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

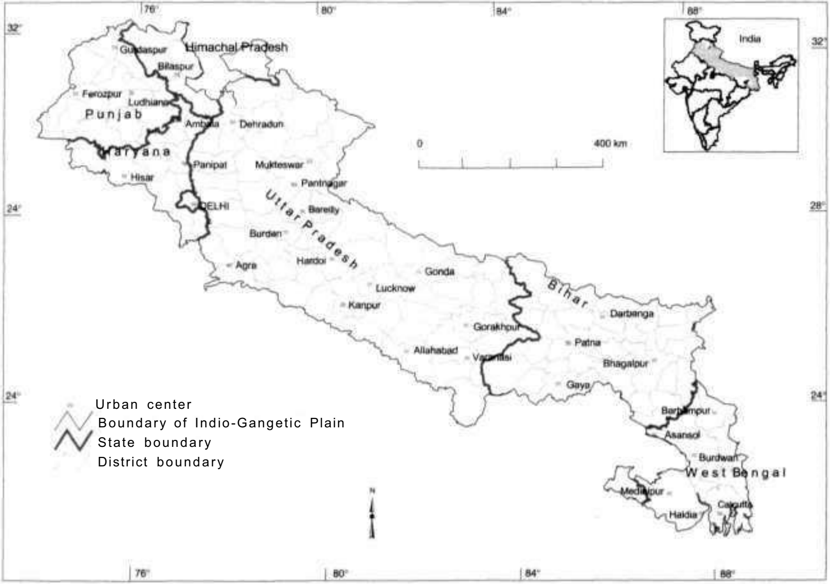

Figure 3.1. Administrative divisions and major urban centers in the Indo-Gangetic Plain of India (includes all districts, irrespective of state, considered to be located in the Indo-Gangetic Plain).

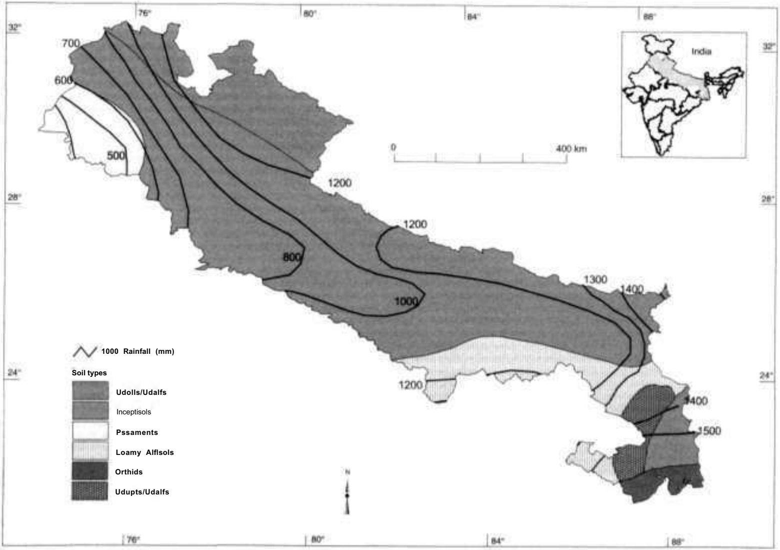

Figure 3.2. Annual rainfall distribution and major soil types in the Indian Indo-Gangetic Plain of India (Source: India Meteorological Bureau and National Bureau of Soil Survey and Land Use Planning).

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.

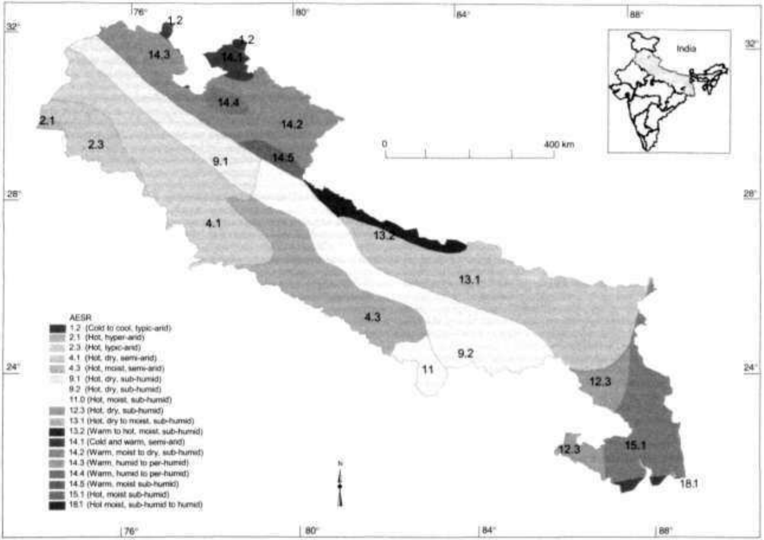

Figure 3.3. Agroecological subregions (AESR) of the Indo-Gangetic Plain of India (Source: 1998 map produced by National Bureau of Soil Survey and Land Use Planning).

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

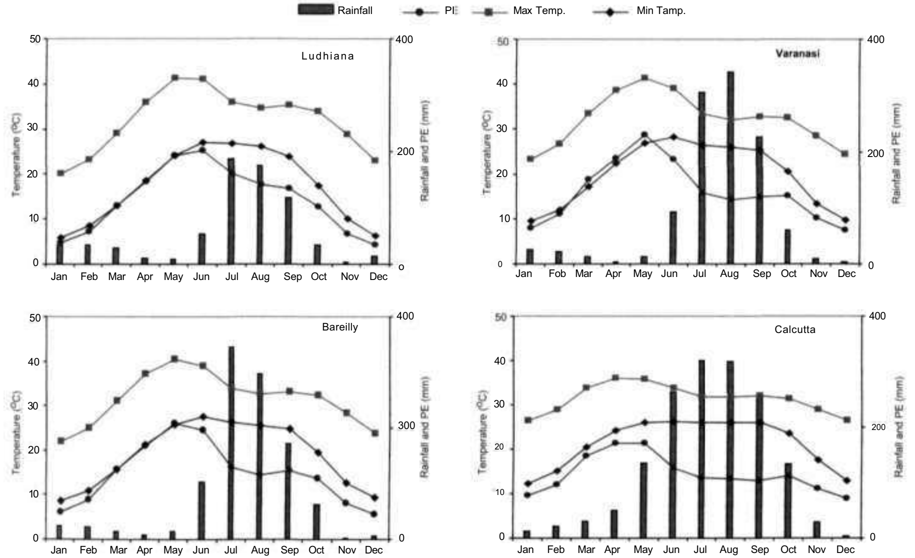

Figure 3.4. Mean monthly rainfall, potential evaporation (PE), and maximum and minimum temperature for representative locations in the Indo-Gangetic Plain of India (Source: India Meteorological Bureau).

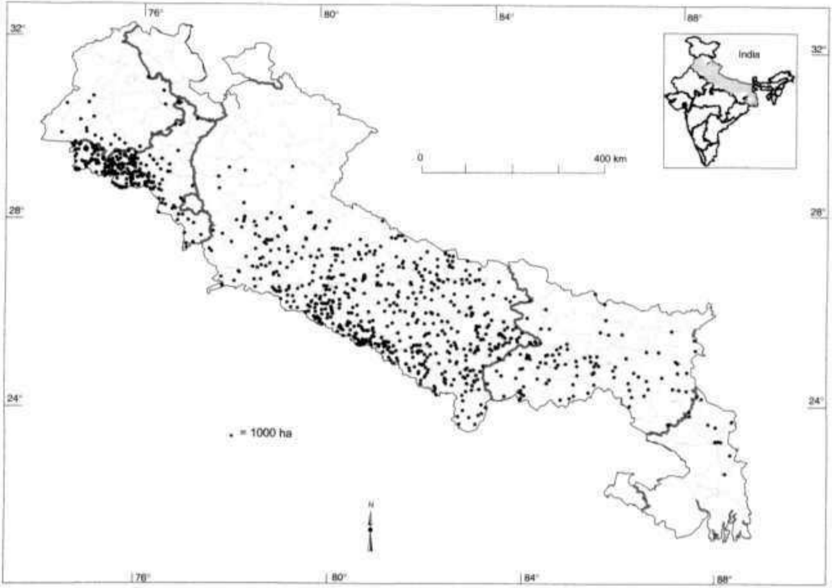

Figure 3.5. Area under chickpea in the indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

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.

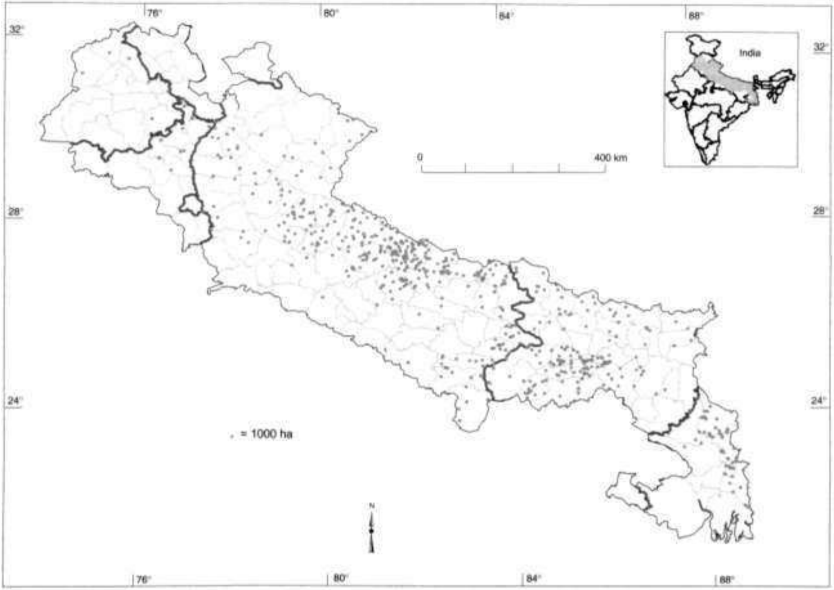

Figure 3.6. Area under lentil in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

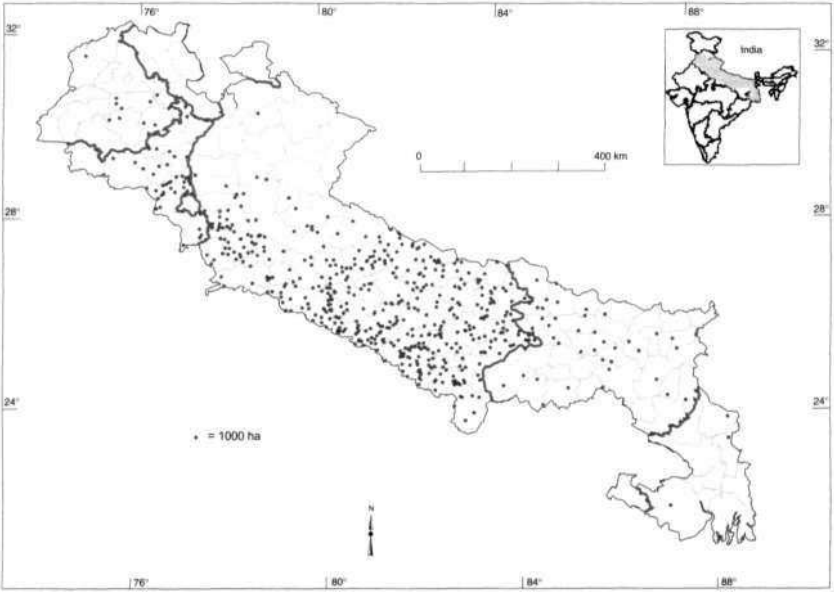

Figure 3.7. Area under pigeonpea in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

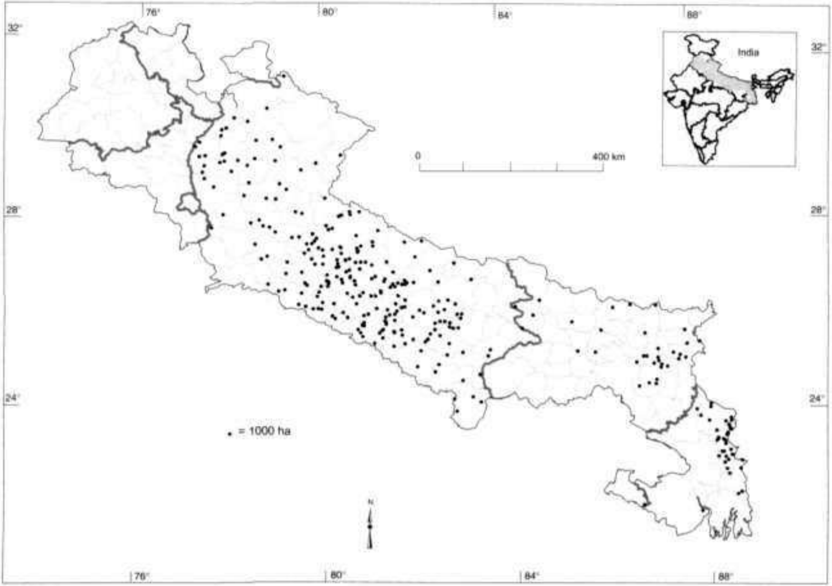

Figure 3.8. Area under black gram in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

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.

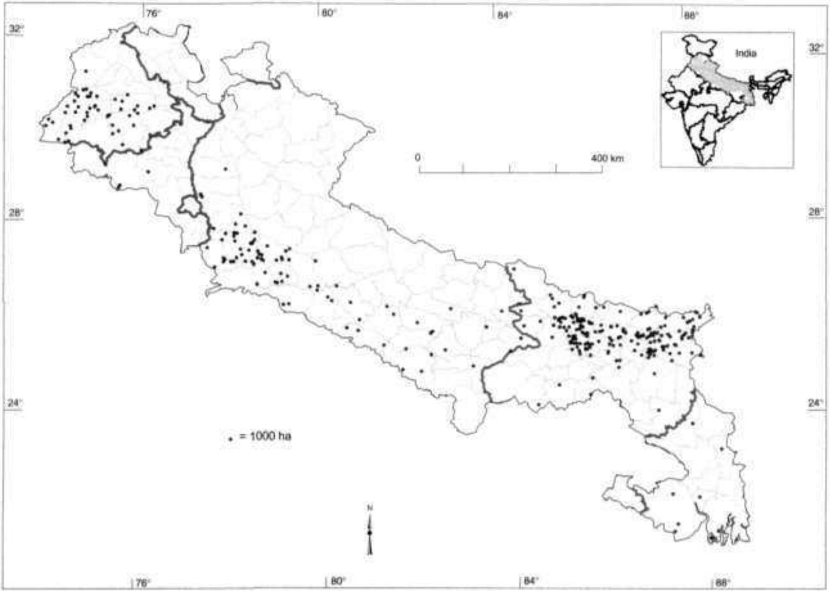

Figure 3.9. Area under mung bean in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

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

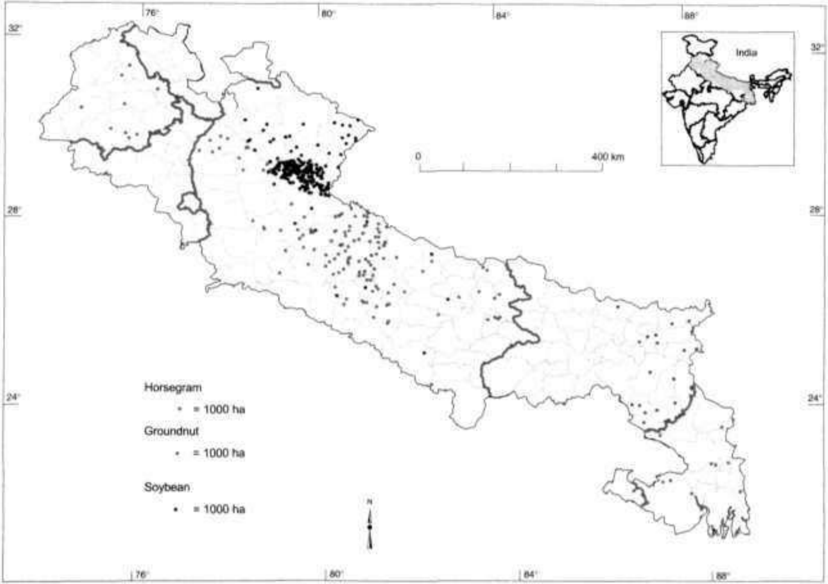

Figure 3.10. Area under groundnut, soybean, and horse gram in the Indo-Gangetic Plain of India, 1992/93 (Source: Directorate of Economics and Statistics, Government of India).

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: Yadhv (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.

	Grain yield[1] (t ha^{-1})		
Location/Crop sequence	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.

	Grain yield (t ha^{-1})		Change in fertility status of soil[1]		
Crop sequence	Rainy season	Winter	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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