding, and yellow mosaic resistant genotypes of mung bean such as PDM 54, ML 267, Pusa 105, and Pant M 2 in the recent past have increased scope for inclusion of mung bean as a catch crop between wheat and rice. However, the success of this system will depend upon the choice of appropriate genotypes of rice and wheat and their timely planting so as to vacate fields with wheat by the end of March or first week of April, assured irrigation, and a community approach to halt the predations of blue bulls (nilgai) and stray cattle. Development of extra-early-maturing varieties of mung bean of 50-55 days duration will further help to popularize this system.

Mung bean and black gram in spring

After harvest of short-duration postrainy season crops such as mustard, potato, pea, or sugarcane, mung bean or black gram can be successfully grown during spring (Mar-May). In fact, spring cultivation of these legumes is increasing rapidly with the availability of yellow mosic resistant and high-yielding (0.8-1.0 t ha^{-1}) black gram varieties such as Pant U 19, PDU 1, and Narendra Urd 1 which mature in 70-75 days. Similarly, release of mung bean varieties PDM 11, Pant Mung 2, and MH 81-1-1 has encouraged spring cultivation. About 100,000 ha area in the states of Punjab, Haryana, and western Uttar Pradesh are currently occupied by spring black gram and mung bean; this can be substantially increased.

Chickpea-cotton sequential cropping

On the uplands of Punjab and western Uttar Pradesh, where cotton is grown as a commercial crop, chickpea can be successfully introduced with the availability of genotypes amenable for late planting. This system will help in sustaining productivity as well as increasing production of chickpea. It has been observed that the cotton-chickpea system is more remunerative than the cotton-wheat system.

Pigeonpea-wheat sequential cropping

The advent oi short-duration genotypes of pigeonpea (140-160 days) such as UPAS 120, AL 15, AL 201, Manak, Pusa 84, and ICPL 151 in the recent past has paved the way for cultivation of pigeonpea in western IGP, which is a non-traditional area for this crop. Pigeonpea-wheat sequential cropping has become popular and area under this system is increasing progressively. About 200,000 ha in western IGP is reported to be under short-duration pigeonpea.

The existing available short-duration varieties are susceptible to sterility mosaic, fusarium wilt, and phytophthora blight, and have a tendency to prolong maturity with late monsoon rains. Therefore, it is imperative to develop genotypes that will mature by early November, well in time for land preparation and sowing of winter crops, and with a yield potential exceeding 2 t ha^{-1}. An example of such genotypes developed is ICPL 88039 that has shown promise for this system (Laxman Singh et al. 1996).

Groundnut-wheat sequential cropping

On uplands having light-textured soils, groundnut cultivation is more profitable than pearl millet, maize, or sorghum. Moreover, wheat in sequence with groundnut is greatly beneficial due to improvement in physical and chemical properties of soil. Policy initiatives to encourage cultivation of groundnut can provide required support in popularization of this system.

Eastern IGP

Short-duration pigeonpea in sequence with wheat

On uplands of eastern Uttar Pradesh, short-duration pigeonpea genotypes, as described for western IGP, can be successfully grown. Since this region receives more precipitation it is imperative that pigeonpea planting should be done in the first fortnight of Jun with pre-planting irrigation so that by the time monsoon rains start the seedlings are strong enough to combat adverse effects of excess moisture. Development of genotypes having tolerance to excess soil moisture, besides other attributes such as disease resistance, would help in popularization of short-duration pigeonpea.

Spring/summer cultivation of black gram and mung bean

Like in western IGP, the eastern region also offers good scope for cultivation of spring black gram and mung bean as well as summer mung bean. Over 200,000 ha area is presently under mung bean. The popular varieties are Pant U 19, Narendra Urd 1, and PDU 1 of black gram and PDM 11, Narendra Mung 1, Sunaina, and Pant M 2 of mung bean. Besides cultivation of these crops after harvest of mustard, potato, pea, wheat, and sugarcane, they are also suitable for intercropping with spring-planted sugarcane and sunflower.

Rice-chickpea/lentil sequential cropping

Development of chickpea varieties amenable for late planting (mid-Dec), such as KPG 59 and Pusa 372, has encouraged cultivation of chickpea after rice, particularly in the tail end of command areas. Under resource constraints, rice-chickpea is more remunerative than rice-wheat. Eastern Uttar Pradesh and northern Bihar show most potential for this system.

In lowland areas with excessive moisture, lentil is a more assured crop than chickpea. Consequently, the rice-lentil system is very popular in the lowlands of eastern Uttar Pradesh, Bihar, and West Bengal. The adoption of the high-yielding, bold-seeded, and wilt resistant variety DPL 62 may encourage expansion of lentil. The small seeded varieties such as DPL 15, PL 40b, and PL 639, being rust resistant, also need to be popularized.

Utilization of rice fallows

Vast areas in eastern IGP are monocropped under medium- and long-duration rice. The non-availability of irrigation water and delay in vacating the field after rice does not normally permit double cropping. The top soil layer generally dries out at the time of harvest of rice and thus planting of a postrainy season crop is not feasible. Under such conditions relay cropping of small-seeded lentil or low-toxin containing khesari (lathyrus) genotypes (e.g., Bio L, 212) could convert these monocropped areas into double cropped ones and thus increase pulse production and sustain productivity of the rice-based system. Lentil or khesari (lathyrus) seeds are broadcast in the standing crop of rice 7-10 days before harvest when there is adequate moisture for germination in the top layer of soil. Expansion of this system will depend upon development of genotypes specially suited for relay cropping and of matching agro-technology, which has not received adequate attention so far.

Cultivation of postrainy pigeonpea and common bean

The eastern IGP receives heavy rains and experiences frequent floods during Jul-Aug, which causes considerable loss to Jul-planted pigeonpea. At times, the crop is completely lost. Under such situations, postrainy season pigeonpea holds promise. Recently released varieties such as Sharad and Pusa 9, which are resistant to alternaria blight and suitable for Sep planting, have proved a boon for extension of postrainy pigeonpea on uplands of eastern Uttar Pradesh, northern Bihar, and West Bengal. The productivity of these genotypes is 2 t ha^{-1}. Since these genotypes are highly thermo-sensitive, their planting period is restricted up to mid-Sep with delayed planting causing considerable loss in productivity. Hence, it is imperative to develop genotypes which could be successfully planted until early October. This will provide greater opportunities to expand pigeonpea cultivation under sequential cropping with short-duration upland crops such as maize, sorghum, and pearl millet.

Common bean is a relatively new introduction in the IGP. This has been possible due to development of high-yielding genotypes (2.5-3.0 t ha^{-1}), such as Udai, HUR 15, and HUR 137, which are suitable for planting in Oct-Nov. This legume, being a high-value and short-duration (115-125 days) crop with few problems of insect pests and diseases and high stability in production, could potentially cover large areas under irrigated conditions. It can be intercropped with potato.

Introduction of black gram and mung bean as winter crops

In some parts of northeastern Bihar and West Bengal where temperatures are moderate during winter, black gram and mung bean can be grown in rice fallows. This will bring additional area under legumes and help in utilizing residual moisture in rice fallows. To encourage this system, there is a need to develop high-yielding and powdery mildew resistant varieties having cold tolerance.

National Policies and Emphasis Towards Legume Production

Several policy measures were initiated by the Government of India to increase production of legumes in the country. The important ones are discussed.

Investment in Research and Development

In the past, investment in legumes research has been very low as compared to rice and wheat primarily due to the national priority for attaining self-sufficiency in food security. During the VII Five-Year Plan period, research investment on legumes was Rs 101.2 million, which was raised to Rs 301.9 million for the VIII Five-Year Plan (Ali 1997). The nodal research organization for grain legumes, the Directorate of Pulses Research, was strengthened and upgraded as the Indian Institute of Pulses Research in 1993, and the erstwhile national network, the All India Coordinated Pulses Improvement Project, was trifurcated and independent coordinated research projects on chickpea, pigeonpea, and "other pulses" were created in 1995. The proposed financial outlay for the Indian Institute of Pulses Research and the three coordinated projects for the IX Five-Year Plan is over Rs 1000 million. Similarly, the two national research centres on groundnut and soybean were strengthened and allocated higher research outlay in successive five-year plans.

Developmental activities gained a new impetus with sanction of a United Nations Development Programme (UNDP)-funded project on 'Increasing Pulses Production through Demonstration and Training' with an outlay of Rs 11 million. The program is being implemented through the Technology Mission on Pulses (TMOP) in 12 districts of Uttar Pradesh from Jan 1997. Another UNDP-sponsored project, "Demonstration and development of low ODAP varieties of grasspea in traditional areas of Madhya Pradesh and Bihar" with an outlay of Rs 5 million has also been sanctioned. The massive investment made under the National Pulses Development Program and TMOP will certainly show its impact in the near future.

Technology Mission

A technology mission on oilseeds was established by the Government of India in 1987 to increase oilseed production. The two legumes, groundnut and soybean, were covered under this mission. The area and production of these two legumes increased substantially after 1987. Legumes (particularly pulses) were not included initially but were brought under the ambit of the technology mission in 1991. The main purpose was to increase production of oilseeds and pulses and minimize their import. Several micro-missions were launched to deal with different aspects of the pulses program (Ali 1997). These were crop production technology, postharvest technology, input and service support to the farmers, and price support, storage, processing, and marketing. The crop production technology micro-mission was operated by the Indian Council of Agricultural Research (ICAR), New Delhi in collaboration with the Department of Agriculture and Cooperatives, Government of India. It envisages evolving profitable crop production and protection technologies for different agroclimatic regions and production environments. The five legumes, chickpea, pigeonpea, black gram, mung bean, and lentil, have been covered under this micro-mission. The major research program is focused on:

- Enhancing genetic resources;
- Enhancing yield potential by 20-40%;
- Breeding varieties for disease and pest resistance;
- Reducing crop duration by 10-20 days;
- Evolving appropriate technology for traditional and non-traditional areas;
- Developing integrated pest management technology;
- Farm mechanization for pulse production; and
- Expanding nucleus and breeder seed production.

To bring awareness among farmers about the improved production technology, a frontline demonstration scheme was also launched. Under this program a large number of demonstrations are undertaken on farmers' fields to show: (1) benefits of improved varieties and production technology over local practices and varieties; and (2) steps to be adopted for improved varieties and production technologies. Farmers and extension personnel are given training in the research institutes and agricultural universities to disseminate the improved varieties and production technologies to larger areas. Farmers are given improved seeds of different legumes in different regions at subsidized prices. It is proposed that the programs initiated under the mission will continue during the IX Five-Year Plan period.

Procurement Prices

The Government of India regularly announces minimum support and procurement prices of pulses along with cereals. It was noted that relative prices of legumes were always kept higher than those of cereals. The Gommission on Agricultural Costs and Prices (CACP) regularly assesses the cultivation costs of legumes compared with cereals, and submits its recommendations to the Ministry of Agriculture, Government of India. It is noted that the Government of India often announces procurement prices of legumes higher than what was recommended by the CACP.

Conclusion

The Indian IGP is largely dominated by cereals, and the region contributes half of the country's cereals production. Rice-wheat and rice-based systems are the predominant cropping systems. These systems are now afflicted by a number of production constraints. The natural resources, particularly soil and water, are threatened because of their over-exploitation. Legumes can play an important role in reversing the process of degradation of soil and water resources, and improving the production potential of the total cropping system.

Important legumes which are widespread in this region are chickpea, lentil, and pigeonpea. Other legumes, which are location specific, are black gram, mung bean, horse gram, khesari (lathyrus), groundnut, and soybean. All legumes are prone to particular diseases and insect pests, and can be adversely affected by nematodes and weeds. Although attempts have been made to develop improved cultivars which are resistant to pests and diseases, not much success has been achieved, particularly with respect to use of host plant resistance by farmers. Systematic information on etiology of legumes pathogens, epidemiology of diseases, biology of insect pests and their threshold levels, and host plant resistance to important insect pests [such as pod borers in chickpea (*Helicoverpa armigera*) and pigeonpea (*Maruca testulalis*)] is not available. Similarly, scant information is available on nematode pathogens affecting legumes production in the Indian IGP. In this context, there is an urgent need to assemble the available components of integrated pest management (such as moderate levels of host plant resistance, cultural practices to disrupt the life cycles of pests, and targeted/need-based use of pesticides), and to validate them in farmers' participatory on-farm research. It is expected that this approach will be able to deliver the pest management components effectively, and hence stabilize the productivity of legumes in the IGR Similarly, there is a need to better understand and tackle the major abiotic stresses limiting legumes production. It is presumed that once the major biotic constraints are more effectively managed for the sustainable production of legumes, the abiotic stresses will be more clearly diagnosed.

A number of socioeconomic constraints also discourage farmers to produce legumes. Most important is lower profitability of legumes in relation to rice and/or wheat. Low profitability of legumes is largely attributed to poor and unstable yield performance. There is a need for research to increase the productivity of legumes so that they can reliably compete with rice and/or wheat in the IGP. Other constraints are higher risk in price and yield of legumes, lower market density, and unassured prices. Although the Government of India announces procurement prices for legumes at higher levels than for cereals, their effective implementation is lacking. There is particular need to strengthen extension efforts to disseminate available legume technologies through on-farm demonstrations and farmers' participatory research. Efforts may also be made to develop appropriate models for crop insurance to encourage legumes production for sustainable agricultural production in the IGP.

There is a vast scope for enhancing legumes production both under irrigated and rainfed ecosystems in the IGP. Legumes can be included in the rice-wheat based cropping system either as catch crops, or grown as spring crops. The scope of extra-short- and short-duration pigeonpea is enormous provided biotic constraints, mainly insect pests, are minimized. In the eastern IGP, there is large scope of utilizing existing rice fallows by growing chickpea, lentil, and khesari (lathyrus) after rice.

More research efforts are needed to better understand the IGP ecosystem in the context of legumes production, and its positive effects on sustainability of the natural resource base.

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4. Legumes in Nepal

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Abstract

Nepal is divided into four major agroclimatic zones, the Terai (part of the Indo-Gangetic Plain to the south), the inner Terai, mid-hills and valleys, and high mountains (in the north). Soil texture varies from rich alluvial deposits in the Terai to course-textured gravel in the high mountains. Annual rainfall varies from 5500 *mm to 3500 mm and temperatures from - 10°C to 35°C. Legumes are important components of Nepalese farming systems and diets. Most of the legumes are grown in different cropping patterns in the Terai. Their yields have remained low, at usually <0.7 t ha*$^{-1}$*, because of a range of hiotic and abiotic constraints.* Botrytis cinerea *and pod borers are the most damaging pests of chickpea and lentil while fusarium wilt and sterility mosaic largely affect the pigeonpea crop. Baseline agronomic research on soil fertility management for cropping systems with grain legumes as component crops is required for different agroclimatic zones, especially in the Terai and inner Terai.*

Introduction

Grain legumes constitute a key component of various cropping systems in Nepal. They occupy more than 311,661 ha (13% of food crops land area) and produce a total of 214,820 t grains (Table 4.1). Grain legumes rank fourth in area and production after rice (*Oryza sativa* L.), maize *(Zea mays* L.), and wheat (*Triticum aestivum* L.). Thus, they significantly contribute to the dietary needs of the people, have considerable potential for export, and can restore soil fertility. Grain legumes are essential components of the Nepalese diet but their consumption is only 9 kg per capita per annum which is four times less than that recommended by the Food and Agriculture Organization of the United Nations (FAO), Italy (36 kg per capita per annum) (FAO 1981).

Legumes are grown in both summer and winter in Nepal. The main summer grain legumes are soybean (*CAycine max* (L.) Merr.), black gram (*Vigna mungo* (L.) Hepper), horse gram (*Macrotyloma uniflorum* (Lam.) Verde.), cowpea (*Vigna unguiculata* (L.) Walp.), mung bean (*Vigna radiata* (L.) Wilczek), and groundnut (*Arachis hypogaea* L.). Major winter grain legumes include lentil (*Lens culinaris* Medic), khesari *(Lathyrus sativus* L.; lathyrus; grass pea), chickpea (*Cicer arietinum* L.), and faba bean *(Vicia faba* L.). Pigeonpea (*Cajanus cajan* (L.) Millsp.) is sown early in the rainy season and harvested in the following spring/summer. Legumes are the second most important crops grown in rotation in rice-wheat cropping systems (RWCS). The main winter grain legumes, lentil, khesari (lathyrus), and chickpea are sown after harvest of rice and cover about 15% (0.23 million ha) of total rice area. Besides the grain legumes,

Table 4.1. Area, production, and yield of major grain legumes in Nepal during 1995/96.

Grain legumes	Area (ha)	Production (0	Yield (kg ha-')
Lentil	157080	117720	749
Chickpea	19080	13640	715
Pigeonpea	25530	19300	756
Black gram	25500	15300	600
Khesari (lathyrus)	34240	18170	531
Horse gram	11640	5610	482
Soybean	20770	13710	660
Others[1]	17810	11400	640
Total	311661	214820	641

1. Others = mung bean, cowpea, groundnut, and faba bean.
Source. Munstry of Agriculture, His Majesty's Government, Nepal.

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some green manure legumes such as dhaincha (*Sesbania cannabina* (Retz.) Pers.) are also grown in limited areas in rice-wheat rotations, between wheat and rice crops.

Although the rice-winter grain legumes cropping system is a long-standing traditional cropping system in Nepal, the introduction of wheat after rice since the early 1960s has relegated the legumes to more marginal rice fields. Since then, the more fertile and irrigated lands have been occupied by rice-wheat rotations which use high input technology including improved seeds and fertilizers. However, the rise in the cost of fertilizers, their unavailability at the right time and low purchasing power of the farmers coupled with the slow growth of irrigation facilities have limited the potential productivity of rice-wheat cropping in Nepal. The national average yields in 1995/96 were 2.4 t ha^{-1} for rice and 1.5 t ha^{-1} for wheat. Besides, there are increasing concerns that the continuous rice-wheat (cereal-based) rotation has caused mining of soil nutrients, and increased incidence of diseases, insect pests, and weeds, resulting in environmental degradation and yield declines.

Therefore, the necessity of inclusion of legumes in RWCS is recognized more than ever due to their ability to enrich the soil fertility through biological nitrogen fixation (BNF), tolerate drought hazards, perform relatively better than other crops on marginal lands, and provide cheaper sources of protein for human nutrition. However, their yield levels are very low, at <0.7 t ha^{-1}, and they cannot compete with other winter crops such as wheat unless market prices are favorable and their indirect benefits to soil fertility and the environment are taken into account. Keeping these points in view, the present initiative was undertaken to:

- Bring out the status of legumes in rice-based cropping systems in Nepal in terms of their distribution, production, and yield trends;
- Understand and illustrate the spatial changes that have occurred in major grain legumes in RWCS during recent years;
- Elucidate the actual and potential role of legumes in RWCS;
- Assess biotic and abiotic stresses limiting legume cultivation and productivity; and
- Identify the constraints and indicate potential areas for expansion of legume cultivation.

Geographic information systems (GIS) software was used to process and analyze the time series statistics on legumes and integrate them with relevant bio-physical and socioeconomic information. It is expected that the information thus produced and presented in this chapter will enable planners, decision makers, and other concerned scientists to better understand the role of legumes in sustaining RWCS in Nepal.

Edaphic and Climatic Features

Nepal is located between latitudes 26°22 N to 30°27'N and longitudes 80°4'E to 88°12'E in the Hindu Kush Himalaya Range of South Asia. Administratively Nepal is divided into 75 districts (Fig. 4.1). Physiographically, the country is divided into 5 regions: Terai, Siwalik, Middle Mountain, High Mountain, and High Himalaya (Fig. 4.2). These regions have distinct geological, climatic, and hydrological characteristics that reflect in soils, vegetation, and land use pattern.

The Terai region is part of the Indo-Gangetic Plain (1GP) to the south and represents only 14% of the total land area of Nepal, but contains about 46% of the gross cultivated area. The rice-wheat/ legumes cropping systems are mostly concentrated in Terai, with very little in the Siwalik and Middle Mountain physiographic regions.

The Terai plain comprises nearly level alluvial tracts, predominantly of medium- to fine-textured sediments. The major soils are imperfectly to poorly drained Haplaquepts in the southern parts; and well drained Hapludolls at the foot of the Churia range (Fig. 4.3). The

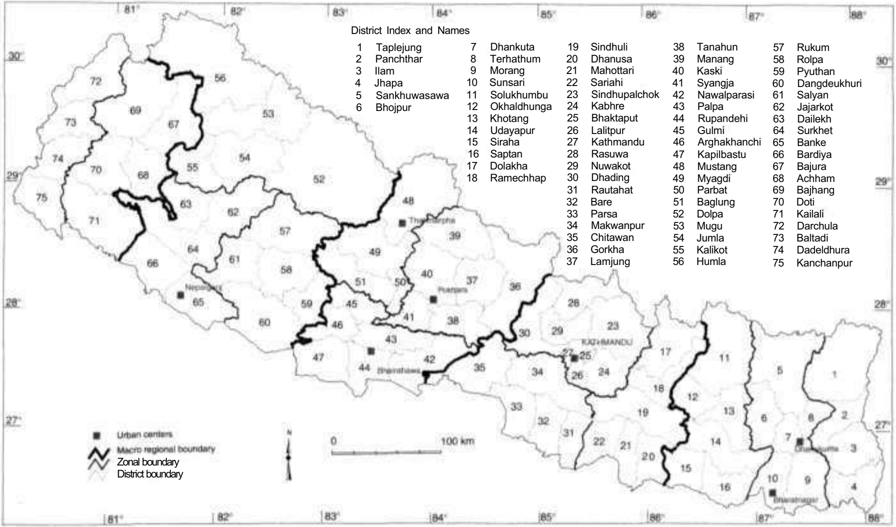

Figure 4.1. Administrative divisions (districts) and major urban centers in legume-growing areas of Nepal.

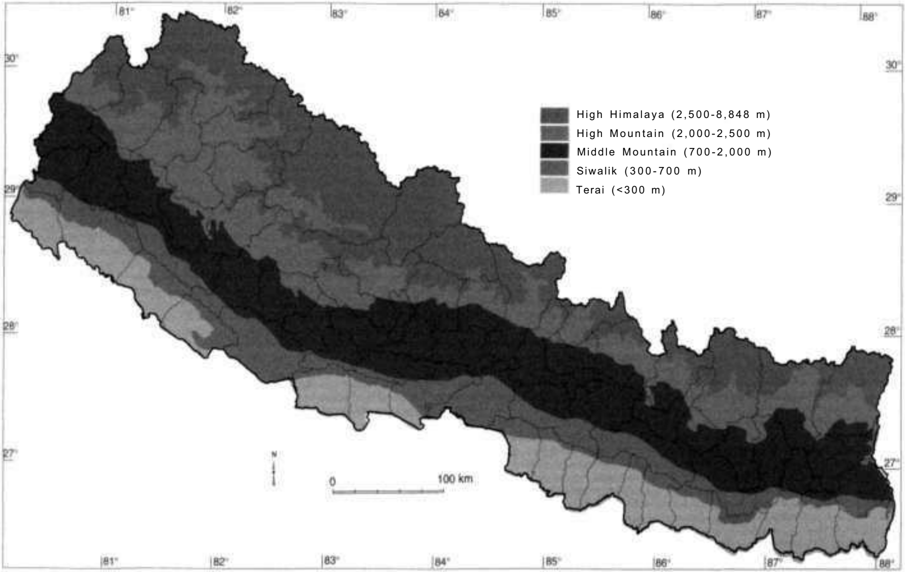

Figure 4.2. Physiographic regions of Nepal (Source: Topographic Survey Branch, Department of Survey, His Majesty's Government, Nepal, 1983).

Haplaquepts are suited for rice in the rainy season and for upland crops including wheat and legumes in the dry season. Most of the Hapludolls are under forest vegetation.

The inner Terai valleys (Chitwan, Dang-Deukhuri, and Surkhet valleys) are covered mainly by moderately coarse to medium-textured alluvial sediments. These valleys consist of series of terraces and flood plains. Most of the lands in these valleys are under intensive cultivation. The dominant soils are well to somewhat excessively drained Dystrochrepts, suited for upland crops (Fig. 4.3). Drought in the dry season limits their agricultural use. However, the low-lying areas with imperfectly to poorly drained Udorthents and Haplaquents are best suited for rice cultivation.

The level of organic matter in most cultivated soils in Terai and inner Terai where RWCS are concentrated (below 2,000 m) is low (<1%). This could represent a major constraint of soil fertility to a sustainable increase in rice-wheat productivity. At elevations above 2,000 m, the soils contain 2-3% organic matter. Cooler climatic conditions and more vegetation coverage are contributing factors to higher organic matter accumulation in this region.

Generally, the soils of Nepal are deficient in nitrogen (N), with phosphorus (P) being the second most important plant nutrient limiting crop yield. Soil tests for potassium (K) generally indicate high levels, but K deficiency has also been reported in recent years (Regmi et al. 1996; Sherchan and Gurung 1997). There is very little evidence of calcium (Ca) and magnesium (Mg) deficiency limiting rice-wheat production. However, soil content of sulfur (S) has been reported low in most of the soils of Nepal indicating that S is a potential limiting nutrient to the growth of legumes, as legumes are susceptible to S deficiency. Micronutrient deficiencies such as zinc (Zn) in rice; boron (B) in wheat, legumes, and vegetables; and molybdenum (Mo) in vegetables and legumes are increasingly observed.

An annual rainfall of 1200-2000 mm occurs in the main rice-wheat/legumes growing areas of the Terai (Fig. 4.4). About 80% of total annual rainfall occurs in the monsoon season between Jun and Sep which is the main rice-growing period (Fig. 4.4). Nepal also receives some winter rains through the westerly weather system. It occurs more in the western part of the Terai and contributes to some extent to winter crops, including wheat and legumes. Some pre-monsoon rains occur during the drier period of Apr-Jun.

In general, the trend in seasonal variations of temperature is similar throughout the country, although the topographic effects influence significantly at the micro-level (Fig. 4.5). Temperatures rise steadily from minimum values in winter during Jan-Feb to maximum values during Apr-May and then fall slightly during the monsoon period due to presence of heavy clouds and rain. Temperatures then drop sharply to winter minimum values. The maximum temperature rises very sharply in spring (Mar-May) while the rise of minimum temperature is gradual. The mean maximum temperature in subtropical agroecological zones where rice-wheat and legumes are cropped is in the range 25-35°C (Fig. 4.5).

Area, Production, and Yield

Spatial Distribution of Area and Yields

Grain legumes are mainly grown in the Terai region. It is interesting to note that the winter legumes, particularly pigeonpea and chickpea, are clustered mainly in three distinct pockets of the Terai region: six districts in central Terai (Siraha, Dhanusha, Mahottari, Rautahat, Bara, and Parsa), three districts in western Terai (Nawalparasi, Rupandehi, and Kapilbastu) and four districts in far western Terai (Banke, Bardiya, Kailali, and Kanchanpur). This is very well related to agroclimatic factors, as these districts fall under sub-humid to moderately dry

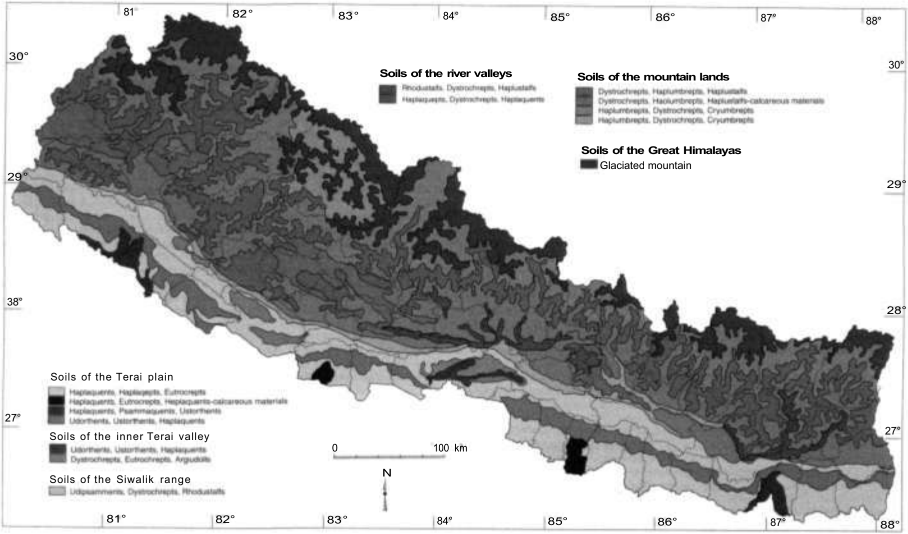

Figure 4.3. Generalized soils map of Nepal (Source: Soil Science Division, Nepal Agricultural Research Council).

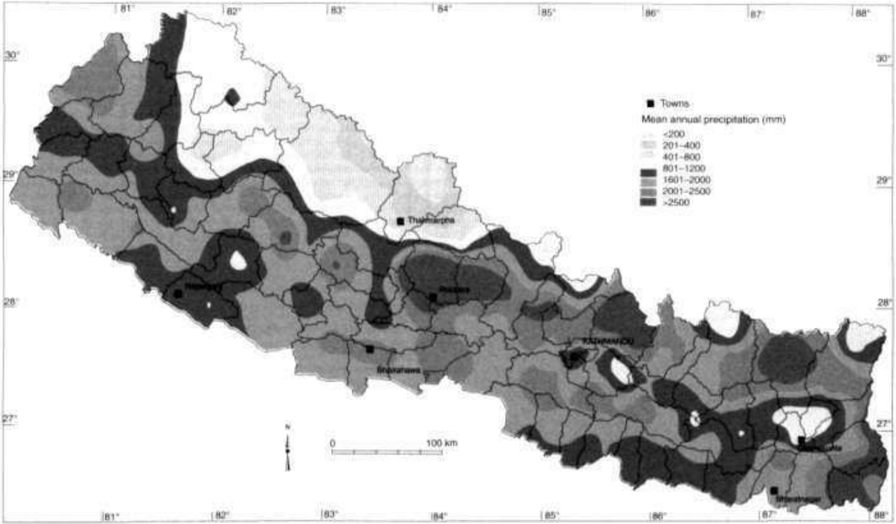

Figure 4.4. Mean annual precipitation in Nepal (Source: Department of Hydrology and Meteorology, Department of Survey, His Majesty's Government, Nepal, 1988).

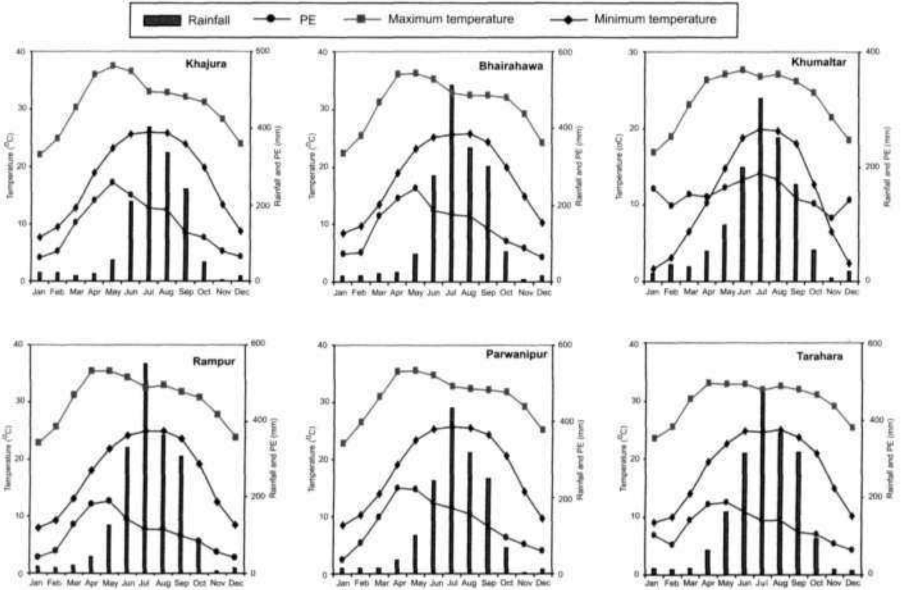

Figure 4.5. Monthly mean rainfall, maximum and minimum temperature (T), and potential evaporation (PE) at some locations representative of legume-growing areas in Nepal (Source: Manandhar and Shakya, 1996).

agroecological regions (Fig. 4.2) where the length of growing period is comparatively shorter (< 160-180 days). The annual rainfall ranges from 1200 mm to 1600 mm (Fig. 4.4), but over 85% of the rain occurs between Jul and Sep (Fig. 4.5).

Lentil

Cultivation of lentil has increased all over the Terai districts during 1984/85 to 1994/95 (Fig. 4.6). In particular, the four districts of central Terai (Sarlahi, Rautahat, Rara, and Parsa) and two districts of the far western Terai (Kailali and Kanchanpur) have shown considerable intensification of lentil cultivation. However, yields remain static at 0.5 to <1 t ha^{-1}.

Khesari (lathyrus)

Khesari (lathyrus) cultivation is more intensively concentrated in the districts of eastern Terai, followed by those in central Terai (Fig. 4.7). The crop area has drastically decreased in most of the districts except Jhapa, Sunsari, and Saptari districts in eastern Terai where the agroclimatic condition is moderately humid (Figs. 4.2 and 4.4) and other winter legume species are sparsely grown. In other districts, khesari (lathyrus) has been replaced by other crops probably due to the increased cultivation of lentil, wheat, sugarcane (*Saccharum officinarum* L.) or other more marketable crops.

Pigeonpea

The cultivation of pigeonpea, however, has intensified further in its traditional niche areas (Fig. 4.8). But it has shown a decreasing trend in the far eastern and western Terai districts. Since pigeonpea is not extensively grown in these districts, it does not significantly affect the national scenario.

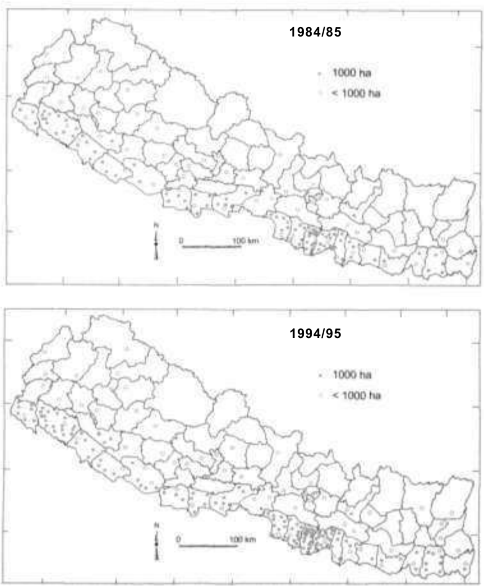

Figure 4.6. Lentil distribution in Nepal in 1984/85 and 1994/95 (Source: Agriculture Statistics Division, Ministry of Agriculture, His Majesty's Government, Nepal).

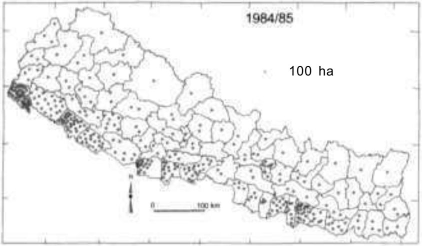

Figure 4.7. Khesari (lathyrus) distribution in Nepal in 1984/85. Data for 1994/95 not available (Source: Agriculture Statistics Division, Ministry of Agriculture, His Majesty's Government, Nepal).

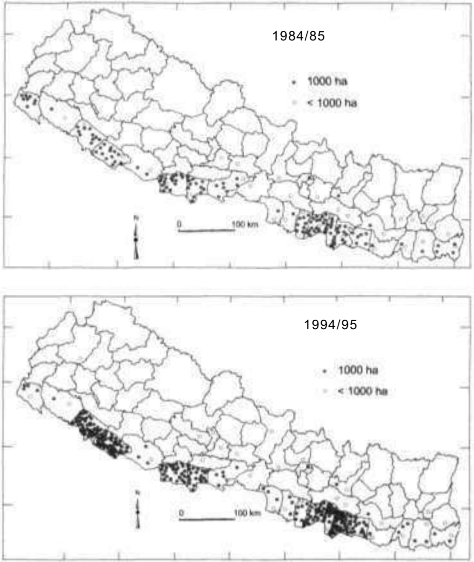

Figure 4.8. Pigeonpea distribution in Nepal in 1984/85 and 1994/95 (Source: Agriculture Statistics Division, Ministry of Agriculture, His Majesty's Government, Nepal).

Chickpea

Contrary to lentil and pigeonpea, chickpea cultivation has decreased in almost all the mid-hill districts as well as in a number of central Terai districts over the 10-year period from 1984/85 to 1994/95 (Fig. 4.9). It is interesting to note, however, that chickpea cultivation has also concentrated in the same three Terai districts (Bardia, Kailali, and Kanchanpur) of far western Nepal where lentil and pigeonpea intensification has also taken place. This shift in chickpea cultivation from eastern to western parts of the country relates to the severe incidence of botrytis gray mold (BGM) *(Botrytis cinerea)* in the eastern part compared to the western part.

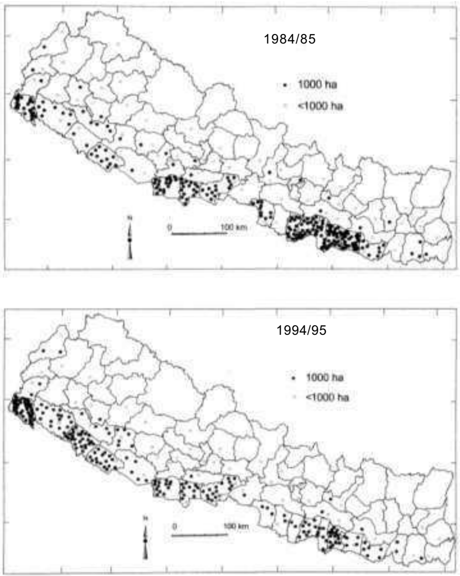

Figure 4.9. Chickpea distribution in Nepal in 1984/85 and 1994/95 (Source: Agriculture Statistics Division, Ministry of Agriculture, His Majesty's Government, Nepal).

Black gram

Black gram is cultivated in hilly areas, mainly in the eastern part of Nepal (Fig. 4.10).

Soybean

Like Black gram, soybean is cultivated mainly in hilly areas, towards the east of the country (Fig. 4.11).

Groundnut

Groundnut is restricted to the central-eastern part oftheTerai (Fig. 4.12).

The expansion of lentil and pigeonpea cultivation could Be due to their increased demand for export and a special support of the Department of Agriculture to lentil cultivation under a World Bank project. The increase of lentil area Has distinctly influenced the trend of total legume area. The decline in khesari (lathvrus) area could Be due to

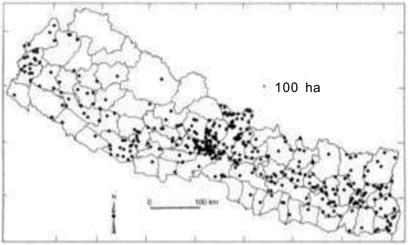

Figure 4.10. Black gram distribution in Nepal in 1994/95 (Source: Agriculture Statistics Division, Ministry of Agriculture, His Majesty's Government, Nepal).

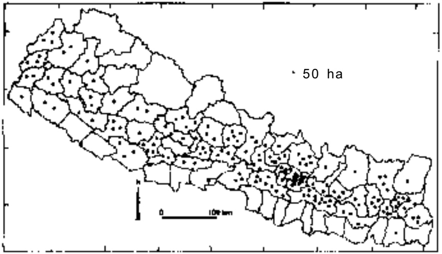

Figure 4.11. Soybean distribution in Nepal in 1994/95 (Source: Agriculture Statistics Division, Ministry of Agriculture, His Majesty's Government, Nepal).

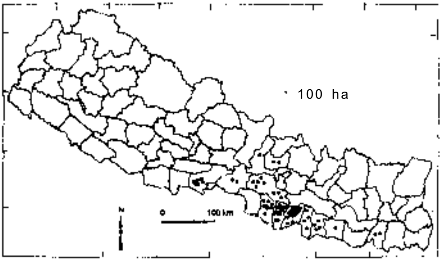

Figure 4.12. Groundnut distribution in Nepal in 1994/95 (Source: Agriculture Statistics Division, Ministry of Agriculture, His Majesty's Government, Nepal).

the Government's prohibition of its cultivation and increased public awareness of its potential role in causing lathyrism if regularly consumed. The decline of chickpea area has been attributed to increased infestation of BGM and fusarium wilt as well as pod borer (*Helicoverpa armigera* Hiibner).

However, there is still further scope for expanding the lentil cultivation, particularly in rainfed rice fields because of less suitability for wheat cultivation due to moisture stress. If the present trend of lentil cultivation continues, the area under khesari (lathyrus) may further decrease in future. Production of lentil has doubled from 58,000 t in 1984/85 to 118,000 t in 1995/96 (Fig. 4.13). Also, the production of pigeonpea has increased by 84% in the same period. But the production of khesari (lathyrus) and chickpea by contrast has declined by 32% and 15%, respectively. The increase and decrease of the total production figures, however, have followed the trends of area of these crops. This indicates that no significant improvement in legume productivity has taken place, as indicated in the yield trends shown in Figure 4.13. In general, the yields have remained low and static. No district has reported yields of >1 t ha^{-1}, although prospects for improvements are shown by the yield potential of improved varieties (Table 4.2). This indicates that attempts made for dissemination of improved varieties and cultivation practices were inadequate as a broad

Table 4.2. Grain legume varieties released in Nepal.

Crop/ Variety	Year of release	Origin	Days to maturity	Yield potential (t ha^{-1})	Released tor region
Lentil					
Sindur	1979	Nepal	148	1.5	Terai and mid-hill
Simirik	1979	India (T 36)	143	1.5	Terai and mid-hill
Sishir	1979	India (P 43)	150	2.0	Terai, inner Terai, and mid-hill

continued

Table 4.2 *continued*

Crop/ Variety	Year of release	Origin	Days to maturity	Yield potential (t ha^{-1})	Released for region
Simal	1989	India (LG7)	143	2.1	Terai, inner Terai, and mid-hill
Sikhar	1989	Pakistan (ILL 4404)	143	2.5	Terai, inner Terai, and mid-hill
Chickpea					
Dhanush	1980	Nepal	144	1.8	Terai/inner Terai
Trishul	1980	Nepal	144	1.7	Terai/inner Terai
Radha	1987	India (LG 74)	142	1.6	Terai/inner Terai
Sita	1987	India (1CCC 4)	140	1.5	Terai/inner Terai
Kosheli	1990	India (ICCC 31)	154	1.6	Western Terai
Kalika	1990	India (ICCL 82198)	152	1.4	Western to Central Terai
Pigeonpea					
Bageshwari	1991	Nepal (PR 5147)	261	2.0	Terai
Rampur Rahar1	1991	Nepal	197	1.5	Central Terai
Soybean					
Hardee	1976	USA	124	2.4	Terai and inner Terai
Hill	1976	USA	166	1.7	Hills
Rensotn	1987	USA	145	1.0	Mid-hill and valley for intercropping
Seti	1989	Taiwan (AVRDC)[1]	150	1.2	Mid-hill and valley for intercropping
Cob	1989	USA	123	2.5	Terai and inner Terai
Lumle-1	1995	Nepal	142	1.7	Inner Terai and hill
Cowpea					
Askash	1989	Nigeria	65	1.0	Terai and inner Terai
Prakash	1989	Nigeria	60	0.8	Terai and inner Terai
Mung bean					
Pusa baisakhi	1979	India	60	1.5	Terai/inner Terai
Black grain					
Kalu	1979	India	85	1.0	Warm Valley

1. Asian Vegetable Research and Development Center.

yield gap exists. There is considerable scope for increasing yields if the production constraints (biotic, abiotic, and socioeconomic) are precisely identified and addressed.

Constraints to Grain Legume Cultivation

Biotic Constraints

Diseases and insect pests are the two most important biotic constraints to the production of legumes in Nepal, but sometimes infestation of weeds can also cause considerable yield loss.

Diseases

There are a large number of diseases recorded in grain legume crops (Table 4.3). Among these, wilt, BGM, and rust are the most serious in most of the legume crops.

Lentil. Vascular wilt, collar rot, rust, and BGM are noted as the most serious diseases in lentil (Table 4.3). They occur widely in the Terai as well as in the hill areas. They may cause considerable loss in grain yield. Botrytis gray mold mainly occurs in the eastern and central region but can be found sporadically throughout the Terai. However, vascular wilt and collar rot are distributed throughout the major growing areas.

Pigeonpea. Fusarium wilt, sterility mosaic, and macrophomina stem canker are the major diseases of pigeonpea (Table 4.3). These diseases occur right across the Terai region, where pigeonpea is grown. Individually, they may cause more than 50% yield loss in pigeonpea.

Chickpea. Botrytis gray mold is the most important disease of chickpea, particularly in the eastern part of the country (Table 4.3),

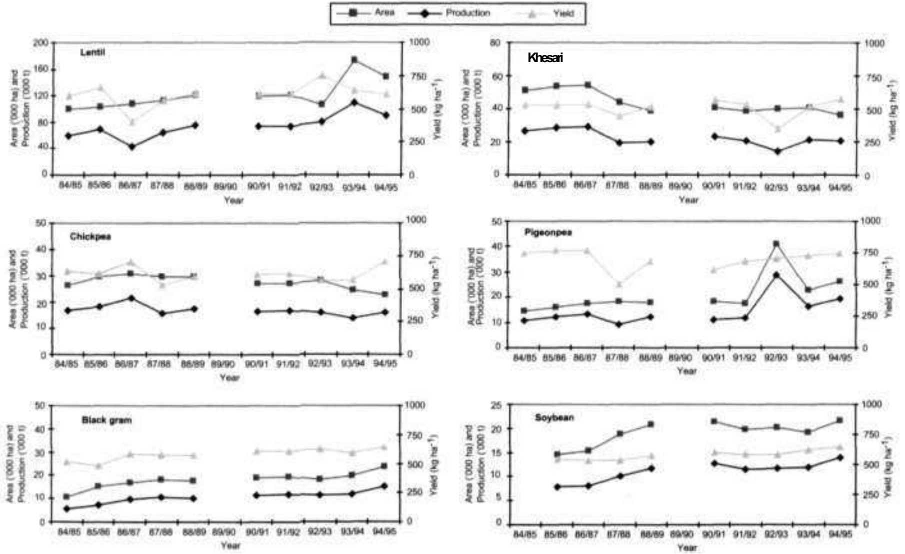

Figure 4.13. Trends in area, production, and yields of the major grain legumes in Nepal (Source: Manandhar and Shakya 1996). Data for 1989/90 not available.

Table 4.3. Diseases of major grain legumes, their distribution, and status in Nepal.

Disease	Causal organism	Distribution	Status
Lentil			
Vascular wilt	*Fusarium oxysporum* f. sp *lentis*	All lentil-growing areas, hill, inner Terai, and Terai	Major
Collar rot	*Sclerotium rolfsii*	Rice-based cropping system	Major
Black root rot	*Fusarium solani*	Hill and Terai	Minor
Rust	*Uromyces viciae-fabae*	Hill and Terai	Major (sometimes)
Gray mold	*Botrytis cinerea*	Hill and Terai	Major (sometimes)
Alternaria blight	*Alternaria alternata*	Hill and Terai	Minor
Pea seedborne mosaic	Pea seedborne mosaic virus	Hill	Minor
Wet root rot	*Rhizoctonia solani*	Hill and Terai	Minor
Pigeonpea			
Wilt	*Fusarium udum*	All pigeonpea-growing areas	Major
Sterility mosaic	Virus (?)	All pigeonpea-growing areas	Major (sometimes)
Alternaria blight	*Alternaria* sp	Eastern Terai and inner Terai	Major in late-sown or rabi pigeonpea
Collar rot	*Sclerotium rolfsii*	Sporadic across whole of lerai	Minor
Macrophomina stem canker	*Macrophomina phaseolina*	All pigeonpea-growing areas (more in western Terai)	Major (sometimes)
Yellow mosaic	Mung bean yellow mosaic virus	Sporadic across whole of Terai	Minor
Phyllosticta leaf spot	*Phyllosticta cajani*	Sporadic across whole of Terai	Minor
Cercospora leaf spot	*Cercospora* sp	Sporadic across whole of Terai	Minor
Botrytis gray mold	*Botrytis cinerea*	Sporadic across whole of Terai	Minor
Chickpea			
Botrytis gray mold	*Botrytis cinerea*	Major in all chickpea growing areas but less in western Terai	Major
Fusarium wilt	*Fusarium oxysporum* f sp. *ciceris*	Major in all chickpea growing areas but less in western Terai	Major
Alternaria blight	*Alternaria* sp	Sporadic across whole of Terai	Minor
Sclerotinia stem rot	*Sclerotinia sclerotiorum*	Sporadic across whole of Terai	Minor
Black root rot	*Fusarium solani*	Major in moist soil conditions	Major (sometimes)
Collar rot	*Sclerotium rolfsii*	Major in moist soil conditions	Major (sometimes)
Dry root rot	*Macrophomina phaseolina* (sclerotial state *Rhizoctonia balaticola)*	Sporadic across whole of Terai	Minor
Chickpea stunt	Bean (pea) leaf roll virus	Sporadic across whole of Terai	Minor
Soybean			
Frogeye leaf spot	*Cercospora sojina*	Hill and high hill	Major
Rust	*Phakopsora pachyrhizi*	Hill and valleys	Major

continued

Table 4.3 *continued*

Disease	Causal organism	Distribution	Status
Bacterial pustule	*Xanthomonas campestris* pv. *glycines*	Hill, valleys, and Terai	Major (sometimes)
Bacterial blight	*Pseudomonas syringae* pv. *glycinea*	Hill and valleys	Minor
Septoria brown spot	*Septoria glycines*	Hill and Terai"	Minor
Anthracnose	*Collectotrichum truncatum*	Hill and Terai	Major (sometimes)
Cercospora blight and leaf spot (purple seed stain)	*Cercospora kikuchii*	Hill and Terai	Minor
Pod and stem blight	*Phomopsis phaseoli*	Hill and Terai	Major (sometimes)
Red crown rot	*Calonectria crotalariae*	Hill and Terai (major in waterlogged conditions)	Major (sometimes)
Soybean mosaic	Soybean mosaic virus	Hill and Terai	Minor
Yellow mosaic	Mung bean yellow mosaic virus	Terai	Major
Black gram and mung bean			
Cercospora leaf spot	*Cercospora* sp	Hill and Terai	Major
Yellow mosaic-	Mung bean yellow mosaic virus	Hill and more in Terai	Major
Powdery mildew	*Erysiphe polygoni*	Hill and Terai	Major (sometimes)
Groundnut			
Early leaf spot	*Cercospora arachidicola*	Hill and Terai	Major
Late leaf spot	*Phaeoisariopsis personata*	Hill and Terai	Major
Rust	*Puccinia arachidis*	Hill and Terai	Minor
Sclerotium stem rot	*Sclerotium rolfsii*	Hill and Terai	Minor
Bud necrosis	Bud necrosis virus	Hill and Terai	Major (sometimes)
Faba bean			
Rust	*Uromyces viciae-fabae*	Hill and Terai	Major
Chocolate spot	*Botrytis fabae*	Hill and Terai	Major
Root rot and wilt	*Fusarium* spp and *Rhizoctonia solani*	Hill and Terai	Minor
Pea seedborne mosaic vims	Pea seedborne mosaic virus	Hill	Minor
Bean yellow mosaic	Bean yellow mosaic virus	Hill	Minor
Pea			
Pea seedborne mosaic	Pea seedborne mosaic virus	Hill and Terai	Major
Powdery mildew	*Erysiphe pisi*	Hill and Terai	Major
Aphanomyces root rot	*Aphanomyces euteiches*	Hill	Minor

Source: Joshi, Sharada, Nepal Agricultural Research Council, personal communication, 1997.

causing as high as 100% loss in yield (NARSC 1989). Regular epidemics of BGM discouraged farmers in the eastern part of the country from cultivating chickpea. As a result the area under chickpea in this region has shown a declining trend and the chickpea area has shifted from the eastern to western Terai districts. Other important and widespread diseases of chickpea are fusarium wilt, collar rot, and black root rot.

Soybean. Cereospera blight and leaf spot, pod and stem blight, and rust are the major diseases (Table 4.3). Rust causes a serious loss in productivity and is distributed in the hilly regions of the country.

Black gram and mung bean. Cereospera leaf spot and yellow mosaic are the major diseases (Table 4.3). Powdery mildew is also observed in some areas of the country.

Groundnut. Leaf spot (early and late) and rust arc considered as the major diseases for groundnut (Table 4.3).

Khesari (lathyrus). Only powdery mildew has been observed in some parts of the country, and its effect on yield reduction is yet to be quantified.

Insect pests

There are a large number of insect pests that infest the legumes (Table 4.4) but only some of them are a threat to the crop. For example, the pod borer (*H. armigera*) is a very serious pest that can cause more than 60% yield damage in chickpea on farmers' fields of Banke and Bardia districts located in the western part of the country (Thakur 1997). It is also a serious pest of pigeonpea. Similarly, *Spilosoma* (*Diacrisia*) *obliqua* Walker (hairy catterpillar) is a major pest of soybean, black gram, mung bean, and groundnut. Aphids are commonly found on khesari (lathyrus), mung bean, black gram, cowpea, and lentil, particularly during dry spells. Insect pests are also major problems in storage where they can damage the seed and cause loss of seed viability. Seeds of pulses are severely damaged by the bruchids, *Callasubruchus chinensis* (L.) and C. *maculatus* Fab.

Weeds

Farmers consider legumes as minor crops and generally do not weed their crops. They allow the weeds to grow and cut them as green forage for cattle as needed in some of the legume crops, particularly pigeonpea. Hence weeds compete with legumes for light, water, nutrients, and space and can cause substantial yield losses. Little research work has been done in this area. Aziz (1993) reported that grain yield loss due to unrestricted weed growth in lentil was around 25% and the critical period of weed competition ranged from 20 days to 30 days after emergence. Depending upon the duration of the crop, the critical period for weed competition in pulses varies from 20 days to 45 days after sowing. Most farmers perform only two operations (sowing and harvesting) in the cultivation of winter grain legumes. As a result, crops are often heavily infested with weeds. Several species of weeds have been recorded in legume crops of which *Cyperus rotundus* L. (nut grass), *Chenopodiwn album* L. (lamb's quarters), and *Vicia sativa* L. (common vetch) are noted as major ones (Table 4.5).

Abiotic Constraints

Various climatic and soil factors limit the productivity of both winter and summer food legumes grown in different agroecological zones in Nepal. Among these, early and terminal drought, excess moisture, adverse temperatures, high humidity, and poor soil fertility are major constraints.

Table 4.4. Insect pests of major grain legumes in Nepal, 1997.

Crop	Insect pests	Status
Lentil	*Agrotis ipsilon* Hufnagel	Major pest in Terai
	Agrotis segetum Schiff.	Major pest in Hill
	Acrythosiphon pisum Harris	Major pest in some geographic regions
	Helicoverpa armigera Hubner	Major pest universally
	Callosabruchus chinensis L.	Major
	Callosobruchus maculatus Fab.	Major
	Phyllotreta sinuata Redt.	Minor
	Athalia sp	Minor
	Adonia variegata Goeze	Minor
Chickpea	*Agrotis ipsilon* Hufnagel	Major pest in Terai
	Agrotis segetum Schiff.	Major pest in Hill
	Plusia orichalcea F.	Major pests in some geographic regions
	Helicoverpa armigera Hiibner	Major
	Callosobruchus chinensis L.	Major
	Callosobruchus maculatus Fab.	Major
Faba bean	*Aphis fabae* Scopoli	Major-
	Aphis craccivora Koch.	Minor
	Nezara antennata Scott.	Minor
	Helicoverpa armigera Hubner	Minor
Pea	*Acrythosiphon pisum* Harris	Major
	Helicoverpa armigera Hiibner	Major
	Bruchus pisorum L.	Major
	Macrosiphum pisum Harris	Minor
	Taeniothrips flavidulus	Minor
	Empoasca sp	Minor
	Phytomyza atricornis Meig	Minor
	Lampides boeticus L.	Minor
Pigeonpea	*Melanagromyza obtusa* Malloch	Major
	Ophiomyia phaseoli Tryo.	Major
	Ophiomyia centrosematis Meijere	Major

continued

Table 4.4 *continued*

Crop	Insect pests	Status
	Bemisia tabaci Genn.	Major
	Callosobruchus maculatus Fab.	Major
	Callosobruchus chinensis L.	Major
	Helicoverpa armigera Hiibner	Major
	Spodoptera litura Fab.	Major
	Exelastis atomosa Walsingham	Major
	Maruca testulalis Geyer	Major
	Alcidodes sp.	Sporadic and minor
	Empoasca fabae Harris	Sporadic and minor
	Nezara viridula L.	Minor
	Liriomyza cicerina Rondani	Minor
	Aphis craccivora Koch.	Minor
	Etiella zinckenella Treitschke	Minor
	Lampides boeticus L.	Minor
Khesari (lathyrus)	*Aphis craccivora* Koch.	Minor
Mung bear	*Spilosoma* (*Diacrisia*) *obliqua* Walker	Major
	Maruca testulalis Geyer	Major
	Helicoverpa armigera Hiibner	Major
	Callosobruchus chinensis L.	Major
	Callosobruchus maculatus F.	Major
	Agrotis ipsilon Hufnagel	Minor
	Aphis craccivora Koch.	Minor
Cowpea	*Maruca testulalis* Geyer	Major
	Bemisia tabaci Genn.	Major
	Aphis craccivora Koch.	Major
	Melanagromyza sp	Major
	Callosobruchus maculatus Fab.	Major
	Callosobruchus chinensis L.	Major
	Empoasca fabae Harris	Minor
	Nezara viridula L.	Minor

Source: B.K. Gyawali, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal, personal communication,1997.

Table 4.5. Common weeds of lentil in Nepal.

Botanical name	Common name	Family
Cvperus rotundus L.	*Motha;* nut grass	Gramineae
Cynodon dactvlon (*L.*) Pers.	*Duvo;* Bermuda grass	Gramineae
Anagalis arvensis L.	Pimpernal	Primulaceae
Capsella bursa-pastoris (L.) Moench)	Shepherd's purse	Cruciferae
Chenopodium album L.	Lamb's quarters	Chenopodiaceae
Spergula arvensis L.	Corn-spurry	Caryophyllaceae
Sciene-biera pinnatifida	Swinecress	Crucifereae
Vicia hirsuta S.F. Grav	Tiny vetch	Leguminosae
Vicia sativa L.	Spring vetch; common vetch	Leguminosae
Alopecurus pratensis L.	Meadow foxtail	Gramineae
Phalaris minor Retz.	Small canary grass	Gramineae

Source. J.D.Ranjeet, Nepal Agricultmal Researchl, Khumaltar,

Early and terminal drought

Early and terminal drought stress is the major problem of legume production. The major legumes [lentil, khesari (lathyrus), and chickpea] are grown on conserved soil moisture in the postrainy season and invariably suffer from terminal drought if there is little or no winter rainfall. If the monsoon rains finish early or the winter legume crops are sown late, there may be insufficient soil moisture for proper germination and emergence, especially in lighter soils.

Excess soil moisture and humidity

Excessive rainfall can occur during the late monsoon season. This can cause substantial yield loss to winter legumes as it delays their sowing. If rainfall occurs at the reproductive stage, it damages flowers and encourages foliar diseases such as BGM in chickpea and lentil, rust in lentil, and leaf spots (early and late) in groundnut. Some of the diseases (e.g., BGM) can, in turn, cause complete yield losses.

High temperature

A sudden rise in temperature in late February and early March severely reduces vegetative growth and pod formation especially in late-sown crops of lentil and chickpea.

Mineral nutrition

Soil acidity poses a serious constraint to legumes in Nepal, where surface soil pH falls below 5.0. Acidity problems are greater in the eastern part of the country due to leaching of bases because of higher rainfall. Consequently, legumes face P deficiency and nodulation problems. Boron has been shown to be a major yield reducer of chickpea and lentil, at least in the inner Terai (Srivastava et al. 1997, 1999). These researchers also report Mo responses in chickpea and Zn responses in lentil. As legumes are generally relegated to more marginal soils, the likelihood of them being limited by nutrient deficiencies increases.

Socioeconomic Constraints

Despite the importance of pulses in Nepalese farming systems, they have only subsidiary status in the total farming systems due to the greater importance given to cereals as staple food crops. Pulses have lower stability in production and higher losses in storage than cereals. Their market prices also fluctuate widely. The Government's as well as farmers' priority is the production of cereal crops such as rice, maize, and wheat. Farmers consider legumes as very sensitive to diseases, pests, and weather conditions; thus high and stable yields cannot be assured.

Crop establishment

As a consequence of the lower status given to pulse crops, farmers take inadequate care of them at sowing, despite availability of knowledge of optimum sowing techniques. Recommended seed rates to obtain optimum plant stands are not followed and usually seed of poor quality (having low germination rate) is used. Pulses are usually broadcast sown on an inadequately prepared seedbed. The net result is poor and uneven plant stands, which mitigate against achieving high yields at an early stage.

Input use

Farmers give least preference to applying agricultural inputs, such as fertilizers or plant protection measures, to pulses. In Nepal, such inputs are relatively high priced and often scarce, and thus reserved for cereals or high value crops. Further, application of fertilizers and irrigation to legume crops can result in excessive vegetative growth, with resultant lodging, disease infestation, and low yield.

Profitability

Lack of storage knowhow and capability for legume grains results in a low farm gate price, with high seasonal fluctuations. Thus, despite low input costs, profitability is low for farmers. There are no organized marketing channels or Government support prices for grain legumes, as for cereals. Low-income farmers bear most of the risk associated with legume production.

Role of Legumes in Cropping Systems

Legumes are mostly grown under rainfed rice-based systems. Therefore, legumes have a special role in the rainfed agricultural system. Because of their deep root systems, ability to produce at least some grain under drought conditions, and general hardy nature, legumes are being used by farmers as risk reduction crops and are intermixed or relay cropped with major cereals (Fig. 4.14). The highly diverse environment in Nepal allows cultivation of different species of legumes. At least twelve grain legume species occur in various agroclimatic conditions of the country. In the monsoon climate that prevails in Nepal, 80% of rainfall occurs during Jul and Sep. Moisture is the limiting factor to successful crop production during winter, from about Nov to Apr, where irrigation is not available. Legumes present various opportunities under these conditions.

Grain legumes are important crops because of their high protein content and in-built capacity to utilize atmospheric N. They help in increasing soil fertility by fixing atmospheric N and improving the soil structure through their deep root system and additions of organic matter to the soil. Since N is the most deficient plant nutrient in Nepalese soils, input of N into the soil is, therefore, essential to increase crop productivity. Thus, the role of legumes in this regard is very important. The amount of N fixed by legumes under various on-farm conditions in Nepal is 33-56 kg ha^{-1} (Pandey et al. 1998). Grain legumes have also proved ideal for growing as mixed crops and intercropping under dryland farming situations of the country.

Farmers' response in] 1 districts on residual effects of legumes in their subsequent crops also revealed that legumes, in comparison to wheat or fallow land, contribute to enhanced yields of rice to the extent of 10-35% (Pande and Joshi 1995).

Pulses are predominantly grown as associated and relay crops with cereals and oilseeds. The summer species are mixed with maize and finger millet (*Eleusine coracana* (L.) Gaertn.) in the hills and some species such as black gram, soybean, pigeonpea, and mung bean are also grown on paddy bunds in low-lying areas. Winter legumes,

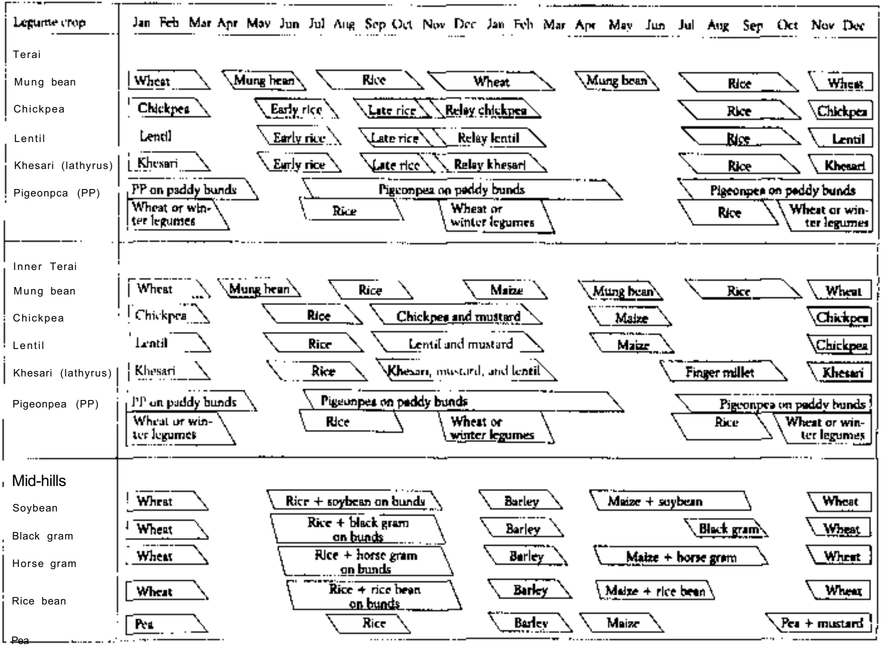

Figure 4.14. Representative cropping systems in major grain legumes producing regions of Nepal (Source: Rachie and Bharati 1985).

especially lentil, chickpea, and khesari (lathyrus), are often intermixed with winter crops such as barley (*Hordeum vulgare* L.), mustard (*Brassica* sp), and linseed (*Linum usitatissimum* L.). Sometimes they are sown as relay crops with late rice when winter moisture is limiting. In other cropping patterns, short-duration mung bean and cowpea are increasingly being planted as catch crops between wheat and rice in irrigated areas of the Terai. The major cropping systems incorporating grain legumes are discussed as follows (Fig. 4.14).

Lentil

Lentil is cultivated as a sole and relay crop with summer season rice and maize in the Terai and inner Terai regions of the country. It is broadcast on saturated soils by the end of Oct to mid-Nov, about 10-20 days before the rice harvest, as a relay crop. Lentil is also grown after upland maize. Lentil is usually sown in Oct-Nov as a mixed crop with mustard; this system is expanding.

Chickpea

Chickpea is grown on relatively heavier soils under the rice-chickpea cropping system. Also, chickpea is cultivated as a mixed crop with linseed, barley, and mustard.

Khesari (Lathyrus)

Khesari (lathyrus) is still the second most important pulse crop in Nepal. It is cultivated as a relay crop with rainy season rice in medium lowland areas of the country. It is broadcast on the saturated soils by the end of Oct to early Nov, about 10-12 days before the paddy harvest. It is the hardiest crop among pulses and can thrive in soils with excess or deficit moisture. Khesari (lathyrus) requires no major input costs and the yield is stable. It faces no major insect or disease problems in the country. But the area of khesari (lathyrus) is decreasing as the Government has banned this crop. Local landraccs have stable yields but are high in neurotoxin content.

Pigeonpea

Pigeonpea is the third most important legume in Nepal. It is mostly grown under upland conditions as a sole crop or mixed crop with maize and on paddy bunds. Pigeonpea on paddy bunds is very popular in the eastern part of the country whereas it is grown mainly as a sole crop in the western part and as a mixed crop in the mid-hills and inner Terai. Long-duration varieties are grown in the western part of the country whereas medium-duration varieties and rabi (postrainy season) pigeonpea are popular in the eastern part. Generally, normal season planting is done during Jun-Jul, with the onset of monsoon rains, whereas rabi planting is done in Aug-Sep.

Soybean

Soybean is a major legume in the mid-hill region of the country. It is mainly grown as a mixed crop with maize. As the maize crop normally receives some intercultural operations and inputs, these factors also contribute to soybean production. Soybean is also grown as a sole crop in some parts of inner Terai where there is market accessibility. It is also grown on paddy bunds in the mid-hills and inner Terai.

Black Gram

Black gram is a comparatively hardy pulse crop and is mostly grown in well-drained upland mid-hill regions of the country after maize harvest or is intercropped with maize. It is a photoperiod-sensitive crop and is location specific. Much genetic variation has been observed in this crop in Nepal. In some areas, scented genotypes have been recorded. It is a most profitable crop for the farmer because it commands a good market price. Yellow mosaic is the major constraint of production in this crop.

Mung Bean

Mung bean area is very much concentrated in the eastern part of the country. It is mostly grown in the RWCS where irrigation facilities are available. It is sown in Mar-Apr and harvested before the onset of the monsoon rains. One or two pickings of pods are done and then the crop residue is incorporated into the soil as a green manure.

Groundnut

Groundnut is mostly grown in a groundnut-mustard cropping pattern in the upland sandy soils and river basin areas of the country. It is planted in May-Jun and harvested in Oct-Nov. Groundnut and pigeonpea intercropping is very popular in some areas of the country where a winter crop is not feasible due to soil moisture deficit.

National Policies and Emphasis Towards Legumes Production

In Nepal, a major portion of cultivated area in the country is under rainfed conditions and pulses have adjusted well in different mixed and intercropping situations and crop rotations. There has been a 30% increase in availability of grain legumes during 1984/85 to 1995/96, as compared to the 2.5% per annum population growth rate. Future research strategies should emphasize the development of short-duration, high-yielding, disease-resistant varieties for multiple cropping systems. Despite the importance of legume crops in Nepal, the 20 years Agriculture Perspective Plan has not considered them as priority crops. However, recently their importance has been realized in national policy considerations.

Prioritization of the Crops

- Relative importance of grain legume species in the national economy in the Terai - lentil, chickpea, pigeonpea, and khesari (lathyrus).
- Location-specific needs, based on environment, food requirement, and cropping systems in the mid-hills - soybean, pea (*Pisum sativum* L.), common bean (*Phaseolus vulgaris* L.; French bean), and black grain.
- Import substitution/export promotion - pigeonpea, chickpea, and lentil.
- Focus on mixed cropping, intercropping and relay cropping - lentil and khesari (lathyrus).

Future Research Priorities for Grain Legumes in Nepal

- Breeding varieties resistant to major biotic constraints such as diseases, insect pests, and nematodes.
- Improving yield levels by developing input-responsive improved plant types.
- Evolving early-maturing varieties suitable for different cropping patterns (intercropping, relay cropping, and sole cropping).

- Germplasm collection and evaluation.
- Identification of efficient strains of *Rhizobium.*
- Development of integrated pest management systems.
- Development of better agronomic practices for major pulses and production systems and postharvest technology.
- Initiate systematic research on horse gram, pea, common bean, and black gram.

Prospects for Increased Production and Use of Legumes

The wide gap between the potential and the national average yields shows that there is a great scope for increasing the grain legume production in Nepal. Moreover, about 30% of the total rice area (420,000 ha) still remains fallow during winter due to various reasons such as lack of soil moisture and late rice planting and harvesting. If this area can be tapped for extending legume cultivation by focused efforts on research and development, legumes area can be doubled. The production can be increased by both increasing productivity and bringing additional area under legumes.

Increasing Crop Productivity

Crop productivity can be increased by popularization of improved varieties of legumes, phosphatic fertilizers, and providing one or two need-based light irrigations. The current technology allows an immediate possibility of raising legumes production. The components of the crop production strategy are discussed below.

Summer mung bean/cowpea/black gram cultivation

There has been an increase in the area under irrigation in Nepal. This has resulted in greater opportunities for increasing the cropping intensity of the farm units. One of the most promising technologies of legumes production in the country has been the cultivation of summer mung bean or cowpea in the irrigated areas. Not only are more synchronous varieties of summer mung bean and cowpea available but new early-maturing, disease-resistant cultivars are making their appearance. Agronomic requirements of this wheat-legume-rice system have also been established.

Extension of early-maturing pigeonpea genotypes in the wheat/maize-mustard belt

A number of early-maturing pigeonpea genotypes which can vacate fields well in time for timely planting of wheat are now available and pigeonpea-wheat or maize-rabi pigeonpea rotations can be followed. The yield potential of these genotypes is 1.5-2.0 t ha^{-1}. There is apparently a great scope for introduction of these genotypes in irrigated areas where long-duration pigeonpea is otherwise an important crop.

Intensified seed production program

There is a great and continuing shortage of seed of improved varieties of pulses. There is thus an urgent need for a large-scale seed production program in the country, that will facilitate the availability of quality seeds of improved varieties to farmers.

Extensive plant protection measures

As pod borer (H. *armigera*) causes serious damage to pulse crops, on-farm implementation of integrated pest management strategies is required. This would involve greater use of cultivars showing some resistance to insect attack or ability to escape from it, combined with need-based use of pesticides, both chemical and biological [nucleopolyhedro virus (NPV)|.

Increasing Area

An extension of area under grain legumes is possible with improved technology available as discussed below.

Irrigated command areas

Double cropping with early- or extra-early-maturing pigeonpea cultivars which mature in 120-155 days can expand the area under pigeonpea. These varieties, if planted as a summer crop in Apr-Jun, with the onset of monsoon rains, can be harvested by late Oct and thus enable normal planting of a wheat crop by mid-Nov. Cultivation of rabi pigeonpea varieties is another possibility and this has resulted in more stable yields than sowing in summer, mixed with maize or millets, as traditionally done. Early-maturing summer mung bean and cowpea varieties released for irrigated areas should be popularized. Intercropping of black gram and mung bean in sugarcane and cotton (*Gossypium* sp) can be extended.

Rainfed areas

Short-duration varieties of lentil and neurotoxin-free khesari (lathyrus) should be popularized for rice fallow areas. The relay cropping of lentil and khesari (lathyrus) has great potential in rice-based systems and large areas can be covered. The seeds, however need to be treated with efficient strains of *Rhizobium.* In the eastern Terai, in conditions of extreme waterlogging and where soils become very hard after drying, neurotoxin-free varieties of khesari (lathyrus) are likely to be more successful than lentil. Intercropping of black gram with maize can be expanded in the mid-hills. Pigeonpea as an intercrop with maize, groundnut, or cotton is another cropping system with potential for expansion.

An integrated approach by government and non-governmental organizations to develop enthusiasm among the farmers for the cultivation of legumes should be attempted. Growing of cereal-cereal sequences may not be sustainable in the longer term because of declining soil health. Therefore, attempts are needed to ensure that legumes at least occasionally break such sequences, as their positive effects on soil health in the IGP region have been well documented (Kumar Rao et ai. 1998).

Conclusion

The grain legumes are predominantly grown as associated and relay crops with cereals and oilseeds. The summer legumes are grown mixed with maize and finger millet in the hills. Some of the legumes such as black gram, soybean, and pigeonpea are also grown along with rice on the bunds of paddy fields. The winter grain legumes [lentil, khesari (lathyrus), chickpea] follow the rice crop and are often intermixed with wheat, barley, mustard, and linseed. They are also occasionally relay planted with late rice when moisture would be limiting. Mung bean and cowpea are at times planted as catch crops for grain and/or green manuring between wheat and rice in irrigated areas.

During the past 10 years (1984/85-1995/96), the area, production, and yields of legume crops have increased on an average by 27%, 60%, and 15% respectively. As a result, the per capita availability of legume grain has increased by 30% from 7 kg person^{-1} annum^{-1} in 1984/85 to ~ 10 kg person^{-1} annum^{-1} in 1995/96 despite a population growth rate of 2.5% per annum. Yet, the per capita legume availability is only one-third of the requirement of 36 kg person^{-1} annum^{-1} (FAO 1981). The slight improvements are probably driven partly by the promotion of export markets and favorable price in the local market and partly by the research and development efforts, particularly in the lentil crop. The winter grain legumes that are predominantly grown in rice-wheat systems occupy a more important place than the summer legumes, by sharing more than 75% of total legume area. Nevertheless, the summer legumes have equal importance in maize-based cropping systems particularly in the hill region.

Among the winter grain legumes, lentil alone occupies 67% of the area and contributes nearly 70% of the total production. The other winter legumes, khesari (lathyrus), pigeonpea, and chickpea, rank second, third, and fourth respectively in coverage and production in the country. Therefore, lentil is the most dominant grain legume grown in RWCS in Nepal.

Insect pests (mainly pod borers] and diseases (mainly foliar) are the most important biotic constraints to legumes production in Nepal. Among abiotic stresses drought ranks as the most widespread and severe yield reducer of chickpea and lentil. There is a need to assemble and validate the available genetic and agronomic components of alleviating biotic and abiotic stresses, so as to develop practical production packages that would result in higher and more stable yields of grain legumes. More detailed constraints analyses than this generalized one would facilitate focused research and development priority setting, so as to better attract funding support to this important aspect of agricultural production and sustainability in Nepal.

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5. Legumes in Pakistan

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Abstract

Agricultural scientists and policy makers in Pakistan are particularly concerned about the demand for food grains for the increasing population of the country. This could be achieved by narrowing yield gaps and raising yield potential of the major grain crops. Wheat and rice are the main staples of Pakistan, yet the food legumes are of strategic importance for the economy and for human nutrition. Agriculture in the country is confronted with the dual problem of low productivity/production of important grain legumes and stagnant and/or declining productivity of the rice-wheat cropping system, the predominant cropping system in Pakistan. Legumes are grown for food, fodder, and green manure. Major food legumes are chickpea, lentil, mung bean, and black gram. Khesari (lathyrus) is exclusively grown in Sind Province as a dual purpose (fodder and grain) legume. While helping the poor to combat malnutrition, legumes can also play a vital role in amending soil health and sustaining productivity, especially of rice-wheat cropping systems. Various biotic and abiotic stresses combined with socioeconomic factors hamper increased production of legumes. All of the legumes, especially mung bean can fit very well in rice-wheat cropping systems. Development of short-duration and disease-resistant cultivars of legumes could prove instrumental in augmenting production of these crops as well as improving the soil health and quality. Production technology appropriate to evolving cropping systems and changing agro-ecological circumstances also needs to be developed and extended to farmers. This chapter discusses factors affecting legume production in Pakistan with the aid of geographic information system (GIS) analysis in mapping area and production of the major grain legumes and identifying locations of the major biotic and abiotic stresses.

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Introduction

In view of the increasing human population and demand for food grains, agricultural scientists are becoming increasingly concerned about the need to close yield gaps and raise yield potential of the major crops in Pakistan. Although most of the food requirement is met from cereals, mainly rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.), an increase in grain legume production is imperative to meet the protein needs of the population. Grain legumes are termed as "gold from the fields" as they are the cheapest source of high quality protein that can help the poor in combating malnutrition. They also can play a vital role in amending soil health, especially in rice-wheat cropping systems (RWCS), which are under threat of declining productivity.

In the rice belt, yield of wheat after rice is unsatisfactorily low (Byerlee et al. 1986). The major concern is to reverse the declining trend in productivity of RWCS so as to ensure food security and self-sufficiency in production. The cereal-cereal cropping system is inherently exhaustive and causes a negative balance of major mineral nutrients even with the application of recommended doses of nitrogen (N) and phosphorus (P) fertilizers (Zia et al. 1992). Greater use of food, fodder, and green manure legumes could improve soil quality and hence productivity and sustainability of rice-wheat rotations.

The major food legumes grown in Pakistan are chickpea *(Cicer arietinum* L.), lentil (*Lens culinaris* Medic), mung bean *(Vigna radiata* (L.) Wilczek), black gram (*Vigna mungo* (L.) Hepper), and khesari (*Lathyrus sativus* L.; lathyrus; grass pea). In addition to these, pigeonpea *(Cajanus cajan* (L.) Millsp.), cowpea *(Vigna unguiculata* (L.) Walp.), moth bean (*Vigtui aconitifolia* (Jacq.) Marechal), common bean (*Phaseolus vulgaris* L.; French bean), and faba bean (*Vicia faba* L.) are minor pulses grown in extremely small areas. All these legumes occupy an area of approximately 1.5 million ha and contribute about 4% of the total grain production of the country. Area and production of lentil and black gram has significantly declined, that of chickpea remained static while that of mung bean has increased in the past decade. The alarming situation of drastic increase in the prices of pulses in general and of lentil and black gram in particular as a consequence of decrease in area and production needs to be addressed.

The main fodder legumes grown in Pakistan are khesari (lathyrus), berseem clover *(Trifolium alexandrinum* L.; Egyptian clover), senji (*Melilotus alba* Desr.; white sweet clover), moth bean, cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.; gaur), and *Sesbania aculeata* Pers. *Sesbania,* cluster bean, and berseem are also used as green manure crops on 5% of the total cultivated land area.

The ultimate goal of future research and development efforts is to increase food legumes production, stabilize income of farm families producing legumes, and bridge the gap between expanding demands and declining per capita availability through:

- Development of high-yielding, disease-resistant, and short-duration varieties;
- Refinement of existing food legumes production technology;
- Establishment of sustainable seed production and dissemination systems for important food legumes; and
- Expansion of area under legume cultivation in the country, e.g., by growing mung bean in rice-wheat areas (mung bean-rice-wheat) and in cotton (*Gossypium* sp)-growing areas (cotton-mung bean-mung bean-wheat-cotton).

The objective of this chapter is to present the current status of legumes in Pakistan, examine recent trends in production, and discuss future prospects. This is done against the background of the agro-environment and socioeconomic influences of where they are grown.

Area, Production, and Productivity

The districts, provinces and major urban centers of Pakistan are given in Figure 5.1. The minor contribution of food legumes in relation to cereals, and the widening gap over time, is illustrated in Figure 5.2. Production of chickpea, lentil, black gram, and khesari (lathyrus) has either remained constant or has declined over the past decade (Fig. 5.3). Area and production of mung bean has increased during recent years (Fig. 5.3) because of introduction of short-duration, synchronous-maturing varieties and availability of irrigation water. The productivity (yield) is essentially stagnant but with some declines during years of severe disease infestation and drought.

Natural calamities such as drought and disease stress render food legumes risky crops and discourage farmers from growing them, resulting in a general decrease in area and production over time. For example, the decrease in area under pulses in 1987/88 and 1988/89 (Fig. 5.3) was due to prolonged drought prevailing in the country especially at planting time. Lentil and black gram were particularly affected. Cultivation of these two crops was mainly concentrated in Sialkot division. With availability of irrigation water in rainfed areas of Sialkot where these pulses were grown, the farmers have shifted to wheat and rice cultivation which they consider as more stable crops. This change occurred due to heavy infestation of weeds and diseases in these legumes with more widespread use of irrigation.

Agroclimatology and Legume Production

Pakistan is located within 24-37°N and 60-75°E (Fig. 5.1). There are four conspicuous seasons in Pakistan: winter, spring, summer, and autumn. Out of a total geographical area of 79.61 million ha only 20.40 million ha are under cultivation. Approximately 80% of

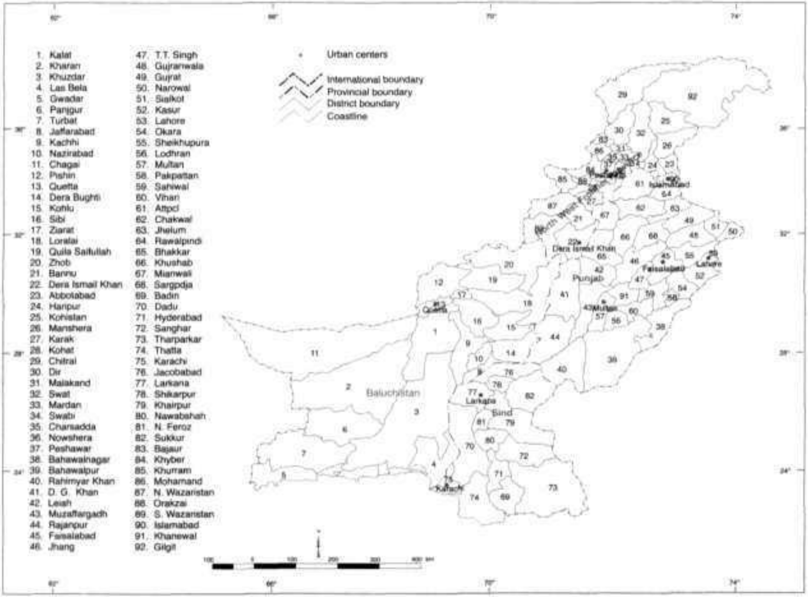

Figure 5.1. Administrative boundaries and major urban centers of Pakistan.

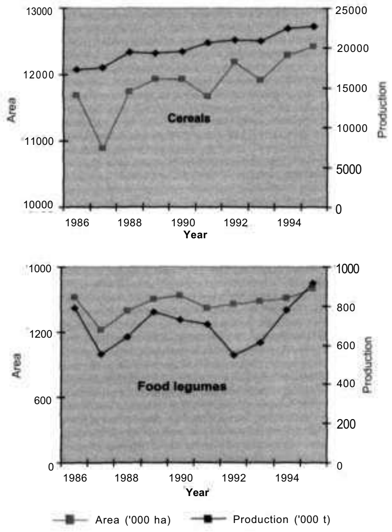

Figure 5.2. Area and production of cereals and food legumes in Pakistan between 1986/87 and 1995/96 (Source: Government of Pakistan 1995-96).

cultivated area is irrigated and the remaining is rainfed (Government of Pakistan 1997-98). Because of the extensive and complex network of irrigation canals, over a level ground area, serious problems of salinity and sodicity have developed in some areas. In cultivated areas, summer average night-day temperatures are 27°C to 45"C (May to Jul) and winter average night-day temperatures are 5°C to 20°C (Dec to Jan). Sometimes, temperatures exceed 45°C and drop down below zero causing heat stress and cold stress problems to crops. Agricultural soils of Pakistan are mainly alluvial and vary from clayey to sandy soils (Fig. 5.4). Clay loam and sandy loam soils are more common. The major crops grown are wheat, rice, cotton, and sugarcane (*Saccharum officinarum* L) while food legumes are relatively minor crops. Annual rainfall and length of growing period distribution in Pakistan are shown in Figures 5.5 and 5.6 respectively. Climatic patterns of four locations representative of major legume-growing regions of the country are shown in Figure 5.7.

Grain legumes are generally cultivated all over the country but they are mainly relegated to marginal soils of rainfed areas. These crops are regarded as requiring minimum agricultural inputs and as labor non-intensive. They are largely confined to subsistence farming and large-scale farmers seldom grow grain legumes.

A brief account of agroelimatic features pertaining to major food legumes is given below,

Chickpea

The major chickpea-producing area is Thal region which contributes about 80% of chickpea production (Fig. 5.8). Thal includes Khushab, Mianwali, Bhakkar, Leiah, and Jhang districts in Punjab Province and Dera Ismail Khan and Bannu districts in North-West Frontier Province (NWFP). The climate of these districts is hot and windy during

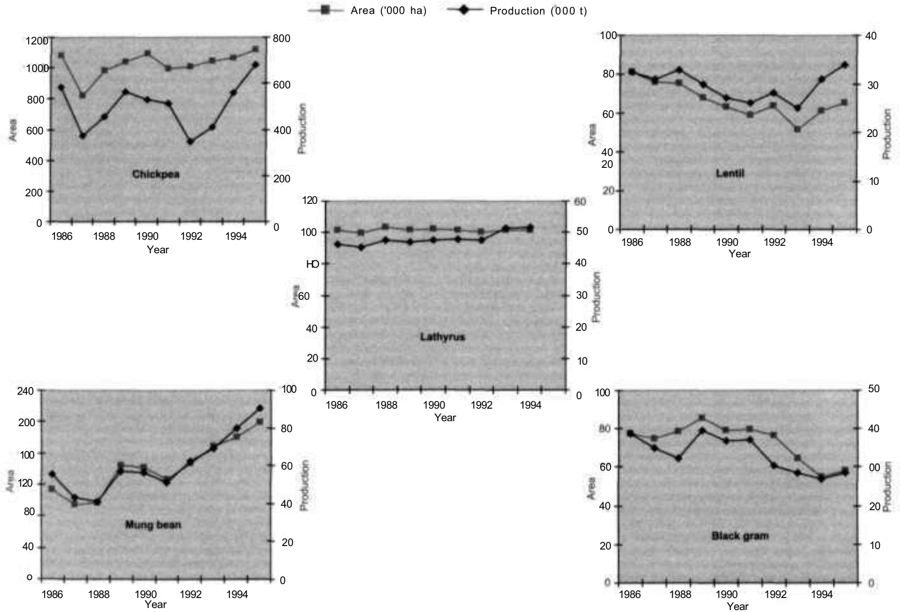

Figure 5.3. Area and production of the major food legumes grown in Pakistan between 1986/87 and 1995/96 (Source: Government of Pakistan 1995-96).

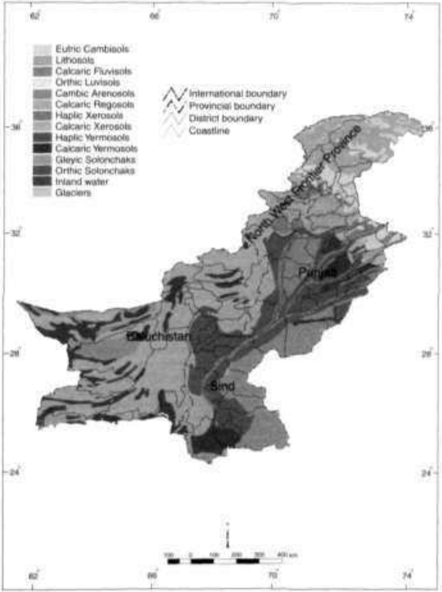

Figure 5.4. The soils of Pakistan according to the FAO-UNESCO World Soil Map.

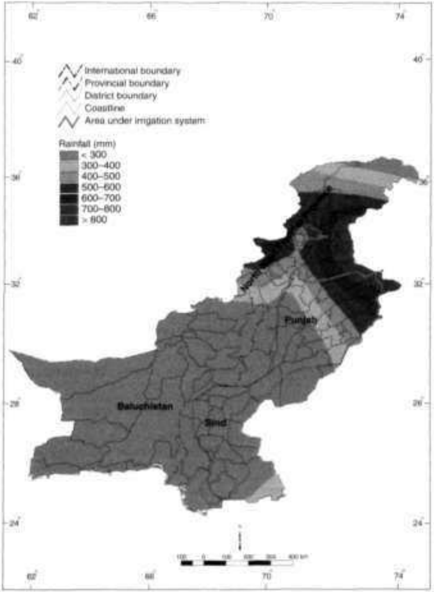

Figure 5.5. Annual average rainfall pattern in Pakistan (Source: International Water Management Institute).

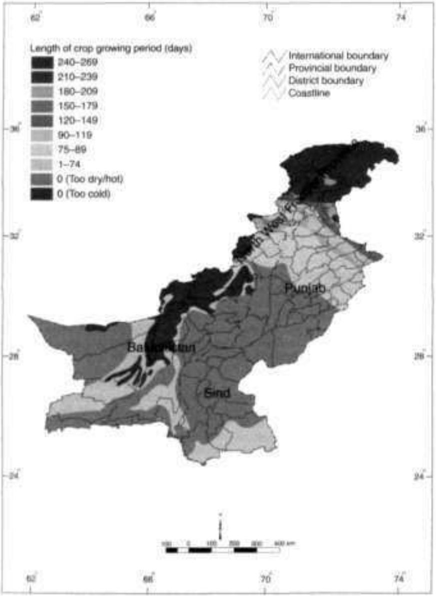

Figure 5.6. Length of crop growing period in Pakistan (Source: FAO, Rome).

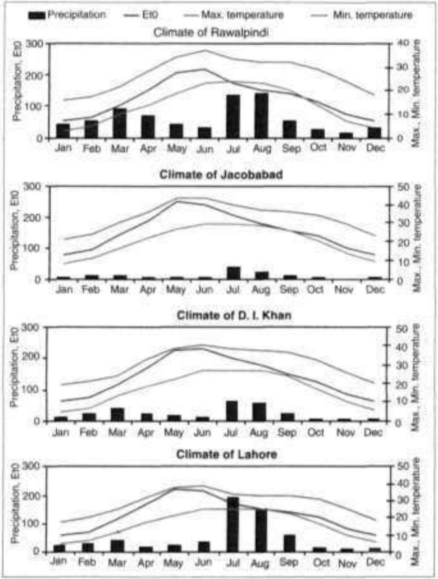

Figure 5.7. Mean monthly precipitation, evapotranspiration (EtO), and maximum and minimum temperatures at locations in major legume-growing regions of Pakistan.

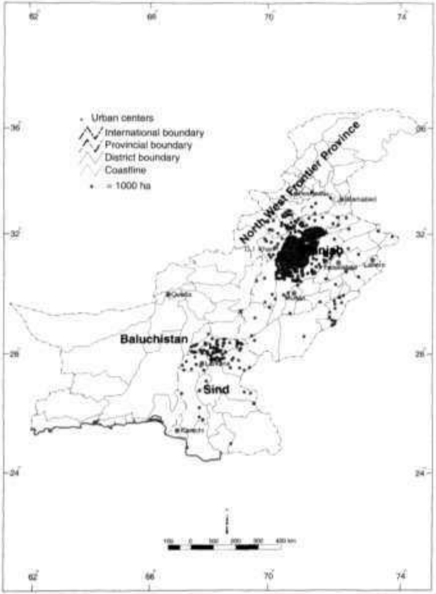

Figure 5.8. Distribution of chickpea in Pakistan, 1994/95 (Source: Government of Pakistan 1994/95).

summer and mild in winter. On the basis of long-term data (more than 20 years) obtained from Khushab, Dera Ismail Khan, and Multan located in the vicinity of Thal, average annual rainfall varies from 261 mm to 385 mm in the northeast and around 169 mm in the south (Fig. 5.5). The annual rainfall follows a bimodal pattern, with about 7096 occurring in summer (Habib et al. 1991).

The soils of the Thal chickpea-growing area in Pakistan are mixed calcareous alluvium which was deposited by either the Indus, Chenab, or Jhelum rivers. Almost the entire area is undulating with sand dunes and interdunal valleys. The soil on dunes is sandy and in the valleys is loamy. There are floodplains near the banks of the Jhelum and Indus rivers (Directorate of Soil Survey 1968).

In Bahawalnagar district in Punjab Province chickpea is grown on about 12000 ha (Fig. 5.8) (Government of Pakistan 1994-95). The climate is very hot and arid with annual rainfall of 100-150 mm. The soils are sandy. In Sind Province, chickpea is mainly grown after rice in Shikarpur, Jacobabad, Sukkur, Larkana, and Nawabshah districts, The climate of this area is very hot and arid. The soils are sandy, loamy, and clayey floodplain soils. Maximum temperature range during the chickpea growing period is 20-37"C and minimum temperature is 6-27°C. In Pothehar region (Fig. 5.8) (Rawalpindi, Chakwal, and Attock districts), farmers ceased chickpea cultivation after 1980 due to susceptibility of the existing cultivars to diseases, especially ascochyta blight. Since 1994, chickpea cultivation has resumed and the area is increasing every year. Annual precipitation in this region varies from 400 mm to 1000 mm. During the chickpea crop season the average temperature range is 19-35°C maximum and 2-18°C minimum.

Lentil

Lentil is grown in most parts of the country (Fig. 5.9). At present

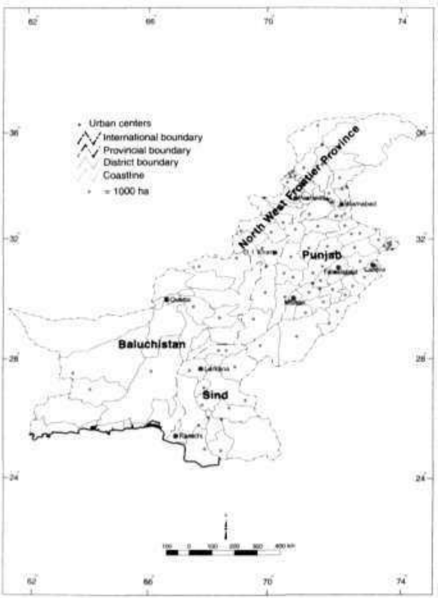

Figure 5.9. Distribution of lentil in Pakistan, 1994/95 (Source: Government of Pakistan 1994-95).

Rawalpindi and Bajaur Agency are the main lentil-growing districts. Lentil grows well in clay loam and clayey soils. The soils of Bajaur Agency are mainly loamy and very shallow. The climate is cool and sub-humid with annual precipitation of 400-500 mm. Rawalpindi soils are well drained, calcareous, loamy regosols. The climate is semi-arid and hot. Annual rainfall in this area ranges from 500 mm to 1000 mm. Temperature sometimes drops below freezing and causes frost injuries to the crops. Lentil is also grown in Jhelum, Gujrat, Gujranwala, and Sialkot districts where soils are silt loam, silty clay loam, and clay loams. In these districts, the annual rainfall ranges from 300 mm to 500 mm. Lentil occupies a considerable area along the Indus river in Sind Province where soils are loamy and clayey floodplain soils. In this region the average maximum temperature at seeding time is 29-33°C, falling to 20-22°C in Dec and Jan, and rising again to 36-37°C at harvest. This area is very hot and arid. The annual rainfall ranges from 100 mm to 150 mm (Khan et al. 1991).

Mung Bean

Mung bean is one of the important summer legumes of Pakistan. The major production area is located in Punjab Province concentrated in Rawalpindi, Mianwali, Bhakkar, and Leiah districts (Fig. 5.10). Relatively little mung bean is produced in other Provinces of the country. The main growing season is kharif (rainy season) (Jul-Oct) which starts with the onset of monsoon rains whereas its cultivation in spring (Mar-Jun) is also practiced in southern Punjab and upper Sind on a small scale. The climate and soil features of the above districts have already been discussed in detail under chickpea and lentil crops.

Black Gram

Most of the black gram area (88%) lies in Punjab Province, which

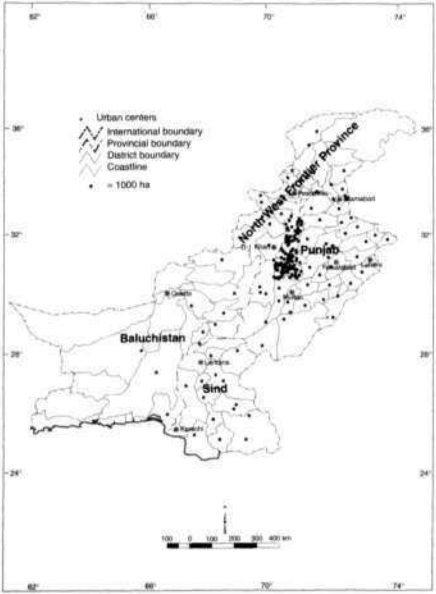

Figure 5.10. Distribution of mung bean in Pakistan, 1994/95 (Source: Government of Pakistan 1994-95).

contributes 84% of total production in the country (Government of Pakistan 1994-95) (Fig. 5.1 1). In Punjab, it is mostly grown in the districts of Rawalpindi, Sialkot, Gujrat, Narowal, and Dera Ghazi Khan. Area and production of black gram is decreasing every year. Climatic and soil characteristics of these districts have been discussed above.

Khesari (Lathyrus)

For a long period, khesari (lathyrus) was grown mainly in Sind Province, and a little grown in Baluchistan (Fig. 5.12). The main districts of its cultivation are Thatta, Larkana, Jacobabad, Shikarpur, and Dadu. The soils of these districts are loamy and clayey floodplain soils (Khan et al. 1991) but it can grow well on all types of soils. The climate is very hot to arid in these areas. The mean annual rainfall is 125 mm. The average maximum temperature at sowing time is 29-33°C, falling to 20-24°C in Dec and Jan and rising again to 36-37°C at harvest time in early Apr. Minimum temperatures vary around 13-18°C at sowing time to 6°C in Dec-Jan and reach around 27"C at harvest (Khan et al. 1991).

Groundnut

Groundnut is consumed mainly as roasted nuts in Pakistan. It is mainly grown in Punjab Province, in and around Rawalpindi district but with smaller areas in NWFP and Sind Provinces (Pig. 5.13). It is normally grown as a rainfed sole crop during the summer monsoon period, but is sometimes intercropped with sorghum (*Sorghum bicolor* (L) Moench) or maize (*Zea mays* L.). Wheat usually follows groundnut in winter.

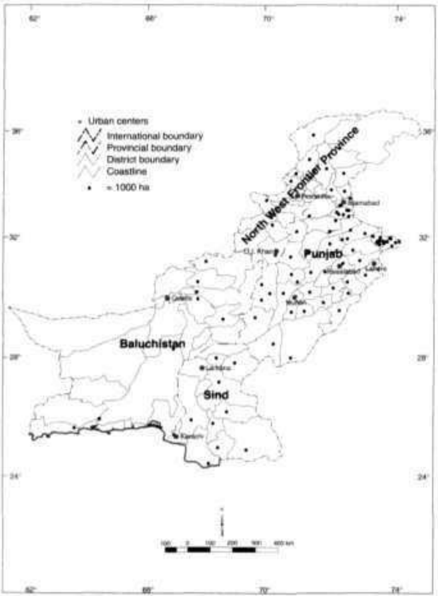

Figure 5.11. Distribution of black gram in Pakistan, 1994/95 (Source: Government of Pakistan 1994-95).

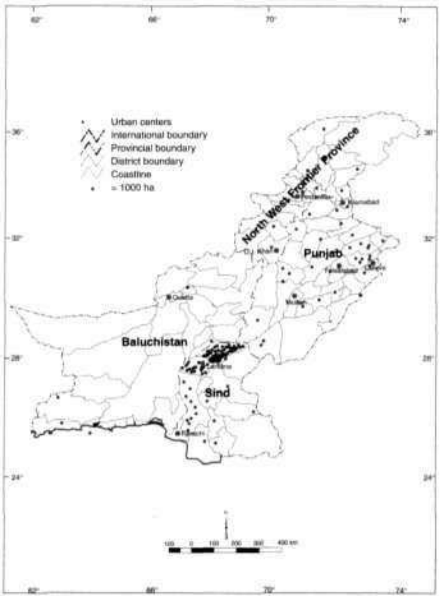

Figure 5.12. Distribution of khesari (lathyrus) in Pakistan, 1994/95 (Source: Government of Pakistan 1994-95).

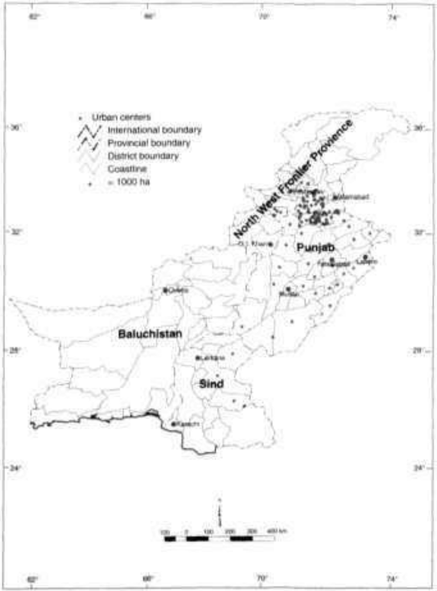

Figure 5.13. Distribution of groundnut in Pakistan, 1994/95 (Source: Government of Pakistan 1994-95).

Production Constraints

All morphological, physiological, phenological, and biochemical processes occurring in a plant culminate in the final product "yield". Any change or disturbance in any one of these processes due to biotic or abiotic stresses on the plant during the vegetative growth and reproductive period decreases the actual yield. The severity of these stresses depends largely on the weather conditions prevailing during the year and varies from year to year. Hence yields of food legumes in farmers' fields usually remain well below established yield potentials. Although it is not possible to eliminate the effects of various biotic and abiotic stresses, the main challenge before scientists in grain legume improvement should be to reduce their effects to the extent possible.

Biotic Constraints

Chickpea

Diseases. Ascochyta blight (*Ascochyta rabiei*) is an important foliar disease and causes 15-50% loss of grain yield in chickpea in the northern areas of Pothohar region and Thal desert (Fig. 5.14). It was first reported in the subcontinent by Butler (1918) in Attock district. Since then the disease has been appearing occasionally in northwestern parts of the country, especially in Attock, Bannu, Kohat, Dera Ismail Khan, and Thal districts (Bashir and Malik 1988). The disease caused extensive losses in 1980 (48%), 1981 (15%), and 1982 (42%) (Nene 1982; Malik and Bashir 1984; Beniwal et al. 1996).

Fusarium wilt is a serious disease of chickpea in the districts of Shikarpur, Jacobabad, Nawabshah, Larkhana, and Sukkur causing annual losses of about 12 million rupees (Fig. 5.14) (Sattar et al. 1953). Akhtar (1956) reported about 75% damage to the crop in severe cases. The disease is caused by *Fusarium oxysporum* f. sp *ciceris* and generally occurs at the seedling and flowering stages. It is common in comparatively dry areas of the country where chickpea is grown (Khan 1979). Root rot and wilt (Fig. 5.14) is a complex of diseases caused by several fungi such as *F. oxysporum* f. sp *ciceris, Rhizoctonia solani, Macrophomina phaseolina* (sclerotial state *Rhizoctonia bataticola), Neocosmospora* spp, *Aspergillus* spp, and *Verticillium albo-atrum* (Khan 1979; Nene 1979). Dry root rot (R. *bataticola)* of chickpea is prevalent in all areas where chickpea is cultivated. The disease is perhaps more common in Sind Province where chickpea is grown after rice. This disease can infest the crop at all vegetative and reproductive stages.

Minor diseases of chickpea in Pakistan are rust *(Uromyces ciceris-arietini),* powdery mildew *(Leveillula taurica),* and alternaria blight (*Alternaria* sp) (Kamal and Mughal 1968). The crop can also be infected with faba bean nectrotic yellows virus, beet western yellows virus, and alfalfa mosaic virus (Bashir et al. 1997). These diseases are of less economic importance in chickpea-growing areas.

Insect pests. Pod borer (*Helicoverpa armigera* Hubner) is the predominant insect pest in Shikarpur, Jacobabad, Larkana, Nawabshah, and Sukkur districts (Fig. 5.14). It also has considerable economic importance in the Pothohar region and Thal desert. All larval stages feed on leaves, tender shoots, and young pods. The fifth and sixth stage larvae are the most voracious feeders. Semilooper *{Autographa nigrisigna* Walker) is another pest of chickpea but it is of less economic importance. It also feeds on leaves, buds, shoots, flowers, and pods.

Weeds. Chickpea is sensitive to weed competition during seedling and early vegetative growth stages. Allowing weeds to grow may result in considerable losses to the crop. Competition from weeds is a serious problem in all chickpea-growing areas. Pothohar and Thal regions are more weed infested (Fig. 5.14). It has been estimated that weeds cause about 15% reduction in chickpca yield on average in the country (Johansen et al. 1994).

Lentil

Diseases. Ascochyta blight (*Ascochyta fabae* f. sp *lentis*) was first recorded in Pakistan during 1982 (Khan et al. 1983). Malik (1983) reported 30-40% reduction in lentil production by ascochyta blight during 1982/83 (Fig. 5.15). Rust (*Uromyces viciae-fabae*) of lentil usually occurs in the foothill districts of the country where precipitation is high (Fig. 5.15). Economically, this disease has less importance. Vascular wilt (*Fusarium oxysporum* f. sp *lentis)* is a disease commonly observed in most of the lentil-growing areas having high atmospheric temperatures (Fig. 5.15). It causes an average 5-10% loss in grain yield. Botrytis gray mold (*Botrytis cinerea*)*,* sclerotinia stem rot (*Sclerotinia sclerotiorum*)*,* and collar rot (*Sclerotium rolfsii*) are minor diseases of lentil (Qureshi et al. 1985). But botrytis gray mold and sclerotinia stem rot are becoming increasingly serious problems.

Insect pests. The lentil crop suffers little from insect damage. Mild attack of spiny lentil pod borer (*Etiella zinckenella* Treitschke) has been observed (Fig. 5.15). The larvae bore into the pods and feed on the seeds and 2-4 pods can be damaged by one larva.

Weeds. Weed infestation is one of the most important constraints of lentil cultivation in Pakistan (Fig. 5.15). The slow growth habit of lentil allows fast-growing weeds to smother the lentil crop and this results in 10-80% yield reduction.

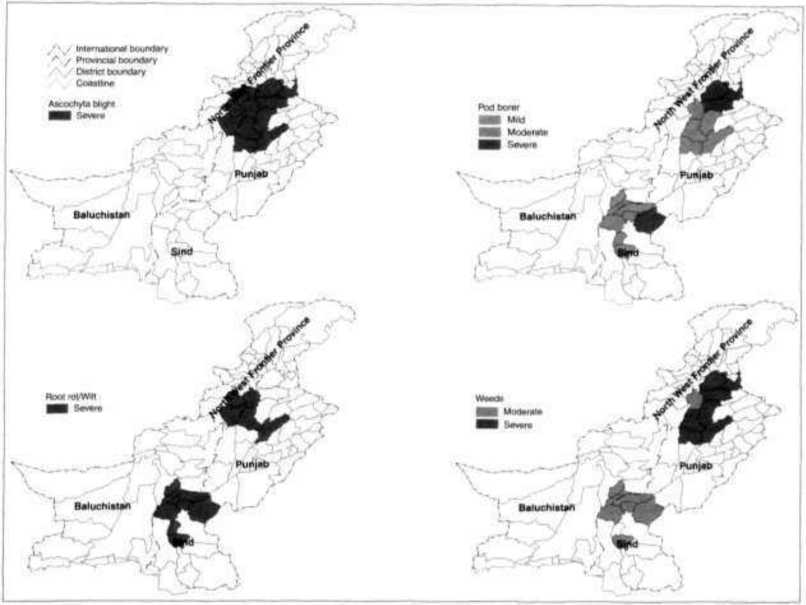

Figure 5.14. Major biotic stresses of chickpea in Pakistan.

Mung bean and black gram

Diseases. Both crops are infected by several diseases caused by fungi, bacteria, viruses, and nematodes. Among them, yellow mosaic, cercospora leaf spot, bacterial blight, and charcoal rot are more common and serious in Pakistan. These diseases reduce grain yield by 16-20% in mung bean and 12-14% in black gram (Bashir and Malik 1988). Yellow mosaic is a serious disease of both mung bean and black gram (Figs. 5.16 and 5.17). Heavy losses are observed annually. This disease is widely spread in South Asia and is caused by the mung bean yellow mosaic virus, transmitted by whitefly (*Bemisia tabaci* Genn.). Leaf crinkle (leaf crinkle virus) is more common on black gram than mung bean. Its infestation prevails in black gram-growing areas of Punjab. It has been reported that 81% yield reduction may occur due to this disease (NARC 1986). Cercospora leaf spot *(Cercospora canescens)* is an important fungal disease of both crops, causing 5-8% yield reduction (Figs. 5.16 and 5.17). It is present in all areas where mung bean and black gram are grown. Anthracnose (*Colletotrichum lindemuthianum*) is a common disease of mung bean and black gram and spreads rapidly during wet and warm weather. Charcoal rot (*Macrophomina phaseolina;* sclerotial state *Rhizoctonia bataticola*) is a serious disease of both the crops and may cause 100% damage in an epidemic. Web blight, choanephora pod rot (*Choanephora* sp), root-knot nematode (*Meloidogyne* sp), bacterial blight, halo blight, and seedling blight have been reported by various pathologists to infest mung bean and black gram (Alam et al. 1984; Qureshi et al. 1984), but these diseases are of less economic importance.

Insect pests. Hairy caterpillar (*Spilosoma* (*Diacrisia*) *obliqua* Walker) is the most important insect pest of mung bean and black gram. It feeds on leaves and causes 30-40% loss in grain yield (Figs. 5.16 and 5.17). Whiteflies attack mung bean and black gram but their main effect is through transmission of viral disease (yellow mosaic) rather than any direct effect on yield reduction. Tobacco caterpillar (*Spodoptera litura* Fab.) is another insect pest of mung bean but its attack is normally mild.

Weeds. Mung bean and black gram are sown at the beginning or during the rainy season. Hence, these crops can be heavily infested by weeds. On average, a 10-20% yield reduction can be attributed to weeds (Figs. 5.16 and 5.17).

Khesari (lathyrus)

Khesari (lathyrus) seems relatively less affected by biotic stresses than other legumes. Foliar and root diseases and insect pests cause only minor yield losses (Johansen et al. 1994), but weed problems can be serious when the crop is grown for grain production.

Groundnut

The main biotic constraints to groundnut are vertebrate pests (e.g., rats, birds, and wild boars), fungal pathogens *(Cercospora arachidicola* causing early leaf spot, *Phaeoisariopsis personata* causing late leaf spot, and *Puccinia arachidis* causing rust), and sucking insects (thrips, jassids, and aphids),

Abiotic Constraints

Food legumes are grown mostly on marginal lands of poor productive potential and under rainfed conditions where farmers hesitate to use improved seed, fertilizer, and pesticides. Risk of crop failure due to abiotic stresses is high. For example in the Thal area, a monocrop of chickpea is grown, mainly as a subsistence crop by low-income farmers

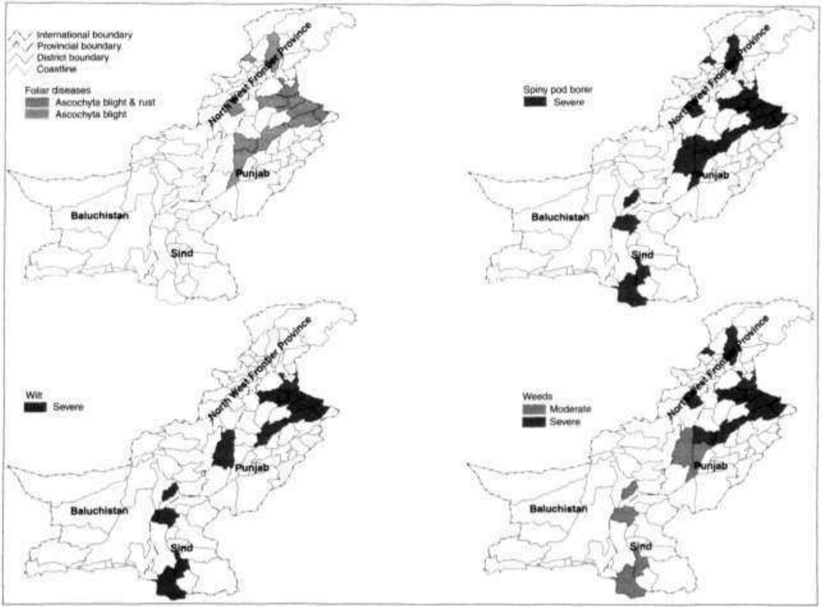

Figure 5.15. Major biotic stresses of lentil in Pakistan.

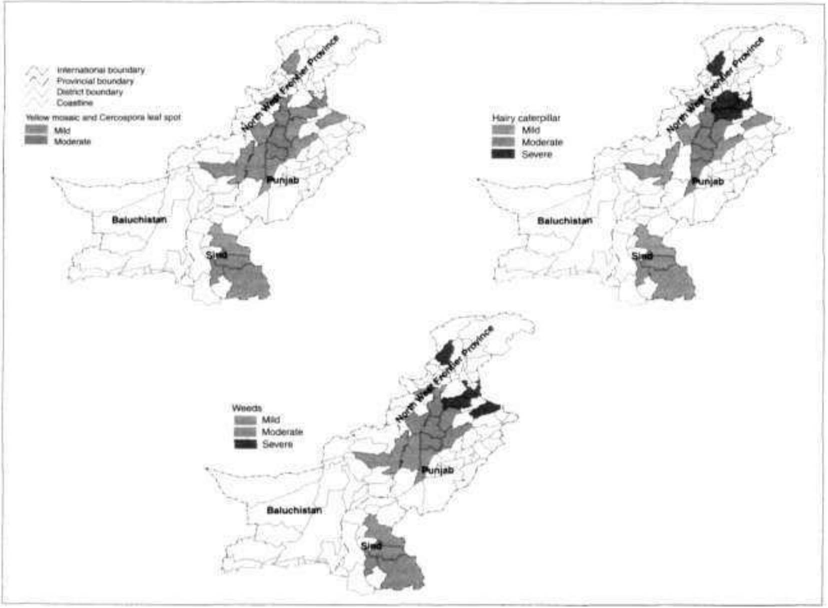

Figure 5.16. Major biotic stresses of mung bean in Pakistan.

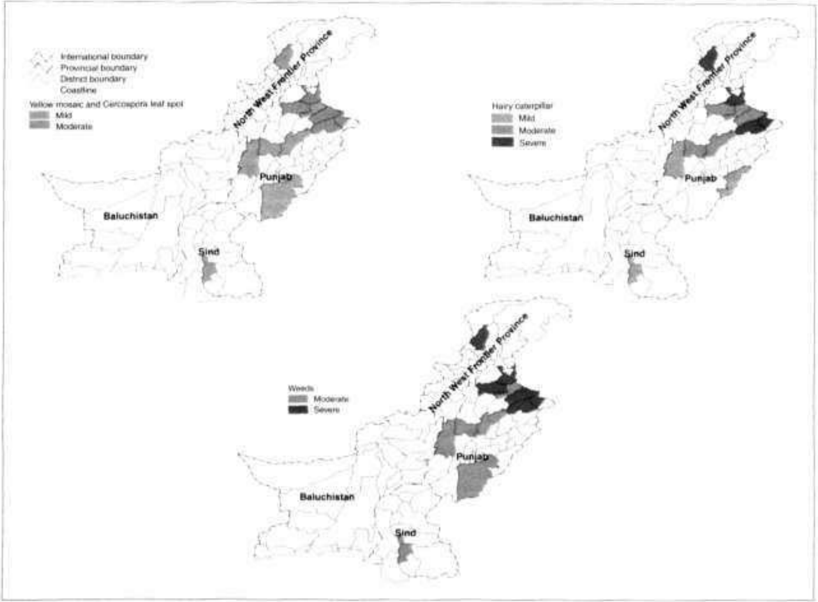

Figure 5.17. Major biotic stresses of black gram in Pakistan.

who do not use any inputs to increase production. The important abiotic constraints of food legumes prevailing in the country are drought stress, low temperature, excess soil moisture, marginal lands, nutrient deficiency, salinity, and sodicity (Fig. 5.18). These constraints are discussed below in order of importance.

Drought stress

Generally, food legumes in the country are grown under rainfed conditions. Rainfall prior to sowing and during crop life span is uncertain. Mung bean and black gram face terminal drought towards maturity. Chickpea and lentil are cultivated on conserved soil moisture after the main rainy season. If rainfall is minimal in September, the area planted to these crops is reduced. Late planting of chickpea and lentil results in poor germination and emergence due to adverse soil moisture conditions and low soil temperatures. Occasionally scattered and non-uniform rainfall distribution occurs and chickpea and lentil suffer from drought stress during vegetative as well as reproductive stages. The crops experience poor plant stand and growth, and shedding of flowers during the reproductive phase. Khesari (lathyrus) is a relatively drought-resistant legume and produces more reliably than other legumes under drought conditions (Johansen et al. 1994; Haqqani and Arshad 1995).

Excess soil moisture

Mung bean and black gram are sown at or before the onset of the monsoon. These crops complete their vegetative and reproductive phases during the rainy season. Occasionally heavy rains in the growing tracts of these crops cause excessive soil moisture stress. Plants die because of poor aeration for roots resulting in low plant population.

Chickpea can also experience excessive soil moisture stress when grown after rice. This can result in iron (Fe) chlorosis in Fe-inefficient chickpea cultivars. When chickpea is relay-sown in rice, seedling establishment is poor due to seed rotting and disease infestation.

Khesari (lathyrus) is tolerant to waterlogged conditions and grows well after the rice crop in Sind Province, either as a relay crop or when sown after rice harvest (Johansen et al. 1994; Haqqani and Arshad 1995).

Frost damage

Onset of freezing temperatures can cause physical injuries in chickpea and lentil plants leading to complete killing. In 1992/93, minimum temperature dropped suddenly from 15°C to below zero in the Thal region. The chickpea crop was severely damaged and 32% reduction in production occurred (Government of Pakistan 1994-95). Temperatures above zero but below 10°C hamper growth of chickpea and lentil and allow weed competition. Such temperatures also cause flower drop.

Nutrient deficiency

In Pakistan, chickpea yield is usually limited by phosphorus (P) deficiency and responses to P fertilizer have been obtained (Johansen et al. 1994; Zahid 1994). Chickpea grown in calcareous soils of high pH (7.5-8.5), particularly under high moisture levels, is susceptible to Fe deficiency (Kannan 1984; Napinder et al. 1984). However, Fe deficiency is not a major yield reducer.

Salinity and sodicity

All food legumes grown in the country, except khesari (lathyrus), are

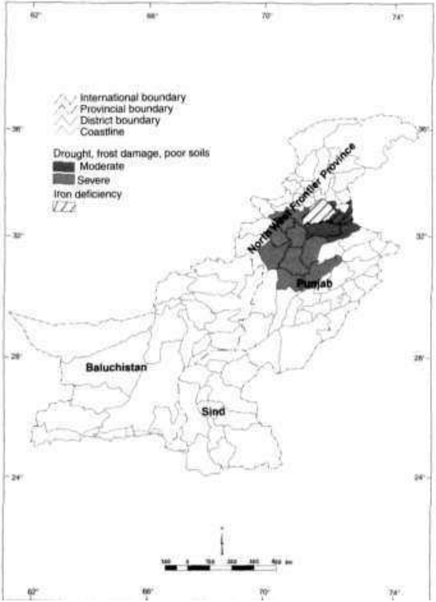

Figure 5.18. Major abiotic stresses of chickpea and lentil in Pakistan.

sensitive to saline and sodic soil conditions. If legumes are grown in these soils, there is poor germination and plants die at the seedling stage. In moderately saline and sodic soils, the grain yield is drastically reduced. Khesari (lathyrus) is relatively resistant to salinity and sodicity and can grow well on saline and sodic soils after rice harvest in Sind Province (Lal and Sarup 1989). However, cultivation of khesari (lathyrus) in Sind and Punjab for grain production is not preferred because of the fear of lathyrism. This disease of humans is an irreversible crippling disorder of the legs caused by ß-N-oxalyl, p-diaminopropionic acid (ODAP) which is produced in khesari (lathyrus).

Socioeconomic Constraints

In modern agriculture, socioeconomic well being of the farmer is a prerequisite to exploit and realize the actual yield potential of the improved cultivars by application of all needed inputs. In Pakistan, food legumes have usually been associated with poor soils, poor people, and rainfed agriculture. They are suhject to a host of biotic and abiotic stresses and thus become risky crops. Hence, farmers' preference is for staple cereal crops and cash crops rather than food legumes. The socioeconomic factors that discourage food legumes production are discussed.

Risk

As food legumes are associated with rainfed agriculture and liable to be attacked by many diseases and insect pests, farmers are generally hesitant to include these as regular crops in their cropping systems. Further, they are reluctant to invest in inputs which would alleviate some of the biotic and abiotic constraints of these crops.

Low economic status

Fanners dwelling in the food legume-growing areas have generally poor economic status. They have low purchasing power which hinders their adoption of improved production technology. Limited educational opportunities in turn limits their exposure to new developments in modern agriculture and they do not realize the significance of new varieties and improved production technology-

Credit facilities

Timely availability of agricultural credit to farmers is essential to meet their production and development needs. Unfortunately, growers of food legume crops do not get their due share from the Government credit facilities. Credit policies remain unidirectional right from planners down to the researchers with greater emphasis on cereals till today. An accumulated effect of lack of credit facilities to pulses growers has contributed to stagnation in area and production of pulses. In the absence of credit facilities poor farmers are unable to purchase high quality improved seed or other inputs needed.

Organizational linkages

The linkages between education, research, and extension and the farmers have remained tenuous. The necessary site-specific, problem-oriented research and transmission of research findings to end users through the agricultural extension system has not successfully occurred on a wide scale. Even the quality seed of varieties released for commercial cultivation is not readily accessible to farmers.

Absence of support prices and marketing

The Government attaches priority to fixing support prices for major cereal and cash crops. Except for chickpea, support prices for food legumes are non-existent. Large fluctuations in market price of grains discourage farmers to grow them. Poor farmers cannot store their produce; they have to sell immediately after the harvest when prices are lowest, to meet their necessities. From a low price at harvest time, the price increases sharply when the pulses produce reaches markets creating a difference of 250 to 300% between the producers' and consumers' prices. In this way, the poor farmer is deprived of a rightful profit. Low market price for the grower and traders' monopoly impose special impediments on food legume production.

Mechanization

Seed drills, harvesters, and threshers suitable for food legumes are also generally not available. Labor for growing food legumes on a large scale without mechanization is also not available. This situation poses difficulties for planting and pre- and postharvest mechanization and is also a serious handicap to increasing area and production of pulses.

Lack of improved seed production and dissemination infrastructure

Improved seed is the basic component of agricultural production technology. Although improved varieties of chickpea, lentil, mung bean, and black gram have been released by pulses breeders for commercial cultivation in Pakistan (Table 5.1), seed supply corporations do not have adequate land area and resources to multiply quality seed of these minor crops. Virtually no seed production and dissemination system exists in the country. Ultimately improved seed is not available to the growers.

Table 5.1. Chickpea, lentil, mung bean, and black gram varieties released in Pakistan after 1980.

Crop/Cultivar	Year of release	Special characteristics
Chickpea		
CM-72	1982	Desi, high yielding, small seeded, tolerant to ascochyta blight.
C-44	1982	Desi, high yielding, bold seeded, tolerant to ascochyta blight, susceptible to iron chlorosis.
AUG 480	1982	Black seeded, small seeded, tolerant to ascochyta blight and fusarium wilt.
Noor 91	1992	Kabuli, high yielding, bold seeded, tolerant to ascochyta blight.
Punjab 91	1992	Desi, high yielding, bold seeded, tolerant to ascochyta blight; in case of delayed maturity susceptible to shattering.
Paidar 91	1992	Desi, high yielding, medium seeded, tolerant to ascochyta blight.
NIFA 88	1992	Desi, high yielding, small seeded, tolerant to ascochyta blight.
DG-92	1989	Kabuli, high yielding, suitable for rice-based system.
Lentil		
Mansehra-89	1989	Bold seeded, early maturing, high yielding, resistant to ascochyta blight and rust, yellow cotyledons.
Masoor 85	1989	Small seeded, high yielding, resistant to ascochyta blight and rust, pink cotyledons, tolerant to collar rot.

continued

Table 5.1 *continued*

Crop/Cultivar	Year of release	Special characteristics
Masoor 93		Medium seeded, high yielding, resistant to aseochyta blight and rust, pink cotyledons.
Mung bean		
NM 121-25	1985	Medium maturity, determinate type, tolerant to yellow mosaic, small seeded, shining seed, released through mutation breeding.
NM 20-21	1985	Early maturity, determinate type, tolerant to yellow mosaic, small seeded, shining seed, susceptible to cercospora leaf spot.
NM 19-19	1985	Medium maturity, determinate type, tolerant to yellow mosaic, small seeded, shining seed, released through mutation breeding.
NM 13-1	1985	Medium maturity, determinate type, tolerant to yellow mosaic, small seeded, shining seed, released through mutation breeding.
NM-51	1991	Early, bold seeded, dull seed color, tolerant to cercospora leaf spot.
NM-54	1991	Early, bold seeded, dull seed color, tolerant to cercospora leaf spot.
Black gram		
Mash-1	1993	Medium maturity, semi-erect, high yielding, tolerant to yellow mosaic.
Mash-2	1993	Early maturity, semi-erect, high yielding, tolerant to yellow mosaic.
Mesh-3	1993	Extra early, erect, high yielding, tolerant to yellow mosaic, suitable for rainfed areas.

Importance of Legumes in Cropping Systems

Wheat and rice are the important constituents of Pakistan's dietary requirement and consequently the RWCS dominate the farming systems in Pakistan, especially in the Indo-Gangetic Plain (1GP). The RWCS covers 0.85 million ha in Punjab and 0.56 million ha in Sind (Zia et al. 1992). Farmers choose among wheat, sunflower (*Helianthus annuus* L), or fodder crops as post-rice crops when irrigation is assured and among wheat, grain legumes, or oilseeds when irrigation is lacking (Woodhead et al. 1993). The overall productivity of the system has come to a plateau, and/or has even declined, over the past twenty years. Wheat yield is often less when it is planted after rice (1.6 t ha^{-1}) than when it is grown after other crops or fallow (2.1 t ha^{-1}). The potential of rice is also yet to be achieved, which at present is yielding about 2.3 t ha^{-1}.

The continuous rice-wheat system has resulted in problems such as low soil nitrogen (N), phosphorus (P), boron (B), and zinc (Zn), and poor fertilizer N-use efficiency (30% compared to 40-50% under upland situations) of the system. As a result, responses to fertilizer application, particularly to N, are well marked. Negative balance of major nutrients even when applied at recommended doses of 120 kg N and 26 kg P ha^{-1} has been reported (Zia et al. 1992). Singh (1988) revealed that wheat after rice in Pakistan responded up to 75 kg N ha^{-1} with marginal response to 22 kg Pha^{-1}. This situation of decreasing soil fertility and related problems in the rice-wheat system calls for determining means to help avert this trend. Balanced application of fertilizer nutrients to realize the appropriate levels of yield is a considerable drain on farmers' resources in view of their prices and limited availability.

In view of sustaining long-term productivity of the RWCS, use and effective management of natural resources needs to be emphasized.

The importance of legumes as restorers and builders of soil health has long been established. The beneficial effects of including legumes in cereal-based cropping systems, whether on succeeding or companion crops, depend on the type of legume, the purpose for which it is grown and the management practices followed. Legumes can potentially fit well into existing cropping systems such as rice-wheat, being shorter in life span, adapted to low input situations, and relatively drought tolerant. An account of farming practices in RWCS relating to important legumes is presented.

Winter Legume-based Rice-Wheat Cropping Systems

Chickpea, lentil, and khesari (lathyrus) are grown after rice on residual moisture. Chickpea and khesari (lathyrus) fit very well into rice-wheat systems in Sind and Baluchistan, as alternatives to wheat. Bhatti (1987) reported that a rice-chickpea rotation gave maximum monetary return, followed by rice-lentil and rice-khesari (lathyrus). However, for the traditional rice belt in Punjab to support rice-chickpea systems on a large scale, high-yielding, early-maturing, ascochyta blight-resistant chickpea varieties and better management techniques with effective pod borer control are needed.

Lentil cultivation once used to be a popular farming practice in Sialkot and Narowal districts of Punjab, but has now been replaced by wheat with the availability of irrigation facilities. Lentil can be reintroduced if rust-resistant, early-maturing cultivars along with appropriate weed control measures are developed. Short-duration varieties of lentil may give better return than the Dec-planted wheat.

Rice-pea *(Pisum sativum* L.)-okra (*Hibiscus esculentus* L.)/wheat cropping pattern is also practiced in Sheikhupura district and some parts of Gujranwala division. Farmers grow short-duration non-aromatic rice from Jun to Sep and pea from the end of Sep to early Dec.

Khesari (lathyrus) and berseem are important winter fodder legumes of the RWCS and are commonly rotated with rice, the latter being less used. Khesari (lathyrus) is favored by the small farmers in Sind Province as it is hardy and tolerant to drought, waterlogging, and salinity and has low production cost. Since land becomes available for planting succeeding crops only very late after rice harvest, khesari (lathyrus) seeds can be broadcast even in standing water of rice fields. This relay-cropped khesari (lathyrus) can also be used as an effective green manure for a succeeding wheat crop. Rice-berseem-rice rotation is also important in some rice-growing areas to the north of the country. Its multipurpose nature has greater prospects in the RWCS. Berseem, besides being a valuable fodder, also improves soil fertility and provides an excellent form of weed control for subsequent rice and wheat crops (Byerlee et al. 1986). A recently practiced system of intercropping in a system of Sep planting of sugarcane is also a potentially viable option. One or two cuttings of berseem could be first harvested as green fodder for livestock and later plowed in as green manure for the standing sugarcane crop.

Summer Legume-based Rice-Wheat Cropping Systems

The major summer and rainy season legumes of Pakistan are mung bean and black gram. Cowpea is also cultivated on a very small area, primarily for fodder purpose. These crops are mainly grown on marginally fertile soils of rainfed areas. Presently, short-duration and photoperiod-insensitive cultivars of these crops (especially mung bean) have good potential to grow in irrigated areas including rice-based cropping systems.

The area under cultivation of mung bean in RWCS is very small at present. Limited availability of short-duration, photoperiod-insensitive, and heat-tolerant mung bean cultivars to grow in the period between harvest of wheat and planting of rice limit adoption of this practice. A common constraint is the limited availability of irrigation water at this time as mung bean requires at least two irrigations in this very hot period for good yield. The disease and insect problems are minimum for pre-rice mung bean. In rice-wheat areas of Punjab, there is an increasing opportunity to grow mung bean and/or black gram for about two and a half months, from the first week of May to the second week of Jul. Cultivars with 60-70 days maturity are required so that land may be vacated in time for the next rice crop. Black gram cultivation is carried out in those areas of the RWCS where water supply is scanty or it depends on rains. Its cultivation in RWCS has been impeded due to non-availability of high-yielding, photoperiod-insensitive, and short-duration cultivars.

Cowpea offers very little scope for inclusion in wheat-cowpea-rice rotations. Insensitivity to photoperiod and resistance to field weathering of pods are prerequisites for a cowpea variety to be sown as a pre-rice crop. No such variety is available at present amongst growers.

The fallow period of 60-70 days between wheat and rice crops could also be effectively used for cultivation of fast-growing, green manure legumes. Growing of a green manure crop before wheat is not possible as there is only a very short turn-around period for land preparation after rice harvest. *Sesbania aculeata* is the potential green manure legume for the rice-wheat system in Pakistan. It is raised for a period of 8-9 weeks as a pre-rice crop and incorporated into the soil during the puddling operation of rice transplanting in Jul. The effect of incorporating *Sesbania* green manure, measured in terms of grain yield, was more pronounced in rice rather than in wheat. *Sesbania rostrata* (Bremek & Oberm), a stem nodulating tropical legume, has given more encouraging results in the local climate (RRS, PARC 1995). Hussain et al. (1995) found that *S. rostrata* produced more biomass and accumulated more N than traditional *S. aculeata.* Sunn hemp (*Crotalaria juncea* L.) and cluster bean are also grown occasionally for green manure purposes. However, the use of green manure crops has gone out of practice due to problems such as high labor cost, shortage of irrigation water, and fitting these crops into prevailing cropping systems without disturbing a remunerative spring crop such as spring maize and fodder crops (Garrity and Flinn 1988). A good plant stand establishment of these crops at low cost is essential for the economic viability of such cropping systems.

Status of Biological Nitrogen Fixation

Research reports on the extent of atmospheric N., fixation by major grain legumes in Pakistan are few. These crops are mainly grown for grain production and seldom evaluated for their N_2-fixing capacity. A two-year survey on N_2 fixation revealed that chickpea, which is grown mostly in harsh environments, on average fixed 38 kg N ha^{-1} (1994/95) and 74 kg N ha^{-1} (1995/96) (Aslam et al. 1997). Mean values for proportion of fixed N in the plant (Pfix), as measured by the natural ^{15}N abundance method were 75% for 1994/95 and 81% for 1995/96. Comparison of Pfix and total N, fixed between crops of Thal and Pothohar regions showed higher levels for the harsher climate of Thal (low rainfall and light-textured, N-deficient soils).

A similar survey has been conducted to ascertain the N_2-fixing capacity of lentil, mung bean, and black gram in NWFP. The results indicated that mean values of Pfix were 78% for lentil and 47% for mung bean and black gram (Shah et al. 1997). Mean values of total N_2 fixed were 47 kg N ha"' (lentil) and 28 kg N ha^{-1} (mung bean and black gram). The lower Pfix and total N_2 fixed values for the summer legumes could be attributed to nitrate suppression of the N_2 fixation process as organic matter mineralization is more active during summer. Correlation analysis of agronomic and N_2 fixation parameters reflected strong effects of shoot dry matter on total N_2 fixation by lentil, and of Pfix on total N_2 fixed by mung bean and black gram.

National Policies and Emphasis Towards Legume Production

Pakistan imported 261,800 t of pulses worth Rs 2965.5 million in 1995-96 to meet the needs of the increasing population. In the 8th Five Year Plan, the production target of 962,000 t pulses was fixed for 1997-98 with the benchmark year (1992-93) production of 780,000 t. To achieve the target, an increase of 23.3% production was needed with an annual growth rate of 4%. The present situation indicates that this target cannot be met. Chickpea contributes 70% of the total grain legume production and there appears to be a shortfall of 86,000 t to meet the needs of domestic consumption in 2000 (Kelley and Parthasarathy Rao 1996). To alleviate the burden of foreign exchange expenditure and achieve the goal of target production, the following national-level policies are proposed:

- Provision of sufficient funds to research institutions and agricultural extension departments preferably following international criteria, i.e., 60% establishment funds and 40% operational funds.
- Establishment of suitable and effective improved seed production programs for pulses and dissemination infrastructure in the country;
- Establishment of an intensive food legume maximization program;
- Provision of credit facilities;
- Fixation and increase of support prices to safeguard the interest of the farmers against undue fall in prices during the postharvest season;
- Provision of agricultural inputs on time;
- Reduction of the gap between producers' and consumers' price through an efficient marketing system that would ensure better returns to the producer;
- Use of riverbeds ("no man's land") for production of winter legumes such as chickpea and lentil; and
- Encouragement, through credit facilities, to use agricultural machinery for cultivation, deep plowing, sowing, harvesting, and threshing.

Prospects for Increased Production and Use of Legumes

Although food legume production is a complex enterprise, requiring considerable technical knowhow if yields are to be raised and stabilized, there are bright prospects of boosting legume production in the country. There is limited scope for horizontal expansion in land area but there are some niches to increase the area in existing cropping systems. Prime emphasis should be given to increasing productivity per unit area to achieve the goal. A breakthrough in the medium term for increasing production can be expected if there is a strong interaction between relevant organizations, institutions, and specialized agencies, at federal, provincial, and grassroot levels.

Area Increase

Chickpea

Chickpea area can be increased through its introduction in rice-wheat cropping systems prevailing in Sialkot, Gujranwala, Gujrat, and Sheikhupura districts of Punjab. Hence, varieties, as well as *Rhizobium* strains, should be developed for moderately saline soils.

This is possible if suitable machinery is provided by the Government to the farmer on a credit basis for preparation of puddled and compacted rice soils, and credit is given for the purchase of pesticide for the control of pod borer. Since cost of production for chickpea is less, and the grain price is double, as compared to wheat, farmers of the area are likely to adopt this rotation, if the above inducements are provided.

Lentil

There is much concern about the situation of lentil production in the country, as its area has considerably decreased. This has been primarily due to its replacement with wheat as the irrigation water became available to the farmers in Sialkot, the major lentil-growing district. The expansion in area and production of lentil is possible through restoration of its cultivation in rice-wheat areas where basmati rice is grown. This requires breeding of short-duration varieties of lentil to follow basmati rice. Other potential niches include intercropping of lentil in wheat in RWCS and in Sep-planted sugarcane. Lentil is very prone to weed infestation, so an effective chemical control is needed to augment productivity of this important legume.

Mung bean

Area and production of mung bean has increased by 43% and 39%, respectively during the past decade, while the national average yield remained stagnant. There is good scope for further expansion of mung bean in terms of area and production in the country. The potential cropping systems are mung bean-rice-wheat and cotton-sunflower-mung bean-wheat. In Bahawalpur area, sunflower is planted during Jan after cotton and harvested in May-Jun. There is a fallow period from Jul to Oct and wheat is planted in Oct-Nov. Mung bean kharif crop can be successfully grown in this rotation. There is considerable scope for an increase in productivity through alleviation of constraints such as weed infestation, insect damage, and diseases; and by timely supply of good quality seed to the farmers.

Black gram

The crop has gone out of cultivation in its traditional area due to greater availability of irrigation facilities and a shift towards rice cultivation. The price of grain is increasing at an alarming rate. Strategies need to be developed to optimize production of this important summer grain legume. The objective could be achieved through development of short-duration cultivars and popularizing intercropping in maize and sorghum, particularly in rainfed areas where it serves as a cover crop to conserve moisture.

Khesari (lathyrus)

The scope for an increase in area of khesari (lathyrus) is not good because it is not popular in areas (Punjab and NWFP) where other legumes can be grown successfully and give more yield with better returns than this crop. Moreover, there is a fear of lathyrism among the people.

Productivity Enhancement

Efforts of pulses scientists have resulted in release of high-yielding and disease-resistant food legume varieties for commercial cultivation in the last three quinquenniums during 1980-1995 (Table 5.1). These varieties show high production potential if properly managed. However, non-adoption of these varieties and their accompanying production technology packages, perhaps because of inadequate dissemination of these, combined with natural calamities, has resulted in a stagnation of national average pulse yields at around 0.5 t ha^{-1}. Efforts are needed to assemble the improved technologies and systematically evaluate and demonstrate them on-farm. A concerted effort in this regard would rapidly boost national productivity to 0.7 t ha^{-1}, considerably minimizing the shortfall in national pulses production.

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6. Biotic Stresses Affecting Legumes Production in the Indo-Gangetic Plain

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Abstract

On the basis of current knowledge, an attempt has been made to categorize the biotic constraints of the grain legumes groum in the rice- and wheat-based cropping systems of the Indo-Gangetic Plain (1GP) of Bangladesh, India, Nepal, and Pakistan. Diseases and insect pests rank high overall, whereas weeds assume greater importance in the rainy season legumes. Nematodes are reported to affect legumes but information on the losses caused by them is scanty. The major contributors to yield losses are foliar diseases and pod borers. Despite the obvious signs of damage caused by various root diseases, their impact on yield is moderate. The diseases of food legumes are also determined by plant type (specifically the configuration of crop canopy), cropping system, imbalances in soil nutrients, and crop rotation but their detailed effects on the incidence and severity of diseases remains unclear. Similarly, interaction between soilborne diseases and nematodes is obvious, but research on their combined effect on yield losses has rarely been documented. For each legume the important diseases, insect pests, and weeds, with prospects for alleviating the constraints, are discussed. Although availability of host plant resistance to the major biotic constraints have so far proven to be of limited use, we suggest that genetic resistance offers greater opportunities for strategic research investments. Redesigning of crop canopies such that they support a less conducive microclimate for infection and spread of fungal diseases needs greater research focus. Also, development of short-duration cultivars to escape drought and drought predisposed diseases such as fusarium wilt (late) in chickpea and aflatoxin infection in groundnut, and the incorporation of drought-resistance traits is worth pursuing. There is a need to understand the consequences of the intensive rice-wheat cropping system on the changing scenario of pests of legumes.

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introduction

Traditionally, food legumes have been important components in the rice (*Oryza sativa* L.) and wheat *(Triticum aestivum* L.) cropping systems of the Indo-Gangetic Plain (IGP). The rice-wheat cropping systems (RWCS) have a long history in the IGP. It has been practiced in Uttar Pradesh (India) since 1872, and in Punjab (Pakistan and India), in Bengal (India and Bangladesh), and probably in Nepal since 1920 (Gill 1994). However, major expansion of this system has taken place since the 1960s with the availability of high-yielding, semi-dwarf, short-duration varieties of rice and wheat which are highly responsive to irrigation and fertilizers. With the expansion of the RWCS (10.3 million ha in India, 1.5 million ha in Pakistan, and 0.5 million ha each in Nepal and Bangladesh) (Gill 1994), traditional pulses in the IGP such as chickpea (*Cicer arietinum* L.) and lentil *(Lens culinaris* Medic.) have been relegated to less favorable environments (Kelley and Parthasarathy Rao 1996). There are increasing concerns that high input rice-wheat cropping rotations in the IGP are reaching productivity limits, and further that the edaphic resource base is under threat due to various degradation processes (Paroda et al. 1994). As the sustainability of such high input systems is increasingly under question throughout the world, it has become necessary to readdress, and further explore the role of legumes in sustainability of RWCS in the IGP.

The 12 most important food legumes grown in RWCS in the IGP are soybean *(Glycine max* (L) Merr.), mung bean *(Vigna radiata* (L,) Wilczek), black gram (*Vigna mungo* (L.) Hepper), groundnut *(Arathis hypogaea* (L), cowpea (*Vigna unguiculata* (L.) Walp.), chickpea, lentil, khesari (*Lathyrus satimis* L.; lathyrus, grass pea), faba bean (*Vicia faba* L.), horse gram (*Macrotyloma uniflorum* (Lam.) Verde), pea (*Pisum sativum* L.), and pigeonpea (*Cajanus cajan* (L.) Millsp.)

(Carangal 1986; Carangal et al. 1987; De Datta and Buresh 1989). The most common legume crops grown before rice are early-maturing mung bean and cowpea. The cool season food legumes that are grown after rice are chickpea, lentil, khesari (lathyrus), pea, and faba bean. The warm season legumes, such as black gram, mung bean, cowpea, horse gram, pigeonpea, soybean, and groundnut, are usually grown in the warm, long-day, rainy season (kharif), along with rainy season rice, but they can be grown during the mild winter of eastern parts of the IGP.

Biotic constraints such as diseases, insect pests, nematodes, and weeds substantially reduce grain yield of these legumes in farmers' fields. The relative importance of these biotic constraints in the IGP is given in Table 6.1. Perusal of the literature on these biotic constraints of legumes in the IGP reveals new records of diseases and insect pests, loss estimations, biology of causal agents, identification of host plant resistance, and pesticide use. Most of these studies have been conducted in controlled experiments. Moreover, all the articles have been based on sole cropping of legumes and none discusses pest ecology in relation to cropping system. The gap between what one reads and what really happens in farmers' fields at the legume pest level in rice- and wheat-based cropping systems remains obscure. The purpose of this chapter is to review the major diseases, insects, nematodes, and weeds of food legumes, commonly grown in rotation with rice or wheat, and outline current and suggested future research on issues related to importance and control of food legume pests in the IGP.

Table 6.1. Relative importance of biotic constraints affecting legumes production in the Indo-Gangetic Plain[1].

Biotic constraint	India	Pakistan	Bangladesh	Nepal
Diseases	+ + +	+ + +	+ + +	+ + +
Insect pests	+ + +	+ +	+ +	+ + +
Nematodes	+	+	+	+
Weeds	+	+ +	+	-

1. Based on the available estimates either published or observed.
- not known or not reported;
+ = always reported, but losses not considered;
+ + = Important, but losses not always known or documented; and
+ + + = documented as a major constraint to crop production

Soybean

Diseases

Soybean is a potentially important crop on rice-wheat lands in India, Nepal, and Pakistan (Carangal 1986; Carangal et al. 1987; Pande and Joshi 1995). Soybean diseases have been comprehensively described by Sinclair (1982) but little is known of the pathology of the crop in the tropics, especially when soybean is grown on rice land or in a rice-wheat cropping sequence (Yang 1980; Pandey 1987).

Fungal diseases

The most important fungal pathogens to attack soybean in the rice lands are the soilborne fungi. Rust (caused by *Phakopsora pachyrhizi)* is the only economically important fungal foliar disease of soybean. The commonly occurring seedling rots and root rots of soybean are discussed below.

Pythium root and seedling rot. The disease is caused by *Pythium ultimum* and *P. debaryanum.* Diseased plants have "wet" roots and seedlings turn brown. Planting good quality fresh seed can minimize the disease incidence. It is advisable to treat the seed with any common seed fungicidal dressing before planting.

Fusarium root rot. The disease is caused by *Fusarium oxysporum.* It normally appears in wet weather followed by heavy rain or floods. Characteristic symptoms of the disease include rotting of seedling roots and dark brown patches on stems. Seed treatment with common fungicides can reduce the incidence of root rot.

Rhizoctonia root rot. The disease is caused by the common soilborne fungus *Rhizoctonia solani.* Brown or reddish brown patches on the lower stem and seedling hypocotyl arc the most conspicuous symptoms of the disease. The disease cannot be economically controlled by fungicides; however, the simple cultural method of ridging soil around the base of the plants reduces the damage.

Phytophthora root and stem rot. The disease is caused by the fungus *Phytophthora sojae.* The stem just above the soil surface turns dark brown. Plants wilt and die. The disease is quite common in low-lying, poorly drained areas, and heavy clay soils. Resistant cultivars and improvement in soil drainage help in minimizing this disease.

Charcoal rot. The disease is caused by the fungus *Macrophomina phaseolina* (sclerotial state *Khizoctonia bataticola)* that normally occurs in dry soils. The lower stem shows black patches like powdered charcoal. The disease is common in hot, dry weather in dry soil. Crop rotations with a non-host crop can reduce charcoal rot incidence.

Anthracnose. Anthracnose of soybean is caused by the seed- and soilborne fungi, *Colletotrichum truncatum* and C. *destructivum.* Pathogens attack both young seedlings and older plants and produce dark brown patches on the stem. Crop rotation and planting of disease-free, fungicide-treated seeds are the recommended effective control measures.

Cercospora blight and leaf spot (purple seed stain). The disease is caused by the pathogen *Cercospora kikuchii.* Infected seeds can produce diseased seedlings. Later the infection spreads to the stem and leaves and produces pale to dark purple stained seeds.

Rust. Rust is the most widely spread and economically important fungal foliar disease of soybean caused by the fungus *Phakopsora pachyrhizi.* It can reduce yields between 30% and 90% (Yang 1980). Light brown to reddish pustules on the underside of leaves are the predominant symptoms of the disease. Diseased leaves may drop off. The Asian Vegetable Research and Development Center (AVRDC), Taiwan has a regional research program on rust of soybean in Asia (Yang 1980); however, no satisfactory host plant resistance to rust is available. Seed treatment with fungicides is the recommended practice to minimize the disease.

Viral diseases

Several viruses affect soybeans, but only a few are economically significant. In the IGP, soybean mosaic (soybean mosaic virus), yellow mosaic (mung bean yellow mosaic virus), and bud blight (tobacco ring spot virus) occur on soybean. The virus diseases of soybean in Asia and Oceania have been reviewed by Goodman and Nene (1976) and Sinclair (1982). Soybean mosaic virus has a narrow host range, and persists between seasons mainly in infected seeds. Hence control by the production and use of virus-free seed has a considerable potential. Sources of resistance to soybean mosaic virus have also been identified, and breeding for resistance is possible (Yang 1980).

Bacterial diseases

Several bacterial species have been recorded on soybeans, but two important and widely distributed bacterial diseases of soybean are bacterial blight caused by *Pseudomonas syringae* pv. *glycinea,* and bacterial pustule caused by *Xanthomonas campestris* pv. *glycines* (Allen 1983). Bacterial blight is more prevalent in the cool, high altitude regions of the tropics. Bacterial pustule is more commonly spread in the lowland humid tropics, although both may occur together. Both are seedborne and sources of host plant resistance are available for both pathogens (Allen 1983). Currently bacterial diseases are considered less important in the IGP.

Nematodes

The importance of diseases caused by nematodes in soybean are generally unrecognized in the IGP. However, nematodes can cause damage to soybean alone or in association with soilborne fungi. Plant parasitic nematodes reported (Allen 1983) on soybean in temperate regions are: cyst nematode (*Heterodera glycines),* root-knot nematode (*Meloidogyne* spp), reniform nematode (*Rotylenchulns reniformis*), and dagger nematode (*Xiphinema* spp).

Insect Pests

A large number of insect pests have been reported on soybean worldwide. About 74 pest species have been reported from the IGP. Most of the pest species have been observed in Uttar Pradesh state of India. Leaf folder (*Hedylapta indicator),* girdle beetle (*Obereopsis brevis),* blister beetle (*Mylabris pustulata* Thunberg), green (or stink) bug (*Nezara viridula* L.), and tobacco caterpillar (*Spodoptera litura* Fab.) have been found damaging leaf, stem, flowers, and pods in the IGP (Singh and Singh 1993). These pests together or alone can cause yield losses of 9-40%. Very little is known about their effective control.

Weeds

Weeds pose a serious threat to soybean cultivation during the early phase of crop growth until 45 days after sowing. Reduction in yield may vary from 27% to 71 % depending upon the type and intensity of weeds, and the time of their occurrence (Muniyappa et al. 1986). Weeding twice at 20 and 40 days after sowing or pre-plant incorporation of fluchloralin (1.0 kg ha^{-1}) or pendimethalin (1.5 kg ha^{-1}) provides sufficient long duration suppression of weeds (Singh and Sharma 1990). Some other promising herbicides are metribuzin (0.25-0.5 kg ha^{-1}) and metalachlor (1.0-1.5 kg ha^{-1}).

Mung Bean and Black Gram

Diseases

More than 16 pathogens have so far been recorded on mung bean and 21 on black gram from Bangladesh alone (Fakir 1983; Ahmed 1985). A similar disease situation has been observed wherever mung bean and black gram are grown in rice fallow lands in India and Nepal (Pande and Joshi 1995). Three diseases that attack both the pulses are considered economically important. These are yellow mosaic (mung bean yellow mosaic virus), cercospora leaf spot (*Pseudocercospora cruenta*), and powdery mildew (*Erysiphe polygoni* and *Oidium* sp).

Yellow mosaic

Yellow mosaic is the most serious limiting factor in mung bean and black gram cultivation in the IGP region. The disease can occur at any stage of crop growth but losses are severe when it occurs at an early stage. Total loss has been reported when the mung bean crop was infected within two weeks of emergence (BARI 1984). A mixture of irregular yellow and green patches are the characteristic symptoms of the disease. The pathogen is transmitted by the whitefly *Bemisia tabaci* Genn. Yellow mosaic has a wide host range and weeds have been reported to harbor the virus and act as a primary source of inoculum (Verma and Subramanyam 1986). Management of the disease seems to be very difficult. However, attempts in India and Bangladesh to identify resistant sources have been made (BARI 1991; Sachan and Yadava 1993). Spraying of systemic insecticides such as aldicarb (Sharma and Verma 1982) and formothion® (Chenulu et al. 1979) were reported most effective in checking the spread of the disease by controlling the whitefly vector.

Cercospora leaf spot

The disease affects both mung bean and black gram. It causes spots of variable sizes and shapes which are purplish at the beginning and later the center becomes grayish in color. This disease also causes premature defoliation. The pathogen was reported to perpetuate in infected debris (Grewal 1988). A few genotypes were found resistant and can be utilized in resistance breeding (Dey et al. 1987; Grewal 1988). Foliar sprays with Bavistin 50 WP® at 0.1% were found effective in controlling the disease (BARI 1986).

Powdery mildew

The disease is serious mostly in the crop sown during Sep-Oct (after rice harvest). It can cause about 40% yield loss (BARI 1987). Disease incidence has also been observed even in the summer-sown crop (after wheat harvest). Powdery masses of spores and mycelia are formed on the leaves which later turn dirty white, leading to defoliation in extreme cases. The disease can be managed in certain areas by early sowing. It can be effectively controlled by 2-3 foliar sprays of Tilt 250 ED* (0.1%), Thiovit 80WP® (0.2%), or Karathane® 0.1% (BARI 1986). Host plant resistance is not available in the commonly grown cultivars of mung bean and black gram. However, a few sources of resistance to powdery mildew are available (Reddy and Vishwa Dhar 1997).

Nematodes

Very little is known about the diseases or disorders caused by nematodes in mung bean and black gram grown in the IGP or elsewhere.

Insect Pests

About 64 species of insects are known to attack mung bean, black gram, and cowpea. The rainy season mung bean and black gram wherever grown in the IGP are generally attacked by leaf hopper (jassids) (*Empoasca kerri* Pruthi), whitefly (*Bemisia tabaci* Genn.), galerucid beetle (*Madurasia obscurella*), and hairy caterpillar (*Spilosoma* (*Diacrisia*) *obliqua* Walker). The importance of whitefly is mainly as a vector of yellow mosaic virus, which is a serious problem in both mung bean and black gram. Major insect pests damaging summer crops of these legumes are thrips (*Caliothrips indicus* Bagnall), whitefly, and jassids. In recent years, yellow mosaic incidence has increased in the summer crop and this has adversely affected the cultivation of summer mung bean in the IGP. Studies on the integrated management of insect pests of mung bean, black gram, and cowpea have been initiated; however, sufficient information has been generated on the chemical control of insect pests damaging these crops in India (Sachan and Yadava 1993).

Weeds

Two weedings during the first 35 days after sowing provide effective control of weeds of mung bean and black gram. Pre-emergencc herbicides such as pendimethalin, fluchloralin, or metalachlor 1.0 kg a.i. ha^{-1} supplemented by one hand weeding was found very effective in controlling weeds (Kundra et al. 1.991).

Lentil

Diseases

Lentil is an important food legume which is commonly grown in rice fallow lands in all the IGP countries. It is largely relay cropped in the rice lands in India, Nepal (Pande and Joshi 1995), and Pakistan and Bangladesh (Johansen et al. 1994). Although the area under lentil is increasing in the Indian subcontinent, the crop, like other food legumes, suffers from a number of diseases caused by fungi, bacteria, viruses, and nematodes. Recently, Khare et al. (1993) and Beniwal and Trapero-Casas (1994) have adequately reviewed the diseases of lentil. The important diseases of lentil, which are the potential constraints to lentil establishment and production in the IGP are discussed.

Fungal diseases

The fungal diseases may be divided into two major groups: the root and stem diseases (seedborne and soilborne) and the foliar diseases. The important root and stem diseases that affect lentil are: vascular wilt i*Fusarium oxysporum* f. sp *lentis*); wet root rot (*Rhizoctonia solani*); dry root rot (*Macrophomina phaseolonia;* sclerotial state *Rhizoctonia bataticola*), collar rot (*Sclerotium rolfsii*), sclerotinia stem rot (*Sclerotinia sclerotiorum*), black root rot (*Fusarium solani),* pythium damping-off (*Pythium aphanidermatum*), and pythium root rot (P. *ultimum*). The pathogens causing root rot and stem diseases are soilborne and attack the lentil crop at the seed, seedling, and adult stages resulting in seed rot, damping-off, will, and root and stem rots (Khare et al. 1979; Khare 1981). Pre-sowing seed dressing with fungicides, such as Bayton 10®, DS 0.25% as a dry seed treatment, was found very effective in reducing incidence of root rot and wilt. Furthermore, the avoidable losses were reduced up to 74% with Bayton 10® and with Vitavax 200* up to 40% (Mortuza and Bhuiya 1988).

The important foliar diseases in lentil growing regions of the IGP are ascochyta blight (*Ascochyta fabae* f. sp *lentis),* rust (*Uromyces viciae-fabae*), powdery mildew (*Erysiphe polygoni* and *Leveillula taurica*), downy mildew (*Peronospora lentis),* and gray mold (*Botrytis cinerea).* Anthracnose (*Colletotrichum truncatum*) and altcrnaria blight (*Alternaria alternata)* also affect lentil. Stemphylium blight (*Stemphylium botryosum*) is a new and most destructive disease of lentil which often causes greater losses in association with botrytis gray mold. It was recorded during 1986 in Bangladesh (Bakr and Zahid 1987). The disease is widespread almost throughout the country but severity is highest in the districts of Jessore, Kushtia, Faridpur, Dhaka, and Pabna. Recently, symptoms resembling stemphylium blight were observed in lentil in eastern India and Nepal (Pande and Joshi 1995). Symptoms of the disease start as pinhead light brown colored spots on leaflets of plants in dense populations. Spots enlarge rapidly and within 2-3 days cover the entire leaflets resulting in the defoliation and death of young twigs. In severe cases, the crop fields exhibit a blighted appearance. However, pods remain green. The pathogen seems to be airborne. The detailed etiology is yet to be studied.

Until now, very limited attempts have been made on the control of fungal diseases of lentil. In most cases a combination of host plant resistance and fungicides has been either suggested or experimentally employed. A critical perusal of literature indicated that both field and greenhouse techniques of selection for resistance to most fungal diseases of lentil have been developed and sources of resistance of several diseases have been identified (Khare et al. 1993). Although considerable work on fusarium wilt of lentil has been done (Kannaiyan 1974; Khare 1980; Khare et al. 1993), hardly any attempts have been made on its control. For ascochyta blight control, recommendations made to lentil growers were based on general pathological principles such as crop rotations, deep plowing of infected debris, early seeding, and use of disease-free seed (Morall and Beauchamp 1988); agar plate test of prospective lentil seed (Prasad and Basuchaudhary 1987); and use of resistant cultivars. Further, seed treatment with fungicides is also emphasized to control the seedborne phase of ascochyta blight (Kaiser and Hannan 1986). The use of resistant cultivars, seed dressing with thiabendazole, sun drying of seed, and foliar fungicide (chlorothalonil and benomyl) have been found effective (Ahmed and Beniwal 1991). For rust, several methods of control including use of resistant cultivars (Singh and Sandhu 1988), seed treatment, foliar fungicidal sprays, and destruction of crop debris have been suggested (Nene et al. 1975; Khare 1981). A significant effect of sowing date and cultivars was observed on lentil rust in India (Singh and Dhingra 1980).

Viral diseases

Diseases caused by viruses include lentil yellows (caused by luteoviruses), yellow mosaic (bean yellow mosaic virus), and cucumber mosaic (cucumber mosaic virus) (Makkouk et al. 1993). Lentil yellows is the most widespread and important viral disease of lentil. It is a syndrome that could be caused by a number of related luteoviruses (bean leaf roll virus, beet western yellows virus, and subterranean clover red leaf virus). The characteristic symptoms are reduced leaf size with mild systemic inter-veinal chlorosis, resulting in yellowing, bunched leaves, and stunted plants. The causal virus(es) is transmitted in a persistent manner by a number of aphid species including *Acrythosiphon pisum* Harris, *Aphis craccivora* Koch., and *Myzus persicae* Sulzer. High disease spread is always associated with aphid vector population. Though symptoms of viral diseases have been observed in lentil crops grown in rice lands of the 1GP, little is known about their etiology.

Nematodes

Four nematode species are known to infect lentils: the root-knot nematode (*Meloidogyne artiella* and M. *javanica*), the root lesion nematode (*Pratylenchus thornei*), the stem nematode (*Ditylenchus* spp), and the cyst nematode (*Heterodera* spp). However, there is no information on the distribution and importance of nematodes in lentil grown in rice lands.

Insect Pests

Bruchids (*Callosobruchus chinensis* L., C. *maculatus* Fab.), aphids (*Aphis craccivora*), army worm (*Spodoptera exigua* Hiibner), pod borer (*Helicoverpa armigera* Hiibner), and green bug (*Nezara virudida*) are the common insect pests reported to attack lentil. Bruchids appear to be the major pest that causes considerable damage to lentil seeds in storage. Other insect pests are of minor importance in the 1GP.

Weeds

Lentil is a poor competitor with weed flora due to its slow growth during the winter. Inadequate weed control may cause yield losses of 20-30% in these crops. The growth period during which weed competition is most deleterious was observed to he 30-60 days after sowing (Bhan and Mishra 1997). Several herbicides are effective for weed control in lentil, but they are rarely used because lentils are more sensitive to herbicide toxicity than other pulses (Singh and Singh 1990).

Chickpea

Diseases

Chickpea is traditionally cultivated in the rice fallows of India, Nepal, Pakistan, and Bangladesh (Pande and Joshi 1995). It is sensitive to excessive soil moisture, high humidity, cloudy, and foggy weather which limit crop establishment, flower production, and fruit set (Kay 1979) and also increase severity of common soilborne (root rots and wilts) and foliar diseases. Chickpea diseases have been comprehensively reviewed by Nene (1980, 1982) and Nene and Reddy (1987). Some of the potentially serious diseases of chickpea in order of importance in the RWCS are: ascochyta blight (*Ascochyta rabiei*), botrytis gray mold (BGM) (*Botrytis cinerea),* fusarium wilt (*Fusarium oxysporum* f. sp *ciceris*), dry root rot (*Macrophomina* bataticola; sclerotial state *Rhizoctonia bataticola*), phytopthora root rot (*Phytophthora megasperma*), damping-off (*Pythium ultimum*), and stunt (bean (pea) leaf roll virus).

Fungal diseases

Diseases of chickpea caused by fungi can be classified into two broad groups: (1) infecting aerial plant parts; and (2) infecting root and stem base (Nene and Reddy 1987). Among the diseases of aerial plant parts, ascochyta blight and BGM have been often epidemic and destructive to chickpea grown in the rice fallow lands of the IGP.

Ascochyta blight. An inclusive bibliography on ascochyta blight is given by Nene et al. (1978) and Saxena and Singh (1984). Losses due to the disease in Pakistan and India have been very extensive. The damage in Pakistan resulted in a severe shortage of pulses during the 1980s (Malik and Tufail 1984). Effective measures to control this disease are integration of host plant resistance (Grewal and Vir 1974), cultural methods (sanitation), seed dressing with fungicides, and foliar application with fungicides (Nene and Reddy 1987).

Botrytis gray mold. Botrytis gray mold of chickpea has been reported from Bangladesh, India, Nepal, and Pakistan (Nene et al. 1984). The disease was responsible for heavy losses in the IGP of India during 1979-82 (Grewal and Laha 1983). Currently the disease has been considered as the major constraint to chickpea production in Nepal, Bangladesh, and northeastern India (Pande and Joshi 1995). Pande (1998) observed 100% crop loss in Nepal and at certain locations in Bangladesh. The BGM pathogen has a wide host range and the inoculum is almost always present in the environment waiting for conducive weather to become active. Recently, options to manage BGM of chickpea have been reviewed (Pande et al. 1998a).

In chickpea, *B. cinerea* is reported to be seedborne, and it can be effectively eradicated by dry seed dressing with vinclozolin (Ronilan*), or carbendazim + Thiram® combination (Grewal and Laha 1983). The disease (BGM) can also be controlled by fungicides, but their widespread and economical use in the largely subsistence farming systems of the IGP where chickpea is grown may not be a viable option. Recently, attempts have been made to assemble the information on integrated disease management of BGM, which involves, use of BGM-resistant cultivars and improved cultural and agronomic practices including economic use of fungicides (Pandc et al. 1998a). These practices are being refined so as to be suitable for adoption by resource-poor farmers in the IGP.

Other diseases infecting the aerial plant parts. Other foliar diseases of minor importance are: alternaria blight (*Alternaria alternate)* reported from Bangladesh and India |and possibly Nepal *[Alternaria* sp)J (Nene el al. 1984), colletotrichum blight *(Colletotrichum dematium*) from central India (Mishra et al. 1995), phoma blight *(Phoma medicaginis)* from India and Pakistan (Haware and Nene 1981), stemphylium blight (*Stemphylium sarciniforme*) from India (Das and Sen Gupta 1961), and rust (*Uromyces ciceris-arietini)* from Bangladesh, Pakistan, Nepal, and India (Nene et al. 1984).

Fusarium wilt. Among the diseases that infect the chickpea root and stem base, fusarium wilt is a serious disease in India, Pakistan, Nepal, and Bangladesh (Nene et al. 1984). No precise information on losses caused by this disease is available from any of these countries. However, considerable loss in yield due to will was reported from India (Singh and Dahiya 1973) and Pakistan (Sattar et al. 1953). The disease can be observed in a highly susceptible cultivar within 25 days after sowing and symptoms are often confused with those of root rots. The propagules of the pathogen *F. oxysporum* f. sp *ciceris* are seedborne and debris-borne (Haware et al. 1978; Haware and Nene 1980). The fungus can survive in soils for more then five years. The disease is favored by alkaline soils (Chauhan 1963). Also, receding soil moisture appears to favor disease development. The seedborne inoculum can be eradicated by seed dressing with Benlate T® (benomyl 30% + thiram 30%) at 0.15% (Haware et al. 1978). Host plant resistance is available (Nene et al. 1981). Use of host plant resistance in combination with seed dressing and sanitation appears to be the most effective control strategy in management of fusarium wilt of chickpea.

Other diseases infecting root and stem base. Dry root rot *(R. bataticola*) has been reported from India (Sharma and Khare 1969), Pakistan and Bangladesh (Nene et al. 1996), and Nepal (Pande and Joshi 1995). Wet root rot (*Rhizoctonia solani*) is common in India in chickpea planted after rice harvest in wet soils (Nene 1980). Black root rot *(Fusarium solani*) was reported from India in 1974 (Grewal 1988), but its importance and distribution in other IGP countries is not known. Phytophthora root rot reported from India (Suryanarayana and Pathak 1968), damping-off reported from India (Nene et al. 1984), and collar rot (*Sclerotium rolfsii*) observed in Bangladesh (BAR1 1991) and Nepal (Pande and Joshi 1995) are assumed to be present in the IGP countries wherever chickpea is grown in wet soils in the presence of abundant organic matter. These diseases are of sporadic occurrence on chickpea and little is known about their economic importance, distribution, etiology, and management.

Bacterial diseases

Bacterial blight (*Xanlhomonas campestris* pv. *cassiae)* has only been reported from India (Rangaswami and Prasad 1960). This bacterium is capable of causing post-emergence damping-off and killing of seedlings. Water soaked lesions on the radicle and softening of infected tissue are the primary symptoms of the disease. The bacterium is seedborne. Presently it is a disease of minor importance and no control measures are known.

Viral diseases

Among the several diseases of chickpea caused by viruses, stunt is the most common disease of importance. The disease has been reported from India, Pakistan, Bangladesh, and Nepal (Nene et al. 1996). Infection during early stages leads to a total loss. The host range of the causal agent, bean (pea) leaf roll virus, appears to be confined to leguminous plants (Kaiser and Danesh 1971; Nene and Reddy 1976). Because of its leguminous host range this viral disease can cause serious losses to grain legumes such as faba bean, lentil, and pea when grown in rice lands.

Nematodes

The two species of root-knot nematodes (*Metoidogyne incognita* and M. *javanica*) have been found to infect chickpea in India, Nepal, and Pakistan (Sharma and McDonald 1990). Nematode infection does not produce characteristic symptoms on aerial parts but reduces plant vigor, delays flowering, and induces early senescence-symptoms that are often confounded with poor soil nutrition. Nematodes interfere with nitrogen fixation and increase the incidence of fusarium wilt (Sharma et al. 1994). In general, research on nematode pests of chickpea has not received adequate attention.

Insect Pests

Chickpea is attacked by up to 57 insect species in the IGP, but only a few of them are considered to be of economic importance. The pod borer (*Helicoverpa armigera*) is the key pest that causes economic losses throughout the IGP. Other insects causing damage in the field are of localized importance. Apart from *H. armigera,* in some parts of India and Pakistan a semilooper (*Autographa nigrisigna* Walker) has also been found to damage chickpea pods (Ahmed et al. 1990). Bruchid (*Callosobruchus chinensis*) is the major pest and causes serious losses to chickpea in storage. Recently, Srivastava and Singh (1996) reviewed the integrated management of chickpea pests and proposed management options to minimize the losses caused by them.

In traditional systems, chickpea was rarely grown as a sole crop. Recent shifts in cropping pattern with emphasis on sole cropping and increased density has resulted in increased pest damage, especially in areas where *H. armigera* has developed resistance to pesticides (Singh 1990; Sachan and Lal 1997).

Weeds

The development of chickpea genotypes amenable for late planting has offered avenues for rice-chickpea sequential cropping, but this exposes chickpea to greater weed competition. The magnitude of yield losses depends on the weed composition and density of weed flora. Unchecked weed growth can reduce chickpea grain yield by 40-50% (Bhan and Mishra 1997). *Chenopodium album* L (lamb's quarters) is a major weed of chickpea crops in the IGP. Hand weeding around 30-45 days after sowing coupled with pre-emergence application of herbicides such as pendimethalin or fluchloralin 1.0 kg a.i. ha^{-1} were found effective to control weeds in chickpea. Hand weeding at 30 and 60 days after sowing or 1.5 kg a.i. ha^{-1} of fluchloralin or pendimethalin, or 0.6 kg a.i. ha^{-1} of metribuzin also gave effective weed control (Ramakrishna and Tripathi 1993). The inclusion of chickpea in the rotation with rice has been observed to reduce the noxious weeds such as *Avena fatua* L. (wild oat) and *Phalaris minor* Retz, (small canary grass) in wheat.

Groundnut

Diseases

Foliar leaf spots occur widely wherever groundnuts are grown in the IGP. Other diseases such as bacterial wilt caused by *Pseudomonas solanacearum,* aspergillus crown rot (*Aspergillus* spp) and sclerotium stem rot *[Sclerotium rolfsii),* and aflatoxin contamination *(Aspergillus flavus; A. niger; A. parasiticus)* are widely distributed in both pre- and post-rice crops in Asia (Middleton et al. 1994; Pande et al. 1996). Very little has been addressed specifically on the diseases of groundnut grown in rice- and wheat-based cropping systems of the IGP.

Fungal diseases

The groundnut fungal diseases observed in the IGP can be divided into seed and seedling diseases, foliar diseases, and diseases of stem, root, and pod. Seed and seedling diseases can have a devastating effect on the prospects for a successful groundnut crop. These diseases are caused by the species of *Pythium, Rhizoctonia, Fusarium,* and *Macrophomina* and are widely distributed. There are several stages of seedling diseases including seed rot, pre-emergence damping-off of seedlings, and post-emergence damping-off of seedlings. These diseases can occur up to the time the stem tissue hardens. The incidence is higher in both pre- and post-rice crops than in the rainy season crop. Seed dressing with fungicides such as captan, captafol, and thiram controls these diseases (Pande et al. 1996).

Cercospora arachidicola causes early leaf spot while *Phaeoisariopsis personata* causes late leaf spot. Both are widely distributed wherever groundnuts are grown in rice fallows. Both the diseases cause premature defoliation and substantial crop losses. Use of partial resistance and judicious use of fungicides have recently been found more economical than the use of fungicide alone (Pande et al. 1996).

Groundnut rust (*Puccinia arachidis*) is widespread in tropical areas, and particularly damaging where it occurs in association with early and late leaf spots. Fortunately moderate levels of host plant resistance to rust in good agonomic backgrounds is available. When resistant cultivars are combined with chemical control, better pod and haulm yields are obtained than with host plant resistance alone.

Among the diseases of stem, root, and pods caused by fungi, sclerotium stem rot *(Sclerotium rolfsii)* is the potentially important disease of groundnut grown in rice fallows. The fungus attacks and kills the whole plant including pods. Mehan et al. (1995) and Pande et al. (1994) have adequately reviewed the stem and pod rots of groundnut and their management.

Contamination of groundnut with aflatoxin is an extremely serious problem in subtropical and tropical regions where groundnut is commonly grown in the rice lands. Aflatoxin produced by *A. flavus* and *A, parasiticus* are the most potent of known carcinogens (Mehan et al. 1991). Aflatoxin can be grouped into pre-harvest contamination and postharvest contamination. Management of aflatoxin contamination of groundnut is achieved by preventing the *A. flavus* group from entering groundnut tissues, either by destroying or diverting the contaminated seeds and adopting improved crop husbandry (Mehan 1988).

Bacterial diseases

The only bacterial disease of importance on groundnut is bacterial wilt. The disease is caused by *P. solanacearum,* an aerobic gram-negative rod-shaped bacterium (Hayward 1964). The disease is more severe in lands not used for rice in Southeast Asia (Mehan et al. 1994).

The pathogen can enter into the clean fields through the use of infected planting material of alternative crops, particularly vegetatively propagated crops such as cassava (*Manihot esculenta* Grantz.). Contaminated soil and water can introduce the organism, but this method of contamination is not considered to be important (Mehan et al. 1994). Bacterial wilt is a potentially important disease of groundnut in the rice fallow lands of IGR The disease can be effectively controlled by integrated host plant resistance and cultural practices (Pande et al. 1998b).

Viral diseases

Groundnut rosette, bud necrosis (bud necrosis virus), peanut mottle, and peanut stripe have been reported from the IGP of India and Nepal (Pande et al. 1996).

Nematodes

In general nematodes can cause upto 12% yield loss in groundnut (Sharma and McDonald 1990). Several species of *Meloidogyne* were found associated with stunted growth, chlorotic leaves, and suppressed root growth in groundnut. However, little is known about damage caused by nematodes in groundnut grown in the IGP.

Insect Pests

More than 100 species of insects are known to feed on groundnut, and about a dozen are commonly observed in the IGP. In general, groundnut insect pests can cause 15-20% reduction in yield. Most of the groundnut pests are polyphagous, widely distributed and sporadic in nature (Ranga Rao et al. 1996).

Weeds

Groundnut is very sensitive to weed competition because of its initial slow growth, short stature, and prostrate growth habit (Naidu et al. 1983). Weeds also interfere with pegging, pesticide application, and harvesting. Hand weeding and inter-row cultivation are generally done after the emergence of weeds and before peg formation. Pre-emergence application of herbicides (simazine, fluchloralin, alachlor, pendimethalin, or metalachlor) provide control of a wide spectrum of weeds throughout the season. Integration of herbicide use with other cultural practices resulted in more efficient control of weeds than use of herbicides alone (Ramakrishna and Tripathi 1993). Specific information on the weeds and their management in groundnut grown in the rice- and wheat-based cropping systems of the IGP is scanty.

Cowpea

Diseases

Cowpea is grown as a grain legume to a limited extent in Nepal (Pande and Joshi 1995) and Bangladesh (BARI 1991) but is more generally used in the IGP as a fodder crop. Cowpea grown before or after rice enriches the soil, helps to break pest and disease cycles that occur in continuous rice-wheat cropping, and thus adds to farm income, albeit indirectly. Furthermore, it performs better than other food legumes on acid soil (Pandey and Ngram 1985). Like other food legumes, cowpea in the IGP, is also attacked by a large number of fungi, bacteria, viruses, and nematodes. However, the following are of actual or potential economic importance (Saxena et al. 1998).

Fungal diseases

Fusarium wilt caused by the fungus *Fusarium oxysporum* f. sp *tracheiphilum* is the most important seed- and soilborne disease of cowpea. Its importance and distribution is not very well documented. Main symptoms of this disease include yellowing, stunting, and rapid death of young plants. Seed treatment with fungicides helps in reducing the disease incidence.

Cercospora leaf spot (*Cercospora canescen* and *Pseudocercospora cruenta),* brown rust (commonly known as rust of cowpea) (*Uromyces appendiculatus),* brown blotch (*Colletotrichum cupsici*)*,* and powdery mildew (*Erysiphe polygoni*) are the major fungal diseases infecting leaves, pods, and other above-ground parts of cowpea.

Cercospora leaf spot is characterized by round spots that arc cherry-red to reddish brown, up to 10 mm in diameter and principally occur on leaves. The disease is seedborne, and therefore seed treatment helps in obtaining a better crop stand. Rust is characterized by blisters on leaves which release powdery reddish-brown spores. In brown blotch, pods, leaves, stems, and veins turn purplish brown, and flower stalks may crack. Pods twist and curl and do not develop in most of the cases. The brown blotch pathogen C. *capsici* is seedborne, and survives in the infected crop debris. Therefore, use of clean seed and destruction of crop debris are the main components of integrated control of this disease. Powdery mildew is a disease of minor importance and is characterized by white patches turning grayish and spreading on leaves and other plant parts. Use of resistant varieties and sulfur-based fungicides give adequate control of the disease (Saxena et al. 1998).

Bacterial diseases

Bacterial blight caused by *Xanthomonas campestris* pv. *vignicola* is the only widespread bacterial disease of cowpea. It starts as tiny water-soaked spots which appear on leaves, then the surrounding tissue dies, and infected tissue turns tan-to-orange in color. The stem may crack and pods become water soaked. Use of clean seed and resistant varieties if available have been suggested to control this disease.

Viral diseases

Cowpea golden mosaic (cowpea golden mosaic virus) and cowpea aphid-borne mosaic (cowpea aphid-borne mosaic virus) are the two most important viral diseases of cowpea, particularly on the crop grown on rice fallow land in South and Southeast Asia (Pande and Joshi 1995). Cowpea golden mosaic virus is transmitted by whitefly (*Bemisia* sp) and it produces intense yellow leaves which after some time become distorted and blistered. Infected plants remain stunted. Cowpea aphid-borne mosaic virus belongs to the group of potyviruses and is seedborne in cowpea throughout the world. It is transmitted by aphids (*Aphis craccivora*). The disease can be reduced by measures that deter migratory aphids from probing, such as cover crops. It can also be controlled by timing crop planting to avoid aphid flights, and by the use of resistant cultivars. The seedborne phase of this virus can be controlled by the use of virus-free seed. Viral diseases of cowpea have been recently reviewed by Saxena et al. (1998).

Nematodes

Generally several polyphagus nematodes have been observed to attack cowpea and substantial yield losses may occur. However, there is no report on the nematodes affecting cowpea grown in the IGP

Insect Pests

Insect pests of cowpea are similar to those of mung bean and black gram (Sachan and Yadava 1993), which have been discussed earlier.

Weeds

Weeds are one of the important biotic constraints in cowpea production. However, very little work has been documented on their occurrence and management in the IGP region.

Faba Bean

Diseases

Faba bean is usually grown in high rainfall areas or with irrigation, or in rice fallows where assured rainfall is expected in winter. It is commonly grown in Nepal and recently its large-scale cultivation in rice fallows has been observed at several places in western and eastern Uttar Pradesh state of India (Pande and Joshi 1995).

Fungal diseases

Again, foliar diseases predominate, with chocolate spot (*Botrytis fabae*) being the most serious yield reducer. Ascochyta blight (*Ascochyta fabae)* and rust (*Uromyces viciae-fabae)* are the other major foliar diseases of widespread distribution. These three diseases are of growing concern and are particularly predominant in Nepal and western Uttar Pradesh. Lines with broad-based resistance to chocolate spot have been identified but progress in developing cultivars resistant to ascochyta blight and rust is slower (Nene et al. 1988). Globally, root diseases are major yield reducers compared to foliar diseases. For example, root rot (*Fusarium solani*) can cause major yield losses (Liu 1984).

Bacterial and viral diseases

In comparison to diseases caused by fungi, diseases caused by bacteria and viruses are of lesser importance. Little is known of the importance, distribution, and etiology of bacterial and viral diseases of faba bean in the IGP.

Nematodes

The most important nematode pests of faba bean are stem nematode (*Ditylenchus dipsaci*) and cyst nematode (*Heterodora goettingiana),* and to lesser extent species of *Meloidogyne* (Sikora and Greco 1990). Host plant resistance to faba bean nematodes is available (Sharma et al. 1994). Very little is known about nematode diseases of faba beans grown in the IGP.

Insect Pests

Insect pests that cause economical damage to faba beans have not been reported from the IGP.

Weeds

There is little published information available on weeds and their management in faba bean crops grown in the IGP.

Khesari (Lathyrus)

Diseases

Khesari (lathyrus) is a robust legume commonly grown after rice in Bangladesh (BARI 1991), eastern India, southern Pakistan, and Nepal (Pande and Joshi 1995). It has a wide agroclimatic adaptability, and is capable of withstanding both drought and waterlogging. Furthermore it can grow well at temperatures ranging from 10°C to 30°C and is successfully relay sown into standing rice.

Most of the research on diseases of khesari (lathyrus) has been done in Bangladesh (BARI 1991). Fourteen pathogens of lathyrus have so far been reported from Bangladesh (Ahmed 1985) and we assume similar disease incidence on khesari (lathyrus) from other regions of the IGP where it is grown. Among the diseases, downy mildew (*Peronospora viciae*) is considered to be the most important, and in Bangladesh alone it is estimated to cause a 17% yield loss (BARI 1986). Symptoms of the disease are the downy growth of mycelium and conidiophores on the adaxial leaf surface. At later stages infected leaves turn grayish to light brown. Resistant sources against the disease have been identified but no precise studies on combining host plant resistance and chemical protection have been undertaken.

Nematodes

Generally it is believed that the three common polyphagus nematodes, cyst (*Heterodera* sp), root-knot (*Meloidogyne* sp), and reniform (*Rolylenchuhis* sp), can cause damage to khesari (lathyrus). However, published reports are not available.

Insect Pests

Perusal of the limited informal reports available on the insect pests of khesari (lathyrus), reveals that aphids (*Aphis craccivora*) are the major pests of this crop wherever it is grown in the IGP (Pande and Joshi 1995).

Weeds

Lamb's quarters (*Chenopodium album*), Bermuda grass (*Cynodon dactylon* (L.) Pers.), field bindweed (*Convolvulus arvensis* L.), spreading day flower *{Commelina diffusa),* green foxtail (*Setaria viridis* Beauv.), and corn sow thistle (*Sonchus arvensis* L.) are the important weeds that have been observed in khesari (lathyrus) fields in the IGP (Pande and Joshi 1995), but precise data on the yield losses caused by weeds in khesari (lathyrus) are not available.

Pea

Diseases

Pea is adapted to a wide range of soil types and environments and is increasing in importance as a crop in the Indian IGP. It has a high grain yield potential and water-use efficiency, especially in short season environments (Siddique et al. 1983). The crop seems particularly well adapted to delayed sowing situations in several parts of western and eastern India and in Nepal (Pande and Joshi 1995), because of their rapid seedling growth, early flowering, and high water-use efficiency for seed production.

Despite the potential of pea to produce high yields, it is subjected to an array of serious fungal, bacterial, and viral diseases that can devastate the crop. Hagedorn (1984) has comprehensively described pea diseases.

Fungal Diseases

Among diseases caused by fungi, seed and seedling diseases are most common. Any environmental or physiological factor which delays seedling emergence and results in uneven stands can predispose developing pea plants to seedling diseases. Such factors may include poor seed vigor, cold and wet soil, poor seedbed preparation, herbicide injury, and low soil fertility. Seedling diseases are mainly caused by rhizoctonia seedling rot (*Rhizoctonia solani*) and pythium seed and seedling rot (*Pythium ultimum*). Host plant resistance to both these diseases is available.

Fusarium root rot (*Fusariwn solani* f. *sp pisi*), aphanomyces root rot *[Aphanomyces euteiches*), and fusarium wilt (*Fusarium oxysporum* f. sp *pisi*) are the important soilborne diseases of pea. Symptomatology, screening procedures, and utilization of host plant resistance in evaluating these biotic constraints have been comprehensively reviewed (Kraft and Kaiser 1993). Negligible information is available on the distribution and importance of root rots particularly when pea is grown in rice fallows. Moderate levels of resistance to these diseases have been identified (Kraft and Kaiser 1993).

Pea also suffers heavy losses due to powdery mildew *[Erysiphe pisi)* and downy mildew (*Peronospora viciae*). Powdery mildew is most severe on maturing crops, but in severe disease years crops can be attacked early in the season. Good sources of resistance to powdery mildew are available in commercial cultivars which can minimize effects of the disease. In contrast to powdery mildew, downy mildew can be a serious disease in cool, foggy weather that occurs in the winter in northern India, Nepal, and Bangladesh. Sources of host plant resistance are available for incorporation into commercial cultivars.

Viral diseases

More than 20 different viruses are reported to naturally infect peas (Hagedorn 1984). Four economically important viruses infecting peas include bean (pea) leaf roll virus (BLRV), pea enation mosaic virus (PEMV), pea seedborne mosaic virus (PSbMV), and pea streak virus (PSV). Reductions in yield and quality of peas infected with these viruses can be disastrous (Hampton 1983). Good progress has been made elsewhere in finding and incorporating resistance to BLRV, PEMV PSbMV, and PSV into commercial cultivars. The epidemiology of all viral diseases of pea, the relationship between planting date, insect vector biology, and environmental conditions, and alternative hosts of viral pathogens need further intensive study. We failed to collect relevant information on pea viral diseases specifically from areas where pea is grown in the IGR However, symptoms resembling viral diseases have been commonly observed on pea crops grown in this region.

Nematodes

The three polyphagus nematodes, cyst (*Hetewdera* spp), root-knot (*Meloidogyne* spp), and reniform (*Rotylenchulus* sp), have been found associated with pea cultivation, but *Heterodera goettingiana* is most harmful (Sikora and Greco 1990). Information on the nematode species causing losses to pea production in the 1GP is not available.

Insect Pests

The major insect pests of peas are aphids *[Acyrthosiphon pisum, Aphis pisum, Aphis craccivora*), bean fly (*Ophiomyia phaseoli T*ry.), leaf miner (*Phytomyza atricornis* Meig), pea leaf weevil (*Sitona lineatus*), and pod borers (*Etiella zinckenella* Treitschke, *Laspeyresia nigricana, Helicoverpa armigera*). Pod borers, especially *L. nigricana,* are extremely difficult to control as they lay eggs on buds and flowers. The larvae make small holes, enter the pods and develop therein. Sources of host-plant resistance to most of the pea pests have been reported (Horber 1978).

Weeds

Commonly occurring weeds which infest crops such as khesari (lathyrus) and lentil have also been observed in pea-growing areas of the IGP.

Pigeonpea

Diseases

Over 60 pathogens have been reported to attack pigeonpea (Nene et al. 1996), but only a few of them are widely distributed in the IGP and are of economic importance. Fusarium wilt (*Fusarium udum*), sterility mosaic [virus (?) transmitted by the eriophyid mite *Aceria cajani* Channabasavannaj, phytophthora blight (*Phytophthora drechsleri* f. sp *cajani),* cercospora leaf spot *[Cercospora* spp), and alternaria blight *{Alternaria* spp) are economically important, wherever pigeonpea is grown in the IGP. The work on pigeonpea diseases has been recently reviewed by Reddy and Vishwa Dhar (1997) and Vishwa Dhar and Chaudhary (1998). Pigeonpea cultivars resistant to sterility mosaic and phytophthora blight are available for IGP countries. Yield losses varied from country to country and season to season (Reddy et al. 1990).

Nematodes

The cyst nematode *Heterodera cajani* is the most important nematode causing considerable damage in pigeonpea. It also attacks cowpea, horse gram, mung bean, black gram, and pea—legumes commonly grown in the IGP. Assessments have not been made under field conditions, but in pot experiments it has been shown that damage occurs when soil population densities exceed 0.1-1 egg g^{-1} (Greco et al. 1997). Little information is available on the control of this nematode and only a limited proportion of pigeonpea gennplasm has been screened for resistance (Sharma et al. 1992).

Insect Pests

The key insect pests of pigeonpea are pod borers *[Helicoverpa armigera* and *Maruca testulalis* Geyer) and podfly (*Melanagromyza obtusa* Malloch), with others such as blister beetle (*Mylabris* spp) and pod sucking bugs being occasional pests in specific locations and/or years. The pod borers cause substantial yield losses every year and are often the primary yield constraints. The damage caused by *H. armigera* in some locations in the IGP varies from 3% to 44% (Chauhan 1992). In general, podfly (M. *obtusa)* causes severe damage in the IGP Integrated pest management options for pigeonpea have been discussed in detail by Shanower (1996).

Weeds

The first quarter to third quarter of the growth cycle of pigeonpea is critical for weed competition, but when the crop is well developed, it will effectively suppress the weeds (Ali 1988). Short-statured cultivars of pigeonpea are more susceptible to weed competition than the tall cultivars. Some of the common weeds associated with pigeonpea (especially in the Indian IGP) and their management have been adequately discussed by Chauhan (1990). Yield losses have been estimated to be as high as 90% (Saxena and Yadav 1976). Hand weeding is effective in case of pigeonpea also. One hand weeding with interculture 30 days after sowing was found to control the majority of early season weed flora. Herbicides such as pendimethalin, alachlor, and fluchloralin suppress weeds throughout the season and result in increased crop yield (Ramakrishna and Tripathi 1993).

Horse Gram

Diseases

Horse gram, which is invariably broadcast into rice fallows in India and Nepal, is perhaps the most neglected food legume crop. It is essentially a crop cultivated by resource-poor farmers and mainly grown on marginal or sub-marginal lands not suitable for other legumes. These lands are characterized by severe moisture and nutrient stress, untouched by any technology and largely confined to traditional subsistence farming systems. This is a legume of last choice and thus it receives almost no inputs. Although two high-yielding varieties, PDM 1 and VZM 1 have been released, negligible information is known about the diseases of horse gram and their distribution (Gopala Raju 1984). Yellow mosaic caused by a gemini virus has been observed in horse gram wherever it is cultivated in rice fallows (Muniyappa et al. 1987).

Insect Pests, Nematodes, and Weeds

Effects of insect pests, nematodes, and weeds on horse gram in the IGP have not been reported, to our knowledge.

Conclusions and Future Research Priorities

Review of the work done in the IGP and elsewhere on biotic constraints of legumes and their management suggests a wide gap of knowledge between the technologies generated and their usefulness in the current perspective of rice- and wheat-based cropping systems of the IGP. Earlier research was mainly on resistant sources and chemical control of a few diseases (including diseases incited by nematodes), insect pests, and weeds. Moreoever all the research was based on monocropped systems. This component approach has not adequately met the needs of the farmers as farmers in each agroclimatic zone/ region encounter concurrently or in succession at least more than one biotic stress in legumes. Further, a close association of biotic stresses with abiotic stresses, such as nutritional imbalances and soil moisture deficit, aggravate the situation and lead to greater crop losses. Therefore, it is necessary to focus our future research priorities on the following aspects:

- Management of biotic (diseases, insect pests, nematodes, and weeds) stresses in cropping systems needs to be considered on a different basis than monoculture.
- Biotic stress management for subsistence farmers should involve combinations of crop production practices and specific technologies aimed at reducing at least key biotic stresses and should focus on the entire cropping system with emphasis on year-round and multi-year management of pest populations.
- Research in cropping systems requires the evaluation of several crops, not separately, but as a package following a prescribed arrangement either in time and space. Therefore, there is a need to evaluate the changing scenario of pests in a crop sequence as a whole. Furthermore, evaluation needs to be done in genetic, agronomic, and pesticide management. Experiments therefore need to be conducted so as to provide adequate data on the affordable and economical use of pest management.
- The subsistence farmer in the IGP, who is hesitant to accept pest control technologies and strategies, can be made to accept those technologies if losses caused by pests, timeliness of pest management, and cost-benefit ratios of various practices to control insect pests, diseases, and weeds are effectively demonstrated and validated. The fact that farmers understand the importance of

insect pest and disease control and accept recommendations to control them with little effort and persuasion, indicates that they would be receptive to a total package of cost effective production technology.

- There is a definite need to develop pest management technology suitable to subsistence farming conditions. To achieve this we need to learn more about the pest ecology, effects of weather, and life cycle pattern. Emphasis should be placed on developing pest management strategies for the farming system as a whole.

Furthermore, targeted research cmphasis is needed in the following areas:

- Mapping of occurrence and severity of major diseases, insects, nematodes, and weeds in different countries of the IGP. The emerging geographic information system (CIS) and global positioning system (GPS) technologies for information gathering and interpretation should be deployed to focus on how cropping system and management practices influence pests or their vector populations.
- A critical study on the epidemiology of diseases and threshold levels of insects, and subsequent development of prediction models needs to be initiated. The precision and accuracy of these models needs to be tested and validated at multilocations for future suitability.
- Multiple disease resistance procedures should be standardized both for root and foliar diseases of legumes in the rice and wheat cropping systems and their unifomi adoption by screening centers on a regional basis should be promoted.
- The science applied to site-specific agriculture including precision agriculture, for profitable production of legumes for the IGP should be developed and evaluated.
- Extensive studies on the exploitation and use of cultural practices, cropping systems, organic and inorganic fertilizers in multiple diseases and pest management packages need to be undertaken. Further, the role of legumes in managing nutrient input and removal needs to be examined, and related to legume pests and their epidemics.
- The potential of local antagonists and bioagents should be tapped and their evaluation carried out to identify the most suitable ones as components of integrated pest management schemes. Biological processes influencing soil health, including microorganisms and weed seed identity and diversity, and crop residue degradation should be determined.
- Crop-based pesticide application schedules against all biotic stresses should be developed. This aspect is highly challenging but is needed by subsistence farmers of the IGP, especially to raise a profitable legume crop in rice fallow lands. This research area needs to involve a multidisciplinary approach where chemicals applied to the legumes need to be assessed in total perspective of the ecology, comprising its effects on predators and parasites, insect pests, weed flora, different diseases (soil and aerial biota), shift in physical and chemical properties of the soil, and environmental hazards. Therefore, approaches that consider integrated chemical and biological pest management; use of multiple diseases and insect pest resistance genes, pesticides, and weed management tools; impact of direct seeding/no-till practices; and legume varietal selection need to be developed.

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7. Management Factors Affecting Legumes Production in the Indo-Gangetic Plain

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Abstract

Grain legumes are very important in the Indo-Gangetic Plain (1GP) countries for their contribution to human and animal nutrition, as components of indigenous cropping systems, and as restorers of soil fertility. Yields of grain legumes have remained low due to several production constraints. There is a undening gap between the growing demand and production of grain legumes in the IGP. Rice and wheat production has increased significantly over the previous decades but the area and production of grain legumes has gradually declined. Various abiotic, biotic, and socioeconomic constraints can explain the poor performance of these legumes, relative to that of major cereals and cash crops. Previous research on improving grain legumes production in the IGP has been relatively limited and lacking in focus. Efforts to develop, assemble, and evaluate improved production technologies have only been recent. Previous research concentrated mainly on varietal improvement. Factors such as inherently limited yield potential, susceptibility to various pests and diseases, and sensitivity to edaphic and microclimatic changes contribute to large variations in the output of grain legumes from year to year. The problem is therefore highly complex, making it difficult to halt the declining trend of grain legumes (in terms of area and production) unless improved cultural practices ensuring sustainable high yields are developed together with promising cropping patterns. It is concluded that substantial increases in the production of grain legumes in the IGP can be achieved by fine tuning management aspects and thereby increasing total system productivity and sustainability.

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Introduction

Grain legumes are important food crops in the Indo-Gangetic Plain (IGP), both for human consumption and animal feed, and form a significant component of the IGP cropping systems. Legumes are considered to be important components of cropping systems because of their ability to fix atmospheric nitrogen (N), add substantial amounts of organic matter to the soil, and produce reasonable yields with low inputs under harsh climatic and edaphic conditions.

The major rite (*Oryza sativa* L.) cropping systems and crop rotations including legumes followed in different IGP countries are summarized in Table 7.1. The area under legumes in rice-based cropping systems is substantial, although it varies across **IGP** countries (Table 7.2). Choice of grain legume to be grown is dictated by various factors such as crop season, rainfall pattern, temperature, soil texture, irrigation water supply, available growing period, and pests and

Table 7.1 Major cropping systems including legumes in the Indo-Gangetic Plain.

Country	Cropping systems
Bangladesh	*Aus* rice/jute-fallow-legumes[1]; *aman* rice-legumes; legumes-*amcin* rice-legumes (upland)
India	Rice-wheat (west and central); rice-rice (east); rice-chickpea/khesari (lathyrus)/lentil/pea; pigeonpea-wheat
Nepal	Rice-legumes-fallow; rice-legumes-early rice; rice-wheat -mung bean
Pakistan	Rice-wheat; rice-chickpea/khesari (lathyrus)/lentil/pea/ berseem clover; rice-flax (linseed)-coriander/pea; mung bean/groundnut-wheat

1. Legumn include chickpea, lentil, and khesari (lathyrus).
Source: Fans et al, (1992).

Table 7.2. Area ('000 ha) under rice-based legume cropping in the Indo-Gangetic Plain.

Description	Bangladesh	India[1]	Nepal	Pakistan
Total area under legumes[2]	785	18790	253	1576
Area under legumes in RBCS	750	1990	197	262

1. Legumes include chickpea, pigconpea, and groundnut.
2. Area under legumes in rice-based cropping systems (RBCS1 and non-RBCS.
Source: Faris et al. (1992),

diseases. In areas with good rainfall, including gradual onset and termination, there is potential to grow mung bean (*Vigna radiata* (L.) Wilczek), black grain *(Vigna mungo* (L.) Hepper), and cowpea *(Vigna unguiculata* (L.) Walp.) before rice; and chickpea (*Cicer arietinum* L.), lentil *(Lens culinaris* Medic), khesari (*Lathyrus sativus* L.; grass pea; lathyrus), pea (*Pisum sativum* L.), soybean *(Glycine max* (L.) Merr.), and cowpea after rice. In areas with gradual termination of rainfall (4-5 wet months and 2-4 dry months), the grain legumes grown after rice are chickpea, lentil, and khesari (lathyrus) in Bangladesh, India, and Nepal, and a third crop of mung bean, horse gram (*Macrotyloma uniflorum* (Lam.) Verdc.), or cowpea in rice-rice sequence in Bangladesh and India. On soil with a high clay or loam content, chickpea, lentil, khesari (lathyrus), pea, and soybean are more dominating, while light-textured soils are predominantly planted to groundnut *(Arachis hypogaea* L.) and horse gram. Temperature also plays an important role in determining the crops to be grown after rice. In areas where the temperature is significantly lower during winter, the most common crops are chickpea, lentil, khesari (lathyrus), and pea. In areas where the temperature is slightly warmer during winter, the most common crops are groundnut, mung bean, black gram, rice bean (*Vigna umbellata* (Thunb.) Ohwi & Ohashi), soybean, and cowpea.

Compared with cereals the genetic yield potential of legumes is generally low (Asthana and Ali 1997). However, as can be seen from the country chapters, grain legume yields realized in farmers' fields are usually less than 1 t ha^{-1}. This is well below the moderate yield potentials of these crops (2-4 t ha^{-1}), indicating a large yield gap. This suggests scope for improved management to narrow this gap.

When grown before or after rice, grain legumes encounter some formidable difficulties compared to other cropping systems because the optimum soil physical conditions for rice and legumes differ substantially. Cropping sequences that include rice and legumes therefore, require special management. The important management constraints and possible remedies for sustained and increased production and productivity of grain legumes in the IGP are discussed below.

Tillage and Mechanization

Legumes are cultivated on a wide range of texturally variable soils, from loamy sand in the west of the IGP to heavy clay in the east. After rice harvest, the use of low energy tillage methods confine cultivation to a shallow depth, giving rise to a compacted layer (the plow pan) which may impede the root growth of crops, particularly in clay soils. The soil usually remains saturated after rice harvest and tillage often takes place with the soil moisture content above the plastic limit, which tends to produce an excessively cloddy surface. Furthermore, the intensive rice cropping decreases soil organic matter resulting in reduced organic bonding of soil particles. Consequently the large pores formed during tillage will tend to collapse during subsequent rainfall and the soil reverts to less favorable structural conditions. While cultivation of wet puddled clay soils produce an excessively cloddy surface soil, tillage of dry soil creates a higher proportion of smaller aggregates. Both conditions are not suitable for good legume crop-stand establishment. Poor germination of grain legumes in a cloddy seedbed is due to less seed-soil contact and reduced water transmission to seeds while the fine aggregates after wetting and drying tend to form a compact seedbed with high soil strength, which impedes emergence.

In upland cropping systems, amelioration of compact layers will be beneficial to both legume crops and rice. But in the lowland system the presence of these compaction layers is a dilemma. It is a necessity for the lowland rice crop, but is a production constraint to the following upland grain legume crop.

Optimum land preparation to facilitate seed germination, seedling emergence, and subsequent growth of legumes needs urgent attention. By adopting simple management techniques substantial increases in the yields of legumes can be achieved. The most common practice for cultivation of mung bean, black gram, cowpea, khesari (lathyrus), and lentil in rice fallows is zero tillage. Although zero tillage significantly reduces the risk of crop failures caused by early season drought, substantially reduces expenses on land preparation, and facilitates timely sowing of several legumes, yield levels are generally low. There is a need to encourage minimum tillage, especially in medium- to heavy-textured soils, in both lowland and upland rice fields of the IGP to provide optimum growth conditions and to realize potential yields of grain legume crops. In the heavy-textured soils good seedbed preparation, especially after rice, is of immense significance. Deep tillage can be used to break the strong compaction layers, preferably along parallel strips at 30-50 cm spacing. Legume crops can be sown on the strip to encourage deeper root development and access to the subsoil water. For example, mung bean can be grown successfully after lowland rice by using a single tine to disrupt the compact zone and by sowing the seeds along the tilled strip without fertilizer or irrigation {Maghari and Woodhead 1984). Draining the field a day before rice harvest followed by one tillage with a rotavator can produce very good soybean yields (Syarifuddin and Zandstra 1987).

Appropriate tillage in light-textured soils is also of prime importance to ensure optimum moisture availability in the seeding zone. Light tillage with a rotavator will resolve the most commonly encountered problem of poor germination, plant stand, growth, and yield of groundnut after rice (Prasadini et al. 1993). Higher uptake of N and phosphorus (P) by lentil was noticed with one plowing compared to zero tillage in sandy loam soils of Uttar Pradesh, India (Tomar and Singh 1991).

Time of sowing

Legumes are generally sown when the opportunity exists in the rice- and wheat *(Iriticum aestivum* L.)-based cropping systems, which is not necessarily their optimal time for sowing. Sowing time is a non-monetary input which can have a profound effect on productivity and success of legumes and of the high-intensity crop production systems. It causes a considerable change in the plant environment with respect to temperature, photoperiod, and availability of soil moisture. Better management of turn-around time between rice harvest and the sowing of the following legume crop can be used to avoid the problem of surface soil drying.

Although date of sowing of legumes depends on factors such as duration of rice/wheat crop, cropping sequence, and the lag time from harvest of the rice/wheat crop until the field is prepared for legume cultivation, there are possibilities for adjustments within the available window to improve the timeliness of sowing. Some modifications in land preparation and sowing practices could be involved to coincide sowing with the appropriate soil moisture condition for good crop establishment. In some cases there is a need to change the variety or sowing date of the preceding crop so that sowing date of the following legumes could be advanced to avoid drought stress during the later growth stages. Generally, short-duration rice or wheat varieties are required if sowing time of legumes is to be optimized. The sowing date adjustments may also require mechanization to reduce the turn-around time and speed up the sowing operation.

In areas with double cropping systems, duration of the two component crops normally covers most of the growing season, leaving little opportunity for adjusting the sowing dates for growing grain legumes. In such areas, the sowing date and duration of legumes should be determined by the maturity of the main crop. This requires development of site specific genotypes and agronomy. However, the recently evolved short-duration genotypes of mung bean and black gram (Singh and Satyanarayana 1997), cowpea (Steele et al. 1985), and soybean (Hume et al. 1985) with relative insensitivity to daylength and tolerance/resistance to diseases (Reddy and Vishwa Dhar 1997) can fit into the narrow summer window of the rice-wheat rotation and offer scope for inclusion of legumes without sacrificing a rice or a wheat crop in any year.

Adequate Crop Stand

Low crop stand is one of the major constraints for low productivity of legumes especially under rice- and wheat-based cropping systems of the IGP. Grain yields of legumes can be improved substantially with an increase in plant density. Under late-sown conditions, the plant growth is often restricted and therefore, a higher population is desired for compensating the yield loss plant^{-1}. However, dense stands attract foliar diseases if appropriate plant protection measures are not adopted.

Appropriate sowing method is important to establish an optimum plant population of legumes. To improve germination and plant stand several sowing techniques can be practiced. One such technique is to dibble the seed at the base of rice stubble. Seeding in rows along with tillage rather than broadcasting increases yields. Drying topsoil is a major determinant to crop establishment when seeds are sown in residual soil moisture situations. Deep sowing is an obvious way to reduce the effect of dry topsoil.

In rainy season legumes such as pigeonpea (*Cajanus Cajan* (L) Millsp.), groundnut, and soybean, crop stand is often vitiated due to water stagnation or poor drainage. Raised seedbed and ridge-furrow beds have been quite effective in ensuring optimum plant stand and increased crop productivity. Sowing on raised beds than on flat beds or ridges in a ridge-furrow bed system will be beneficial. Seedling emergence can also be increased and hastened by soaking legume seeds in water before seeding (seed priming), use of bold seeds, and seed pelleting.

Crop and Cultivar Selection

A possible agronomic solution to alleviate the problem of crop establishment in rice- and wheat-based cropping systems of the IGP is to select legume crops that are capable of penetrating hard soil horizons. Seeds of some legume crops have better ability to overcome mechanical resistance over others. Groundnut has higher root elongation rates than pigeonpea and pea when soil mechanical resistance was increased from 0 to 3 MPa (So and Woodhead 1987). Seedling emergence and subsequent vigor is also dependent on seed quality and genotype. Growth chamber studies clearly showed that large seeds had more vigorous growth than smaller seeds (Patanothai and Ong 1987). Therefore, selection of crop, appropriate variety, and use of good quality seed are prime prerequisites.

Soil Amelioration

Effective management of surface soil organic matter can improve the structural stability of the soils in rice- and wheat-based cropping systems of the IGP. This can be achieved through mulching, green manuring, stubble incorporation, and relay cropping of short-duration legumes. Opportunity exists for fitting mung bean or black gram into the narrow window of the rice-wheat rotation. Recent large-scale expansion of black gram following rainy season rice in coastal Andhra Pradesh, India (Satyanarayana et al. 1997) opens new opportunities for similar expansion of black gram in coastal Orissa and West Bengal in India and in southern Bangladesh.

The establishment and early root development of legume crops in puddled soils can be improved by using gypsum or slaked lime as sources of calcium. As puddling results in soil dispersion, the application of gypsum is expected to improve the physical conditions of the soil following rice.

Waterlogging can be a serious constraint to the success of legume crops. Where the probability of excessive water during the early part of crop growth is high, several methods can be considered. Firstly, use of calcium ameliorants to improve structure and drainage may be useful, particularly in soils dominated by exchangeable sodium and/or magnesium. Secondly, the use of legumes (e.g., soybean, mung bean, and black gram) that can better adapt to waterlogging conditions and are better suited to high moisture conditions early in the season, compared to other legumes such as chickpea, pea, and lentil.

Nutrient Management

Adequate and balanced supply of plant nutrients is essential for achieving and sustaining higher productivity of legumes. Nutrient management in legumes under rice-wheat cropping systems is rather complex and has received low priority in the past. Most of the studies on fertilizer use in legumes are individual crop based and thus the results have only limited application.

Although legumes derive a large proportion of their N requirement through biological nitrogen fixation (BNF), a starter dose of 10-15 kg N ha"^{1} is often recommended, although microbiologists argue that this reduces nodulation and N, fixation. However, in fields where the rhizobial population is low, late-sown legumes respond to applications of up to 40 kg N ha"^{1}. The application of N may not only be directly beneficial to the legume but may also benefit the succeeding cereal crops, perhaps due to improvement in soil physical conditions because of the legume.

Phosphorus (P) is the most critical plant nutrient for legumes. The soils of the IGP are generally low to medium in available P content and therefore application of 17-26 kg P ha^{-1} will prodvice favorable effects on grain legumes. The All India Coordinated Agronomy Research Project conducted 709 trials with chickpea, 583 with pea, 173 with mung bean, and 179 with black gram in farmers' fields to determine the response of legumes to applied P; the mean response (kg grain) to each kg of P at 29 kg P ha^{-1} was 31 in chickpea, 6 in pea, 1.6 in mung bean, and 3 in black gram (Prasad 1979).

In recent years sulfur (S) deficiency has been observed in the rice-wheat belt of northern India due to increased cropping intensity and use of S-free fertilizers (urea and diammonium phosphate). The S deficiency is more pronounced in legumes than cereals due to comparatively higher S requirement in the former for producing grain. In multilocational studies under the All India Coordinated Pulses Improvement Project during 1991-94, pigeonpea responded up to 40 kg S ha^{-1} whereas chickpea, lentil, black gram, and mung bean showed significant response up to 20 kg S ha^{-1} (*Table* 7.3) (Ali and Singh 1995).

Table 7.3 Productivity (t ha^{-1}) of grain legumes as influenced by sulfur application in the Indo-Gangetic Plain of India during 1991-94.

Legume	No. of locations	Sulfur rate (kg ha^{-1}) 0	20	40
Chickpea	5	1.42	1.86	1.90
Lentil	3	1.02	1.47	1.46
Pigeon pea	6	1.19	1.35	1.52
Black gram	3	0.83	1.00	0.95
Mung bean	3	0.99	1.18	1.16

Source: Ali and Singh (1995).

Responses of legumes to micronutrients such as zinc (Zn), molybdenum (Mo), iron (Fe), manganese (Mn), and boron (B) have also been observed. In chickpea, application of 25 kg zinc sulfate ($ZnSO_4$) ha^{-1} improved nodulation, root growth, and yield (Singh and Gupta 1986) and increased uptake of Zn, Fe, and P (Dravid and Goswami 1987). Lentils are highly susceptible to Zn deficiency and an improvement in yield with soil application of 12.5-15 kg $ZnSO_4$ ha^{-1} has been observed. Foliar sprays of $ZnSO_4$ with lime have also been effective in correcting Zn deficiency in chickpea and lentil.

Molybdenum (Mo), being a constituent of nitrate reductase and nitrogenase enzymes, considerably influences BNF in legumes. In calcareous soils of northern Bihar, India and in Terai areas of Nepal, B deficiency is widespread and application of 0.5-1.0 kg B ha^{-1} proved effective in improving chickpea yields. Poor podding that is sometimes observed in autumn-sown (rabi; postrainy season) and long-duration pigeonpea in the eastern IGP is also suspected to be due to B deficiency. Multilocational trials on micronutrients showed that foliar application of 0.5 kg ferrous sulfate ha^{-1} improved productivity of chickpea by 450 kg ha^{-1} over the control (Takkar and Nayyar 1986). Since genotypic variation in susceptibility to micronutrient deficiency has been observed in chickpea, lentil, and pigeonpea, efforts should be made to choose tolerant and efficient cultivars, which do comparitively better when grown on micronutrient-deficient soils.

As legumes can fix atmospheric N in their nodules through *Rhizobium,* this needs to be fully exploited. The quantum of N fixed by legumes is influenced by several physical, environmental, and biological factors. Lack of native rhizobial population also appears to be one of the major constraints for poor nodulation. Use of efficient rhizobial inoculants can enhance productivity of grain legumes by 10-15%. Legume species not only differ in nodulation capacity but cultivars within a species also differ significantly, suggesting that host factors are also important determinants of nodulation. Thus it is possible to select cultivars that can nodulate better and fix higher N (Kumar Rao et al. 1998).

The increases in fertilizer prices impose serious limitations to the farmer in using optimum inputs for sustaining high productivity of rice-wheat systems. This calls for alternate, cheaper sources of nutrients. The role of organic manures in maintaining soil productivity has been well documented but their use needs to be more widespread. The ready availability of chemical fertilizer has caused a reduction in the use of organic matter. Increased use of organic manures is urgently needed because of greater incidence of multiple nutrient deficiencies, deterioration of soil physical properties, and declining trends in productivity.

A multilocational long-term experiment conducted in India indicated that 25-50% of the N requirements of wet season rice can be substituted through compost/farmyard manure, crop residues, or green manure. The time gap between the harvest of wheat and transplanting of rice permits 6-8 weeks for growing a legume (mung bean, black gram, cowpea, *Sesbania* sp) lor seed, fodder, or green biomass for incorporation in the soil. Studies have further indicated that incorporation of legume biomass can save 30-60 kg N ha ' (Tiwari et al. 1980; Meelu and Rekhi 1981). Mung bean straw buried after picking pods before transplanting rice could save as much as 60 kg N ha ' (Rekhi and Meelu 1983). In all experiments reported in the rice-wheat areas, inclusion of legumes for seed or fodder has helped to increase the total productivity and profitability of the system. Mixed cropping of maize (*Zea mays* L.) Icowpea for fodder purpose during summer after the harvest of wheat also increases the profitability of the sequence.

In view of the potential role of legumes in contributing to cropping system sustainability in the region through their ameliorative effects on soil health (in terms of additions of fixed N and soil organic matter) without having to sacrifice a rice or wheat crop in any year, strong efforts are needed all across the IGP to introduce legumes where soil organic matter is generally declining and more rational N cycling is needed. However, there is a need for better quantification of legume contributions through systematic long-term experiments and systems modeling.

Water Management

Drought of different intensity is experienced in rainfed areas of the IGP at various growth stages of legumes. Response to limited irrigation has been observed in most of the grain legumes. Among various crops, common bean (*Phaseolus vulgaris* L.; French bean) was found to be more responsive to irrigation followed by pea. The success of mung bean as a catch crop (during summer months) in the rice-wheat system is solely dependent upon adequate supply of irrigation. Late-sown chickpea in sequence with rice also needs irrigation compared to the normal sown crop, probably due to restricted root growth with late sowing.

Pod initiation has been found to bo the most critical stage in most of the legumes. However, the initial soil profile moisture and soil types largely determine the requirement of subsequent irrigation. Similarly, excess moisture or waterlogging reduces oxygen concentration in the rhizosphere and thus affects BNF activity and nutrient availability with consequent yield reduction. Therefore, it is imperative to provide good drainage, especially in low-lying areas.

Weed Management

In early stages of growth, legumes are poor competitors to weeds and consequently suffer heavy yield losses. Yield losses due to weeds in the IGP were 44% in pigeonpea, 50% in black gram, and 42% in chickpea. The nature and magnitude of crop-weed competition is influenced by several factors such as crop species, cropping system, sowing time, plant population, moisture availability, and fertility conditions. Weed competition has adverse effect on crop yield and BNF.

Short-statured and early-maturing legumes such as black gram, mung bean, cowpea, and soybean can be intercropped in wide spaced crops such as pigeonpea to reduce the weed menace. Among various legumes, cowpea is more efficient in smothering weeds, followed by mung bean and soybean. Fast-growing legumes both as sole crops and intercrops suppress weeds and improve physical and biological conditions of the soil and provide high economic returns. In addition various chemical, cultural, and mechanical options are also available for effective and economic weed management in legumes. For more information on weed management see Pande et al. (in this volume).

Strategies for Increasing Legume Production in the IGP

Even though legumes enhance fertility restoration, break pest and disease cycles, and improve rhizosphere conditions in rice- and wheat-based cropping systems of the IGP their primary purpose of cultivation is for grain. Good growing conditions are required for both optimal N fixation and grain yield. Most of the agronomic and genotypic improvements for legumes in the past have heen done for optimal conditions. However, introduction of legumes in rice- and wheat-based cropping systems would be an opportunity cropping, largely under conditions of unfavorable soil moisture, texture, nutrients, and weather. Therefore, there is a need to develop genotypes and management practices to overcome production constraints and to reduce the opportunity costs involved in this cropping. Some steps in this direction are suggested below:

- Delineation of agroecological zones with length of growing season combined with soil types to identify crops and cultivars that can be grown in a given region.
- Identify crops with good seedling vigor for good crop establishment and plant stand.
- Development of legume crop genotypes with early-maturity; drought, cold, and salinity tolerance; resistance to insect pests and diseases for a given production system or ecoregion.
- Identify varieties suitable for late sowing and relay sowing and tolerant to excess moisture for areas having waterlogging/flooding problems.
- Incorporation of seed dormancy, as found in lentil and khesari (lathyrus), in other legumes.
- Efficient *Rhizobium* strains and crops genotypes to enhance symbiotic N, fixation.
- Introduction of early maturing, but high yielding, rice and/or wheat varieties to increase turn-around time for land preparation to ensure proper crop establishment.
- Assess fertilizer requirements and application methods for crop sequences and mixed cropping systems rather than for single crops.
- Production and distribution of quality seed of adapted high-yielding varieties.
- Develop and market low-cost farm implements to facilitate timely sowing and harvesting of legumes.

Conclusion

Introduction of grain legumes in rice- and wheat-based cropping systems of the IGP is an opportunity cropping, largely under conditions of unfavorable soil moisture, soil texture, nutrient supply, and weather. Grain legumes in rice- and wheat-based cropping sequences, therefore, require special management. Most of the agronomic and crop improvement research for grain legumes in the past has been done for optimal conditions. There is an urgent need to initiate appropriate location-specific and/or ecoregion-based production technologies to overcome the production constraints and reduce opportunity costs of grain legumes in the IGP. Recent location-specific examples of dramatic improvements in production of grain legumes strongly suggest that this is feasible. Considerable scope exists for substantial production increases of grain legumes in the IGP provided appropriate agronomic management is given to ensure increased system productivity and sustainability.

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8. Total Factor Productivity of Rice-Wheat Cropping Systems in India - The Role of Legumes

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Abstract

During the past three decades, the rice-wheat cropping systems (RWCS) in India significantly contributed to enhancing food grain production and achieving food self-sufficiency and food security. The production system now is under threat due to stagnating or declining total factor productivity. Legumes can play a significant role in enhancing the factor productivity of this most important and productive production system in the country. Ironically, rice and wheat have replaced the principal legumes over a period of time. With the availability of high-yielding and short-duration varieties of important legumes, there is a need to incorporate them in RWCS to improve the sustainability of the system so as to meet future food grain demands without degradation of the natural resource base.

Introduction

Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping systems (RWCS) gained prominence from the mid-1960s with the introduction of short-duration and high-yielding varieties of rice and wheat. The rotation has spread in the most fertile regions and has covered about 10 million ha in the Indo-Gangetic Plain (IGP) of India. It is more popular in the non-traditional rice-growing states of Punjab, Haryana, and Uttar Pradesh, and less in traditional rice-growing states of Bihar and West Bengal. The impressive performance of the system during the past three decades resulted in a quantum jump in the production of rice and wheat, which largely contributed in achieving the food self-sufficiency in India. The food grain production in India increased from about 90 million t in 1964-65 to about 190 million t in 1994-95 at an annual growth rate of >2.5%.

While the rapid growth in rice and wheat production yielded high dividends, it was realized during the late 1980s that gains might not be sustainable. Currently, there is a growing concern about the sustainability of RWCS, as the growth rates of rice and wheat yields are either stagnating or declining (Paroda et al. 1994). The productivity of rice and wheat in some parts of India has already ceased to increase and in a few states it has shown declining trends. Chaudhary and Harrington (1993) have shown that the expansion in rice and wheat area in Haryana has halted, growth in rice productivity has slowed down, and historical sources of productivity growth have exhausted much of their potential. Cultivation of rice and wheat has become less profitable over time. The threat is further aggravated when it is realized that the country needs to meet the growing food grain requirement of about 220.5 million t by 2001-2 and 243.2 million t by 2006-7 (Kumar and Mathur 1996). It is expected that about 80% of the total food grain demand will be for rice and wheat (Kumar 1997). The annual shortfall in the supply of rice and wheat by 2020 was projected to be about 32 million t.

The main questions now being raised by scientists and policy makers in this regard are:

- To what extent is the sustainability of the RWCS threatened?
- How can legumes and organic manures sustain the productivity of the system?
- How can any damage that has so far occurred be alleviated?

This chapter examines these issues to better characterize the performance of the RWCS. More specifically, the objectives of the

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chapter are to:

- Assess the significance of the RWCS in improving the food security of India.
- Diagnose changing use of traditional and modern inputs in the RWCS.
- Analyze the indicators of sustainabilily in RWCS.
- Examine the role of legumes in improving the sustainability of RWCS.

Methodology

Study Area

The study is confined to the 1GP of India. The entire region can be divided into two major cropping systems: (1) RWCS, and (2) Rice-based cropping systems. The former is largely confined to Punjab, Haryana, and Uttar Pradesh, and to some extent in Bihar and West Bengal, where rice and wheat are grown in a sequence. The second system is practiced more in large parts of Bihar and West Bengal, and to some extent in eastern Uttar Pradesh, where land is either kept fallow or cultivated to rice in the postrainy season.

Data

Data on area, production, yield, irrigated area, adoption of high-yielding varieties, farm harvest prices of rice, wheat, and important legumes were collected from published sources from 1970 to 1995 (Government of India 1995). This dataset was complemented by the farm-level data on yield, and use of inputs and their prices, which were collected from the 'Comprehensive Scheme for the Study on Cost of Cultivation of Principal Crops', Directorate of Economics and Statistics, Government of India.

Quantification of Sustainability

Total (actor productivity (TFP) is one measure of quantifying sustainability of any system. Lynam and Herdt (1988) argued that the appropriate measure of output, which determines sustainability of the crop, cropping system, or farming system is the TFP. It is defined as the total value of all output produced by the system over one cycle divided by the total inputs used by the system over one cycle of the system. It measures the amount of increase in total output, which is not accounted for, by the increase in total inputs. A sustainable system would have a non-negative trend in TFP over the period of concern. Later, Ehui and Spencer (1990) used inter-temporal factor productivity to measure the sustainability of a crop or farming system. During the past two decades or so, several studies on TFP have been published for India (Evenson and Jha 1973; Rosegrant and Evenson 1992; Sidhu and Byerlee 1992; Kumar and Mruthyunjaya 1992; Kumar and Rosegrant 1994; and Jha and Kumar 1996).

This paper used the Divisia-Tornqvist index (Diewert 1976) to measure TFP as an indicator of sustainability. The total output, input, TFP, and input price indices were computed as follows:

Total output index (TOI):

$$TOI_t / TOI_{t-1} = (Q_{it} / Q_{it-1})\,(R_{it} + R_{it-1})^{1/2}$$

Total input index (TII):

$$TII_t / TII_{t-1} = (X_{it} / X_{it-1})\,(S_{it} + S_{it-1})^{1/2}$$

TFP:

$$TFP_t = (TOI_t / TII_t)$$

Input price index (IPI):

$$IPI_t / IPI_{t-1} = (P_{it} / P_{it-1})\,(S_{it} + S_{it-1})^{1/2}$$

where, 'R_{lt}' is the share of output, 'j' is total revenue, 'Q ' is the output 'j', 'S_{it}' is the share of input 'I' in total input cost, 'X_{it}' is input 'I', 'P_{it}' is the price of input 'I', and 't' is the time variable. By specifying $TOI_{t\ 1,}$ TII, and IPI are equal to 100 in the base year (1981-82), the above equations provide the indices of total output, total input, TFP, and input prices for the specified period 't'. The real cost of production of different crops was computed by deflating the cost of production by the IPI.

Significance of the RWCS

Extent of the RWCS

Precise information on extent of RWCS is not available. Some estimates are being made, which reveal that RWCS area was spread over 10 million ha in the IGP of India in 1993 (Table 8.1). During the past three decades, the area under this system has risen by more than 6 million ha. About 75% of the total rice area and 63% of wheat area in the IGP was under the RWCS in 1993. The state level disaggregation showed that entire rice area in Punjab and Haryana, and about 96% in Uttar Pradesh was under the RWCS. In Bihar, the corresponding figure was 40%. Negligible rice area in West Bengal was under this cropping system. On the other hand, almost all the wheat area (which is too low when compared with rice area) in Bihar and West Bengal was in rotation with rice. The corresponding wheat area in the RWCS in Punjab and Uttar Pradesh was >60%. It was 36% in Haryana. This suggests that about 40% of the wheat area in Punjab and Uttar Pradesh, and about 64% in Haryana was rotated with crops other than rice.

Table 8.1. Estimated area under rice-wheat cropping systems in the Indo-Gangetic Plain (IGP) of India[1].

	Area of rice-wheat system (million ha)		Area under rice-wheat rotation as percentage of total rice area		Area unde rice-wheat rotation as percentage of total wheat area	
State	1983	1993	1983	1993	1983	1993
Punjab	1.4	2.0	100	100	44	63
Haryana	0.5	0.7	100	100	30	36
Uttar Pradesh	5.1	5.3	94	96	61	61
Bihar	1.7	1.9	37	40	96	96
West Bengal	0.1	0.3	2	4	41	98
IGP	8.8	10.0	72	75	58	63
All India	11.5	12.3	29	30	49	52

1. Average of triennium ending 1983 and 1993
Source: Government of India (1995).

Cereal Production and RWCS

The RWCS has substantially contributed to the food grain basket of the country, which made India a self-sufficient nation. During 1993, the RWCS contributed more than 50% of the cereal production in the IGP (Table 8.2). About 75% of Punjab's cereal production was from the RWCS. More than 50% of the cereal production in Uttar Pradesh and Bihar was contributed by the RWCS. In Haryana, 45.7% of the cereal production was contributed by the RWCS. In West Bengal, it was less than 10%. At aggregate level, the RWCS contributed >50% to total cereals production in the IGP. Thus sustainability of the RWCS in the IGP is of great significance to meet the country's growing demand for food grain.

Rice and Wheat Procurement

The significance of the RWCS can be seen by the procurement of rice and wheat from the region (Table 8.3). The available information

Table 8.2. Contribution of rice-wheat cropping systems (RWCS) in total cereal production in the Indo-Gangetic Plain (IGP) of India.

State	Production from RWCS (million t)		Total cereal production (million t)		Contribution of RWCS in total cereal production (%)	
	1983	1993	1983	1993	1983	1993
Punjab	8.2	14.1	13.9	19.7	59.0	74.6
Haryana	2.6	4.3	6.2	9.4	41.9	45.7
Uttar Pradesh	14.8	20.4	24.0	33.2	61.7	61.7
Bihar	3.9	5.5	7.7	8.9	58.6	61.8
West Bengal	0.9	1.1	6.9	12.4	13.0	8.9
IGP	29.9	44.7	58.7	83.6	50.9	53.5
All India	35.6	50.4	125.6	160.7	28.3	31.4

Source: Government of India (1995).

showed that about 76% of the total food grains in the country were procured from the IGP in 1994-95. About 95% of wheat and 60% of rice procurement came from the IGP. Punjab alone contributed about 60% of wheat and 42% of rice in total food grain procurement in the country. These evidences confirm that the RWCS is the backbone of the public distribution system and food security of the poor. Any threat to this system may seriously affect the food security of the poor living within and outside of IGP.

Table 8.3. Procurement of food grains (million t) in 1994-95 by government agencies from the Indo-Gangetic Plain (IGP) of India.

State	Rice	Wheat
Punjab	5.8	7.3
Haryana	1.4	3.1
Uttar Pradesh	0.7	1.3
Bihar	Negligible	0
West Bengal	0.2	0
IGP	8.2	11.7
All India	13.7	12.3
Share of IGP in all India (%)	6.0	9.5

Declining Growth in Production

Currently, the issue of concern is the stagnating yields of rice and wheat in the most productive regions of the IGP. To verify the emerging concern, state-wise growth rates in production, area, and yield of rice and wheat were computed for 1972-85, 1985-95, and 1972-95 periods (Table 8.4). Although yields of rice and wheat showed increasing trends, the rates of growth in production during 1985-95 were lower in comparison with those during 1972-85 in Haryana and Punjab. Annual compound growth rate of rice yield in Punjab was 4% during 1972-85, while it declined to 0.9% in 1985-95. The corresponding changes in growth rates of rice yields in Haryana were 3.7% and 0.8%. The area expansion was the major source of production growth in these states. In other states, the yields were yet to reach the potential level, and there was still enough scope to increase yields of rice. In case of wheat, the yield growth rates were positive and increased from 2.8% in 1972-85 to 4.2% in 1985-95 in the IGR Yield increase was still a main source of increasing wheat production in all the states. Slower rate of growth in production of rice and wheat during 1985-95 as compared to 1972-85 in Punjab and Haryana is a matter of serious concern as these states contribute major share of total food grain procurement for rest of the country.

Input Use Pattern

Changes in the Input Use

Date on cost of cultivation for the years 1976, 1985, and 1992 were used to examine the changes in traditional and modern inputs in the

Table 8.4. Annual compound growth rates (%) of area, production, and yield of rice and wheat in the Indo-Gangetic Plain (IGP) of India.

		Rice			Wheat		
State	Parameter	1972-85	1985-95	1972-95	1972-85	1985-95	1972-95
Punjab	Production	14.8	4.0	9.7	5.1	2.9	4.5
	Yield	4.0	0.9	2.3	2.6	2.3	2.5
	Area	10.8	3.1	7.4	2.5	0.6	1.5
Haryana	Production	9.8	4.3	6.4	6.1	4.7	5.8
	Yield	3.7	0.8	1.9	2.7	3.2	3.0
	Area	6.1	3.5	4.5	3.4	1.5	2.8
Uttar Pradesh	Production	4.6	3.7	4.2	6.7	7.1	6.9
	Yield	3.1	3.3	3.2	3.7	6.4	5.0
	Area	1.5	0.4	1.0	3.0	0.7	1.9
Bihar	Production	-1.0[1]	-0.3[1]	1.1	1.7	3.6	3.1
	Yield	-0.8[1]	-0.9[1]	1.5	0.5	2.8	1.9
	Area	-0.2[1]	-1.2	-0.3	1.2	0.8	1.2
West Bengal	Production	0.5	4.6	3.2	-2.1	-1.2[1]	-1.8
	Yield	0.5	3.3	2.6	0.0	-0.8[1]	0.0
	Area	0.0	1.3	0.6	-2.1	-2.0	-1.8
IGP	Production	3.2	3.4	3.3	5.4	4.9	5.2
	Yield	2.2	2.8	2.5	2.8	4.2	3.8
	Area	1.0	0.6	0.8	2.6	0.8	1.4

1. Not significant

RWCS (Tables 8.5 and 8.6). Two important features were observed: (1) use of inorganic fertilizers has remarkably increased, while that of organic sources of nutrients, namely farmyard manure and legumes, have declined; and (2) irrigation and improved varieties have almost reached the ceiling levels. Almost 90% area was sown under high-yielding varieties, about 80% area was under irrigation, and 260 kg ha^{-1} of chemical nutrients were used in rice and wheat. Fertilizer

Table 8.5. Annual compound growth rates (%) of inputs and yield in the rice-wheat cropping systems in the Indo-Gangetic Plain (IGP) of India during 1976-92.

Input/Yield	Punjab	Haryana	Uttar Pradesh	IGP
Traditional inputs				
Seed	0.7	0.4	-1.7	-1.4
Manure	0.3	-10.4	-10.2	-5.6
Modern inputs				
Fertilizers	3.9	3.9	5.3	5.5
Pesticides	14.8	22.9	11.0	17.2
Labor and machine				
Human labor	-2.6	-1.0	-1.5	-1.8
Bullocks	-12.9	-9.1	-5.5	-6.9
Machines	3.8	2.8	7.0	6.3
Rice-wheat				
Yield	2.5	1.7	2.1	2.4

Table 8.6. Estimated factor shares (%) in total cost of production of rice and wheat in the Indo-Gangetic Plain (IGP) of India[1].

	Punjab		Haryana		Uttar Pradesh		IGP	
Factor	I	II	I	II	I	II	I	II
Land	26	38	24	26	26	23	26	28
Seed	4	3	4	3	6	6	5	5
Labor	24	17	22	22	22	22	22	21
Bullocks	8	1	14	3	17	10	15	6
Machines	5	12	5	10	4	11	4	11
Fertilizer	15	12	11	12	9	8	10	10
Manure	1	<0.5	1	<0.5	3	<0.5	2	<0.5
Pesticide	<0.5	3	<0.5	3	<0.5	<0.5	<0.5	1
Irrigation	10	6	11	11	5	6	6	7
Interest due	7	8	8	10	8	13	8	11

1. I = 1974-76; II = 1990-92.

consumption in rice and wheat crops in Punjab was about 400 kg ha^{-1} in 1992, while in Uttar Pradesh it was <200 kg ha^{-1}. Sidhu and Byerlee (1992) reported that in some of the major developed districts of Punjab, such as Ludhiana, fertilizer has already exceeded the recommended dose. Hence, growth in the use of fertilizer and fertilizer's marginal contribution to yield are expected to be substantially lower in the future than what were realized in the past.

Adoption of high-yielding varieties and irrigation coverage have almost reached the ceiling level although scope still exists to adopt several new high-yielding varieties and efficient methods of using water and other critical inputs to attain higher growth in yield. In contrast to the use of high-yielding varieties and irrigation, which had reached a high level in almost all major RWCS areas during the early period, use of fertilizer [NPK (nitrogen, phosphorus, potassium)] continued to increase rapidly from about 107 kg NPK ha^{-1} in 1976 to 259 kg NPK ha^{-1} in 1992—an annual growth rate of 5.5%. By 1992, average fertilizer use had reached over 85% of the recommended dosage in Punjab, 60% in Haryana, and about 50% in Uttar Pradesh. In the 1980s, the use of pesticides/herbicides was too low, which increased manifold in Punjab and Haryana in early 1990s as compared to 1980s.

In contrast to the use of inorganic fertilizers, there was strong evidence that use of organic manure has declined substantially in the IGP. At aggregate level, it declined by about 5% annually during 1976-92 period, and its consumption decreased to <2 t ha^{-1} in 1992 from about 5 t ha^{-1} in 1976. This decline might have occurred because the cropped area has expanded much faster than the livestock numbers as bullocks have been replaced by tractors.

The use of labor-saving technologies, especially the tractors, has expanded rapidly and substituted for human and bullock labor (Table 8.6). The most prominent change has occurred in the use of animals; the annual growth rate has declined by 13% in Punjab, followed by 9% in Haryana, and 6% in Uttar Pradesh. The annual growth rate of human labor use has also decreased by 1-3%. The share of bullocks in the total cost of rice and wheat production fell sharply, while that of machines (largely tractors, harvesters, and combine) increased rapidly. The share of modern inputs in total cost has increased substantially over the past two decades in the IGP.

Real Cost of Production

As expected, with rapid technical change, the unit cost of production (at constant prices) of rice and wheat decreased steadily at an annual rate of 3.2% in Punjab, 2.6% in Haryana, and 2.4% in Uttar Pradesh during 1976-92 (Table 8.7). The unit cost of production of rice and wheat continued to decline during the 1985-92 period. However, the rate slowed down to -1.8%) in Punjab and -1.7% in Haryana, while it stagnated in Uttar Pradesh. The decline in the unit cost of production due to technological change and input subsidies has resulted in substantial increase in the marketable surplus of wheat and rice. These contributed to food security mainly by inducing sharp decline in real prices of rice and wheat grains (Table 8.8). Many of the benefits of higher efficiency in the use of inputs and lower unit costs of

Table 8.7. Trends in indices of unit cost of rice and wheat production at constant prices in the Indo-Gangetic Plain (IGP) of India.

	Index (%)			Annual growth rate (%)		
State	1976	1985	1992	1976-85	1985-92	1976-92
Punjab	185	131	114	-4.3	-1.8	-3.2
Haryana	173	131	116	-3.4	-1.7	-2.6
Uttar Pradesh	160	120	118	-2.7	0.0	-2.4
IGP	168	123	114	-3.3	-1.0	-2.9

Table 8.8. Trends in indices of per unit prices of rice and wheat at constant prices in the Indo-Gangetic Plain (IGP) of India.

	Index (%)			Annual growth rate (%)		
State	1976	1985	1992	1976-85	1985-92	1976-92
Punjab	109	96	99	-1.5	0.2[1]	-1.2
Haryana	123	104	133	-2.0	3.1	0.2[1]
Uttar Pradesh	105	94	102	-1.2	0.9	-0.7
IGP	106	93	104	-1.3	0.9	-0.7

1. Not significant.

production that technological change has generated were shared by both fanners and consumers. The farmers gain because of higher crop yields and production, while the consumers benefited by higher purchasing power due to lower prices. The fall in prices of grains have benefited the urban and rural poor more than the upper income groups, because the former spend a much larger proportion of their income on these crops than the latter (Kumar 1997).

Table 8.9. Trends in indices of total factor productivity (TFP) in rice-wheat cropping systems in the Indo-Gangetic Plain (IGP) of India.

	Index[1] (%)			Annual growth rate (%)		
State/Index	1976	1985	1992	1976-85	1985-92	1976-92
Punjab						
Input	47	137	172	10.9	3.3	7.2
Output	36	135	178	14.0	4.1	9.1
TFP	76	98	103	3.2	0.8	1.9
Harvana						
Input	63	114	156	5.3	5.2	4.2
Output	53	118	162	7.7	5.1	5.6
TFP	84	104	104	2.4	-0.1[2]	1.4
Uttar Pradesh						
Input	89	94	I N	0.9	3.5	1.4
Output	88	121	137	3.1	2.3	2.9
TFP	99	128	120	2.2	-1.2	1.6
IGP						
Input	78	105	128	3.2	3.5	3.4
Output	70	126	152	6.1	3.1	4.9
TFP	89	120	119	2.9	-0.4[2]	1.5

1. Average figures for triennium ending 1976, 1985, and 1992; the base year is 1980.
2. Not significant.

Total Factor Productivity (TFP)

Measurement of TFP

The average annual growth rates of outputs, inputs, and TFP indices for the RWCS in the Indian states of IGP are given in Table 8.9. The results revealed that in Punjab, the input index during 1976-92, has risen at the rate of 7.2%, whereas it was 4.2% in Haryana and 1.4% in Uttar Pradesh. With the input and technological change, the output increased by 9.1% in Punjab, 5.6% in Haryana, and 2.9% in Uttar Pradesh. Thus the TFP growth rate (during 1976-92 period) in the RWCS was estimated at 1.9% in Punjab, 1.4% in Haryana, and 1.6% in Uttar Pradesh. Overall in the IGP, the annual increase was 3.4% for input index, 4.9% for output index, and 1.5% for TFP index. The growth in the TFP was responsible for about 21% increase in output growth of rice and wheat in Punjab, 25% in Haryana, and 55% in Uttar Pradesh. The highest growth in rice-wheat production during 1976-92 was attributed to higher use of inputs in Punjab followed by Haryana and Uttar Pradesh. This suggests that the future output growth will largely be achieved by using more inputs. However, in these states use of modern inputs had already reached high levels in the early period.

During the period 1976-85, the growth in output was almost equally contributed by the growth in use of inputs and TFP. Later (1985-92), the growth rate in TFP for the RWCS declined (-1.2%) in Uttar Pradesh, near stagnated (0.8%) in Punjab, and totally stagnated (-0.1%) in Haryana. Such a phenomenon has two important implications: (1) the qualitative change due to improved technology has disappeared in the IGP; and (2) positive growth in output has been achieved as a result of input quantities. Negative and stagnating growth in the TFP is a matter of concern in the IGP.

Role of Legumes

Earlier studies (Kumar and Mruthyunjaya 1992; Rosegrant and Evenson 1992; Kumar and Rosegrant 1994) showed that research, extension, infrastructure, and literacy were the important sources of growth in TFP. Historically, legumes are known to improve soil fertility. Their importance has more significance in the RWCS where organic sources of soil fertility improvement have rapidly declined. Ladha et al. (1996) documented potential benefits of legumes in sustaining soil fertility. Joshi (1998) documented evidence that legumes contributed in saving nitrogenous fertilizers and improving soil fertility.

To confirm the role of legumes in the sustainability of the RWCS, legumes area is included as one of the variables in the TFP decomposition model along with a trend variable. Inclusion of trend variable was to capture the aggregate effect of research stock, expenditure on extension, infrastructure, and literacy on TFP. The estimated TFP decomposition equation for the RWCS in IGP is given below:

Ln TFP = 3.7125 + 0.1382" Ln ARLEG + 0.0445" T - 0.0011" TT
(3.98) (5.68) (2.81)

Adjusted R^2 = 0.60

where Ln = natural logarithm; TFP = index of TFP in RWCS; ARLEG = index of legume area; T = trend variable (starting from 1973); TT = square term of trend variable. Figures in parentheses are the student t-statistics, and ** is significance at 1% probability level.

The effect of legume area on TFP of RWCS is positive and highly significant which suggests that the role of legumes is of crucial importance for the growth in productivity and for sustaining the RWCS in IGP. Legumes productivity may be encouraged to improve the sustainability of rice and wheat crops in IGP.

Summary and Conclusion

The RWCS is spread in the most fertile regions covered by the IGP. In India, the system is prominent in the states of Haryana, Punjab, and Uttar Pradesh, where three-quarters of the total rice area and more than half of the wheat area is under the RWCS. The production system contributes about one-third of India's total cereal production. As high as 95% of the wheat procurement, and 60% of rice procurement comes from the RWCS of the IGP. The sustainability of the RWCS in IGP is critical for the country's public distribution system and food security.

The share of TFP in the growth rate of rice and wheat production is declining. The yield growth is more input based. The use of modern inputs (e.g., high-yielding varieties, irrigation, chemical fertilizers, and pesticides) in the IGP has already been achieved to a high level. The organic sources of nutrients (such as organic manure and legumes area) are rapidly declining in the RWCS. Further scope of increasing yield of rice and wheat from modern inputs and area expansion seems to be remote. Better management of existing soil and water resources can enhance the growth in yield and production of the RWCS.

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9. Socioeconomic Constraints to Legumes Production in Rice-Wheat Cropping Systems of India

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Abstract

Despite lower cost of production and higher output prices of legumes, their profitability has remained too low in comparison with rice and wheat. Even if the existing subsidies on fertilizers and electricity for irrigation are withdrawn, it was shown that the rice-wheat cropping sequence remains most profitable. Inclusion of legumes in the system helped in conserving the natural resource base, particularly soil fertility and groundwater, but at the cost of profit, food grain production, and unemployment of fixed resources. The prime need is to break the existing yield barriers of legumes and design innovative policies on risk and resource management.

Introduction

The rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping systems (RWCS) which cover about 10 million ha of the Indo-Gangetic Plain (IGP) of India are showing multiple problems. The two major problems are related with (1) production levels of rice and wheat, and (2) sustainability of soil and water resources. On the production side, the key problem is the stagnating or declining yields of rice and wheat. The traditional sources of growth in food grain production have been exhausted (Joshi et al. 1994). An issue of greater concern is that the total factor productivity of rice and wheat is also showing declining trends (Kumar and Mruthyunjaya 1992; Kumar and Rosegrant 1994; Kumar et al., in this volume). With regard to resource degradation, there is a threat of deteriorating soil nutrient status and groundwater level. The available reports reveal that soils in RWCS have become deficient in some macronutrients (e.g., nitrogen and sulfur) and micronutrients (e.g., zinc, manganese, and iron). Similarly, the water table is fast receding in good quality (saline, alkaline) acquifers (Joshi and Tyagi 1991), while increasing in poor quality acquifers. These problems need to be solved to increase food grain production in a sustainable manner to meet the present and future demands from the most inherently fertile and intensively cropped region in the country.

Crop diversification through legumes can play an important role in addressing many of the problems arising in RWCS. Legumes complement cereals in both production and consumption. In the production process legumes improve soil fertility status, require less water than cereals, and their rotation with cereals helps control diseases and pests. On the consumption side, legumes are the cheapest source of protein in the vegetarian diet and supplement mineral and vitamin requirements. Despite their value in production and consumption, the area under legumes in RWCS has declined after the introduction of improved technologies during the mid-1960s (Joshi 1998). Several reasons for the declining status of legumes have been reported. These include: (1) government focus on support of cereals; (2) lack of superior technology for legumes; (3) biotic constraints related to diseases in legumes; (4) abiotic constraints such as soil salinity, waterlogging, and frost; and (5) socioeconomic constraints. Little has been analytically reported on socioeconomic constraints to legumes production in RWCS. This study is an attempt to address the socioeconomic factors constraining legumes production.

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More specifically, the study empirically examines the socio-economic issues, which may be relevant for researchers and policy makers on legumes production in RWCS. The specific objectives are to:

- Identify the major socioeconomic constraints that affect legumes production.
- Examine alternative options to alleviate the identified socio-economic constraints.
- Identify opportunities for legumes in RWCS.

Methodology

Data and Sample

The analysis is based on both secondary and primary data. The secondary data were collected from published sources on area, production, yield, and prices of legumes, rice, and wheat (Government of India 1995, 1998). To collect primary data, Karnal district in Haryana was purposely selected because of two specific reasons: (1) rice-wheat is the predominant cropping system in Karnal than in other districts of Haryana; and (2) area under legumes in this district has rapidly declined with the advent of the green revolution in the mid-960s. It was envisaged that conclusions derived from this district would be relevant for other regions in Punjab and Uttar Pradesh, which practice intensive RWCS and have similar agroclimatic features.

Seventy farmers were randomly selected by following a systematic sampling scheme. A three-stage sampling procedure was adopted to select blocks, villages, and farmers. At the first stage, a cluster of four blocks, namely Indri, Karnal, Nilokheri, and Nissing, was selected on the basis of largest area under rice and wheat. In the second stage, seven villages were randomly selected. In the third stage farmers were sampled, making a sample size of 70 farmers.

Primary data were collected through personal interview in a specifically designed questionnaire for the year 1996/97. Data on item-wise cost of production of different crops, their yield levels and profitability were collected from sample farmers. Information on irrigation schedule, water charges, and electricity charges were also collected.

Analytical Framework

Economics of crop production was computed for each crop to evaluate the profitability of rice and wheat in comparison with legumes. Profitability of different crop rotations was also compared with the rice-wheat sequence. These comparisons were made with and without irrigation and fertilizer subsidy. The purpose was to examine whether subsidies in irrigation and fertilizer changed the economics of different crops, particularly rice and wheat.

Five indicators were assessed to examine the trade-off between rice-wheat and legumes. These indicators were: (1) profit; (2) food grain production; (3) fixed resources; (4) groundwater; and (5) soil nutrients. The trade-off values for each indicator were computed as follows:

$$TO_i = (C_i - L_i)/L$$

where, TO_i is the trade-off for i^{th} indicator; C. is the value of i^{lh} indicator for cereals (rice or wheat); and L is the value of i^{th} indicator for legumes (pigeonpea (*Cajanus cajan* (L.) Millsp.), chickpea (*Cher arietinum* L.), or berseem clover (*Trifolium alexandrinum* L.; Egyptian clover)].

Legumes in the Existing Cropping System

The cropping pattern followed by the selected sample farmers in 1996/97 indicated that rice and wheat were the major crops of the study area, to the extent of occupying 81 % of the total cropped area (Table 9.1). Legumes (grain, fodder, and summer) covered only 9% of the total cropped area. Important grain legumes were pigeonpea, chickpea, lentil (*Lens culinaris* Medic), mung bean *(Vigna radiata* (L.) Wilczek), and black gram (*Vigna mungo* (L) Hepper) which occupied about 3.4% area. Berseem and lucerne (*Medicago sativa* L.; alfalfa) were the fodder legumes, which covered 3,5% of the total cropped area. During summer, *Sesbania* sp was grown in about 2.2% of the cropped area. Area under oilseeds and other commercial crops [e.g., sugarcane (*Saccharum officinarutn* L)] was negligible. It was noted that farmers were maintaining about 3.5% area under fodder during the rainy season, particularly sorghum (*Sorghum bicolor* (L.) Moench) and maize (*Zea mays* L.), while berseem and lucerne were the main fodder crops during winter. Although legumes area in this dominant RWCS was less than 10%, it was much higher than area of other crops. This indicated that legumes were still preferred besides rice and wheat although the extent was small.

Table 9.1. Cropping pattern in selected villages, of Karnal district in Haryana. India, 1996/97.

Crop group	Crop	Area (%)
Cereals (grain)	Rice	43
	Wheat	38
	Others (maize)	0.2
Cereals (fodder)	Sorghum, maize	3.4
Legumes (grain)	Pigeonpea, chickpea, lentil, mung bean, and black gram	3.4
Legumes (fodder)	Rerseem and lucerne	3.5
Legumes (summer)	*Sesbania* spp	2.2
Oilseeds	Mustard, toria, and sunflower	2.8
Commercial crops	Sugarcane	3.2
Others	Others	0.6

Source: Based on on-farm survey, 1996-97.

Profitability of Legumes vs Rice and Wheat

Profitability is the most important criterion for allocating area to alternative crop choices. Profitability of a crop is largely influenced by cost of production, crop yields, and output prices. Table 9.2 presents the economics of rice, wheat, and important legumes (pigeonpea, chickpea, lentil, and berseem). Despite substantially lower cost of cultivation of legumes when compared with that of rice and wheat, the profitability of different legumes did not consistently match that of rice and wheat. However, berseem clover was more profitable than wheat but it was solely grown for fodder purposes, and its area expansion was restricted by market considerations.

Table 9.2. Cost and net profit of rice, wheat, and legumes in selected villages of Karnal district, in Haryana, India, 1996/97.

Crop	Cost (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})
Rice	13150	30200	17050
Wheat	11825	23725	11900
Pigeonpea	5515	14180	8665
Chickpea	7015	16590	9575
Lentil	6075	13135	7060
Berseem	9180	22800	13620

Source: Based on on-farm survey, 1996-97.

Lower net profit of legumes when compared with that of rice and wheat was mainly due to their poor yield performance. However, output prices of all legumes were much higher than those of rice and wheat. Yields of legumes were so low that higher output prices could not make them more profitable than rice and wheat (Table 9.3). The output prices of pigeonpea were just double those of rice whereas the yield level of rice was four times higher than pigeonpea. Similarly, chickpea prices were almost double those of wheat prices, but wheat yields were 60% higher than chickpea yields.

Analyzing historical trends in the prices of legumes, rice, and wheat, it was noted that the minimum support and procurement prices of all legumes announced by the government were always kept higher than those of rice and wheat (Table 9.4). Historically, yields of legumes were always substantially lower than those of rice and wheat in Haryana, Punjab, and Uttar Pradesh. It was noted that yields of rice and wheat increased much faster than legumes in these states (Table 9.5). The analysis clearly reveals that a yield breakthrough in legumes was not realized as in rice and wheat. Although a number of improved cultivars of various legumes were developed, they were not widely disseminated due to lack of knowledge of the farmers.

Table 9.3. Yield and grain prices of rice, wheat, and important legumes in selected villages of Karnal district in Haryana, India, 1996/97.

Crop	Yield (kg ha^{-1})	Price (Rs kg^{-1})
Rice	4250	6.80
Wheat	4030	5.00
Pigeonpea	1035	13.00
Chickpea	1460	11.00
Lentil	960	13.00

Source: Based on on-farm survey, 1996-97.

Table 9.4. Minimum procurement prices (Rs t^{-1}) of rice, wheat, and important legumes.

Crop year	Rice[1]	Wheat	Chickpea	Pigeonpea
1975/76	740	1050	900	na[2]
1980/81	1050	1170	1750	1900
1985/86	1420	1620	3000	2600
1990/91	2050	2250	4800	4500
1995/96	3600	3800	7000	8000
1996/97	3800	4750	7400	8400

1. Refers to common type of paddy.
2. na = not applicable.
Source: Government of India (1998).

Table 9.5. Average yield (kg ha^{-1}) of rice, wheat, and important legumes in major rice- and wheat-growing states of the Indo-Gangetic Plain in India.

State	Year	Rice	Wheat	Chickpea	Pigeonpea
Harvana	1975/76	2060	1980	820	210
	1980/81	2600	2360	630	1080
	1985/86	2800	3090	820	1070
	1990/91	2770	3480	720	950
	1995/96	2272	3640	1010	790
	1996/97	2964	3880	800	1133
Punjab	1975/76	2550	2370	990	500
	1980/81	2740	2730	580	1000
	1985/86	3180	3530	910	1100
	1990/91	3230	3710	740	820
	1995/96	3050	3827	892	880
	1996/97	3397	4234	920	850
Uttar Pradesh	1975/76	930	1360	720	1470
	1980/81	1050	1650	860	1450
	1985/86	1490	2000	860	1360
	1990/91	1830	2170	880	1230
	1995/96	1889	2423	690	1010
	1996/97	2121	2668	930	1139

Source: Government of India (1995, 1998).

Profitability of Alternative Cropping Sequences

The profitability of the rice-wheat cropping sequence was compared with other alternative cropping sequences. This analysis was done under three alternative options: (1) existing prices of fertilizers and electricity charges paid by the farmers for irrigation; (2) without electricity subsidy for extraction of groundwater for irrigation; and (3) without fertilizer and electricity subsidy for irrigation. Results of this exercise are presented in Table 9.6. It was noted that rice-wheat-black gram was the most profitable crop sequence with the prevailing subsidies in fertilizers and electricity for irrigation. It was followed by rice-berseem and rice-wheat-mung bean sequences. The adoption of these three crop sequences was limited in the study area due to resources and market constraints. Cultivation of black gram and mung bean requires much water after the harvest of wheat, whereas berseem area expansion was restricted due to the limited market determined by livestock population. Profitability of the rice-wheat sequence, the most popular in the study area, was higher than those of rice-chickpea and pigeonpea-wheat. It was noted that even if the existing subsidies on fertilizer and electricity for irrigation were withdrawn, the rice-wheat rotation was still the most profitable crop sequence. The analysis confirmed that from the profitability point of view it was logical for the farmers to allocate area for rice-wheat sequence. Substitution of legumes for rice or wheat means loss in earnings of the farmers. To introduce or substitute legumes in RWCS, profitability of legumes needs to be raised substantially. It would come through a substantial increase in their yield levels, which could be attained through dissemination of appropriate technologies on farmers' fields.

Table 9.6. Profitability ('000 Rs ha^{-1}) of various crop rotations under different scenarios in Karnal district, Haryana, India.

Crop rotation	With subsidy[1]	Without subsidy in fertilizer	Without subsidy in electricity and fertilizer
Rice-wheat-black gram	31.4	30.2	22.5
Rice-berseem	30.6	29.8	20.9
Rice-wheat-mung bean	30.5	29.2	21.5
Rice-wheat	28.9	27.8	20.6
Rice-chickpea	26.6	26.0	20.0
Pigeonpea-wheat	20.5	19.7	18.0

1. Subsidy in fertilizer and electricity for irrigation.
Sourer: Derived from data of on-farm survey, 1996-97.

Trade-off between Legumes and Competing Crops

Rice and wheat arc clearly the most profitable crops. However, in terms of resource degradation, RWCS is threatening the sustainability of the existing production system and the natural resource base. Thus the role of legumes becomes important in improving the sustainability of the natural resource base. An analysis was undertaken to examine the trade-off if rice was substituted by pigeonpea and wheat by chickpea, lentil, or berseem. Five criteria were assessed to examine the trade-off due to inclusion of legumes in the existing production systems. These were: (1) profit; (2) food grain production; (3) fixed assets (farm implements and machinery); (4) groundwater; and (5) soil nutrients (nitrogen). It is obvious that majority of the farmers maximize profit, food grain production, and utilize fixed resources.

The results of this analysis are presented in Table 9.7. Trade-off values were computed as explained in the analytical framework section. The trade-off values for replacing rice by pigeonpea were examined and it was observed that farmers would lose about 49%

Table 9.7. Trade-off (percentage change) in replacing rice or wheat with legumes in Karnal district, Haryana, India, 1996/97'.

Indicator	Pigeonpea	Chickpea	Lentil	Berseem
Profit	-49	-19	-41	+ 2
Food grain	-76	-64	-76	
Fixed resources	-57	-49	-61	-43
Groundwater	+95	+85	+83	-125
Soil nutrients	+65	+73	+75	+56

1. In rice-wheat cropping system, rice was substituted by pigeonpea and wheat by chickpea, lentil, and

2. Herseem is a fodder legume.
Source: Derived from data of on-farm survey, 1996-97

Table 9.8. Marginal value products (Rs) of inputs for rice, wheat, pigeonpea, and chickpea, in Karnal district, Haryana, India, 1996/97[1].

Input	Rice	Pigeonpea	Wheat	Chickpea
Fertilizer	5.2	-4.9	2.2	1.6
Irrigation	-2.8	601.9	7.2	-186.7
Machinery	278.3	na[2]	70.6	624.2

1. Marginal value products were derived from the production functions estimated for each crop by regressing gross value of output with three independent variables. namely fertiliser, irrigation, and machinery. These values indicate additional gain (if positive) or loss (if negative) by subsequent increase in the level of the respective input.
2. na = not applicable as no machinery was used for pigeonpea cultivation.
Source: Derived from data of on-firm survey, 1996-97.

profit. The region would need to sacrifice 76% food grain production and 57% of the fixed resources would remain unutilized. However, on the positive side, the region would save about 95% of the groundwater and 65% of the nitrogenous fertilizer. Assessing trade-off between wheat and chickpea, it was noted that farmers would lose about 19% profit. The region would sacrifice about 64% food grain production, and about 49% fixed resources would not be utilized, which have high opportunity cost. As a gain, chickpea cultivation would save about 85% of groundwater and 73% of nitrogenous fertilizer. Similar trade-offs were observed for wheat and lentil. Interestingly, the trade-off between wheat and berseem (a fodder legume) was different, and there was negligible loss in profit. This was despite the groundwater used for berseem being much more than that used for wheat. Thus substitution of wheat by this fodder legume would mean further over-exploitation of groundwater.

Production functions were also estimated by treating value of outputs of different crops as dependent variables and use of fertilizer, irrigation, and machinery as independent variables. Marginal value products of independent variables for rice, wheat, pigeonpea, and chickpea were computed (Table 9.8). The marginal value products of different factors of rice and pigeonpea indicated that there was over-utilization of irrigation water in rice, and excess use of fertilizer in pigeonpea. In case of chickpea and wheat, the marginal value products of fertilizer for wheat was more than that of chickpea. This suggests that with limited availability of fertilizer, first priority for fertilizer application would go to wheat because of its higher marginal value products. Marginal value products for irrigation water for wheat was positive but negative for chickpea. This is because the chickpea crop is sensitive to excess water.

This analysis suggested that there was a trade-off between different indicators when legumes substituted rice and wheat. Although there was a loss in terms of profit, food grain production, and use of fixed resources, there were substantial gains in conserving groundwater and nitrogenous fertilizers. In view of the trade-off between important indicators, it is necessary to develop an optimum combination of RWCS with inclusion of some legumes in the production system to improve the sustainability of water and soil resources and meet the basic objectives of farmers.

Market and Prices

Another most important constraint to legumes production in RWCS is lack of adequate output markets. Markets for legumes were thin and fragmented in comparison with rice and wheat, which have assured markets (Byerlee and White 1997). It has been observed that government procurement for legumes was not effective as it was for rice and wheat. Farmers on many occasions did not get the minimum prices announced by the government.

The price spread (or the market margin) for legumes was much higher than that of rice and wheat due to higher postharvest costs. The share of farmers' returns in consumers' price was much lower for legumes than for rice and wheat. It was estimated that the price spread for pigeonpea dhal was Rs 15 kg^{-1}, while it was less than Rs 1 kg^{-1} for rice (Joshi and Pande 1996). The price spread for chickpea was Rs 3.20 kg^{-1}, whereas it was only Rs 1.20 kg^{-1} for wheat. The estimates on farmers' share in consumers' rupee in the case of pigeonpea was about 40%, and about 85% for rice. For chickpea it was about 35%, and for wheat it was as high as 91%.

The above results showed that farmers are not really benefited by higher market prices of legumes. To encourage legumes production in RWCS, similar mechanisms of their procurement as for rice and wheat need to be evolved.

Risk

Risk is one of the most important constraints in legumes production. Production of legumes is relatively more risky that that of rice and wheat. The price and yield risks of legumes were much higher than those of rice and wheat (Joshi and Pande 1996). The coefficients of variation in yields of rice, wheat, pigeonpea, and chickpea in the RWCS were computed for all the districts in the Indian states of IGP. It was noted that the coefficients of variation of chickpea and pigeonpea yields were greater than those of wheat and rice in most of the districts. This suggests that legumes were more prone to risk due to crop failure (represented by yields) in comparison with rice and wheat. Similarly, price fluctuations (post- and preharvest) in chickpea and pigeonpea were higher than those in rice and wheat. These findings clearly suggested that yield and price risks were hindering adoption of legumes in the RWCS.

Challenges for Future

The analysis presented above suggested that the major constraints in legumes production in RWCS were their lower profitability when compared with that of rice and wheat. Despite a lower cost of cultivation and higher output prices of legumes than rice and wheat, the low profit was mainly due to their poor yield performance. This was due to lack of any significant technology breakthrough as was witnessed for rice and wheat. There has been a significant change over time in yield levels of legumes. It is estimated that if pigeonpea was to compete with rice, its yields must be increased from the current 1 t ha^{-1} to about 2 t ha^{-1}. Similarly, lentil yields must be raised from < 1 t ha^{-1} to at least 1.4 t ha^{-1} to compete with wheat. Chickpea yields are approaching levels that would allow it to compete with wheat. The estimates suggested that average chickpea yields must be increased from 1.51 ha^{-1} to 1.61 ha^{-1}. Although chickpea is now competitive with wheat with respect to yield, the risk factor due to diseases and insect pests in chickpea remains high and needs due attention.

In the future, legumes research has to better compete with advanced research in rice and wheat. Biotechnology research in rice and wheat has already made headway. With the new technology frontier in rice and wheat, the existing low yield levels of legumes will further displace them from the production system. It is therefore necessary that more resources should be allocated for advanced research in legumes to face the challenge. Efforts should be strengthened to enhance yield potential of extra-short-duration pigeonpea, chickpea, and hybrid pigeonpea (Joshi and Pande 1996).

Production risk is another area which needs more focused attention. More disease resistant varieties with high yield potential should be introduced in the RWCS. Unless more stable and high-yielding varieties of different legumes are introduced, the probability of increased adoption of legumes in RWCS is remote. Another challenge for future policy research is to create assured output markets for legumes. The markets should be such that farmers get at least minimum procurement prices of their produce as they always get for rice and wheat. The second issue concerning markets for legumes is to reduce the postharvest losses as well as costs. High processing costs leads to higher price spread. There is a need for research to develop appropriate technologies which could minimize the processing losses in legumes.

Summary and Conclusion

It is evident that rice and wheat were more profitable than legumes but consumed more groundwater and soil nutrients. Legumes can play an important role in conserving groundwater and soil nutrients, especially nitrogen.

Rice and wheat were more profitable than legumes even without fertilizer and irrigation subsidies. Therefore, merely withdrawing subsidies from fertilizers and electricity for groundwater may not solve the problem of sustainability of natural resources (groundwater and soil nutrients) in RWCS. Crop diversification through introduction of legumes can play an important role in improving the sustainability of the production system. But the challenge is to break legume yield barriers, and design innovative policies on risk and resource management.

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10. Regional Opportunities for Warm Season Grain Legumes in the Indo-Gangetic Plain

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Abstract

The major warm season grain legume crops grown in the region of the Indo-Gangetic Plain (IGP) are pigeonpea, mung bean, block gram, cowpea, groundnut, and soybean, There has been a general decline in their area and production in the region over recent decades, coinciding with intensification of cereal-dominated cropping systems such as the rice-wheat rotation. Various abiotic, biotic, and socioeconomic constraints can explain the poor performance of these legumes, relative to that of cereals and cash crops. Further, there is little government price and policy support for grain legumes, compared with the major cereals. These legumes generally remain as subsistence crops, with a consequent reluctance of farmers to invest in key inputs that could raise and stabilize yields to economically competitive levels. Nevertheless, there is evidence that the regional demand for the products (e.g., grain, vegetable oil, and fuelwood) of these legumes remains or is increasing. Further, in view of increasing questions about the long-term sustainability of cereal-based monocropping, there is a rationale for substantially increasing the proportion of legumes in cropping systems of the IGP. There is thus a case for stimulating their production in the region.

There are several niches in the IGP where legume cultivation can be substantially increased, particularly to take advantage of recent improvements in genotype and agronomic practices. There are also several recent location-specific examples, inside and outside of the region, of dramatic improvements in production of grain legumes (e.g., mung bean in Pakistan); it is worthwhile analyzing the reasons for success with a view to emulating the success in specific niches of the IGP. Invariably, the way forward for each of these crops is to move towards commercialization of their production, initiated by appropriate policy incentives. It is concluded that there can be substantial increases in production of these legumes in the IGP without undue competition with rice or wheat. On the contrary, greater use of legumes in rice- and wheat-based cropping systems should ultimately improve total system productivity and sustainability.

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Introduction

Several important tropical grain legumes are generally well adapted to the long-day period, from Apr to Oct, in the Indo-Gangetic Plain (IGP). They are usually short-day plants, with flowering and the reproductive growth phase induced by the short daylengths and declining temperatures of the approaching winter. An exception is groundnut *(Arachis hypogaea* L) where only partitioning of assimilates to pods is favored, in some genotypes, by short-day conditions (Bell et al. 1992). These tropical legumes have their temperature optima for most growth and development processes within the range of 20-40°C, which is the usual temperature limits *of* the IGP during the long-day period.

The important tropical legumes for the IGP are pigeonpea (*Cajanus cajan* (L.) Millsp.), mung bean *(Vigna radiata* (L.) Wilczek), black gram (*Vigna mungo* (L) Walp.), cowpea *(Vigna unguiculata* (L.) Walp.), groundnut, and soybean *(Glycine max* (L.) Merr.). In the eastern part of the IGP (Bihar and West Bengal states of India and in Bangladesh), the winters are sufficiently mild to support growth of these crops in this season, although perhaps not at optimum growth rates. But there are some advantages of growing these tropical legumes in the mild winters, which will be elaborated.

Increasing cultivation of rice and wheat in rotation has reduced opportunities for cultivation of these legumes in the traditional manner. Thus, these pulses were relegated to the marginal areas for cereal cultivation (Ali et al. 1997). However, new opportunities for their cultivation are arising as a result of development of novel genotypes and agronomic practices for these legumes, and problems arising in some of the intensive, non-legume cropping systems. For example, the advent of extra-short-duration and photoperiod-insensitive mung bean varieties makes feasible their cultivation in the narrow cropping window between harvesting of wheat (*Triticum aestivum* L.) and planting of rice (*Oryza sativa* L.) in the rice-wheat cropping systems (RWCS).

The IGP of India grows by far the largest area of warm season grain legumes, as compared to the other IGP countries, but in the Indian IGP, areas are stagnant in the case of pigeonpea and *Vigna* spp and noticeably declining for groundnut and soybean (Table 10.1). In the

Table 10.1. Harvested area ('000 ha) and yield (t ha^{-1}) of warm season grain legumes averaged for the 3-year periods 1985-87 and 1995-97 for South Asian countries, all of Asia, and all of the world.

	Pigeonpea		*Vigna* spp[1]		Groundnut[2]		Soybean	
Entity	1985-87	1995-97	1985-87	1995-97	1985-87	1995-97	1985-87	1995-97
Harvested area								
Bangladesh	6.2	6.0	127	120	29.1	35.3	-[3]	
India - total	3,162	3,517	9,181	9,267	6,983	7,549	1,470	5,354
India - IGP[4]	668	657	843	906	185	167	127	33
Nepal	15.9	25.3	24	38			15.9	21.1
Pakistan	0.8	-	185	250	61.4	105.0	5.2	4.6
Asia	3,254	3,802	13,211	13,889	11,952	13,139	11,943	15,742
World	3,568	4,135	25,764	26,306	18,946	22,563	52,500	63,671
Yield								
Bangladesh	0.74	0.50	0.64	0.69	1.15	1.14	-	
India - total	0.77	0.66	0.34	0.38	0.81	1.07	0.64	1.04
India - IGP	1.10	0.99	0.50	0.56	0.96	1.03	0.88	1.11
Nepal	0.75	0.76	0.54	0.50	-	-	0.53	0.55
Pakistan	0.63	-	0.49	0.47	1.04	1.09	0.49	1.25
Asia	0.61	0.66	0.53	0.58	1.19	1.57	1.27	1.43
World	0.76	0.66	0.58	0.55	1.13	1.34	1.87	2.10

Source: FAOSTAT.

1. For South Asian countries represents almost entirely mung bean and black gram but for "Asia" and "World" includes all *Phaseolus* spp and *Vigna* spp.
2. Groundnut in shell.
3. No data recorded.
4. Values for the Indo-Gangetic Plain (IGP) of India arc derived from All et al. (in this volume) but the most recent 3-year time period is 1993-95 instead of 1995-97.

other 1GP countries, areas are either stagnant or in some cases increasing, for pigeonpea in Nepal, for *Vigna* spp in Nepal and Pakistan, for groundnut in Bangladesh and Pakistan, and for soybean in Nepal (Table 10.1). Yields of warm season grain legumes have generally been stagnant over the previous decade, apart from the yield increases in the relatively small areas of soybean grown in the 1GP of India and Pakistan (Table 10.1).

Prices of the grain of the warm season legumes have risen, in comparison with other food items, but this is unlikely to be a result of declining consumer preference for pulses (Ali and Abedullah 1998). There is a continuing demand in the region for the traditional products of these tropical legumes. The major demand is for dhal (dry, dehulled split seed) made from the grain of the tropical pulses, particularly for pigeonpea in India and Nepal. There is seemingly an insatiable demand for vegetable oil derived from groundnut or soybean. The legumes under discussion are the main sources of essential vitamins and minerals which are otherwise in marginal supply in the region, as well as of protein. Pigeonpea is increasingly valued as a source of fuelwood, due to an increasing scarcity of firewood in the region. Also of importance, but not widely recognized or quantified, is the existing and potential role of these legumes in contributing to cropping system sustainability in the region through their ameliorative effects on soil health (Ali et al. 1997; Kumar Rao et al. 1998).

Therefore, in view of the continuing, and increasing demand for these legumes (as suggested by price rises of the main products), as well as their potential for contributing to sustainability of the system, there seems a strong rationale for increasing their production within the region. The alternative is to import these products from outside of the region. This chapter highlights opportunities across the region for increasing production of these tropical legumes. Conclusions are drawn from the situation presented in the country chapters of this volume and from the Workshop discussions, and supported by published work as appropriate. Each legume is considered separately, although mung bean and black gram are considered together, because of the quite similar sets of constraints, cropping system options, and potential opportunities for each.

Pigeonpea

Need and Scope

The strongest demand for pigeonpea is in the central IGP, in Uttar Pradesh and Bihar states of India and the Terai of Nepal. There is an increasing demand for pigeonpea grain in the rest of India as well. There is limited demand for pigeonpea grain at the eastern (Bangladesh) and western (Pakistan) ends of the IGP, but there is a potential for export to India for the pigeonpea grown in these regions. Currently, Myanmar and Nepal export pigeonpea to India.

Reports on the substantial and valuable residual effects of pigeonpea, in terms of additions of fixed nitrogen (N) and soil organic matter to the cropping system, have recently been compiled by Kumar Rao et al. (1998). Thus pigeonpea is a desirable crop from the point of view of system sustainability, all across the IGP where soil organic matter is generally decreasing and more rational N cycling (such as through organic matter) is needed. Pigeonpea can therefore substitute green manure crops in having substantial residual benefits with a bonus of grain yield (an immediate return for the farmer). However, there is a need for better quantification of this comparison through conduct of long-term experiments and systems modeling.

Adaptation

Due to the limitation caused by risk of frost, long-duration pigeonpea (LDP), which is sown in Jun-Jul and harvested in the following Apr-May, and rabi (postrainy season) pigeonpea, sown in Sep and harvested in Apr, are adapted only in the eastern half of the IGP (east of about 80° E). Thus short-duration pigeonpea (SDP) and extra-short-duration pigeonpea (ESDP) (see Gupta et al. 1989 for pigeonpea growth duration nomenclature), which is normally sown in May-Jun and harvested in Oct-Nov, is required in the western IGP (west of 80° E). Development of frost-tolerant LDP or rabi pigeonpea would be difficult and ranks as a low priority in genetic improvement of pigeonpea.

On the other hand, cultivation of rainy season SDP or ESDP in the eastern IGP is severely constrained by insect pests [*Maruca lestulalis* Geyer (legume pod borer), *Helicoverpa armigera* Hubner (pod borer), and *Melanagromyza* spp (podfly)], waterlogging, and rain damage to maturing pods. However, some of these SDP and ESDP genotypes may be suitable for rabi cultivation in eastern IGP (Ahmed et al. 1996).

Major Abiotic and Biotic Constraints

For SDP and ESDP, insect pests [primarily *H. armigera, M. testulalis,* and *Mylabris pustulata* Thunberg (blister beetle)] pose the severest constraints to yield realization and yield stability. Components of integrated pest management (IPM) strategies are available (Lal et al. 1996) but large-scale evaluation of improved packages is yet to be done. Other constraints limiting yields and discouraging further adoption of SDP and ESDP are waterlogging, salinity, drought (in rainfed areas of the western IGP of India), sterility mosaic (SM) |caused by virus (?)], and phytophthora blight *(Phytophthora* f. sp *cajani).* Significant alleviation of these constraints relies mainly on improvement of genetic resistance to these factors, a long-term process; progress in this regard is summarized in Laxman Singh et al. (1996).

Although the main advantage of rabi pigeonpea is escape of *Helicoverpa* damage, as pods mature during the coldest time of the year when insect incidence is lowest, this pest remains the greatest threat to this crop. Other major yield reducers of this crop are waterlogging (if sown before the monsoon rains cease), drought (if late sown), podfly, alternaria blight *(Alternaria* spp), and phytophthora blight.

For LDP the major constraints are podfly, SM, and fusarium wilt (*Fusarium udum*)*;* waterlogging, salinity, and phytophthora blight pose lesser problems. There are good sources of host plant resistance to the major biotic constraints (Reddy et al. 1990; Lai et al. 1996) but they are yet to be assembled in agronomically superior cultivars and their value in alleviating these stresses demonstrated on a large scale in farmers' fields. Poor podding observed sometimes in rabi pigeonpea and LDP in the eastern IGP is suspected to be due to boron (B) deficiency; this is currently under test in Nepal (S P Srivastava, Nepal Agricultural Research Council, Rampur, Nepal, personal communication).

Socioeconomic Constraints

The socioeconomic constraints that limit increased production of pigeonpea in the IGP can be summarized as follows:

- Lack of well-developed markets for pigeonpea, especially in non-traditional pigeonpea areas where long-distance movement would be involved.

- Lack of appreciable consumption outside of India.
- Inadequate processing units, for dhal, in production areas.
- Lack of policy support, in the same way that rice and wheat are supported.
- High risk in production, and its predictability, due to vulnerability to weather and biotic stress, and consequent price fluctuations.
- Limited availability of key inputs, such as quality seed and effective insecticides.
- Limited information on the non-grain value of pigeonpea, e.g., sustainability contributions, household fuel, and building materials.
- Limited knowledge of farmers on the latest production technologies for the crop.
- Increasing labor costs tor pigeonpea cultivation, necessitating mechanization, particularly in the western IGP of India.
- The long-duration of the crop, even of so-called SDP varieties in northern India, that makes it difficult to fit in with rice and wheat cultivation.

Priority Needs and Opportunities

The priority needs and opportunities for pigeonpea can be summarized as follows:

- On-farm evaluation and demonstration of existing technologies, in an attempt to narrow the gap between yields realized on farmers' fields and those on research stations.
- Special attention to alleviate seed production and distribution problems. The partially outcrossing behavior of pigeonpea results in rapid loss of varietal purity when different genotypes are grown adjacent to each other. Therefore, particular precautions in seed production are necessary to ensure dissemination of improved varieties, such as insistence on proper isolation distances and development of varieties with cleistogamous behavior (Laxman Singh et al. 1996). Development of pigeonpea hybrids (Saxena et al. 1996) should be pursued not only to improve yield potential but more importantly to commercialize pigeonpea seed production. However, in practice this means development of cytoplasmic male sterile systems, now under way (Saxena et al. 1996). Success here would mean that pigeonpea could lead the way among grain legumes in terms of a commercialized seed industry.
- There is a need for a focused and systematic research effort on the key constraints to pigeonpea, with insect pest management having first priority. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India used to assume this role but research reorganization and funding constraints have severely limited such efforts.
- There is a need to develop short-duration cultivars with high yield potential (e.g., 3-5 t ha^{-1}) that could strongly compete with modern improved cereal varieties.
- There is a need for improved quantification, including monetary evaluation, of the "other products" of pigeonpea, particularly residual benefits.
- Improvement of the "policy and marketing environment" for pigeonpea, along with that of other grain legumes.

Conclusion

By extending existing pigeonpea production technologies to fanners' fields, area expansion and yield increases (>20 %) would be feasible across the region. We propose that it would be possible to meet the large and increasing demand for pigeonpea grain in the central IGP from within the IGP region itself.

Focused and concerted research efforts on the major constraints to pigeonpea production offer promise of higher and more stable yields (1.5-2.0 t ha^{-1}). It is further suggested that large increases in pigeonpea production can occur without jeopardizing the required increases in rice and wheat production and, over the longer term, enhancing it through sustainability contributions.

Mung Bean and Black Gram

Need and Scope

Mung bean and black gram occupy important niches in the agriculture of the IGP, with potential for expansion in existing and new niches. Yield potential of these crops in India is around 3 t ha^{-1} but yields in experimental fields range from 1.0 t ha^{-1} to 1.5 t ha^{-1} and that in farmers' fields remain at 0.3-0.5 t ha^{-1} (Lawn and Ahn 1985; Jeswani and Baldev 1990). These crops are grown mostly as mixed crops or intercrops with rainy season crops, and also as sole crops in both summer and winter in the eastern IGP and in summer in Pakistan. The country chapters of this volume have suggested the scope for expanding the summer cultivation of mainly mung bean where irrigation is available, between wheat and rice crops, and of both crops as post-rice crops in the mild winters of coastal, eastern IGP. Both mung bean and black gram are important as green manure crops, after harvest of one or more flushes. The beneficial residual effects on subsequent rice or wheat crops in the IGP region have been documented by Ali et al. (1997) and Kumar Rao et al. (1998).

Adaptation

Mung bean and black gram are quantitative short-day tropical legumes (Lawn and Ahn 1985). Especially for long-duration types, crop phenology is sensitive to daylength, temperature, rainfall, and humidity. Long days prolong flowering and maturity, stimulate successive flushes and cause uneven pod maturity. There are large genotype x environment interactions in the subtropics, by comparison with the tropics, driven by such environmental influences. This contributes to the site specificity of particular genotypes. However, there are recently evolved short-duration genotypes which are relatively insensitive to daylength (Lawn and Ahn 1985; Singh and Satyanarayana 1997).

Growth of these crop plants is adversely affected by cold temperature, with frost causing plant death. Plants can survive over a wide temperature range above freezing but growth processes are slowed at cooler temperatures (<20° C) (Lawn and Ahn 1985). This constrains expansion of these crops as post-rice crops in the colder subtropics. Mung bean can produce at temperatures up to 40°C, but temperatures beyond this range, that can be experienced in the summers in the western IGP, can limit crop performance when it is grown between wheat and rice crops.

Both legumes are susceptible to weathering damage to maturing pods due to rainfall, but black gram genotypes seem more tolerant of such damage. Both crops have limited tolerance of prolonged waterlogging, although black gram seedlings appear more tolerant (Satyanarayana et al. 1997; Singh and Satyanarayana 1997). Greater waterlogging tolerance would encourage expansion of these crops as relay crops to follow rice in parts of the eastern IGP where winters are warmer.

Major Abiotic and Biotic Constraints

The major abiotic constraints faced by both legumes are drought in the western IGP, due to limited availability of irrigation water, and waterlogging and weathering damage in the east. As indicated in the country chapters, the major biotic constraints to both crops all across the IGP are yellow mosaic (rnung bean yellow mosaic virus), cercospora leaf spot, powdery mildew, pod borers, whitefly (*Bemisia tabaci* Genn.) (in transmitting viruses), and bruchids (*Callosobruchus* spp).

Socioeconomic Constraints

As for pigeonpea, yields and area expansion of mung bean and black gram are widely limited by inadequate availability of improved seed and knowledge of optimum cultivation practices, limited policy and marketing support, and inadequate storage and processing facilities. An exception to this situation, however, is the recent expansion of mung bean in Punjab province of Pakistan (Ali et al. 1997). These crops also face the problem of unavailability of labor for harvesting, thus necessitating development of mechanization.

Priority Needs and Opportunities

Progress has been made in developing short-duration (55-65 days), bold seeded (6-7 g 100^{-1} seeds) mung bean varieties with tolerance/ resistance to powdery mildew and cercospora leaf spot (Reddy and Vishwa Dhar 1997). In India, yellow mosaic resistance in mung bean and black gram is now available for transfer to adapted backgrounds and some resistant, high-yielding lines are also available for more widespread testing (Reddy and Vishwa Dhar 1997). In Pakistan, there has been an accelerated development of yellow mosaic resistant mung bean lines, with 90% adoption achieved by 1997 (Ali et al. 1997). More rapid dissemination of yellow mosaic resistance in other countries is required. Incorporation of weathering tolerance would promote expansion of these crops. There is also scope for strategic research that would lead to an increase in yield potential beyond 3 t ha^{-1} (Satyanarayana et al. 1997; Singh and Satyanarayana 1997).

Systematic exploitation of the wide variation of genetic diversity of the crop in crop improvement efforts is recommended. This could facilitate more adoption of niche- and cropping system-specific varieties for maximizing yield in different agroclimates across the IGP In this regard, a more focused effort is needed on adaptation of mung bean genotypes, and perhaps also black gram, to the cropping window between wheat and rice in Apr-Jun. Improved tolerance of high temperatures and accompanying high dessication conditions is needed. Labor-saving and mechanization innovations are also required. Emphasis needs to be placed on integrated, rather than component-wise, management of the major pests and diseases, and to improved crop husbandry in general.

Conclusion

It is suggested that there be a concerted effort, applicable across the entire IGP, in fitting mung bean into the summer window of the rice-wheat rotation. Various fragmented studies suggest scope for this system but remaining bottlenecks discourage widespread adoption by farmers (e.g., flaws in plant type, labor/cultivation problems, and timely availability of irrigation water). This system offers the best scope for legume amelioration of the rice-wheat system without having to sacrifice a rice or wheat crop in any year .

There is also scope to learn from the recipes of recent examples of expansion of these crops in the region, so that they can be repeated in other niches. Such examples include recent expansion of mung bean cultivation as a winter crop in southern Bangladesh (M Abu Bakr, Bangladesh Agricultural Research Institute, personal communication, 1999), expansion of mung bean in Punjab province of Pakistan (Ali et al. 1997), and the recent large expansion of black gram following rainy season rice in coastal Andhra Pradesh, India (Satyanarayana et al. 1997). There is scope for evaluating the latter example for its applicability to coastal Orissa and West Bengal in India and to southern Bangladesh.

Cowpea

Need and Scope

In India and Pakistan, cowpea is grown almost exclusively for fodder, as long-duration types during the rainy season. Some dual purpose types are grown in rice fallows during winter in southern Bangladesh. There is only a small localized demand specifically for cowpea grain.

Adaptation

Most of the cowpea area in South Asia is in India, it being a relatively minor crop in Bangladesh, Nepal, and Pakistan. Among grain legumes, and indeed all crops, it is well adapted to marginal soils and drought Stress situations. The germplasm available ranges from long-duration, photoperiod-sensitive, indeterminate types to short-duration (60-70 days), photoperiod-insensitive, determinate types (Singh and Sharma 1997).

Major Abiotic and Biotic Constraints

Despite its relative drought tolerance, drought stress often limits the growth of cowpea, as manifested by intermittent stress in the rainy season and terminal stress of the winter-grown crop. There are good prospects of combating drought stress in cowpea by further genetic enhancement of its drought resistance through exploiting escape (i.e., shorter growth duration) and incorporating resistance traits (Subbarao et al. 1995). When grown after rice, cowpea can be constrained by waterlogging, either from residual moisture from rice cultivation or winter rains falling on bunded fields. Excess moisture in the rooting zone and humid canopy conditions promote excessive vegetative growth which in turn encourages crop lodging and disease attack. Further, cowpea is better adapted to acid soils than alkaline ones, thus making it not well suited to the usually alkaline soils of the IGP.

Weeds pose a major constraint to rainy season cowpea. Diseases affecting the crop in the IGP include basal stem rot, choanephora pod rot *(Choanephora* sp), pink rust *[Phakopsora pachyrhizi),* cercospora leaf spot, bacterial blight and canker (*Xanthomonas campestris* pv. *vignicola),* viruses (cowpea aphid mosaic virus), and nematodes (Steele et al. 1985). Major insect pests are aphids *(Aphis* spp), bean fly (*Ophiomyia* sp), blister beetle *(Mylabris* sp), *Maruca testulalis,* and bruchids (Steele et al. 1985).

Socioeconomic Constraints

In South Asia, cowpea faces all of the previously mentioned constraints associated with subsistence pulses. It also faces the handling and marketing constraints faced by fodder crops. A study of adoption constraints for improved technologies for cowpea in southern Bangladesh revealed all of the problems associated with cultivation of a subsistence crop, such as lack of knowledge about or access to production technology, the low input-low output nexus, and lack of organized marketing (Barman et al. 1990). However, in the target area of this study, cowpea was the second most important crop after rice.

Priority Needs and Opportunities

There is scope for a more detailed geographic information system (GIS) analysis to delineate potential areas in the IGP for the different cowpea types (fodder, grain, dual purpose). This would assist in exploiting the genotype x environment interactions applicable in the IGP region and guide how most effectively to incorporate drought and waterlogging resistance traits. There is a need to better prioritize the pest and disease constraints applicable to the IGP and design host plant resistance breeding efforts and integrated management practices accordingly. There is a need to identify genotypes better adapted to alkaline soil conditions. Short-duration, indeterminate, photoperiod-insensitive types may have a role to play in the wheat-rice summer cropping window, but further genetic improvement work and establishment of optimum cultural practices is needed to achieve this. There is a need for further improvement of genotypes and cultural practices for fodder and dual purpose types for specific agro-environments. Seed aspects, from production, through storage, to distribution of improved seed to farmers, also need attention.

Conclusion

The largest scope for increasing cultivation of cowpea in the IGP is in marginal lands, where it has a comparative advantage over most other rainfed crops. However, there is scope for increasing its cultivation in the wheat-rice summer window and after rice in warmer areas of the eastern IGP. The demand and scope for use of fodder and dual purpose types should increase, with the expansion of dairy enterprises and realization of the need to improve animal nutrition. Development of a regional "cowpea project" would seem viable, at least to assemble and help disseminate the existing but fragmented technology.

Groundnut

Need and Scope

Groundnut contributes to 40% of the oilseeds basket in India but such a contribution is negligible in the other 1GP countries. However, in India, production of other oilseeds, such as soybean, rape (*Brassica napus* L.), and sunflower (*Helianthns annuus* L.), is growing at a faster rate than groundnut. Actually, there has been an overall decline in groundnut production across the IGP in recent decades, despite a generally conducive physical environment and ever-increasing demand for the crop's products. On the other hand, there is an expanding groundnut production scenario, especially for oil, in non-IGP parts of India but limited expansion in Nepal, Bangladesh, and Pakistan (Reddy et al. 1992).

Since the mid-1970s, production of irrigated postrainy season groundnut has expanded in India, to now cover 17% of the total 8 million ha sown area (Reddy et al. 1992). The overall average pod yield for India is around 1 t ha^{-1} but for postrainy season (or rabi) groundnut it is 1.7 t ha^{-1}. Orissa is the leading state for postrainy season groundnut and in Bangladesh most production occurs in this season also.

There is an ever-increasing demand for confectionery groundnut but suitable varieties and cultural conditions are rare, despite potentially conducive environmental conditions in the IGP region. The residual effects of groundnut on subsequent crops appear minimal, due to removal of all plant parts except deeper roots from the field at harvest. However, the haulms are prized as fodder.

Adaptation

Rainy season (or kharif) groundnut is mostly rainfed and grows during Jun/Jul-Oct. Many of the problems faced by this crop are associated with excessive vegetative growth and poor partitioning to reproductive growth. The crop has been primarily bred to grow as a sole crop and available cultivars are not well adapted to intercropping.

Postrainy season (or rabi) groundnut is sown in Oct-Nov and harvested during Mar-Apr. It is grown with irrigation or on residual soil moisture in former water courses or after rice. However, there is a paucity of groundnut genotypes of appropriate duration and with low temperature tolerance to exploit the vacant rice fallows and exposed water courses that abound in the eastern IGP during winter.

Summer groundnut, grown during Jan/Feb-May/Jun, relies almost exclusively on irrigation. It follows early maturing winter crops, such as potato (*Solanum tuberosum* L.), rape, and mustard (*Brassica* spp). Suitable genotypes with high water-use efficiency, heat tolerance, and of short-duration are needed.

Major Abiotic and Biotic Constraints

In the western IGP, intermittent drought stress is the major problem faced by rainy season groundnut. Biotic stresses faced by this crop include early leaf spot (*Cercospora arachidicola*), late leaf spot *(Vhaeoisariopsis personata),* aflatoxin contamination *(Aspergillus* spp), bud necrosis (bud necrosis virus), sclerotium stem rot *(Sclerotium roljsii*)*,* white grubs *(Lachnosterna* sp), thrips, jassids, and aphids *(Aphis craccivora* Koch.). Descriptions of these biotic constraints, and how they manifest themselves in northern South Asian conditions can be found in Reddy (1988) and Reddy et al. (1992).

The threat of drought stress is high for both rabi and summer groundnut; terminal stress in receding soil moisture situations and intermittent drought stress during summer. Subbarao et al. (1995) have proposed drought management options for groundnut. In winter, low temperatures (<20°C) can limit growth of groundnut and in summer temperatures above 40°C can be deleterious (Sankara Reddi 1988). In the eastern IGP, groundnut faces B and calcium (Ca) deficiencies and acid soil limitations when not grown on alluvial soils of recent origin. In alkaline soils with excess moisture, iron (Fe) deficiency can be a problem (Reddy et al. 1992). Foliar diseases for rabi and summer groundnut are much less serious than for rainy season groundnut, due to more conducive canopy microclimate conditions during the rainy season. However, rabi and summer groundnut crops are affected by the same suite of soilborne diseases, viruses, and insects as mentioned for rainy season groundnut.

Socioeconomic Constraints

A major constraint to increased groundnut production in the IGP is the relatively high labor and input costs, as most cultivators are resource-poor with little access to credit. There are market infrastructure problems and a paucity of local oil extraction facilities to create an assured market. Production and dissemination of quality seed of improved genotypes to farmers is lacking.

Priority Needs and Opportunities

Development efforts are needed to bridge the large yield gap between farmer's fields and on-station potential especially for rainy season groundnut. A necessary first step is a concerted "quality seed" production and distribution effort. Approaches such as the "oilseeds mission" in India (Reddy et al. 1992) are suggested for Bangladesh, Nepal, and Pakistan.

Better understanding is needed of potential niches, along with their advantages and constraints, the applicable genotype x environment interactions and appropriate plant traits to best exploit those niches.

Research efforts need to better focus on the priority constraints, as delineated in the country chapters, and develop niche-adapted varieties accordingly. There is a particular need for development of adapted confectionery types, and organized markets for them. There is scope for exploration of improved production management practices, such as plastic mulching (Gowda et al. 1996).

Major emphasis should be given to exploration of mechanization and labor-saving options. There appears to be good potential for developing "groundnut development projects" in the region.

Conclusion

The environment of the 1GP is generally conducive for oilseed and confectionery groundnut, with numerous specific niches. However, further diagnostic studies of some of the potential limitations, such as photoperiod and temperature responses, B and Ca deficiency, and acid soil effects, are required. The situation is ripe for "development" thrusts using existing knowledge, but with focused research inputs on some bottlenecks, to facilitate commercialization of the crop for which there is a large and growing demand. When considering the potential niches, it is apparent that there is scope for substantially increased groundnut production in the region without competition for rice or wheat area.

Soybean

Need and Scope

There has been a massive increase in area and production of soybean in India over the past two decades from 0.6 million ha in 1980/81 to 5.2 million ha in 1996/97 and from 0.4 million t in 1980/81 to 5.2 million t in 1996/97 (FAO 1998). This expansion has largely occurred as a rainy season crop, in Madhya Pradesh, and only to a much lesser extent in Maharashtra, Rajasthan, and Uttar Pradesh. Soybean in India provides a good example of commercialization of a crop, leading to its rapid expansion in production. Technological innovations in soybean cultivation combined with organized marketing and government policy support led to expansion in its area and production. This followed the establishment of 154 oil extraction mills by 1995 (Ali 1996). Some 85% of the crop is used for oil production, which includes the export of high protein meal (Bhatnagar 1994).

By the year 2000, it is predicted that 6.5 million ha of soybean will be planted in India, yielding an average of 1 t ha^{-1} (Bhatnagar 1994). This provides an outstanding example of how production of a legume can expand, provided all of the critical factors are in place. The situation for soybean in India contrasts with that in the other IGP countries; viz., 20,000 ha yielding 0.61 ha^{-1} in Nepal in 1993/94; 2,000 ha yielding 0.61 ha^{-1} in Pakistan in 1991/92 (from 5,000 ha in the mid-1980s); and 1,000 ha in Bangladesh in 1993 (Source: FAOSTAT).

Adaptation

Although soybean has done particularly well in Madhya Pradesh, outside of the IGP, the IGP environment is conducive to soybean, with a yield potential of 3.5-4.51 ha^{-1} (Bhatnagar 1994). It can only be grown as a rainy season crop in the western and central IGP but it can be grown in the autumn and winter in the eastern IGP after jute (*Corchorus capsularis* L.) or rice. Compared with other grain legumes in the region, soybean is less constrained by pests and diseases but more susceptible to drought stress and less adapted to local rhizobia. Soybean can fix up to 100-200 kg N ha ' if properly nodulated

(Gibson et al. 1982), but this would probably be dependent on rhizobial inoculation in the IGP. Among other grain legumes, soybean is particularly tolerant of waterlogging conditions, which contributes to its success in the waterlogging-prone Vertisols of Madhya Pradesh. Soybean is susceptible to pod shattering and has poor seed storage characteristics.

Major Abiotic and Biotic Constraints

The major abiotic constraints to soybean in the IGP are drought, salinity/alkalinity, and specific nutrient deficiencies (sulfur (S), zinc (Zn), and B]. Biotic stresses are mostly local in nature. Stresses include rust (*Phakopsora pachyrhizi*), cercospora blight and leaf spot (purple seed stain) (*Cercospora kikuchii),* frogeye leaf spot *[Cercospora sojina),* anthracnose (*Colletotrichum truncatum*), pod and stem blight *(Phomopsis phaseoli*), bacterial pustule (*Xanthomonas campestris* pv. *glycines*), yellow mosaic, hairy caterpillar, and stem fly (Hume et al. 1985).

Socioeconomic Constraints

The recent history of soybean in Madhya Pradesh provides a good example of expansion through commercialization, whereby the various socioeconomic constraints to adoption were obviously overcome. This example can be emulated at several locations in the IGP provided appropriate policy, development initiatives, and the required inputs are put in place. The alternative is for soybean in the IGP to continue languishing under the "subsistence, local consumption syndrome".

Priority Needs and Opportunities

An examination is needed of how the "Madhya Pradesh model" for soybean expansion can be applied in the IGP, particularly in Bangladesh, Nepal, and Pakistan. Using current knowledge, there is scope for soybean development projects aiming at its commercialization. A first step may be the development of small-scale agroprocessing facilities and measures to improve seed storage. Use of rhizobial inoculants seems mandatory for soybean cultivation (unless large doses of N fertilizer are applied, thereby negating potential sustainability contributions of soybean cultivation), and increased inoculation practice by farmers may have spillover effects for other legumes that could benefit by inoculation of rhizobia. Mechanization possibilities suitable for small holder farmers also need to be explored.

Soybean would be a candidate, along with extra-short-duration pigeonpea, to replace rice in non-flooding areas with irrigation limitations (i.e., not enough irrigation water to support rice throughout the season). It is suggested that there be genotype x environment and "crop potential" analyses done for soybean in the IGP, using crop modeling and GIS. Increased efforts in research on production constraints are needed in Bangladesh, Nepal, and Pakistan, where the crop is currently considered as a "poor cousin" among grain legumes and oilseeds.

Substantial expansion of soybean cultivation in the IGP can make a significant contribution to closing the protein and vegetable oil deficits in the IGP. Compared to most crops, and certainly other legumes, there is a huge research resource base, and ongoing activity (due primarily to the importance of the crop in USA), on which to draw to tackle constraints afflicting soybean in the IGP Stimulation of soybean production in the IGP through commercialization of the crop could have knock-on effects for other grain legumes with potential in the region, particularly groundnut, pigeonpea, and mung bean.

Overall Conclusions

There is considerable scope for substantially increased production of tropical grain legumes, including those that can be grown during winter in the eastern IGP, without undue competition for rice and wheat area, but with a promise of increased sustainability of rice- and wheat-based systems. This is particularly true for the short-duration legumes such as mung bean. For most of the legumes considered, technology-driven "commercialization" seems the way forward, to create small-scale agroprocessing and thus income and employment opportunities in the IGP. This particularly applies to soybean and groundnut, with their multiple uses.

For each legume, there is good scope for formulation of development projects at the regional or country level. Convincing cases could be made for returns on project investment, especially if the sustainability effects of legume cultivation is also included. There is a possibility of emulating several success stories of legume expansion in the region; these include, soybean in Madhya Pradesh and black gram in rice fallows of Andhra Pradesh, in India, mung bean in Pakistan and Bangladesh, and the promise of the hybrid pigeonpea seed industry.

It is proposed that there be further in-depth crop-wise analysis, using genotype x environment, GIS, and crop modeling techniques now available, to help formulate and update research and development priorities. It would be further desirable to calculate "sustainability value" of each legume x system, so as to calculate the real value of the legume in a long-term systems perspective.

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11. Regional Opportunities for Cool Season Food Legumes for Sustainable and Enhanced Food Production, and Crop Diversification in the Indo-Gangetic Plain

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Abstract

Cool season food legumes (CSFL), mainly chickpea, lentil, khesari (lathyrus), faba bean, and pea, are important constituents of the diet of the people of the Indo-Gangetic Plain (IGP). In the traditional agricultural production systems of this ecoregion, these legumes were important crops. However, the area and production of CSFL in the IGP has decreased over the past two decades. Regional production is inadequate to meet regional demand, which increasingly has to be supplemented through imports. Large increase in demand of CSFL is projected in these countries over the coming decade.

Major reasons for the decrease in area and production of CSFL arc preference of farmers to grow input-responsive, and more profitable rice and wheat crops and their reluctance to grow CSFL because of the uncertain yield that they can expect to harvest. Uncertainty in yield is associated with aberrant climatic conditions, and related pest and disease incidence.

Technology and/or components of technology, effective in alleviating the major abiotic and biotic constraints to CSFL production, are readily available from the published literature. However, these have by and large not reached farmers. With widespread adoption of improved technologies, higher yields could more reliably be harvested. This would further motivate farmers to expand area under these crops because CSFL production would be perceived as less risk-prone and quite profitable. Additional benefits would accrue from greater sustainability of the production systems into which these crops are introduced. Institutional support (incentives and farmer-friendly policy) that would ensure dependable income to farmers will be necessary for rapid adoption of new technologies. It is suggested that short-term, focused research and development projects could quickly result in greater availability of these pulses and reverse the declining trends in area under these crops.

Introduction

Cool season food legumes (CSFL), mainly chickpea (*Cicer arietinum* L), lentil (*Lens culinaris* Medic), khesari *{Lathyrus sativus* L.; lathyrus, grass pea), faba bean (*Vicia faba* L.), and pea (*Pisum sathmm* L.) are essential constituents in the food habits of the people in the Indo-Gangetic Plain (IGP). The major CSFL account for nearly 38% of total pulse area, and 64% of total pulse production in the four countries sharing the IG P (Table 11.1). In these countries production is generally inadequate to meet local demand, and the deficit is met through imports. Annual yield fluctuates widely (Fig. 11.1). Farmers, therefore, consider these and other grain legumes as very uncertain and risk-prone crops to grow.

The primary reason for the uncertainty of yield harvested at the end of the crop season in the IGP is aberrant weather conditions which cause extremes of soil water stress, ranging from drought to excessive soil moisture (waterlogging) and high atmospheric humidity. When protracted wet periods (high humidity) coincide with flowering and podding stages, as it prevails in the IGP, it often encourages development of foliar diseases in chickpea [Ascochyta blight (*Ascochyta rabiei)* and botrytis gray mold (BGM) (*Botrytis cinerea*)] and in lentil [rust (U*romyces viciae-fabae*) and stemphylium blight (*Stemphylium botryosum*)]. A close relationship between microclimatic conditions and incidence of BGM (Butler 1996) and ascochyta blight has been documented in chickpea (Jhorar et al.

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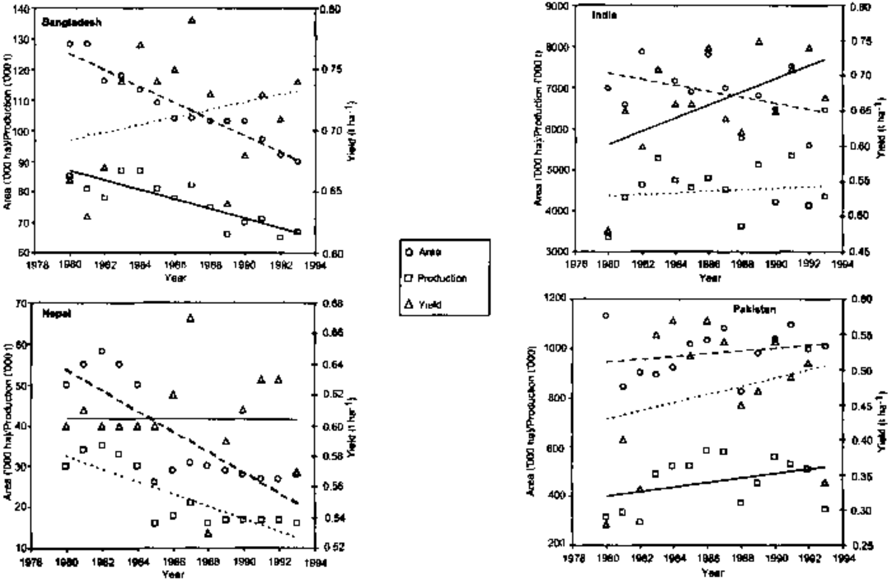

Figure 11.1. Time trends in area, production, and productivity of chickpea in Bangladesh, India, Nepal, and Pakistan (Source: FAO 1998).

Table 11.1. Area and production of cereals, pulses, and cool season food legumes in the Indo-Gangetic Plain (IGP) countries.

Country	Cereals	Pulses	Chickpea	Lentil	Dry peas	Green peas
Area ('000 ha)						
Bangladesh	7,825	706	85	207	33	-
India[1]	100,037	26,317	7,347	1,193	577	148
Nepal	3,251	328	20	155	-	
	12,288	1,762	1,095	65	140	9
IGP	123,401	29,113	8,547	1,620	749	157
Production ('000 t)						
Bangladesh	29,009	525	62	169	21	-
India'	218,354	14,836	5,818	907	593	2,150
Nepal	6,341	222	14	114	-	
Pakistan	25,009	1,029	611	33	77	62
IGP	278,713	16,613	6,505	1,223	692	2,212

1. All of India.
Source: FAOSTAT (1998).

1997). In 1996/97 and 1997/98 seasons yield losses due to BGM were very large in chickpea and lentil in Bangladesh and Nepal. Farmers failed to harvest seed to plant these crops in 1998.

Above-average and well-distributed winter rainfall during the crop season, and protracted rainfall at the end of the monsoon period induces excessive vegetative growth, lodging of crops, disease incidence, and ultimately lower yield. On the other hand, deficient and early cessation of monsoon rains, and inadequate winter rainfall, results in terminal drought (because >90% of these crops are grown rainfed) and heat stress in CSFL. Yield losses due to drought in these crops have been estimated to range between 20% and 50% (Saxena et al. 1993). Also, higher incidence of insect pests (pod borers, particularly *Helicoverpa armxgera* Hubner) and of wilt (*Fusarium* spp) are often observed in years when there is a greater degree of terminal drought and heat stress.

The present-day varieties of CSFL used by the farmers, which mainly comprise local landraces, seem quite susceptible to the adverse effects of soil and climate, diseases, and insect pests, even though they have evolved with them. Farmers, therefore, consider cultivation of CSFL as highly risk-prone. In comparison, rice (*Oryza sativa* L.) and wheat (*Triticum aesthmm* L.), the most important cereal food crops in the IGP, produce more assured and stable yields and higher economic returns under similar soil and climatic conditions. Rice and wheat crops also enjoy government policy support. These factors have motivated farmers to favor cereal-dominated production systems. Expansion in rice and wheat area in the IGP has been at the cost of area under legumes (see Ali et al., in this volume). However, in many recent reports from the IGP, questions have been raised about the sustainability of rice-wheat production systems because of the declining trends in factor productivity (Paroda et al. 1994). This potential threat, though a cause of serious concern, offers new opportunities to introduce CSFL in rice-wheat cropping systems (RWCS) because legumes have long been known to negate the adverse effects of continuous cropping with cereals. Another factor that would favor promotion of cultivation of CSFL is that the demand for these crops is predicted to increase considerably in the next decade (Kelley et al. 1997).

Thus, successful introduction or inclusion of CSFL in RWCS could indeed be realized, or new production systems formulated which have CSFL as a component crop. Research publications on CSFL grown in South Asia at least indicate that there is adequate knowledge and information available on these crops, and technologies or components of technologies formulated, to feasibly alleviate the major constraints to production. A major lacuna seems to be inadequate formulation of potential technology packages by multidisciplinary teams of scientists, and their validation in on-farm trials.

Analysis of Constraints and Potential Opportunities

Increase or decrease in crop production is a direct function of cultivated area and yield. Relative contribution of each component depends upon which of the two has been limiting production most. In chickpea, evidence shows that either of the factors could play a dominant role, depending upon the situation. A large-scale expansion in chickpea area in Turkey and Australia, and an associated impact on chickpea production, has taken place in the past two decades (Fig. 11.2). In Turkey, area expansion occurred through introduction of chickpea in fallow lands, and in Australia the crop has primarily replaced wheat and ley pastures. The impact of area expansion was so large that a large increase in production occurred despite the fact that there were decreasing trends in productivity. This decrease in productivity may be because the new areas brought under chickpea were not ideally suited for chickpea cultivation. Alternatively, development of appropriate technology (including adapted varieties) for the new areas did not precede the rapid expansion in chickpea area.

In contrast, increase in chickpea productivity (yield) in India not only offset the effect of huge decline in chickpea area in the past two decades, by nearly 1.0 million ha, but contributed to a small although insignificant increase in production (Fig. 11.1). A major decrease in chickpea area in India occurred in the IGP, particularly in Haryana and Punjab states, in the past two decades. The area decreased in Haryana from 1.0 million ha to <0.6 million ha, and production from 0.6 million t to 0.35 million t. In Punjab, area decreased from 0.35 million ha to <0.05 million ha, with a proportionate reduction in production.

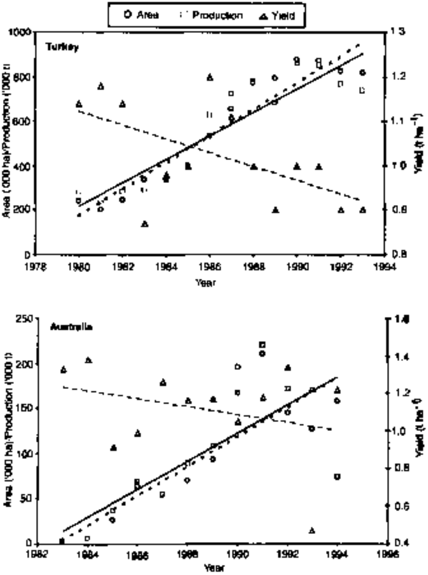

Figure 11.2. Time trends in area, production, and productivity of chickpea in Australia and Turkey (Source: FAO 1998).

Major Constraints to Production

A number of constraints—biotic, abiotic (climatic), edaphic, agronomic management, and socioeconomic—afflict CSFL production in the IGP. Instability of yield is mostly due to abiotic and biotic constraints and because of these fanners are reluctant to grow these crops with the present-day varieties and technology available to them.

Biotic Constraints

Almost all diseases reported in the literature that affect CSFL seem to occur in one or the other IGP country (see the country chapters in this volume). However, the constellation of major diseases seems to vary from one ecoregion to another. For example, in chickpea, BGM is of major concern in the eastern parts of the Indian IGP, while ascochyta blight is most important in the western IGP (see Ali et al., in this volume). This is primarily due to differences in climatic conditions, in particular, microclimate conditions (Butler 1996). Similar differences are noted when one compares the IGP countries, viz., BGM in Bangladesh and Nepal, and ascochyta blight in Pakistan and western parts of Indian IGP.

Relative importance of various diseases and insect pests (as given in the country chapters), affecting CSFL production across the IGP countries is summarized below.

Diseases

Chickpea	Fusarium wilt (*Fusarium oxysporum* f. sp *ciceris*) > BGM = ascochyta blight > collar rot (*Sclerotium rolfsii)* and root rots
Lentil	Vascular wilt *[Fusarium oxysporum* f. sp *lentis*) = rust > stemphylium blight > collar rot (S. *rolfsii)* = root rots > BGM
Khesari (lathyrus)	Downy mildew (*Peronospora* sp) = powdery mildew (*Erysiphe* spp)
Faba bean	Chocolate spot (*Butrytis* sp) = rust (*U. viciae-fabae)*
Pea	Powdery mildew *(Erysiphe pisi)* = pea mosaic virus

Insect pests

Chickpea	Pod borer (*H. armigera)* = bruchids *(Callosobruchus* spp) > semilooper *(Autographa nigrisigna* Walker)
Lentil	Bruchids > lima bean pod borer (*Etielia zinckenella* Treitschke) > aphids
Khesari (lathyrus)	Aphids
Faba bean	Aphids
Pea	Pod borers = bruchids

Nematodes

Nematodes arc not recognized as major constraints across the IGP countries. But in some areas in western parts of the Indian IGP, yield loss due to nematode infestation has been estimated at 12-15% (Sharma and Rahaman 1998). However, there have been too few yield loss surveys to know the extent of damage caused by nematodes.

Weeds

Weeds are a serious constraint across all the IGP countries. Yield losses are estimated at 25% in lentil in Nepal (see Pandey et al., in this volume) and 42% in chickpea in India (see Ali et al., in this volume). Farmers neglect weeding CSFL in general, compared to cereals, perhaps because of uncertain returns on the effort required. Indeed, in Nepal they permit weeds to grow and use them as green silage for cattle.

Climatic and Soil Constraints

Abiotic constraints commonly reduce yields of most CSFL (chickpea, lentil, faba bean, and pea), except khesari (lathyrus). Khesari (lathyrus) seems to be more tolerant to extremes of soil water stress conditions, ranging from waterlogging to drought (see Ali et al., in this volume). Severity of these constraints have been ranked on the basis of information given in the country papers in this book as follows:

Chickpea	Drought > heat > chilling = excess soil moisture
Lentil	Drought > heat > excess soil moisture
Khesari (lathyrus)	No significant abiotic constraint
Faba bean	Drought = heat
Pea	Drought = heat

Effect of soil type in modifying drought stress seems to be minimal as the soils in the region are mostly deep and alluvial. But the variation in climatic conditions is quite large even within a country in the region, e.g., rainfall and thermal regimes in the eastern and western parts of Indian IGP (see Ali et al., in this volume). These variations have a direct bearing on the occurrence and severity of drought, heat, and cold stress. Indirect effects of these variations in climate are large in modifying the severity and occurrence of various diseases through their influence on microclimate (Butler 1996).

Mostly, CSFL are grown on marginal lands, generally not preferred for the cultivation of cereal crops. These lands are often poor in soil physical properties and fertility status. Despite the fact that CSFL are known to be very sensitive to factors such as soil salinity, extremes of pH (soil acidity and alkaline conditions) (Saxena et al. 1993), attempts are made to grow these crops in such unfavorable soil environments.

Except when grown in rotations with other crops that are well fertilized, CSFL almost ubiquitously face phosphorus deficiency (Tandon 1987). There are increasing reports of other elements, such as sulfur (Tandon 1991) and boron (Srivastava et al. 1997, 1999), limiting yields of CSFL. Farmers take few, if any, corrective measures against known or suspected nutrient deficiencies in CSFL.

Poor Plant Stands

In rice-based production systems, it is common to observe poor and non-uniform plant stands. The problem seems to be more severe in chickpea following a rice crop because of the atypical soil physical conditions that result from soil puddling. Field surveys of plant stands of chickpea in farmers' fields in central, north, and northeast India, covering important chickpea-growing areas in the IGP, show that the plant stands usually are less than one-half of the recommended plant population (Fig. 11.3).

Farmers generally use seed rates far below the recommended ones. Also, the seed viability is often poor. These factors result in poor plant stand establishment and ultimately lower yields. Preparatory cultivation prior to sowing is not satisfactory, a problem particularly encountered when CSFL are sown after the harvest of paddy. The broadcast method of sowing also contributes to the poor and non-uniform plant stands because of random distribution of seeds and some seeds may fall in dry surface soil layers. Also, soilborne diseases and insect pests can reduce initial plant stand even after the seeds have germinated and seedlings have emerged.

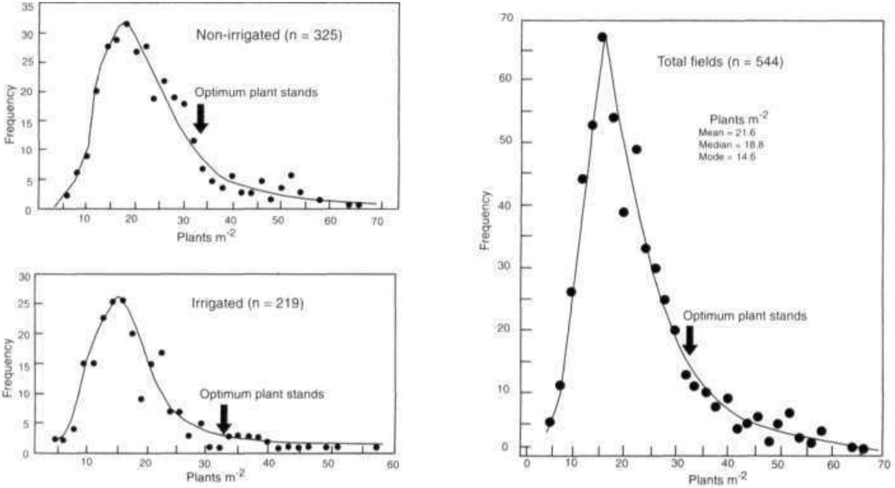

Figure 11.3. Variation of plant stands of chickpea in non-irrigated, irrigated, and all farmers' fields in central and northern parts of India (Note: Vertical arrows indicate recommended optimum plant density for realizing maximum yield; n = number of farmers' fields) (Source: Field surveys conducted by ICRISAT, 1973-78).

Timely Sowing and Harvest

Mechanization of operations is becoming an increasing necessity in high intensity cropping systems. Timely availability and high cost of labor for manual operations make mechanization of operations essential. This is particularly true when CSFL follow rice in a cropping sequence, because of the short turn-around time for preparation of paddy fields to sow CSFL. For lentil and chickpea, sowing and harvesting operations have been successfully mechanized on experimental stations and also demonstrated under on-farm conditions and on large-scale farmers' fields. However, to benefit small holder farmers, cheap and readily acceptable options of mechanized operations need to be developed and popularized.

Socioeconomic and Policy Constraints

In many of the IGP countries it is well recognized that large increases in pulse production will be required to meet the demand of 2010. In Bangladesh, this increase in demand is projected to be around 30% and in Pakistan at 23% over the current levels of production. Wide fluctuation in prices of legume crops, with particularly low prices at the time of harvest and steep rises in prices soon afterwards, has a strong negative impact on farmers' preference to grow these crops. Government policies on subsidies and procurement prices still favor cereals over pulses. Even though improved varieties of CSFL and agronomic packages that would ensure their higher and more stable yields exist, farmers remain unwilling to invest in CSFL because of these continuing risk factors. Increasing reliance of governments on imports to meet local demands of CSFL is a further discouragement to farmers to attempt their cultivation.

Technological Options Readily Available for Alleviating Constraints

Recent literature shows that a good understanding of the major constraints to CSFL production has been achieved (e.g., Summerfield 1988; Muehlbauer and Kaiser 1994; Asthana and Chandra 1997; IFLRC III 1997). Also, focused, periodic reviews on chickpea have been held (ICRISAT 1976, 1980, 1990). It is evident from the published literature that options to significantly alleviate most of the biotic and abiotic constraints to CSFL production, listed as important in the IGP countries discussed here, are readily available. Many significant achievements have been made in finding genetic solutions as resistant/tolerant varieties or germplasm (Table 11.2) (Singh 1994). Also, for the management of those stresses for which high levels of genetic resistance are not available, integrated management options are available, including the management of weeds (Table 11.3). To increase the effectiveness of the genetic component, strategies and approaches have also been proposed (Table 11.4).

This tempts us to state that the legumes scenario has changed fundamentally, with regard to technology generation from the time when Borlaug (1973) made the statement, "Neither new high yielding varieties of grain legumes (pulses) nor improved technology have been developed; so gradually part of the land that once grew pulses has shifted in winter to wheat and in summer to maize or rice." However, it is disappointing to note that despite concerted efforts and progress made so far in identifying effective genetic and integrated management technology, very little progress is apparent in on-farm conditions in alleviating the major yield reducing constraints to CSFL production. The declining trends in chickpea area and production in the IGP of India, Bangladesh, Nepal, and Pakistan (Fig. 11.1) perhaps is a result of this gap in transfer of technology. One may speculate that

Table 11.2. Sources of resistance to diseases and pests and of other useful traits in pulse crops available in India.

Trait	Research location/center[1]	Genotypes
Chickpea		
Ascochyta blight and fusarium wilt resistance	Ludhiana	GL 83119, GL 84038, GL 84096, GL 84107, GL 88341, GL 91058, GL 91060
	Hisar	H 83-84, H 83-60
	Patancheru (ICRISAT)	FLIP 83-7-C, FLIP 82-74-C, FLIP 86-60, FLIP 85-90, FLIP 86-41, ICCV 89445, ICC 1272, ICC 3137, ICC 4076
Asc:ochyta blight, fusarium wilt, and botrytis gray mold resistance	Ludhiana	GL 88341, GL 88395, GL 88356, GL 84107, GL 88366, *Cicer bijugum, C. judaium, C. pinnatifidum*
Fusarium wilt and root rot resistance	Hisar	H 86-84, H 86-18
	Patancheru (ICRISAT)	ICC 8383, ICC 10466
Root rot and stunt resistance	Hisar	H 86-84, H 86-18
Ascochyta blight resistance	Hisar	E100Y, E 100Y(m), E 101, Gaurav,H 86-18
	New Delhi (IARI)	BG 261
	Pantnagar	BRG 8, EC 26446, PG 82-1
	Patancheru (ICRISAT)	NEC 206, ILC 191,ILC202, ILC 1069, ICC 1009, ICC 4846, ICC 6103, ICC 6671, ICC 7002, ICC 10302

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Ludhiana	GL 84099, GL 84107, GL 86143, GL 91058, GL 91059, GL 91060
Wilt resistance	Pantnagar	P 436-2, GPS-1
	New Delhi (IARI)	BGM 443, BG 246
	Kanpur (CSAU)	WR315(K 315), KW 17, Avrodhi
	Srtganganagar	GNG 426
	Sehore	JG74,JG315,GW6,GW3-1, GW8.JG 1265
	Rahuri	Phule G 81-1-1, Phule G 87207, Phule G 86185
	Hisar	H 81-73, H 86-8, H 86-72
	Kanpur (IIPR)	PDG 83-34, DCPW I, DCPW 2, DCPW 3, DCPW 4, DCPW 5
	Ludhiana	GL 87079, GPF 7035
	Badnapur	BDN 9-3, BDNG 77, BCP 4, BCP 72, BCP 87, PPK 1, PPK 2
	Patancheru (ICRISAT)	ICC 671, ICC 2664, ICC 3345, ICC 4483, ICC 6687, ICC 8383, ICC 9032, ICC 9041, ICC 1038, ICC 10466, ICC 11233, ICC 11329, ICC 12234, ICC 12240, ICC 1226, ICC 85221, ICC 84225, ICCC 32,1CCV 10, ICCV 18, ICCV 19
Botrytis gray mold resistance	New Delhi (IARI)	BG 276
	Patancheru (ICRISAT)	Dhanush, ICC 1069, ICC 11321, 235-38

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
Pod borer resistance	Kanpur (IIPR)	PDE 2, PDG 84-10
	Patancheru (ICRISAT)	ICC 12483, ICC 506, P 202, P 927, DDG 128,
	Ludhiana	ICC 3580, GL 645, Desi 3108
	Hisar	LHR 69, P 696-1
Root-knot nematode resistance	Kanpur (CSAU)	K 1122
	New Delhi (IARI)	BG 302
	Indore	IG218
	Junagadh	GCP 11
Bold seed (>20g 100^{-1} seed mass)	Pantnagar	RGG 8
	Durgapura	DGM 65, DGM 471, DGM 474, DGM 726, RSG 143, RSG 216, RSG 220, RSG 259, RSG 503-1, RSG 536, RSG 538
	Kanpur (CSAU)	K 850, KTP 1
	Sehore	JG 1265
	Patancheru (ICRISAT)	ICC 42, ICC 7617, ICC 81001, ILC 3-83, ILC 35, ILC 76, ILC 116, ILC 3396, ICC 1507, ICC 3859, ICC 5712, ICC 5434, ICC 9647
	Rahuri	N 31,Phule G5
	Akola	AKG 40
	New Delhi (IARI)	Pusa 256, BG 273, BG 329
	Badnapur	BDNG 342
	Gulbarga	Annigeri

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Hisar	Arjun, Bheema, H 85-69, E 100Y.H 86-18
	Varanasi	KLD 1-83
Double pod	Sehore	JG 62
	Akola	133-84
	Rahuri	Sele 436
	Patancheru (ICRISAT)	Annigeri mutant
	Varanasi	HUG 211, HUG 201, HUG 237
	Durgapura	RSG 44, RSG 538
Compact plant type	Hisar	H 86-143, H 90-237
Multiseeded pod	Hisar	HMS 6
	Varanasi	HUG 211, HUG 201, HUG 237
	Durgapura	RSG 540
	Patancheru (ICRISAT)	ICC 12118, ICC 1052
	Akola	B 85-2-1, B 85-2-2
Large pod	Hisar	H 82-46
	Patancheru (ICRISAT)	Giant pod recombinant
Early maturity (130-140 days)	Sehore	JG 74
	Patancheru (ICRISAT)	ICC 14627, ICCV 2, ICC 88201, ICC 89244
	Kanpur (IIPR)	PDG 84-16
	SK Nagar	Chaffa
	Durgapura	RSG 44, LD 153, RSG 524, RSG 580, RSG 515

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Gulbarga	Annigeri
	Badnapur	BCP 3, 3CP 4
Tall plant	Durgapura	2D 287, DGM 663, DGM 727, RSG 236, RSG 255, RSG 261, RSG 291, RSG 538, RSG 668
	Patancheru (ICRISAT)	ICC 8101, ICC 8922, ICC 8923
	New Delhi (IARI)	BG 261, BG 273,BG 274
Higher no. of primary branches	Kanpur (CSAU)	Type 3
	Patancheru (ICRISAT)	ICC 7002
	Hisar	Bushy mutant
Higher no. of secondary branches	Varanasi	JM 2106, C. *reticulatum* H 86-156, H 86-170
Tolerance to salinity	Hisar	H 893-84, H 81-69, H 85-10
	Karnal	CSG 8893, CSG 8894, CSG 8862
Lentil		
Rust resistance	Pantnagar	PL 406, PL 639, PL 81-17
	New Delhi (IARI)	Precoz, L4152
	Palampur	Vipasa, HPL 1
	Ludhiana	LL 30,LL 56,LL 78, LL 112, LL 116,LG 128, LL147, LG170, LG 171, LG 186, LG 231,LG 265

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Kanpur (I1PR)	DPL 15, DPL 16, DPL 21, DPL 44
Fusarium wilt/root rot resistance	Pantnagar	UPL 175, PL 81-17, PL 406, PL 639
	Dholi	RAU 101, PL 77-2
	Ludhiana	LG 171
	New Delhi (IARI)	L 1304
	Almora	VL 104
	Kanpur (I1PR)	DPL 16
Ascochyta blight resistance	Pantnagar	PL 639
	Palampur	Vipasa
	Ludhiana	LL 301.LG 60, LG 112, LG 170, LG 171, LG 178, LG 186, LG 231
	Dholi	PL 77-2
Bold seeded (>2.5 g 100[1] seed mass)	New Delhi (IARI)	Precoz, L 4076, L 4163
	Hisar	LH 84-8
	Kanpur (CSAU)	K 75
	Sehore	JLS 1, Sehore 74-3
	Ludhiana	LG 170, LG 171, LG 327, LG 362, LL 295, LL 443
	Kanpur (IIPR)	DPL 15, DPL 38, DPL 44, ILL 4354
	Palampur	HPL 4
Early maturity (< 125 days)	Sehore	JLS 1, Sehore 74-3
	New Delhi (IARI)	Lens 830, Precoz
	Berhampore	Ranjan
	Akola	PKVL1
	Kanpur (IIPR)	DPL 47, DPL 21

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
Khcsari (lathyrus)		
Low neurotoxin content	Raipur	RP 137-77, Rewa 2-25, LS 619-2-4-87, Rewa 2-28, Pusa 24 selection
	New Delhi (IARI)	P 28, Bio-R-231, Bio-L-222, Bio-R-203, Bio-R-202
Powdery mildew resistance	Raipur	Rewa 2-206, LSD 1-149, LSD 1-195, LSD 3-209, LSD 3-2, JRL 6,JRL 47, RPL 31-77, Rewa 2-28, RL 298-104, 619-2-4-146, JRL 55-48
Downy mildew resistance	Raipur	298-10,619-2-4-146
Thrips resistance	Raipur	JRL 141, Rewa 2-29, RPL 31-83, LS 8545, LS 8246, NC 84-269
Pea		
Powdery mildew resistance	Kanpur (CSAU)	T 10, 6578, 6588, Rachna, KPMR 85, KFPD 4, KPMR 146, KMPR 149, KPMR 157, KPFD 10
	Pantnagar	Pant P 5, DP 2
	New Delhi (1ARI)	DMR 1, DMR 6, DMR 8, DPR 1
	Jabalpur	JP 179,JP 501,A/2
	Faizabad	NDP 90-84
	Hisar	HFP 4, HFP 8712, HFP 8718, H 877

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Ludhiana	LPF 48, LPF 56, LPF 57, LPF 58, LPF 80, LPF 81, LPF 82
	Varanasi	S 143, A 474-288
Rust resistance	Jabalpur	JP 50-A/2,JP 179,JPB 7, JPU 496
	Kanpur (CSAU)	P 16, P 20, P 43
Leaf miner resistance	Jabalpur	JP 9.JP 130.JP 179
	Kanpur (CSAU)	P 29, P 402, P 200
Pod borer resistance	Kanpur (CSAU)	P 144, P 26-4, P 76-68
Bold seeded (>20g 100[1]seed mass)	New Delhi (IARI)	Pusa 10
	Kanpur (CSAU)	KPSD1, 6112, KP 58, KFPD 10
	Dholi	RAU 37
	Varanasi	BHU 74, HUP 5
Dwarf plant type	IARI	Pusa 10, Harbhajan, DDR 1
	Hisar	HFP 4
	Kanpur (CSAU)	KPMR 11
	Ludhiana	PG 3
Leafless plant type	Hisar	HFP 4
	Varanasi	S 143
	Ludhiana	LBG 41, LPF 56, LPF 57, LPF 61, LPF 75
	Kanpur (CSAU)	KPMR 14, KPMR 15
High protein	Varanasi	BHU 397, BHU 484, PI 280064

1. ICRISAT = International Crops Research Institute tor the Semi-Arid Tropics; IARI = Indian Agricultural Research Institute; CSAU = Chandra Sekhar Azad University of Agriculture & Technology, IIPR = Indian Institute of Pulses Research.

Table 11.3. Management technologies for alleviation of biotic constraints to production of cool season food legumes.

Management technology	Reference
Diseases	
Options to manage botrytis gray mold of chickpea	Haware et al. (1993, 1997) Pande et al. (1998)
Integrated management of pigeonpea and chickpea wilt diseases	Khare et al. (1997)
Integrated management of fungal foliar diseases of chickpea and lentil	Haware and Gurdeep Singh (1997)
Development and implementation of forecaster for plant disease management	Kushalappa (1997)
Integrated management of viral diseases of grain legumes	Anupam Varma and Jain (1997)
Chickpea diseases and their control	Nene and Reddy (1987)
Nematodes	
Nematodes and their control in chickpea	Greco (1987)
Management of nematodes of food legumes	Greco et al. (1997)
Insect pests	
Integrated pest management of pod borer complex of chickpea and pigeonpea in India	Sachan and Lal (1997)
Eco-friendly pest management of *Helicoverpa armigera* in chickpea	Chari et al. (1998)
Biological control of insect pests of pulse crops	Singh (1997)
Chickpea insect pests and their control	Reed et al. (1987)
Weeds	
Weeds and their control in chickpea	Bhan and Kukula (1987)
Integrated approach to weed management in pulse crops	Bhan and Mishra (1996)

Table 11.4. Approaches in improving adaptation of chickpea to manage biotic and abiotic constraints in cool season food legumes.

Theme/Title	Reference
Integrated management of botrytis gray mold of chickpea: agronomic and physiological factors	Saxena and Johansen (1997)
Strategies for improving drought resistance	Subbarao et al. (1995)
Screening for salinity tolerance and nutrient acquisition	Saxena (1987) Saxena et al. (1994)
Development of high nodulation capacity in chickpea	Rupela(1997)
Chickpea ideotypes	Saxena and Johansen (1990a,b) Saxena et al. (1997)

the recommended solutions to problems have not reached the farmers or are not being adopted.

Strategies to Realize Impact of Potential Technology in Short Term

It seems quite reasonable to conclude that there is a big gap between the availability of technology and its on-farm popularization. We believe strongly that a significant impact in the near term (2 to 3 years) can be made and a substantial increase in area and production of CSFL can be achieved with the existing information/technologies. We point out to some of these options and suggest that these be implemented as "Operational Research Projects".

Improvement in Plant Stands

It should be possible to double the prevailing low yields under on-farm conditions through improvement of plant stands alone. A number of factors which are known to affect plant stands can be overcome with relative ease through adoption of simple agronomic management practices. For example, seedbed preparation can be improved; recommended seed rate can be used; seeds can be primed (pre-germinated); seed dressing with chemicals can be applied to overcome soilborne insect pests and diseases; and seed can be sown with country seed drills in moist soil instead of sowing by the broadcast method.

Diseases

For soilborne diseases, good levels of genetic resistance arc available (Table 11.2). In the case of diseases for which genetic resistance is low or not available at present, integrated management options are available (Table 11.3). These options should be able to minimize the yield reducing effects of these diseases at least by 50% in most of the years, except perhaps when they appear in severe epidemic form.

Insect Pests

Stored grain pests can be easily managed and virtually eradicated (Reed et al. 1987). Among all constraints the pod borer *H. armigera,* a polyphagus insect pest, appears to be the most difficult to manage. Recent reports (Table 11.3) on the integrated management of this insect pest shows that some progress has been made (Chari et al. 1998).

Adaptation of CSFL into Available Niches

It is now feasible to fit CSFL into various niches in the highly productive rice-rice or rice-wheat production systems. Adaptation of chickpea and lentil has been improved greatly in recent years by developing varieties of extra-short, short, and medium duration to fit these appropriately into available niches of rice-based cropping systems. Also, combinations of cultivar and appropriate agronomy to adapt chickpea to late-sown conditions, a necessity in most rice-based cropping systems, are now available (Krishnamurthy et al. 1983). On soil types that do not come into condition to prepare land for sowing legume crops in sequence or under very wet soil conditions, a choice of appropriate crop, e.g., khesari (lathyrus), can be made.

Mechanization of Sowing

Although more development work is needed, it is possible to adapt planting and harvesting machinery for use in legumes cultivation in the 1GP.

Profitability of Cultivation

The belief that it is less profitable to grow legumes, is primarily related to the risk-prone nature (instability in yield due to abiotic and biotic stresses) of the present-day varieties of these crops. If this constraint can be alleviated, or the risk is substantially reduced, the cultivation of CSFL will be equally or even more profitable than cereals even with a modest but assured yield level of 1 to 1.5 t ha^{-1}, which is around 30-50% of potentially realizable yield of the present-day cultivated varieties, in the case of chickpea. Other factors that would be in favor of high economic returns from CSFL production are the high price, at least 3 to 4 times more than the cereal crops, and low requirement of chemical fertilizers because of high efficiency in accessing essential nutrients through root traits (Saxena 1996), e.g., nitrogen (N) through efficient biological nitrogen fixation (BNF) (Rupela and Saxena 1987) and phosphorus through acidification of rhizosphere (Ae et al. 1991). Recent identification of high mineral N-tolerant symbioses (Rupela and Johansen 1995) shows promise in further enhancing efficiency of BNF in the presence of high levels of soil mineral N, which generally exist after the harvest of high input rice crops.

Conclusion

From the evidence presented it seems quite realistic to expect that a substantial impact can be made on CSFL production in a short period. This can be achieved with the available knowledge and technology, or components of technology which would result in enhancing the on-farm realizable yield and also area expansion under the crops. An urgent need is to demonstrate that these improved packages of practices are indeed viable in on-farm conditions. A dedicated multidisciplinary team of scientists and extension personnel along with the target farmers, need to be involved together in the technology evaluation process. Trouble shooting of unanticipated problems encountered could be done by the team and new research programs undertaken to refine the technology. An example of such an approach is underway to attempt to rehabilitate chickpea in Nepal, after cultivation of the crop had been almost eliminated by the severe BGM epidemics of 1996/97 and 1997/98 (Pande 1999).

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12. Research and Development Priorities for Legumes and Legume-based Cropping Systems in the Indo-Gangetic Plain

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Introduction

In this chapter, attempts have been made to synthesize, in summary form, the major recommendations presented in the previous chapters and discussed during the workshop. Although, for the convenience of classification, warm season and cool season legumes have been differentiated in the previous chapters, henceforth both groups are considered in unison. There are similar trends and constraints in both groups and they are indeed merging in terms of their adaptation and distribution, due to development of genotypes of wider adaptation than traditional landraces and with less sensitivity to environmental factors such as photoperiod and temperature.

There is a need to substantially reverse the overall negative trends for legumes area and productivity in the Indo-Gangetic Plain (IGP). Development of sustainable cropping systems requires reintroduction of legumes in cereal dominated cropping systems, and crop diversification generally. Food legumes are complementary to, rather than competitive with, cereal crops in both the cropping system and the human diet. Suggestions for progress are discussed. But progress will ultimately depend on formation of multidisciplinary working groups implementing focused research and development (R&D) endeavors. The major requirement is for an integrated approach to R&D and associated policy issues.

System Characterization

While the current study presents a broad picture for the IGP, there is a need for more specific geographic information systems (GIS), modeling, and genotype x environment analyses to establish options and priorities in particular niches. Some of the regional or country-wide generalizations made here may need modification when scaled down to specific target sub-regions (Fresco 1995). Care is thus needed in using maps and datasets of appropriate scale in the process of scaling up or down. As was apparent in an earlier GIS workshop (Pande et al. 1999), remote sensing techniques may have progressed to the extent of being able to use them to verify and accurately monitor the area sown to specific crops. This possibility needs to be followed up because of the urgent need to improve crop statistics, particularly of legumes which are generally considered as minor crops and given less attention in all respects. Sound data on crop statistics are a prerequisite to developing sound R&D strategy and to monitoring changes in cropping patterns (which will influence future R&D strategy). A reliable database is also necessary for systematic and meaningful constraint diagnosis and yield loss assessment, and for opportunity assessment.

There remain uncertainties about some of the grain legumes area and production data that will need validation by ground survey. There is an urgent need to institute systematic recording of area and production data for green manure and fodder legumes; at least sample ground surveys are needed in the short term to obtain some idea of their extent. These crops represent considerable actual and potential value in terms of soil amelioration and animal production and deserve

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better quantification than hitherto attempted. Better statistics are also needed on legumes in mixed cropping and intercropping systems, to avoid currently apparent problems of both over- and underestimation of legume cultivation.

Policy Issues

In developing a conducive policy environment for promotion of legume cultivation, a starting point would be to examine recent examples of rapid increases in legume production. Some examples within the IGP are referred to in this volume [e.g., mung bean (*Vigna radiata* (L.) Wilczek) in Pakistan; and lentil (*Lens culinaris* Medic.) in Nepal and northern India], and there are several from adjacent to the IGP [e.g., soybean (*Glycine max* (L.) Merr.) in Madhya Pradesh; and black gram (*Vigna mungo* (L.) Hepper) in coastal Andhra Pradesh] and from further afield (e.g., as mentioned in Muehlbauer et al. 1998). It can then be assessed how such success could be emulated for other legume x agroecosystem targets in the IGP, by focusing on alleviation of the most relevant biological, environmental, or socioeconomic constraints.

As reported in the country chapters, there appears to be large scope for increased grain legume production in the IGP without competing for rice (*Oryza sativa* L.) or wheat (*Triticum aestivum* L.) area. This can come from legume yield gap reduction, increased legume cultivation on marginal lands usually not sown to rice or wheat or in rice fallows, and utilization of the cropping window between wheat and rice crops. Occasional replacement of a rice or wheat crop with a legume can be argued as sustaining long-term cereal production, as compared to the risk of declining system yields with continuous cereal cropping. It is particularly suggested that more focused and concerted efforts are needed to better adapt legumes to post-rice environments and for exploiting the wheat-rice summer cropping window. Constraints to adoption of green manure and fodder legumes need closer examination (Lauren et al. 1998).

At least over a longer time frame, cropping systems change in any case, irrespective of conscious human effort to change them. But now appropriate tools (e.g., GIS, crop and systems models, and remote sensing) are available that would permit realistic scenario analyses to illustrate possibilities of better cropping options and adverse consequences of following particular cropping patterns. These tools should be made widely available and applied to cropping systems analysis in the region. However, cropping system diversification should be considered an overall goal and not just confined to legumes as alternatives to cereals; in the IGP, crops such as vegetables, potato (*Solanum tuberosum* L.), sugarcane (*Saccharum officinarum* L.), cotton (*Gossypium* sp), and mustard (*Brassica* sp) need to be considered.

In view of the technical difficulties of rotating crops with rice (flooded soils), greater use of upland rice cultivation should be explored—a paradigm shift. There is a need for quantification and pricing of the "sustainability value" of various legumes x agroecosystems.

The perception of pulses as a "crop of the poor" needs to be changed in view of the rapidly increasing demands from urban middle income earners. Improved production will rely on considering pulses as commercial crops rather than traditional subsistence crops. Lack of technical change characterizing most legume crops in the IGP has resulted in their relatively high price to consumers, as compared to cereals. World trade liberalization may exacerbate these effects if steps are not taken to make legumes of the IGP commercially competitive with grain legumes that can be imported. A policy environment that does not discriminate against grain legumes, without unduly advantaging them over other alternative crops, needs to be carefully considered. Excessive price support and input subsidies may not help in the long term. Policies favoring production and dissemination of quality seed are an essential first step.

Strategic Research Requirements

There is a need to more specifically design ideotypes and breed legume genotypes for defined agroecological niches in the IGP. In most cases of rapid expansion of legume production, the process has been led by development of novel, better adapted genotypes. In the IGP, there is a particular need to develop grain legume genotypes with high yield potential and stability of yield for well-endowed (in terms of water, nutrients, and climate) environments. High partitioning to reproductive structures is needed to accompany the usually existing potential for high biomass production. A long-term approach and commitment for genetic improvement efforts along these lines is required. Recent advances in plant physiology and molecular biology make it more feasible to design and create appropriate plant types for specific niches in the IGP, in a shorter time scale than possible by conventional breeding approaches. Some case studies need to be initiated and followed through. The possibility of incorporating botrytis gray mold resistance into chickpea through genes derived from other species (Pande et al. 1998) could be a suitable candidate. Recent research also indicates the greater feasibility, than earlier considered, of incorporating genes conferring greater resistance of legumes to waterlogging and salinity/sodicity, thereby conferring greater stability against problems faced by legumes in irrigated areas. Consumer preference and seed quality parameters should be considered in the breeding program, to have a better adapted genotype which produces grain preferred by the consumers.

Rather than merely focusing on breeding of better legumes for particular cropping systems in the IGP, a holistic cropping systems approach is needed to recommend to plant breeders appropriate traits for all crops that would fit into the system. An example would be shortening of the duration of rainy season rice to allow more timely planting of post-rice legumes or other winter crops.

Research is needed to develop practical options of improving stand establishment of legume crops that follow rice as well as in upland areas. There are various seed treatment options, such as seed priming, fungicide application, rhizobial inoculation, and fertilizer pelleting, that do not yet seem to have been fully explored or exploited. The need for "starter doses" of nitrogen (N) for legumes (e.g., in late planting of winter legumes) is still debatable and can only be resolved by further experimentation. Weed competition is an increasing constraint for legume crops in the IGP and strategies, taking account of the total cropping system, need to be formulated. Use of herbicides and exploitation of herbicide resistance in legumes are issues that must be addressed.

Water management is the key to successful legume cultivation in areas with access to irrigation, whether to apply enough water to alleviate drought stress or prevent waterlogging.

More long-term experiments (> 10 years) with legume treatments are needed to better understand residual effects and confidently develop and validate systems models for use in scenario analysis. The concept of "soil health" should provide a focus in considering residual benefits of legumes, accounting for both detrimental and beneficial (e.g., mycorrhizae) effects.

There is a need for intensified research on mechanization and labor-saving options applicable to small holdings of resource-poor farmers. This is another prerequisite to commercialization of legume crops.

Development Efforts

In the first instance, intensified efforts are needed to narrow the yield gap for legumes between what is possible on research stations and what is realized in farmers' fields. On-farm research approaches, linking efforts of researchers and extensionists in farmers' fields, are recommended (Gowda et al. 1993). Demonstration that high and stable yields are possible could stimulate development of agro-processing industries, in turn creating increased and reliable demand for the legume crop. Along with on-farm research and extension activities, it would be necessary to establish viable seed production and distribution schemes with appropriate quality control. Self-contained farmer-to-farmer schemes would seem most viable. The technology transfer process should also be directed towards consumers, by promoting greater understanding of quality and human health aspects of consuming legume products (e.g., proteins, vitamins, and minerals).

Conclusion

Despite declining production trends for most legumes in most parts of the IGP, there is a case for attempting to substantially reverse these trends. Compelling reasons for this are ever-increasing demands for legume products by the population of the IGP and the need to improve cropping system sustainability through increased cultivation of legumes. A fundamental problem to be overcome in significantly increasing legume production is to change the prevailing perceptions of their status as subsistence crops and have them considered as commercial crops. This will require aggressive on-farm demonstration of the many seemingly viable technical options to alleviate the major abiotic and biotic stresses constraining the production of legume crops in the region, involving both improved genotypes and better agronomic management. Careful targeting of strategic research will be required to tackle some of the more intractable problems. Demonstration of high and stable yields with cost efficient management should encourage farmers to increase legume cultivation, in a process of technology-led production increase. To achieve this, a more holistic and integrated approach by relevant public sector research and extension agencies, non-governmental organizations, and the private sector, than hitherto achieved, is required.

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About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CG1AR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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Cornell University, located in upstate New York, USA, includes 13 colleges and schools. The university's 13,510 undergraduates and 5,970 graduate and professional students come from all 50 states of the USA and more than a 100 countries. Cornell is an Ivy League university and also the land-grant institution for New York State, committed to the three functions of the land-grant system in America: teaching, research, and extension. As such it is a unique combination of public and private divisions. Interdisciplinary study and research are Cornell hallmarks, as is attention to undergraduate education. The university's 2,340 faculty members are active teachers as well as researchers. State and Federal government agencies, industries, and foundations and other non-profit organizations are all potential sources of research support. Stemming from the university's land-grant role are Cornell Cooperative Extension (an education-outreach program for New York State residents) and the notion that the fruits of Cornell research should extend into the public domain.

Cornell University has been a leader in the arena of international agricultural and rural development for much of this century. The Department of Soil, Crop, and Atmospheric Sciences (SCAS) has had a long and distinguished history at Cornell. Studies in soil and crop science at Cornell have existed from the early days of the university. Today SCAS has over 30 faculty members who teach over 50 courses. The SCAS mission is to develop research teaching, and extension programs that will provide pragmatic solutions to agricultural and environmental problems, produce an educated populace, and advance the understanding of basic natural processes. The research program of the Department is one of the largest in the College.

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ISBN 92-9066-418-5 Order code: BOE 028 597-99