4. Legumes Production in Traditional and Improved Cropping Systems in India

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INTRODUCTION

This paper reviews the traditional cropping systems of legume growing in India and the status of the agronomic research for legume improvement. The low yields of legume crops and the shortage of pulses as indicated by increasing prices have emphasized a greater need for research and as a result the "All-India Coordinated Projects" for the improvement of grain legumes and oilseeds (including groundnut) were established in the late 1960s. The setting up of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India has given further impetus to legume research. Improved genotypes of legume crops suitable for intercropping and multiple cropping systems have recently been developed.

As rainfed crops, legumes are mostly mixed or intercropped with cereals or long-season and widely-spaced crops. Cropping systems research has identified - compatible crops for intercropping and the optimum proportions and spatial arrangements that yield maximum intercropping advantage. Responses of legumes to inoculation and nitrogen have so far been inconsistent but considering the low cost involved in the rhizobium culture, the use of inoculum seems to ensure proper nitrogen nutrition. The response of legume crops to phosphorus is significant when

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applied to phosphorus-deficient soils and rates between 30-40 kg P_2O_5/ha are worth recommeding. Pests and diseases restrict legume production and even as chemical methods of control are known, the development of cultivars resistant to pests and diseases is emphasized. There is considerable scope for increasing pulse production by popularizing the improved methods of intercropping, growing pulses even in non-traditional areas, cultivating them in off-season, or growing them together with another crop in a traditionally mono-cropped area.

Pulses* are the chief source of dietary proteins in India. They are grown on 23.5 million ha with an annual production of 12.2 million mt, Even as this quantity represents 27.8 per cent of world production and puts India as one of the leading grain legume producing nations, pulses are still in short supply in the country. The net per capita availability of pulses has decreased from 75 g/day in 1958 to 40 g/day in 1974 which is far below the daily nutritional requirement (7). This shortfall in domestic supply may be attributed to a shift from pulse production to the production of cereals which, in turn, is a result of expanded irrigated areas and marked improvement in the yield performance of some cereal crops. The steady increase of population and the rising costs of animal proteins, however, will continue to influence greater demand for pulses.

The statistics of important grain legumes in India are shown in Table 1. Chickpea or gram *(Cicer arietinum* L.) and pigeonpea or "tur" *(Cajanus cajan)* which together account for 61 per cent of the total pulse production, are the principal grain legumes; chickpeas are grown in the post-rainy season (Oct.—March) and pigeonpeas are planted in the rainy season (June-Oct.). Other legumes grown exclusively in the post-rainy season are lentil *(Lens culinaris Medic),* "khesari" or grasspea *(Lathyrus sativus* L.) and peas *(Pisum sativum* L.). Mungbean or green gram *(Vigna radiata)* "urd" or black gram *(Vigna mungo)* and cowpea *(Vigna sinensis)* are grown in both seasons but the post-rainy season crop is possible only in the warmer parts of the country. Where irrigation is available these can also be grown in the summer. Other grain legumes grown in the rainy season with limited regional importance are field beans *(Lablab purpureus* L.) Sweet mothbean *(Vigna acantifolia),* cluster beans *(Cyamopsis tetragonolobus)* and soybean *(Glycine max).* Groundnut *(Arachis hypogaea)* is the major oil seed legume grown in both seasons but in the post-rainy season the crop is mostly confined to the irrigated areas of peninsular India.

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* Grain legumes, excluding groundnut and soybean.

Table 1. Area, Production and Other Characteristics of Important Legume Crops, India

Legume Crop	Planted Area (1,000 ha)[1]	Production (1,000 mt)[1]	Average Yield (kg/ha)	Experimental Yield (kg/ha)	Growing Season	Maturity (Days)
Pigeonpea	2,660	1,911	663	1,500-3,500	Rainy	120-270
Chickpea	8,221	5,450	718	2,000-4,500	Post-rainy	100-150
Mungbean	2,525	854	338	1,000-2,400	Rainy, post-rainy, summer	65-80
Urdbean	2,260	698	309	1,000-2,000	Rainy, post-rainy, summer	80-110
Horse gram	2,053	710	345	500-1,000	Rainy, post-rainy	100-120
Lentil	987	432	438	1,000-1,500	Post-rainy	90-100
Khesari	1,564	609	389	400-700	Post-rainy	100-120
Pea	582	348	600	2,000-3,000	Post-rainy	100-140
Groundnut	7,548	6,387	846	2,000-3,000	Rainy, post-rainy, summer	90-130
Soybean	303[2]	292[1]	964	1,500-3,500	Rainy, post-rainy, summer	90-140

1 Directorate of Economics and Statistics, Ministry of Agriculture and Irrigation, Government of India, 1979.

2 Relates to 1978.

CAUSES OF POOR YIELDS OF LEGUMES

Although grain legumes occupy about 21 per cent of India's total area planted to food crops, their contribution to the total food grains supply is only 12 per cent. Low yields of grain legume crops account for this inadequacy. A comparison of the average yields of some pulses with those obtained in experimental plots suggests that very little of their existing potential is actually realized by farmers. Moreover, less research on pulses is done compared with cereals or other commercial crops. Some of the reasons that explain the poor yields of legumes are:

(a) They are primarily grown as rainfed crops on a wide range of soil types extending to marginal lands where other crops usually fail. While 29 per cent of the total area planted to cereals in India has assured irrigation water that of legumes is only 8 per cent (12). However, 17 per cent of the chickpea area receives irrigation.

(b) Fertilizers are generally not applied to grain legume crops nor are they adequately protected against pests and diseases.

(c) The legume cultivars used as planting materials are poor-yielding, less responsive to inputs and susceptible to pests and diseases, e.g., the groundnut cv TMV-2 which has been in use for more than 20 years now is highly susceptible to leaf spots and rust, Although some legumes yield substantial dry matter, their grain yield is low because of a poor harvest index. Pigeonpea represents an extreme case where the grain yield of late- and medium-maturing cultivars is only 10-20 per cent of the total dry matter. The late-maturing cultivars of pigeonpea are grown only once a year.

(d) The stand of the post-rainy season legume crops is poor considering that they grow and develop towards the dry season when soil moisture is scanty.

(e) Legume crops do not compete well for soil nutrients with other crops in the traditional mixed and intercropping systems with which they are usually grown together. Their productivity is greatly reduced when they represent a minority among the mixed crops.

IMPROVED GRAIN LEGUME VARIETIES

There is an urgent need to develop short-season and high-yielding varieties of grain legumes to enable them to compete well with other crops and be appropriate for multiple cropping systems. In the case of genotypes meant for intercropping, specific plant characters and growth patterns advantageous to the legume crop need to be considered (47). Improvement in plant type for higher harvest index, response to management and resistance to pests and diseases also need to be incorporated in the development of new legume varieties.

When the "All India Coordinated Project" for the improvement of pulses and oil seeds was launched in the late 1960s, research on legumes started to be strengthened; e.g., improved genotypes have since been developed for pigeonpea, chickpea, mungbean, lentil, "urd", cowpea and groundnut (Table 2). A wide range of pigeonpea genotypes are now available for growing in different situations such as double cropping with wheat, intercropping and post-rainy season cultivation. Similarly, the new genotypes of mungbean, "urd" and cowpea are photo-insensitive, early-maturing and can be grown throughout the year, and some of them are fairly tolerant to diseases. The recently released cultivars of post-rainy season legumes, especially chickpea, which have high yield potential and better seed quality than the local cultivars. Some attention has also been given to the nutritional quality of pulses. In this respect, the "khesari" varieties of Pusa 10 and Pusa 17 have been identified as containing lower levels of neurotoxic substances which cause lathyrism. However, minor pulses like horse gram, field beans, mothbean, etc., have yet to receive special attention, including the development of genotypes responsive to fertilizer and resistant to diseases.

AGRONOMIC CONSIDERATIONS AND IMPROVED CROPPING SYSTEMS

Pigeonpea

(a) Rainy-season mono-crop

Pigeonpea, as a mono-crop, is planted in limited areas. They are usually the early-maturing (130-150 days) cultivars. Recently, however, the growing of pigeonpea with wheat and other pulses in the northern plains of the country has started to gain popularity. The pigeonpea-wheat combination has been successful because of the availability of high-yield, early-maturing (5 months) varieties of pigeonpea and the high yield potential of dwarf wheat varieties even as the planting of wheat in this sequence is delayed until January. Pigeonpea is sown at the onset of the rainy season by the first week of July in 50-75 cm rows and with a population of 75,000 to 80,000 hills/ha (1, 20). This particular pulse can make use of the residual nutrients from fertilizer applied to the preceding wheat crop (43) and, in turn, enrich the soil with humus from the leaves that it sheds (35). On the basis of returns and investment on

Table 2. Improved Varieties of Legume Crops, India

Legume Crop	Zones*			
	North & North Western	North Eastern	Central	Peninsular
Pigeonpea				
Extra early maturing and early maturing (120-140 days)	Prabhat, UPAS-120, ICPL81, 4-84, Pant A-l	BR-183, DL74-1, ICPL-1, 4-64	HY5, J9-19, CO-3, DL74-1	Sehore l97, HY1, HY5, 4-84, CO-1
Medium-maturing (160-180 days)	Mukta, T21, Pusa ageti	BR-65, JA5, No. 148, Kanke 3, LRG30, LRG36	No. 148, Khargone 2, GS-1, LRG30, C-11, R60, BDN-2	BDN1, JA3, GS-1, HY2
Late-maturing (200 days)	B517, T7, T-17, NP (WR)15	Gwaliro 3, HAU2, Bahar, Basant	NP (WR) 15, T7, Gwaliro 3	--
Urdbean	T9, T27, Pusa 1, Mash 48, Mash 1-1, U-l9, U36	Type 77, T9, Type 65, Pusa 1	Pusa 1, No. 55, Khargone 3, T9, Mash 48, Navin, B-102, B76	T9, No. 55, D6-7, CO-1, CO-3, ADT-1, PDM 71-1, PDM 71-2
Mungbean	ML-l,Type 1, G6S, Typc-2, Type 51, PS-10, Jawahar 45, ML 5	Shela, D45-6, Guj-l,Guj-2, K851	Jawahar 45, Khargone 1, Kopargaon, Pusa-Baisakhi, Krishna-11	CO-1, ADT-1, Jawahar 45, Pusa Baisakhi
Cowpea	Pusa, Phalguni, No. 455, 779, FS68, EL48	Same as Western Zone	Pusa Dophasal; Pusa phalguni	New era, C-152, U-16, U37, 779, K16, PTbl
Chickpea (Desi)	C-235, Type-3, H208, F61, BG203, K468, Pant G 114	G-130, C-235, Type-3, K850, H208, BG209, JG74, Pant G 110	JG315, BG200, K468, BG203	Annegiri, Chaffa, JG221, Jyothi, BDN 9-3
(Kabuli)	K4, K5, L-550, C-104, Hima	L-550, Hima, K4	L550, C-104	L550, C-104
Pea	T-163, K9, PS-110, PS60, EC33866, Bonnville	T-163, PS409, PS49, BR-12	PS-110, K9, L-116	PS49.PG2, L-116
Lathyrus	PS-1, P393, S3	PS-1, P396, S3	PS24, LSD6, PS6,P396	PS-1, P24, P396
Lentil	Type 36, L9-12, Pant L209, Pant L406, Pusa 4, Pant 838	LG7, Pusa 8, T36, BR25, No. 26, B77	Pant 838, JLs-1, L9-12, P43, Pusa 1	---
Groundnut	T28, T64, C-501. J-11, Punjabi, M-13, GAUG-10	AK-12-24	AJ-12-24, Gangapuri, Jyoti, Kopergoan	TMV2, Kadiri 3, Spanish improved, TMV-10, S206, Pol-1, Pol-2

Source: Singh, 1980; Singh, 1979; Pandey et al 1979, All India Coordinated Research Project on Oil Seeds, Annual Report, 1976.

* *North and North Western Zones:* Uttar Pradesh, Punjab, Rajasthan, Haryana and Gujarat.
North Eastern Zone: Bihar, West Bengal and Orissa.
Central Zone: Parts of Uttar Pradesh, Madhya Pradesh and Maharastra.
Peninsular Zone: Andhra Pradesh, Tamilnadu, Kerala and Karnataka.

fertilizer, the pigeonpea-wheat sequence has been more profitable than the common cereal-wheat sequences. Wherever irrigation is available, an early-maturing variety of mungbean can be grown after a wheat crop. The three-crop sequence of pigeonpea-wheat-mungbean has the potential yield of 2.5 mt/ha to 3 mt/ha of pulses and 3.5 mt/ha to 4 mt/ha of wheat (52).

The delayed planting of wheat in the above systems has been a concern to some farmers but the introduction of extra-early maturing varieties of pigeonpeas (Pant A-l, Pant A-3, UPAS-120) that mature in 4 months has not only helped to hasten the growing period of wheat but also increased wheat yields. Even with the use of the 5-month pigeonpea varieties returns can be increased by 25 per cent to 51 per cent when intercropped with early-maturing mungbean "urd", or soybean (15, 52). Indeed, the advent of early-maturing pigeonpea varieties has popularized the multiple cropping system in the north Indian plains.

(b) Post-rainy season mono-crop

Even as the pigeonpea is primarily a rainy-season crop, it has long been grown during the post-rainy season periods in small areas of Gujarat (71). At the ICRISAT, research work has since 1975 been undertaken in order to assess the potential of pigeonpea as a post-rainy season crop. The peculiarity of pigeonpea, however, is that the low temperature and short day-length prevailing after the rainy season force the plants to develop and bear pods prematurely, hence poor yields. For example, the regular-season cultivars of the medium-maturing (160-180 days) varieties and the late-maturing (200-240 days) ones matured in only 120-140 days when planted after the rainy season. Other studies have also shown that the medium-maturing cultivars promised yields of 1,220-1,800 kg/ha when grown after the rainy days (31).

In the meantime, investigation along this line of work has extended to other states. In the north eastern provinces, yields above 3,000 kg/ha have already been obtained (48). The shortened crop growth of pigeonpea during the post-rainy season can be compensated by making a high plant density of 250,000 hills/ha. So far, September plantings have generally given maximum yields. After September, yields are considerably reduced.

The promise of pigeonpea as a post-rainy season crop has opened new vistas in pulse production. It can be fitted into multiple cropping systems suitable for irrigated and rainfed areas. In areas with assured rainfall, pigeonpea planted after maize or sorghum (16) and wherever possible, relay planting may be considered since pigeonpea responds to early planting. On the uplands of the eastern provinces (Bihar, Orissa, West Bengal) pigeonpea can be grown after rice, maize or finger millet

(21, 48). Also, attempts are being made to introduce pigeonpea in rice fallows similar to the current practice with mungbean or "urd" in peninsular India (32).

(c) Intercropping

Much of the pigeonpea grown in India are the medium- and late-maturing (170-270 days) cultivars of which more than 90 per cent is intercropped (25, 18). The slow growth of pigeonpea and its adaptability to wide-row spacings provide an excellent opportunity for intercropping with early-maturing crops in order to utilize efficiently the early-season resources. The common intercrops planted with pigeonpea and which are also the latter's competing cereal/crops are sorghum, maize, millets and rice; the low-growing legume crops (groundnuts, soybean, cowpea and "urd"); or the cash crops with growth patterns similar to pigeonpea (castor and cotton). Farmers that plant two or more crops in varying proportions and spatial arrangements in the traditional system generally do this based on family needs rather than a decision to provide an optimum balance of competition. As a matter of fact, farmers generally sow all crops (in intercropping) simultaneously at the start of the rains in June or early July. In regions with extremely low rainfall and shallow soils, the early-maturing cereals or legumes are the predominant intercrops. But in areas with increased rainfall these crops are replaced by slightly late-maturing crops like sorghum and maize. On the other hand, in areas where rainfall exceeds 1,000 mm, rice replaces all other intercrops (3). The competitiveness of the inter-crops increases with an increase in their height and/or maturity, and, consequently, reduces the chance of pigeonpea to compete well (45).

The sorghum/pigeonpea intercrop is an important combination in the Deccan plateau where sorghum is the staple food. The local practice is to grow 6-12 rows of sorghum alternating them with 1 or 2 rows of pigeonpea at 30-45 cm row spacing. The objective of planting a high proportion of sorghum is to get a "full" yield of sorghum (as much as the yield of a single sorghum crop). But this system is inefficient because the small proportion of pigeonpea cannot make efficient use of the late-season resources after the sorghum is harvested. Studies have shown that the companion crops can be planted at a row arrangement of 2 sorghum: 1 pigeonpea and that maintaining the optimum plant population of sorghum as in a mono-crop (15 to 18 hills/m^2) can ensure a near "full" yield of sorghum. In a sorghum/pigeonpea intercropping study on vertisols at the ICRISAT, sorghum yielded 94 per cent of the normal yield of a mono-crop and pigeonpea (also maintained at 100 per cent plant population as in a mono-crop (4 or 5 bills/m^2), has given 72 per cent of the normal mono-crop yield or a total advantage of 66 per cent over the mono-crops (Table 3). On alfisols, the relative yields of both crops have been slightly less than those observed on vertisols because of poorer moisture conditions. It must be emphasized here that the above advantages have been obtained by simply growing the two crops together without any additional investment. This is very important for the small farmers. Apart from higher productivity grains, the sorghum/pigeonpea combination has proved less risky than when grown individually. An estimation of the probability of failure of different cropping systems to obtain specified "disaster levels" of income reveals that for a "disaster" income of Rs. 1,000/ha, sorghum fails one year in eight; pigeonpea one year in five, and shared failure (if one intercrop fails), one year in 13. In contrast, the intercropping system failure is estimated at only once in 36 years (46).

Table 3. Comparative Yields and Land Equivalent Ratios, Two Types of Intercropping System

(Alfisol) Sorghum/Pigeonpea (2:1)			(Vertisol) Pearl Millet/Groundnut (1:3)		
Item	Yield (kg/ha)	Land equivalent ratio*	Item	Yield (kg/ha)	Land equivalent ratio*
Single crop			*Single crop*		
Sorghum	4,500	1.00	Pearl millet	2,370	1.00
Pigeonpea	1,314	1.00	Groundnut	2,332	1.00
Intercropping			*Intercropping*		
Sorghum	4,240	0.94	Pearl millet	1,177	0.50
Pigeonpea	945	0.72	Groundnut	1,796	0.77
Total		1.66	Total		1.27

Source: ICRISAT, 1977-1979 average.

* Refers to the equivalent land area for each intercrop when planted individually in order to attain the same yields when intercropped.

Since a sorghum/pigeonpea combination already provides a high proportion of sorghum plant population, any further improvement has to come from pigeonpea. For this purpose, efforts have been made to increase pigeonpea yield by increasing its plant population and by evaluating suitable genotypes. Although its response to higher plant density has not been substantial, yields increased by 15 per cent when the plant population was doubled its single crop optimum level. The genotypes that are initially compact in growth but later spread out have shown a better adaptation to intercropping than those whose growth is compact throughout the season (47).

The pigeonpea/groundnut combination is extensive in peninsular India on red and sandy loam soils. Pigeonpea is spaced 2-7 m apart and interspersed with 8-20 rows of groundnut. Although this means a high ratio of groundnut plants, that of pigeonpea is as low as in the traditional sorghum/pigeonpea system. An optimum combination is 5-6 rows of groundnut alternating 1 row of pigeonpea. This does not affect the normal development and growth of groundnut and still allows a uniform distribution of pigeonpea (4). Experiments on 5 alfisol locations at ICRISAT showed that a ratio of 5 groundnut to 1 pigeonpea under optimal single-crop populations yields 82 per. cent for groundnut and 85 per cent for pigeonpea or a 67-per cent advantage over single crops.

There has been little experimental work on intercropping pigeonpea with crops having similar growth habit such as castor or cotton. Preliminary observations show less than a 20-per cent advantage for a pigeonpea/castor combination (45). Much remains to be known whether such intercropping has beneficial effects with regard to crop stability and pest problems.

(d) Ratooning

The post-rainy season pigeonpea crop is capable of ratooning for either grain or forage. Ratoons from a regular, single crop of some cultivars has yielded up to 500-800 kg/ha grains which is equivalent to 50 per cent of the regular crop yield (55). However, the yield of ratoons of intercropped pigeonpea was comparatively poor: only 100-200 kg/ha. But since ratooning gives an extra yield without any additional cost of production, it may be worth considering. When ratooning is contemplated, consideration should be given to harvesting only the branches that bear pods to enable the vegetative parts left behind to quickly set pods.

Early-Maturing Legumes

Mungbean and "urd" bean are the leading early-maturing legumes which are grown throughout India over a wide range of soil types. During the rainy season they are grown predominantly as intercrops with cereals or long-season crops like cotton and pigeonpea. However, as a catch crop they are grown singly in order to free the land in time for the ensuing main-season crops. The seeds are usually broadcast at the start of the rains (20-25 kg/ha) except in intercropping where they may be mixed in the same row with the companion crop or sown in separate rows. When the onset of rain is delayed or when the rainy season is short, these legumes are more profitable than the normally grown cereals (6). When grown as post-rainy season crops, these legumes are cultivated by the "utera" or "paira" system where pre-germinated seeds are broadcast 3-5 days before the harvest of rice (Nov.—Dec,), and the crop matures on residual moisture. This practice has been popular for several decades now in the deltas of South India and can be further extended to other rice growing areas in all the four states in peninsular India which are not currently cropped with pulses (33, 24). After the harvest of the post-rainy season crop, early-maturing legumes can be planted in the summer wherever water is available. This practice is becoming very popular, particularly with the early-maturing mungbean and "urd". Mungbean is grown in northern India as a single crop following the wheat harvest (15), or, as an intercrop in widely-spaced sugarcane or cotton fields (65, 70). The cost of production for the post-rainy season and summer legume crops is relatively low considering that the crop can utilize fertilizer residues from the preceding crops. In addition, pest problems are not serious, particularly in the summer. Irrigation at 50 per cent depletion of available water has been shown to be optimum during the summer (50).

Mothbean and clusterbean are highly drought-resistant and are frequently grown with other crops in the extremely dry areas of Rajasthan, Maharastra, Uttar Pradesh, and Punjab. Two crops of clusterbean are possible: one in the rainy season (July—Oct.) and the other, in the summer (March—June) with irrigation (60). Cowpea is grown mostly as a subsidiary crop that is planted with cereals throughout the country. In some areas cowpea is grown as a single crop in rotation with finger millet, cotton or paddy (23, 24).

Horse gram is the counterpart of mothbean, clusterbean or lathyrus in southern India in terms of its adaptation to poor soils and low rainfall. It matures in about 100-120 days and is mostly used as cattle feed. It is a rainfed crop and is grown with sorghum, pigeonpea or millets. Horse gram is an extremely useful contingency crop when rains are delayed and other crops cannot be grown. In high rainfall upland areas of Orissa, a sequence of groundnut — horse gram and finger millet — horse gram has shown very promising results (21).

Improved Methods of Intercropping Early-Maturing Legumes

The short-season legumes do not compete very well with cereals in an intercropping system. This is because the latter are raised for important family needs. Therefore, the farmers tend to maintain 100 per cent of the cereal plant population even when intercropped with legumes. In the process, the cereals outdo the legumes in the utilization of both sunlight and soil nutrients. Studies have shown that sorghum or millet can be planted in paired rows with cereals without affecting the yield of either crop provided that an optimum plant population is maintained. The distance between the pair of rows can be as close as 30 cm and the inter-pair distance can be as wide as 90 cm. This helps increase the proportion of legume plant population between the pair of rows as well as reduce the competition from the companion cereals (56). For sorghum, a paired method of 30/90 cm with two rows of intercrops has shown a higher productivity than other planting systems. However, the scope for reducing cereal population in intercropping needs to be considered, especially the high-yield cultivars which can yield higher than the traditional ones even at reduced plant population. Also, the impact of the competition between legumes and cereals can be cushioned by delaying the planting of cereals 2-3 weeks after the establishment of the legume crop (41). This can be a useful intercropping practice for cereals which do not have a critical planting time (e.g., setaria, pearl millet, and eleusine millet).

Post-Rainy Season Legumes

(a) Traditional Systems

Post-rainy season pulses are cool-weather crops grown during the winter months of October through March. Chickpea is grown on a wide range of agroclimates from less favourable peninsular India (3 to $3^1/_2$ months growing season) to the most favourable northern plains (5 to 6 months growing season). It is either planted as a single crop or intercropped with wheat, barley, mustard, linseed or safflower. In rainfed areas, it is grown after a fallow or after a rainy-season crop where rainfall is higher and soils are heavier. In irrigated areas, chickpea follows maize or rice. Khesari is a very hardy crop and represents the extreme case of legume adaptation to adverse conditions. Khesari and lentil are broadcast in different kinds of soils usually in rotation with rice; lentil is sometimes intercropped with mustard. The sowing of these legumes extends from October through December and are essentially raised as dry crops.

(b) Agronomic Considerations

Date of planting — Temperature and soil moisture prevailing towards the close of the rainy season influence the optimum planting time for post-rainy season pulses. Experiments at several locations of the "All India Pulse Project" indicate that planting in the second fortnight of October was best for chickpea in the plains of northern India. In the peninsular zone, the first fortnight was optimum. However, in the humid sub-tropical area, planting can preferably be delayed until the middle of November as the crops planted early often suffer from *Sclerotinia* blight (50). When temperature or soil moisture is not optimum at the normal growing time, the planting of pulses can be delayed. However, the scope for adjusting planting time in rainfed areas is much less than in irrigated areas. The optimum time for planting of other pulses is also around the middle of October (15, 30).

Plant population/seeding rate — Chickpea and lentil have a high degree of plasticity to plant population; for instance, a population of 8 to 100 hills/m^2 has not affected the yield of some chickpea cultivars (14). Under rainfed conditions high plasticity is extremely useful in compensating poor crop stands. However, a stand of 20-25 hills/m^2 can be considered as satisfactory. The differences between row spacings ranging from 15 cm to 60 cm have not been significant but 30 or 45 cm rows are convenient. Seeding rate varies depending on the seed size, and allowing for field problems, the small seeded "desi" types may require 40-50 kg/ha and large seeded "kabuli" types, 60-70 kg/ha. Lentil requires a seeding rate of 40-60 kg/ha and peas,.60-100 kg/ha (50).

Irrigation — Chickpea responds to supplemental water in the absence of adequate stored moisture or winter precipitation (52). Studies conducted in the pulse project have shown that in the northern plains, chickpea needs only to be irrigated once or twice depending on the soil type and initial soil moisutre. On light textured soils, irrigation at the preflowering stage (45 to 75 days) and/or at pod-filling stage has consistently increased yields. On heavier soils, one irrigation has proved sufficient at late vegetative phase. However, chickpea has responded to even 4 irrigations on deep vertisols at ICRISAT in southern India where moisture evaporation is higher than in the north. In southern India, irrigation has increased the crop growing period and produced 126 per cent more yield over an unirrigated control (54). Among other post-rainy season crops, pea is mostly grown in irrigated areas. Moisture stress at the pre-flowering and pod development stages has been severe on yields, hence one irrigation at each of these stages is recommended (5). Lentil does not require more than one irrigation which can be given at pre-flowering or pod development stage (50, 5).

Intercropping — Intercropping can be very important during the post-rainy season planting in order to take advantage of the remaining moisture in the soil. However, the crops should be compatible and should complement each other in drawing moisture from different soil depths. Intercropping work for post-rainy season has been mostly confined to such combinations of chickpea with cereals (wheat, barley, sorghum) and oilseeds (safflower, linseed, mustard, "toria"). Several research reports indicate that inter-cropping chickpea with these crops can give higher returns than individual crops under rainfed conditions (52). On the other hand, this report is contradicted by others (8, 11) who contend that any advantage gained could be due to less temporal difference between the companion crops. The beneficial effect of intercropping, wherever observed, has been in alternate rows of broadcast seeds (53, 3). Since the cereals are dominant, their plant population ratio should be carefully determined in order to obtain a favourable balance of competition. For instance, combinations of chickpea/safflower and chickpea/sorghum at ICRISAT have shown a maximum advantage of 18-20 per cent in alternate' rows and at a very low plant population for sorghum or safflower (5-6 pl/m^2) (72).

Groundnut

As a rainfed crop in the rainy season, groundnut is predominantly intercropped with cereals (pearl millet, sorghum and maize) and long-season crops (cotton, castor and pigeonpea). It is grown essentially as a single crop in the post-rainy season and summer where irrigation water is available. Considerable emphasis is being given to groundnut in these seasons, especially in the command areas of new irrigation projects in order to stabilize oilseed production (28). The single crop requires a stand of 30 to 40 hills/m^2 which can be planted conveniently in rows spaced at 30 cm apart.

The objective of intercropping with cereals or pigeonpea is to produce a food crop for the family needs and obtain some cash by marketing groundnut. As a cash crop, groundnut is usually the predominant companion crop (3) although this traditional practice does not necessarily result in maximum intercropping advantage. Studies have shown that in the case of pearl millet (80-day maturity) 1 row millet: 3 rows groundnut at 30 cm apart was optimum. This row arrangement (groundnut, 10 cm and millet, 15 to 20 cm), has produced yields equivalent to 50 per cent of the normal yield of single millet crop and 77 per cent for groundnut, or an overall advantage of 27 per cent for intercropping over single cropping (Table 3). Although the temporal difference between the two crops did not exceed 3 weeks, this advantage was due to the efficient use of resources, particularly sunlight (49). As the competition from companion crops increases, the groundnut plant population may have to be higher, as is evident in the combination of sorghum/groundnut which has given the maximum advantage of 30 per cent at 1 row sorghum: 4 rows groundnut (26).

The objective of intercropping with long-season cash crops (cotton and castor) is to make use of their wide inter-row space of 1-2 m and to provide insurance against crop failure should the rains be scanty or cease unusually early. The inclusion of 2-3 rows of groundnut can increase the returns by 50-60 per cent over yields of either crop when planted singly (39, 19).

RESPONSE TO INOCULATION AND FERTILIZER

Inoculation

It is generally believed that the common grain legumes do not respond to *rhizobium* inoculation. But experiments of the "All India Pulse Project" at several locations contradict this belief. Experiments with chickpea in 1975-79 showed significant responses in 50 per cent of the trials and, in some cases, the yield increase exceeded 125 per cent. Inoculation was generally more beneficial in rainfed areas for crops planted after rice (58,. 16). Response to inoculation was wide-spread for soybean but moderate for lentil, peas, mungbean and "urd" bean (15). Pigeonpea usually develops nodules well and, as such, has not shown much benefit from inoculation. And inoculated groundnut crops have often suffered decreased yields instead. This condition is partially attributed to the competition between the introduced *rhizobium* strain and the inherent ones present in the soil (66). Considering that the cost of inoculation is insignificant, it is recommended as a cheap and safe method of ensuring proper nitrogen nutrition for legume crops.

Nitrogen

The nitrogen requirement of grain legumes is twice that required for cereals to produce the same quantity of grains (14). However, legumes generally meet this high demand for nitrogen by their property of symbiotic fixation. Some legumes have shown positive response to small doses of nitrogen ranging from 15 to 25 kg N/ha, especially in farmer's fields (29) and on poor soils at experiment stations (52, 63). Legume response to nitrogen has been negligible on fertile soils and where the legumes were grown immediately after heavily fertilized crops (9, 50). Based on a review of 123 experiments, it was observed that in 48 per cent of the trials a low dose of nitrogen (5-14 kg N/ha) was profitable for rainfed chickpea, particularly on alluvial and medium black soils (42). However, for irrigated chickpeas nitrogen application was risky. Pigeonpea responses to nitrogen have been negligible (38). Observations in other legumes show that nitrogen requirements have not exceeded more than 15-20 kg/ha.

Phosphorus

The need of legumes for phosphorus fertilizer is felt to be greater than that for nitrogen. A 25-per cent increase in legume yields can be obtained by applying 33.6 kg P_2O_5/ha, and an additional dose of 33.6 kg would result in a further increase of 15 per cent (40). Response was generally more on mixed red and black soils and laterite soils compared with alluvial soils or vertisols. Exceptions were observed for horsebean and lathyrus which gave high responses on alluvial soils. On alluvial sandy loams of the northern plains, chickpea responded to fertilizer application of up to 40 kg P_2O_5 (30). On soils with low available phosphorus, the response was linear up to 75 kg/ha or more (52). Based on an analysis of 144 experiments, it was found that it is not profitable to grow chickpea in either irrigated or rainfed conditions even as responses to fertilizer were significant (42). Pigeonpea has shown a more positive and significant response to phosphorus at some places in northern India (20, 43). However, the medium- and late-maturing cultivars in the central and southern regions did not show any response to phosphorus even on sites where cereals (sorghum, millet) have responded even to small doses of 5-10 kg/ha phosphorus (2, 16, 17). This condition may be attributed to the ability of the crop to make use of residual or inherent phosphorus in the soil (43). The response of other legumes to phosphate varied markedly depending on the available phosphorus condition in the soil and the fertilizers applied to the preceding crop when planted in rotation (68). However, for most of the short-season legumes, the profitable phosphorus dose would be within 30-50 kg/ha (36, 15, 59, 51).

The need for potash application has not been determined so far for any of the legumes. Similarly, responses to micro-nutrients have been limited mostly to intensive cropping systems and on problem soils. Pigeonpea has shown zinc deficiency at some places which can be corrected by a foliar spray of 0.5 per cent $ZnSO_4$ with 0.25 per cent lime (52). On calcareous soil, response to sulphur has been observed in "urd" bean and groundnut (37, 10). Some chickpea cultivars exhibited iron chlorosis on vertisols and made yield increases up to 35 per cent when sprayed with 0.5 per cent ferrous sulphate (16).

LEGUME RESIDUES AND THEIR EFFECT ON CROPPING SYSTEMS

Grain legumes that mature in dry weather are cut at ground level or pulled, and threshed by beating the cut stalks with sticks or trampling by cattle. For those harvested in wet weather, pods are usually picked leaving behind the residues which are incorporated into the soil. After the grains are threshed, the vegetative portion, including the husk ("bhusa") is used as fodder or ploughed back into the soil. However, groundnut haulms are invariably used to feed cattle; usually preserved for off-season use. The pigeonpea stalks are used as fuel.

Legumes have been playing an important role in traditional agriculture. Their beneficial effect in increasing nitrogen condition of the soil has been amply demonstrated (68). This is evidenced by yields obtained from cereal crops grown immediately after legumes which are higher than those obtained from other cereal crops (68). When legumes are rotated with other crops, they have been shown to yield 37 to 58 per cent higher net returns than, say, fallow or sorghum-wheat rotations (61). The residual effect of legumes on soil condition varies considerably, e.g., groundnut and cowpea are known to increase the yield of the succeeding crop (pearl millet) by 23-24 per cent which is equivalent to the effect of a 60-kg N/ha application on another millet crop grown after a millet; mungbean did not influence millet yield; and pigeonpea influence was intermediate (13). In traditional intercropping systems, it has been suggested that legumes can benefit a companion cereal crop during the growing season but evidence to this effect has been scanty (64). Moreover, competition from cereal crop can adversely affect the nitrogen fixation process by the legume crop and the subsequent residual benefit; this detrimental effect may increase with increased nitrogen application to the cereal crop (ICRISAT, unpublished data).

WEED CONTROL

Farmers control weeds by hand-weeding for the closely-planted crops (e.g., mungbean, cowpea or groundnut), or, by the use of bullock-drawn blade harrows for pigeonpea planted in wide-spaced rows. One weeding by hand is sufficient for the early-maturing and intercropped legumes but two weedings may be required for legumes that mature relatively late (e.g., groundnut). The intercropping of slow-growing pigeonpea with competitive cereal crops can help avoid frequent weedings (44). Considerable research work has been done on the use of herbicides as weed control but their use is limited because they are costly, not readily available, difficult to use in intercropping systems and, above all, cheap labour is available for hand-weeding.

YIELD LOSSES DUE TO PESTS AND DISEASES

A number of pests and diseases cause severe yield losses to legumes. Both pigeonpea and chickpea have a common major pest, the pod borer (*Heliothis armigera)* and the former is also affected by a pod fly *(Melanagromyza obtusa).* Surveys have indicated that pod damage by these insects can range from 15 to 88 per cent (16). Field experiments at ICRISAT under sprayed and unsprayed conditions have shown that 2-3 sprays of 0.35 per cent Endosulphan (35EC) during flowering and pod formation stages of legume crops can check the major pests, hence improve economic returns (Table 4). The short-season legumes are affected by beatles, lepedopteron larvae and jassids; even 1 or 2 sprays given, especially in the reproductive stage, have shown significant yield increases (15).

Diseases of legume crops are equally destructive. The major diseases of pigeonpea are sterility mosaic, *phytophthora* blight and wilt (*Fusarium udum).* Chickpea is affected by wilt *(Fusarium oxysporum)* and root rot *(Rhizoctonia* sp). Seed treatment with 2-3 g/kg seeds of captan or thiram can protect the plant from wilt damage although this may not entirely eliminate the disease. Cultural methods like crop rotation involving legumes once in 2 or 3 years and intercropping of pigeonpea with sorghum, have been found to reduce the incidence of wilt (38). The low-growing and dense-canopy legumes (mungbean, "urd", etc.), provide a congenial microclimate, particularly in the hot and humid rainy season, hence conducive to the incidence of yellow mosaic, leaf spots, leaf wrinkler and powdery mildew. Virus diseases can be checked by spraying against the vectors but other diseases are, in general, difficult to control.

The major insects that affect groundnut are leaf minor, white grub, jassids and aphids; thrips are important as vectors of bud necrosis virus. Diseases are much more serious and the important ones are leaf spots *(Cercospora arachidicola* and *Cercosporidium personatum)* and rust. Protection from insects alone has resulted in little advantage but controlling diseases by frequent sprays of Daconil (1.8 kg/ha at 10-day intervals) has further resulted in a 232-per cent yield increase over insect protection (Table 4).

Table 4. Effect of Insecticide and/or Fungicide Spray on Legume Yields

Legume Crop	Yield of		Per cent Increase
	Unsprayed crop (kg/ha) A	Sprayed crop (kg/ha) (B)	(A/B)
Chickpea	632	915	45
Pigeonpea	408	1,027	152
Moongbean[1]	560	1,065	90
Pea[1]	1,179	1,757	49
Groundnut[2]	1,455	4,817	232

[1] IARI, 1971 and ICRISAT.

[2] Fungicide spray against rust and leaf spot. The insects were controlled in both sprayed and unsprayed crops.

Chemical control of legume diseases is difficult. Therefore, an inexpensive and effective method is the use of resistant cultivars as planting materials. Pathologists at ICRISAT have identified resistant cultivars against the major diseases of pigeonpea, groundnut and chickpea and are currently being used in the breeding programmes for developing resistant genotypes.

INCREASING PULSE PRODUCTION

In order to meet the growing demand for pulses, the area planted to legume has to be increased without sacrificing other equally important crops. In addition to some of the proposals mentioned earlier, the possibilities are by (i) growing legumes as intercrops; (ii) adapting them into multiple cropping systems; (iii) intercropping legumes with compatible ones in areas with assured rainfall where single cropping is the practice; (iv) examining the prospects for pulses in off-season and non-traditional systems; and (v) improving pulse performance in problem soils (saline and water-logged conditions) by developing cultivars suitable for such situations.

There is a considerable area of rainfed crops in India still not intercropped, e.g., only one-fourth of total groundnut area (0.8 million ha) and a small percentage of sorghum area (0.25 million/ha) in Tamil Nadu is intercropped but all of which could be effectively brought under intercropping with pigeonpea (33). Intercropping can also be extended to the long-season and widely-spaced crops (sugarcane, cassava) and plantation crops (banana, coconut and palmyra). The red and laterite soils are generally single-cropped although in several areas of the country, residual moisture is available to grow short-season crops. Early maturing mungbean, "urd" or cowpea can be grown in these places before the main crop, or, immediately after harvest of the main crop. (24, 69). The deep vertisols in central India where only a post-rainy season crop is grown can be double-cropped by growing a rainy season crop of maize or soybean without affecting the yields of post-rainy season crops (16, 67). The traditional crop wheat in this region does not perform well and can be substituted by the more efficient chickpea (22). In the irrigated areas, pulses can be grown between two main crops (27).

Considerable scope, therefore, exists for increasing pulse production in India. However, for a successful adoption of new cropping schemes, concerted efforts are required for the concerned government agencies to organize demonstrations; provide timely supply of seeds, credit and market facilities; and a realistic support price scheme.

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