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

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Abstract

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

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introduction

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

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

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

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

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

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

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

Soybean

Diseases

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

Fungal diseases

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

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

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

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

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

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

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

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

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

Viral diseases

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

Bacterial diseases

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

Nematodes

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

Insect Pests

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

Weeds

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

Mung Bean and Black Gram

Diseases

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

Yellow mosaic

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

Cercospora leaf spot

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

Powdery mildew

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

Nematodes

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

Insect Pests

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

Weeds

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

Lentil

Diseases

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

Fungal diseases

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

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

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

Viral diseases

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

Nematodes

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

Insect Pests

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

Weeds

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

Chickpea

Diseases

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

Fungal diseases

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

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

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

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

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

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

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

Bacterial diseases

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

Viral diseases

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

Nematodes

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

Insect Pests

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

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

Weeds

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

Groundnut

Diseases

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

Fungal diseases

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

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

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

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

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

Bacterial diseases

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

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

Viral diseases

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

Nematodes

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

Insect Pests

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

Weeds

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

Cowpea

Diseases

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

Fungal diseases

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

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

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

Bacterial diseases

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

Viral diseases

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

Nematodes

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

Insect Pests

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

Weeds

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

Faba Bean

Diseases

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

Fungal diseases

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

Bacterial and viral diseases

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

Nematodes

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

Insect Pests

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

Weeds

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

Khesari (Lathyrus)

Diseases

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

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

Nematodes

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

Insect Pests

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

Weeds

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

Pea

Diseases

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

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

Fungal Diseases

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

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

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

Viral diseases

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

Nematodes

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

Insect Pests

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

Weeds

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

Pigeonpea

Diseases

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

Nematodes

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

Insect Pests

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

Weeds

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

Horse Gram

Diseases

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

Insect Pests, Nematodes, and Weeds

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

Conclusions and Future Research Priorities

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

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

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

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

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

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

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