11. Regional Opportunities for Cool Season Food Legumes for Sustainable and Enhanced Food Production, and Crop Diversification in the Indo-Gangetic Plain

N P Saxena[1], W Erskine[2], Jagdish Kumar[1], and C Johansen[1]

Abstract

Cool season food legumes (CSFL), mainly chickpea, lentil, khesari (*lathyrus*)*, faba bean, and pea, are important constituents of the diet of the people of the Indo-Gangetic Plain (IGP). In the traditional agricultural production systems of this ecoregion, these legumes were important crops. However, the area and production of CSFL in the IGP has decreased over the past two decades. Regional production is inadequate to meet regional demand, which increasingly has to be supplemented through imports. Large increase in demand of CSFL is projected in these countries over the coming decade.*

Major reasons for the decrease in area and production of CSFL arc preference of farmers to grow input-responsive, and more profitable rice and wheat crops and their reluctance to grow CSFL because of the uncertain yield that they can expect to harvest. Uncertainty in yield is associated with aberrant climatic conditions, and related pest and disease incidence.

Technology and/or components of technology, effective in alleviating the major abiotic and biotic constraints to CSFL production, are readily available from the published literature. However, these have by and large not reached farmers. With widespread adoption of improved technologies, higher yields could more reliably be harvested. This would further motivate farmers to expand area under these crops because CSFL production would be perceived as less risk-prone and quite profitable. Additional benefits would accrue from greater sustainability of the production systems into which these crops are introduced. Institutional support (incentives and farmer-friendly policy) that would ensure dependable income to farmers will be necessary for rapid adoption of new technologies. It is suggested that short-term, focused research and development projects could quickly result in greater availability of these pulses and reverse the declining trends in area under these crops.

1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

2. International Center for Agricultral Research in the Dry Areas, PO Box 5466, Aleppo. Syria.

Introduction

Cool season food legumes (CSFL), mainly chickpea (*Cicer arietinum* L), lentil (*Lens culinaris* Medic), khesari *{Lathyrus sativus* L.; lathyrus, grass pea), faba bean (*Vicia faba* L.), and pea (*Pisum sathmm* L.) are essential constituents in the food habits of the people in the Indo-Gangetic Plain (IGP). The major CSFL account for nearly 38% of total pulse area, and 64% of total pulse production in the four countries sharing the IG P (Table 11.1). In these countries production is generally inadequate to meet local demand, and the deficit is met through imports. Annual yield fluctuates widely (Fig. 11.1). Farmers, therefore, consider these and other grain legumes as very uncertain and risk-prone crops to grow.

The primary reason for the uncertainty of yield harvested at the end of the crop season in the IGP is aberrant weather conditions which cause extremes of soil water stress, ranging from drought to excessive soil moisture (waterlogging) and high atmospheric humidity. When protracted wet periods (high humidity) coincide with flowering and podding stages, as it prevails in the IGP, it often encourages development of foliar diseases in chickpea [Ascochyta blight (*Ascochyta rabiei)* and botrytis gray mold (BGM) (*Botrytis cinerea*)] and in lentil [rust (U*romyces viciae-fabae*) and stemphylium blight (*Stemphylium botryosum*)]. A close relationship between microclimatic conditions and incidence of BGM (Butler 1996) and ascochyta blight has been documented in chickpea (Jhorar et al.

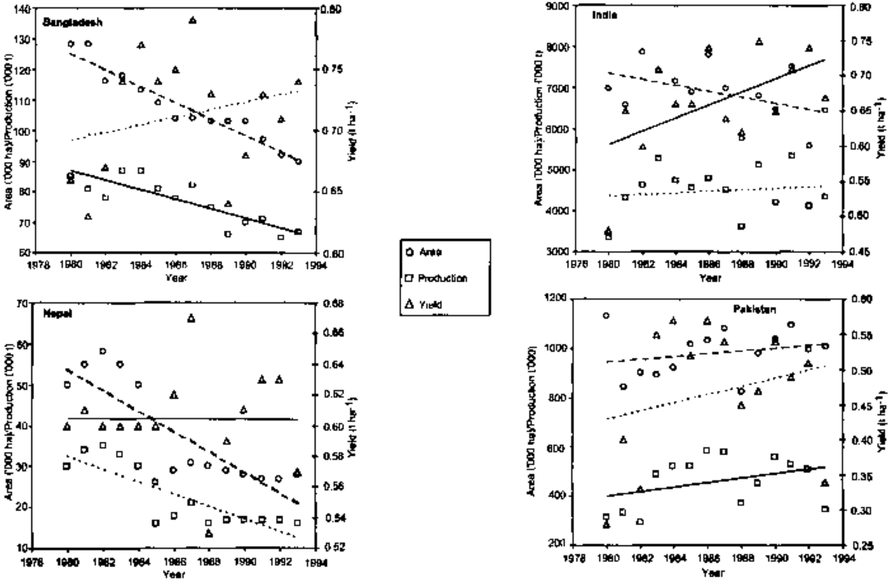

Figure 11.1. Time trends in area, production, and productivity of chickpea in Bangladesh, India, Nepal, and Pakistan (Source: FAO 1998).

Table 11.1. Area and production of cereals, pulses, and cool season food legumes in the Indo-Gangetic Plain (IGP) countries.

Country	Cereals	Pulses	Chickpea	Lentil	Dry peas	Green peas
Area ('000 ha)						
Bangladesh	7,825	706	85	207	33	-
India[1]	100,037	26,317	7,347	1,193	577	148
Nepal	3,251	328	20	155	-	
	12,288	1,762	1,095	65	140	9
IGP	123,401	29,113	8,547	1,620	749	157
Production ('000 t)						
Bangladesh	29,009	525	62	169	21	-
India'	218,354	14,836	5,818	907	593	2,150
Nepal	6,341	222	14	114	-	
Pakistan	25,009	1,029	611	33	77	62
IGP	278,713	16,613	6,505	1,223	692	2,212

1. All of India.
Source: FAOSTAT (1998).

1997). In 1996/97 and 1997/98 seasons yield losses due to BGM were very large in chickpea and lentil in Bangladesh and Nepal. Farmers failed to harvest seed to plant these crops in 1998.

Above-average and well-distributed winter rainfall during the crop season, and protracted rainfall at the end of the monsoon period induces excessive vegetative growth, lodging of crops, disease incidence, and ultimately lower yield. On the other hand, deficient and early cessation of monsoon rains, and inadequate winter rainfall, results in terminal drought (because >90% of these crops are grown rainfed) and heat stress in CSFL. Yield losses due to drought in these crops have been estimated to range between 20% and 50% (Saxena et al. 1993). Also, higher incidence of insect pests (pod borers, particularly *Helicoverpa armxgera* Hubner) and of wilt (*Fusarium* spp) are often observed in years when there is a greater degree of terminal drought and heat stress.

The present-day varieties of CSFL used by the farmers, which mainly comprise local landraces, seem quite susceptible to the adverse effects of soil and climate, diseases, and insect pests, even though they have evolved with them. Farmers, therefore, consider cultivation of CSFL as highly risk-prone. In comparison, rice (*Oryza sativa* L.) and wheat (*Triticum aesthmm* L.), the most important cereal food crops in the IGP, produce more assured and stable yields and higher economic returns under similar soil and climatic conditions. Rice and wheat crops also enjoy government policy support. These factors have motivated farmers to favor cereal-dominated production systems. Expansion in rice and wheat area in the IGP has been at the cost of area under legumes (see Ali et al., in this volume). However, in many recent reports from the IGP, questions have been raised about the sustainability of rice-wheat production systems because of the declining trends in factor productivity (Paroda et al. 1994). This potential threat, though a cause of serious concern, offers new opportunities to introduce CSFL in rice-wheat cropping systems (RWCS) because legumes have long been known to negate the adverse effects of continuous cropping with cereals. Another factor that would favor promotion of cultivation of CSFL is that the demand for these crops is predicted to increase considerably in the next decade (Kelley et al. 1997).

Thus, successful introduction or inclusion of CSFL in RWCS could indeed be realized, or new production systems formulated which have CSFL as a component crop. Research publications on CSFL grown in South Asia at least indicate that there is adequate knowledge and information available on these crops, and technologies or components of technologies formulated, to feasibly alleviate the major constraints to production. A major lacuna seems to be inadequate formulation of potential technology packages by multidisciplinary teams of scientists, and their validation in on-farm trials.

Analysis of Constraints and Potential Opportunities

Increase or decrease in crop production is a direct function of cultivated area and yield. Relative contribution of each component depends upon which of the two has been limiting production most. In chickpea, evidence shows that either of the factors could play a dominant role, depending upon the situation. A large-scale expansion in chickpea area in Turkey and Australia, and an associated impact on chickpea production, has taken place in the past two decades (Fig. 11.2). In Turkey, area expansion occurred through introduction of chickpea in fallow lands, and in Australia the crop has primarily replaced wheat and ley pastures. The impact of area expansion was so large that a large increase in production occurred despite the fact that there were decreasing trends in productivity. This decrease in productivity may be because the new areas brought under chickpea were not ideally suited for chickpea cultivation. Alternatively, development of appropriate technology (including adapted varieties) for the new areas did not precede the rapid expansion in chickpea area.

In contrast, increase in chickpea productivity (yield) in India not only offset the effect of huge decline in chickpea area in the past two decades, by nearly 1.0 million ha, but contributed to a small although insignificant increase in production (Fig. 11.1). A major decrease in chickpea area in India occurred in the IGP, particularly in Haryana and Punjab states, in the past two decades. The area decreased in Haryana from 1.0 million ha to <0.6 million ha, and production from 0.6 million t to 0.35 million t. In Punjab, area decreased from 0.35 million ha to <0.05 million ha, with a proportionate reduction in production.

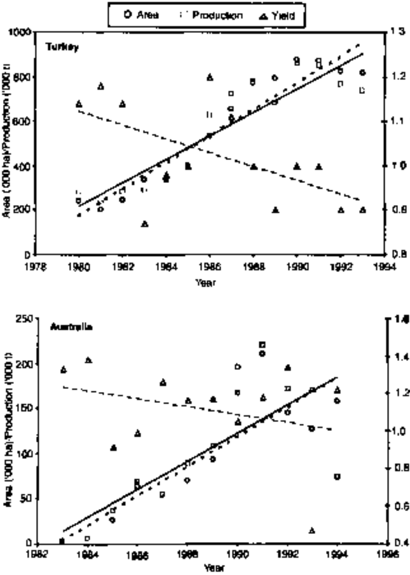

Figure 11.2. Time trends in area, production, and productivity of chickpea in Australia and Turkey (Source: FAO 1998).

Major Constraints to Production

A number of constraints—biotic, abiotic (climatic), edaphic, agronomic management, and socioeconomic—afflict CSFL production in the IGP. Instability of yield is mostly due to abiotic and biotic constraints and because of these fanners are reluctant to grow these crops with the present-day varieties and technology available to them.

Biotic Constraints

Almost all diseases reported in the literature that affect CSFL seem to occur in one or the other IGP country (see the country chapters in this volume). However, the constellation of major diseases seems to vary from one ecoregion to another. For example, in chickpea, BGM is of major concern in the eastern parts of the Indian IGP, while ascochyta blight is most important in the western IGP (see Ali et al., in this volume). This is primarily due to differences in climatic conditions, in particular, microclimate conditions (Butler 1996). Similar differences are noted when one compares the IGP countries, viz., BGM in Bangladesh and Nepal, and ascochyta blight in Pakistan and western parts of Indian IGP.

Relative importance of various diseases and insect pests (as given in the country chapters), affecting CSFL production across the IGP countries is summarized below.

Diseases

Chickpea	Fusarium wilt (*Fusarium oxysporum* f. sp *ciceris*) > BGM = ascochyta blight > collar rot (*Sclerotium rolfsii)* and root rots
Lentil	Vascular wilt *[Fusarium oxysporum* f. sp *lentis*) = rust > stemphylium blight > collar rot (S. *rolfsii)* = root rots > BGM
Khesari (lathyrus)	Downy mildew (*Peronospora* sp) = powdery mildew (*Erysiphe* spp)
Faba bean	Chocolate spot (*Butrytis* sp) = rust (*U. viciae-fabae)*
Pea	Powdery mildew *(Erysiphe pisi)* = pea mosaic virus

Insect pests

Chickpea	Pod borer (*H. armigera)* = bruchids *(Callosobruchus* spp) > semilooper *(Autographa nigrisigna* Walker)
Lentil	Bruchids > lima bean pod borer (*Etielia zinckenella* Treitschke) > aphids
Khesari (lathyrus)	Aphids
Faba bean	Aphids
Pea	Pod borers = bruchids

Nematodes

Nematodes arc not recognized as major constraints across the IGP countries. But in some areas in western parts of the Indian IGP, yield loss due to nematode infestation has been estimated at 12-15% (Sharma and Rahaman 1998). However, there have been too few yield loss surveys to know the extent of damage caused by nematodes.

Weeds

Weeds are a serious constraint across all the IGP countries. Yield losses are estimated at 25% in lentil in Nepal (see Pandey et al., in this volume) and 42% in chickpea in India (see Ali et al., in this volume). Farmers neglect weeding CSFL in general, compared to cereals, perhaps because of uncertain returns on the effort required. Indeed, in Nepal they permit weeds to grow and use them as green silage for cattle.

Climatic and Soil Constraints

Abiotic constraints commonly reduce yields of most CSFL (chickpea, lentil, faba bean, and pea), except khesari (lathyrus). Khesari (lathyrus) seems to be more tolerant to extremes of soil water stress conditions, ranging from waterlogging to drought (see Ali et al., in this volume). Severity of these constraints have been ranked on the basis of information given in the country papers in this book as follows:

Chickpea	Drought > heat > chilling = excess soil moisture
Lentil	Drought > heat > excess soil moisture
Khesari (lathyrus)	No significant abiotic constraint
Faba bean	Drought = heat
Pea	Drought = heat

Effect of soil type in modifying drought stress seems to be minimal as the soils in the region are mostly deep and alluvial. But the variation in climatic conditions is quite large even within a country in the region, e.g., rainfall and thermal regimes in the eastern and western parts of Indian IGP (see Ali et al., in this volume). These variations have a direct bearing on the occurrence and severity of drought, heat, and cold stress. Indirect effects of these variations in climate are large in modifying the severity and occurrence of various diseases through their influence on microclimate (Butler 1996).

Mostly, CSFL are grown on marginal lands, generally not preferred for the cultivation of cereal crops. These lands are often poor in soil physical properties and fertility status. Despite the fact that CSFL are known to be very sensitive to factors such as soil salinity, extremes of pH (soil acidity and alkaline conditions) (Saxena et al. 1993), attempts are made to grow these crops in such unfavorable soil environments.

Except when grown in rotations with other crops that are well fertilized, CSFL almost ubiquitously face phosphorus deficiency (Tandon 1987). There are increasing reports of other elements, such as sulfur (Tandon 1991) and boron (Srivastava et al. 1997, 1999), limiting yields of CSFL. Farmers take few, if any, corrective measures against known or suspected nutrient deficiencies in CSFL.

Poor Plant Stands

In rice-based production systems, it is common to observe poor and non-uniform plant stands. The problem seems to be more severe in chickpea following a rice crop because of the atypical soil physical conditions that result from soil puddling. Field surveys of plant stands of chickpea in farmers' fields in central, north, and northeast India, covering important chickpea-growing areas in the IGP, show that the plant stands usually are less than one-half of the recommended plant population (Fig. 11.3).

Farmers generally use seed rates far below the recommended ones. Also, the seed viability is often poor. These factors result in poor plant stand establishment and ultimately lower yields. Preparatory cultivation prior to sowing is not satisfactory, a problem particularly encountered when CSFL are sown after the harvest of paddy. The broadcast method of sowing also contributes to the poor and non-uniform plant stands because of random distribution of seeds and some seeds may fall in dry surface soil layers. Also, soilborne diseases and insect pests can reduce initial plant stand even after the seeds have germinated and seedlings have emerged.

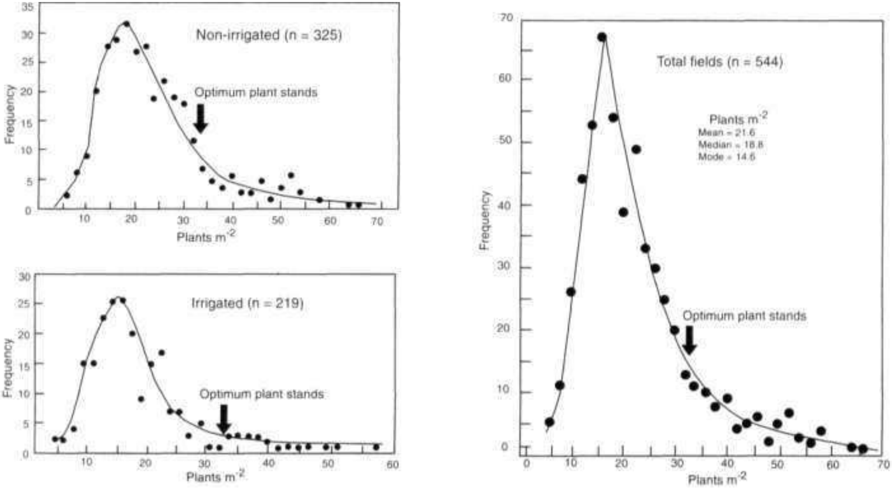

Figure 11.3. Variation of plant stands of chickpea in non-irrigated, irrigated, and all farmers' fields in central and northern parts of India (Note: Vertical arrows indicate recommended optimum plant density for realizing maximum yield; n = number of farmers' fields) (Source: Field surveys conducted by ICRISAT, 1973-78).

Timely Sowing and Harvest

Mechanization of operations is becoming an increasing necessity in high intensity cropping systems. Timely availability and high cost of labor for manual operations make mechanization of operations essential. This is particularly true when CSFL follow rice in a cropping sequence, because of the short turn-around time for preparation of paddy fields to sow CSFL. For lentil and chickpea, sowing and harvesting operations have been successfully mechanized on experimental stations and also demonstrated under on-farm conditions and on large-scale farmers' fields. However, to benefit small holder farmers, cheap and readily acceptable options of mechanized operations need to be developed and popularized.

Socioeconomic and Policy Constraints

In many of the IGP countries it is well recognized that large increases in pulse production will be required to meet the demand of 2010. In Bangladesh, this increase in demand is projected to be around 30% and in Pakistan at 23% over the current levels of production. Wide fluctuation in prices of legume crops, with particularly low prices at the time of harvest and steep rises in prices soon afterwards, has a strong negative impact on farmers' preference to grow these crops. Government policies on subsidies and procurement prices still favor cereals over pulses. Even though improved varieties of CSFL and agronomic packages that would ensure their higher and more stable yields exist, farmers remain unwilling to invest in CSFL because of these continuing risk factors. Increasing reliance of governments on imports to meet local demands of CSFL is a further discouragement to farmers to attempt their cultivation.

Technological Options Readily Available for Alleviating Constraints

Recent literature shows that a good understanding of the major constraints to CSFL production has been achieved (e.g., Summerfield 1988; Muehlbauer and Kaiser 1994; Asthana and Chandra 1997; IFLRC III 1997). Also, focused, periodic reviews on chickpea have been held (ICRISAT 1976, 1980, 1990). It is evident from the published literature that options to significantly alleviate most of the biotic and abiotic constraints to CSFL production, listed as important in the IGP countries discussed here, are readily available. Many significant achievements have been made in finding genetic solutions as resistant/tolerant varieties or germplasm (Table 11.2) (Singh 1994). Also, for the management of those stresses for which high levels of genetic resistance are not available, integrated management options are available, including the management of weeds (Table 11.3). To increase the effectiveness of the genetic component, strategies and approaches have also been proposed (Table 11.4).

This tempts us to state that the legumes scenario has changed fundamentally, with regard to technology generation from the time when Borlaug (1973) made the statement, "Neither new high yielding varieties of grain legumes (pulses) nor improved technology have been developed; so gradually part of the land that once grew pulses has shifted in winter to wheat and in summer to maize or rice." However, it is disappointing to note that despite concerted efforts and progress made so far in identifying effective genetic and integrated management technology, very little progress is apparent in on-farm conditions in alleviating the major yield reducing constraints to CSFL production. The declining trends in chickpea area and production in the IGP of India, Bangladesh, Nepal, and Pakistan (Fig. 11.1) perhaps is a result of this gap in transfer of technology. One may speculate that

Table 11.2. Sources of resistance to diseases and pests and of other useful traits in pulse crops available in India.

Trait	Research location/center[1]	Genotypes
Chickpea		
Ascochyta blight and fusarium wilt resistance	Ludhiana	GL 83119, GL 84038, GL 84096, GL 84107, GL 88341, GL 91058, GL 91060
	Hisar	H 83-84, H 83-60
	Patancheru (ICRISAT)	FLIP 83-7-C, FLIP 82-74-C, FLIP 86-60, FLIP 85-90, FLIP 86-41, ICCV 89445, ICC 1272, ICC 3137, ICC 4076
Asc:ochyta blight, fusarium wilt, and botrytis gray mold resistance	Ludhiana	GL 88341, GL 88395, GL 88356, GL 84107, GL 88366, *Cicer bijugum*, C. *judaium*, C. *pinnatifidum*
Fusarium wilt and root rot resistance	Hisar	H 86-84, H 86-18
	Patancheru (ICRISAT)	ICC 8383, ICC 10466
Root rot and stunt resistance	Hisar	H 86-84, H 86-18
Ascochyta blight resistance	Hisar	E100Y, E 100Y(m), E 101, Gaurav,H 86-18
	New Delhi (IARI)	BG 261
	Pantnagar	BRG 8, EC 26446, PG 82-1
	Patancheru (ICRISAT)	NEC 206, ILC 191,ILC202, ILC 1069, ICC 1009, ICC 4846, ICC 6103, ICC 6671, ICC 7002, ICC 10302

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Ludhiana	GL 84099, GL 84107, GL 86143, GL 91058, GL 91059, GL 91060
Wilt resistance	Pantnagar	P 436-2, GPS-1
	New Delhi (IARI)	BGM 443, BG 246
	Kanpur (CSAU)	WR315(K 315), KW 17, Avrodhi
	Srtganganagar	GNG 426
	Sehore	JG74,JG315,GW6,GW3-1, GW8.JG 1265
	Rahuri	Phule G 81-1-1, Phule G 87207, Phule G 86185
	Hisar	H 81-73, H 86-8, H 86-72
	Kanpur (IIPR)	PDG 83-34, DCPW I, DCPW 2, DCPW 3, DCPW 4, DCPW 5
	Ludhiana	GL 87079, GPF 7035
	Badnapur	BDN 9-3, BDNG 77, BCP 4, BCP 72, BCP 87, PPK 1, PPK 2
	Patancheru (ICRISAT)	ICC 671, ICC 2664, ICC 3345, ICC 4483, ICC 6687, ICC 8383, ICC 9032, ICC 9041, ICC 1038, ICC 10466, ICC 11233, ICC 11329, ICC 12234, ICC 12240, ICC 1226, ICC 85221, ICC 84225, ICCC 32,1CCV 10, ICCV 18, ICCV 19
Botrytis gray mold resistance	New Delhi (IARI)	BG 276
	Patancheru (ICRISAT)	Dhanush, ICC 1069, ICC 11321, 235-38

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
Pod borer resistance	Kanpur (IIPR)	PDE 2, PDG 84-10
	Patancheru (ICRISAT)	ICC 12483, ICC 506, P 202, P 927, DDG 128,
	Ludhiana	ICC 3580, GL 645, Desi 3108
	Hisar	LHR 69, P 696-1
Root-knot nematode resistance	Kanpur (CSAU)	K 1122
	New Delhi (IARI)	BG 302
	Indore	IG218
	Junagadh	GCP 11
Bold seed (>20g 100^{-1} seed mass)	Pantnagar	RGG 8
	Durgapura	DGM 65, DGM 471, DGM 474, DGM 726, RSG 143, RSG 216, RSG 220, RSG 259, RSG 503-1, RSG 536, RSG 538
	Kanpur (CSAU)	K 850, KTP 1
	Sehore	JG 1265
	Patancheru (ICRISAT)	ICC 42, ICC 7617, ICC 81001, ILC 3-83, ILC 35, ILC 76, ILC 116, ILC 3396, ICC 1507, ICC 3859, ICC 5712, ICC 5434, ICC 9647
	Rahuri	N 31,Phule G5
	Akola	AKG 40
	New Delhi (IARI)	Pusa 256, BG 273, BG 329
	Badnapur	BDNG 342
	Gulbarga	Annigeri

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Hisar	Arjun, Bheema, H 85-69, E 100Y.H 86-18
	Varanasi	KLD 1-83
Double pod	Sehore	JG 62
	Akola	133-84
	Rahuri	Sele 436
	Patancheru (ICRISAT)	Annigeri mutant
	Varanasi	HUG 211, HUG 201, HUG 237
	Durgapura	RSG 44, RSG 538
Compact plant type	Hisar	H 86-143, H 90-237
Multiseeded pod	Hisar	HMS 6
	Varanasi	HUG 211, HUG 201, HUG 237
	Durgapura	RSG 540
	Patancheru (ICRISAT)	ICC 12118, ICC 1052
	Akola	B 85-2-1, B 85-2-2
Large pod	Hisar	H 82-46
	Patancheru (ICRISAT)	Giant pod recombinant
Early maturity (130-140 days)	Sehore	JG 74
	Patancheru (ICRISAT)	ICC 14627, ICCV 2, ICC 88201, ICC 89244
	Kanpur (IIPR)	PDG 84-16
	SK Nagar	Chaffa
	Durgapura	RSG 44, LD 153, RSG 524, RSG 580, RSG 515

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Gulbarga	Annigeri
	Badnapur	BCP 3, 3CP 4
Tall plant	Durgapura	2D 287, DGM 663, DGM 727, RSG 236, RSG 255, RSG 261, RSG 291, RSG 538, RSG 668
	Patancheru (ICRISAT)	ICC 8101, ICC 8922, ICC 8923
	New Delhi (IARI)	BG 261, BG 273,BG 274
Higher no. of primary branches	Kanpur (CSAU)	Type 3
	Patancheru (ICRISAT)	ICC 7002
	Hisar	Bushy mutant
Higher no. of secondary branches	Varanasi	JM 2106, C. *reticulatum* H 86-156, H 86-170
Tolerance to salinity	Hisar	H 893-84, H 81-69, H 85-10
	Karnal	CSG 8893, CSG 8894, CSG 8862
Lentil		
Rust resistance	Pantnagar	PL 406, PL 639, PL 81-17
	New Delhi (IARI)	Precoz, L4152
	Palampur	Vipasa, HPL 1
	Ludhiana	LL 30,LL 56,LL 78, LL 112, LL 116,LG 128, LL147, LG170, LG 171, LG 186, LG 231,LG 265

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Kanpur (I1PR)	DPL 15, DPL 16, DPL 21, DPL 44
Fusarium wilt/root rot resistance	Pantnagar	UPL 175, PL 81-17, PL 406, PL 639
	Dholi	RAU 101, PL 77-2
	Ludhiana	LG 171
	New Delhi (IARI)	L 1304
	Almora	VL 104
	Kanpur (I1PR)	DPL 16
Ascochyta blight resistance	Pantnagar	PL 639
	Palampur	Vipasa
	Ludhiana	LL 301.LG 60, LG 112, LG 170, LG 171, LG 178, LG 186, LG 231
	Dholi	PL 77-2
Bold seeded (>2.5 g 100[1] seed mass)	New Delhi (IARI)	Precoz, L 4076, L 4163
	Hisar	LH 84-8
	Kanpur (CSAU)	K 75
	Sehore	JLS 1, Sehore 74-3
	Ludhiana	LG 170, LG 171, LG 327, LG 362, LL 295, LL 443
	Kanpur (IIPR)	DPL 15, DPL 38, DPL 44, ILL 4354
	Palampur	HPL 4
Early maturity (< 125 days)	Sehore	JLS 1, Sehore 74-3
	New Delhi (IARI)	Lens 830, Precoz
	Berhampore	Ranjan
	Akola	PKVL1
	Kanpur (IIPR)	DPL 47, DPL 21

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
Khcsari (lathyrus)		
Low neurotoxin content	Raipur	RP 137-77, Rewa 2-25, LS 619-2-4-87, Rewa 2-28, Pusa 24 selection
	New Delhi (IARI)	P 28, Bio-R-231, Bio-L-222, Bio-R-203, Bio-R-202
Powdery mildew resistance	Raipur	Rewa 2-206, LSD 1-149, LSD 1-195, LSD 3-209, LSD 3-2, JRL 6,JRL 47, RPL 31-77, Rewa 2-28, RL 298-104, 619-2-4-146, JRL 55-48
Downy mildew resistance	Raipur	298-10,619-2-4-146
Thrips resistance	Raipur	JRL 141, Rewa 2-29, RPL 31-83, LS 8545, LS 8246, NC 84-269
Pea		
Powdery mildew resistance	Kanpur (CSAU)	T 10, 6578, 6588, Rachna, KPMR 85, KFPD 4, KPMR 146, KMPR 149, KPMR 157, KPFD 10
	Pantnagar	Pant P 5, DP 2
	New Delhi (1ARI)	DMR 1, DMR 6, DMR 8, DPR 1
	Jabalpur	JP 179,JP 501,A/2
	Faizabad	NDP 90-84
	Hisar	HFP 4, HFP 8712, HFP 8718, H 877

continued

Table 11.2 *continued*

Trait	Research location/center[1]	Genotypes
	Ludhiana	LPF 48, LPF 56, LPF 57, LPF 58, LPF 80, LPF 81, LPF 82
	Varanasi	S 143, A 474-288
Rust resistance	Jabalpur	JP 50-A/2,JP 179,JPB 7, JPU 496
	Kanpur (CSAU)	P 16, P 20, P 43
Leaf miner resistance	Jabalpur	JP 9.JP 130.JP 179
	Kanpur (CSAU)	P 29, P 402, P 200
Pod borer resistance	Kanpur (CSAU)	P 144, P 26-4, P 76-68
Bold seeded (>20g 100[1]seed mass)	New Delhi (IARI)	Pusa 10
	Kanpur (CSAU)	KPSD1, 6112, KP 58, KFPD 10
	Dholi	RAU 37
	Varanasi	BHU 74, HUP 5
Dwarf plant type	IARI	Pusa 10, Harbhajan, DDR 1
	Hisar	HFP 4
	Kanpur (CSAU)	KPMR 11
	Ludhiana	PG 3
Leafless plant type	Hisar	HFP 4
	Varanasi	S 143
	Ludhiana	LBG 41, LPF 56, LPF 57, LPF 61, LPF 75
	Kanpur (CSAU)	KPMR 14, KPMR 15
High protein	Varanasi	BHU 397, BHU 484, PI 280064

1. ICRISAT = International Crops Research Institute tor the Semi-Arid Tropics; IARI = Indian Agricultural Research Institute; CSAU = Chandra Sekhar Azad University of Agriculture & Technology, IIPR = Indian Institute of Pulses Research.

Table 11.3. Management technologies for alleviation of biotic constraints to production of cool season food legumes.

Management technology	Reference
Diseases	
Options to manage botrytis gray mold of chickpea	Haware et al. (1993, 1997) Pande et al. (1998)
Integrated management of pigeonpea and chickpea wilt diseases	Khare et al. (1997)
Integrated management of fungal foliar diseases of chickpea and lentil	Haware and Gurdeep Singh (1997)
Development and implementation of forecaster for plant disease management	Kushalappa (1997)
Integrated management of viral diseases of grain legumes	Anupam Varma and Jain (1997)
Chickpea diseases and their control	Nene and Reddy (1987)
Nematodes	
Nematodes and their control in chickpea	Greco (1987)
Management of nematodes of food legumes	Greco et al. (1997)
Insect pests	
Integrated pest management of pod borer complex of chickpea and pigeonpea in India	Sachan and Lal (1997)
Eco-friendly pest management of *Helicoverpa armigera* in chickpea	Chari et al. (1998)
Biological control of insect pests of pulse crops	Singh (1997)
Chickpea insect pests and their control	Reed et al. (1987)
Weeds	
Weeds and their control in chickpea	Bhan and Kukula (1987)
Integrated approach to weed management in pulse crops	Bhan and Mishra (1996)

Table 11.4. Approaches in improving adaptation of chickpea to manage biotic and abiotic constraints in cool season food legumes.

Theme/Title	Reference
Integrated management of botrytis gray mold of chickpea: agronomic and physiological factors	Saxena and Johansen (1997)
Strategies for improving drought resistance	Subbarao et al. (1995)
Screening for salinity tolerance and nutrient acquisition	Saxena (1987) Saxena et al. (1994)
Development of high nodulation capacity in chickpea	Rupela(1997)
Chickpea ideotypes	Saxena and Johansen (1990a,b) Saxena et al. (1997)

the recommended solutions to problems have not reached the farmers or are not being adopted.

Strategies to Realize Impact of Potential Technology in Short Term

It seems quite reasonable to conclude that there is a big gap between the availability of technology and its on-farm popularization. We believe strongly that a significant impact in the near term (2 to 3 years) can be made and a substantial increase in area and production of CSFL can be achieved with the existing information/technologies. We point out to some of these options and suggest that these be implemented as "Operational Research Projects".

Improvement in Plant Stands

It should be possible to double the prevailing low yields under on-farm conditions through improvement of plant stands alone. A number of factors which are known to affect plant stands can be overcome with relative ease through adoption of simple agronomic management practices. For example, seedbed preparation can be improved; recommended seed rate can be used; seeds can be primed (pre-germinated); seed dressing with chemicals can be applied to overcome soilborne insect pests and diseases; and seed can be sown with country seed drills in moist soil instead of sowing by the broadcast method.

Diseases

For soilborne diseases, good levels of genetic resistance arc available (Table 11.2). In the case of diseases for which genetic resistance is low or not available at present, integrated management options are available (Table 11.3). These options should be able to minimize the yield reducing effects of these diseases at least by 50% in most of the years, except perhaps when they appear in severe epidemic form.

Insect Pests

Stored grain pests can be easily managed and virtually eradicated (Reed et al. 1987). Among all constraints the pod borer *H. armigera,* a polyphagus insect pest, appears to be the most difficult to manage. Recent reports (Table 11.3) on the integrated management of this insect pest shows that some progress has been made (Chari et al. 1998).

Adaptation of CSFL into Available Niches

It is now feasible to fit CSFL into various niches in the highly productive rice-rice or rice-wheat production systems. Adaptation of chickpea and lentil has been improved greatly in recent years by developing varieties of extra-short, short, and medium duration to fit these appropriately into available niches of rice-based cropping systems. Also, combinations of cultivar and appropriate agronomy to adapt chickpea to late-sown conditions, a necessity in most rice-based cropping systems, are now available (Krishnamurthy et al. 1983). On soil types that do not come into condition to prepare land for sowing legume crops in sequence or under very wet soil conditions, a choice of appropriate crop, e.g., khesari (lathyrus), can be made.

Mechanization of Sowing

Although more development work is needed, it is possible to adapt planting and harvesting machinery for use in legumes cultivation in the 1GP.

Profitability of Cultivation

The belief that it is less profitable to grow legumes, is primarily related to the risk-prone nature (instability in yield due to abiotic and biotic stresses) of the present-day varieties of these crops. If this constraint can be alleviated, or the risk is substantially reduced, the cultivation of CSFL will be equally or even more profitable than cereals even with a modest but assured yield level of 1 to 1.5 t ha^{-1}, which is around 30-50% of potentially realizable yield of the present-day cultivated varieties, in the case of chickpea. Other factors that would be in favor of high economic returns from CSFL production are the high price, at least 3 to 4 times more than the cereal crops, and low requirement of chemical fertilizers because of high efficiency in accessing essential nutrients through root traits (Saxena 1996), e.g., nitrogen (N) through efficient biological nitrogen fixation (BNF) (Rupela and Saxena 1987) and phosphorus through acidification of rhizosphere (Ae et al. 1991). Recent identification of high mineral N-tolerant symbioses (Rupela and Johansen 1995) shows promise in further enhancing efficiency of BNF in the presence of high levels of soil mineral N, which generally exist after the harvest of high input rice crops.

Conclusion

From the evidence presented it seems quite realistic to expect that a substantial impact can be made on CSFL production in a short period. This can be achieved with the available knowledge and technology, or components of technology which would result in enhancing the on-farm realizable yield and also area expansion under the crops. An urgent need is to demonstrate that these improved packages of practices are indeed viable in on-farm conditions. A dedicated multidisciplinary team of scientists and extension personnel along with the target farmers, need to be involved together in the technology evaluation process. Trouble shooting of unanticipated problems encountered could be done by the team and new research programs undertaken to refine the technology. An example of such an approach is underway to attempt to rehabilitate chickpea in Nepal, after cultivation of the crop had been almost eliminated by the severe BGM epidemics of 1996/97 and 1997/98 (Pande 1999).

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