Pest Management in Pulses Under Rice-Wheat Crop Diversification

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Abstract

Concerted research and developmental efforts supported by government policies brought a paradigm shift in favour of rice-wheat cropping system (RWCS) in the last three decades in the Indian Indo-Gangetic plain (IGP). This shift has relegated traditional pulses such as chickpea and lentil to less favourable environments. There are increasing concerns that high input rice-wheat cropping rotation in the IGP is reaching productivity limit, and further that the edaphic resource base is under threat due to various degradation process. As the sustainability of such input systems is increasingly under question throughout the IGP, it has become necessary to readdress, and further rehabilitate pulses for the sustainability of the RWCS. However, the evidences revealed that pulses are prone to several abiotic, biotic and socio economic constraints in augmenting their production. Among biotic constraints important ones are diseases and insect pests. Together these two biotic constraints can cause a total loss to a pulse crop. Enormous opportunities exist for production of pulses with integrated pest management (IPM) in the RWCS, such as short duration mungbean as a summer crop, pigeonpea in rotation with rice, and chickpea and lentil in rotation with wheat. It is, therefore, critical to delineate the promising niches in the RWCS for each pulse crop and introduce appropriate IPM technology with available components of pest management. Also, there is a need to create a favourable environment for pulse cultivation and IPM promotion through policy support. This paper critically examines the niches for rehabilitation of pulses and promotion of IPM for sustainability of the RWCS.

1. Introduction

India is a major pulse producing country in the world sharing about 35% area and 28% production. Area under pulses has remained static during the past 30 years and has not been able to keep pace with growth in population. This resulted in a sharp decline in per capita consumption (13 kg year^{-1}) and exorbitant increase in domestic prices of pulses.

Pulses have been traditionally grown as a component crop in the rice *(Oryza sativa* L.) and wheat *(Triticum aestivum* L.) cropping systems (RWCS) of the Indo-Gangetic Plain (IGP) of India. However, increased irrigation and introduction of high yielding and input responsive varieties of rice and wheat during the Green Revolution phase has led to the increase in area under mono-cropping of rice or rice-wheat, replacing the traditional sustainable cereal-pulse cropping systems. As a result, rice and wheat ousted the dominance in cropping systems by replacing more than 20 crops each in rainy and post-rainy seasons. Presently, the RWCS constitutes 57.4% of the total area devoted to food grain production in India. In the IGP, rice and wheat together account for more than 75% of the total area, and in some states like Punjab it is even more. Continuous cultivation of rice and wheat resulted in declining productivity, depletion of soil nutrients and water resources, and frequent outbreak of pest and disease epidemics, thus emphasizing the need for crop rotation. Since pulses have the capacity of biological nitrogen fixation (BNF) through symbiotic association of *Rhizobium*, there is a need and demand to revitalise pulse crops in the RWCS to improve soil fertility and maintain long-term sustainability of this production system (Ali and Kumar, 2002). It is in this context that attempts were made to analyze the RWCS critically and identify the niches for greater inclusion of pulses in this system. A fundamental approach to overcome the insignificant increase in pulse production in the RWCS is to consider them as commercial crops and manage their biotic, abiotic and socio economical constraints. This region shows huge potential for expansion of pulses either as a catch crop, summer crop or sole crop as a component for crop rotation in different cropping systems. Diseases and insect pests (Table 1) were the major biotic constraints for successful reintroduction and profitable production of pulses in the RWCS (Pande *et al.*, 2000). The available trends show that pulse area is gradually increasing in the RWCS. The present paper discusses opportunities for the reintroduction of pulses in RWCS and management of their diseases and insect-pests.

2. Niches and Scope of Pulses for Diversification of RWCS

Rice-wheat and rice-based cropping systems are the most important systems, with rice-wheat rotation covering about 10 million ha in the IGP. Legumes including pulses account for 5 million ha which is nearly14% of the total pulse area in the country (Ali *et al.*, 2000). This region, largely dominated by Inceptisol soils has large spatial variation in rainfall pattern (268 mm in the extreme North to 1600 mm in the extreme East), and other agroclimatic characteristics such as temperature regime, length of growing season, and evapotranspiration. Despite these variations, chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* L.) and pigeonpea (*Cajanus cajan* L.) are being cultivated as major pulses in the RWCS across eastern and western IGP (Table 2). In irrigated lands, rice and wheat are grown in rotation, and inclusion of pulses becomes essential in lieu of the declining soil fertility and water resources. Pulses on account of their short duration, ability to thrive better under harsh climate

Crop	Biotic constraint	Pest/Pathogen
Mungbean (*Vigna radiata* L.)	Fungi	*Pseudocercospora cruenta* (cercospora leaf spot), *Erysiphe polgoni* and *Oidium* sp. (powdery mildew)
	Viruses	Mungbean yellow mosaic virus (yellow mosaic)
	Insects	Jassids, *Empoasca kerri* Pruthi (leaf hopper), *Bemisia tabaci* Genn. (whitefly), *Madurasia obscurella* (galerucid beetle), *Caliothrips indicus* Bagnall (thrips)
Pigeonpea (*Cajanus Cajan* L.)	Fungi	*Fusarium udum* (Fusarium wilt), *Phytophthora drechsleri* f.sp. *cajani* (Phytophthora blight)
	Viruses	Pigeonpea sterility mosaic virus (sterility mosaic)
		Insects *Helicoverpa armigera*, *Maruca testulalis* Geyer (pod borers), *Melanagromyza obtusa* Malloch (podfly)
Chickpea (*Cicer arietinum*)	Fungi	*Ascochyta rabiei* (ascochyta blight), *Botrytis cinerea* (botrytis gray mold), *Fusarium oxysporum* f. sp. *ciceris* (fusarium wilt). *Rhizoctonia bataticola* (dry root rot)
	Viruses	Bean leaf roll virus (stunt)
	Insects	*Helicoverpa armigera* (pod borer), *Callosobruchus chinensis* (bruchids)
Lentil (*Lens culinaris* L.)	Fungi	*Fusarium oxysporum* f. sp. *lentis* (vascular wilt), *Rhizoctonia solani* (wet root rot), *Rhizoctonia bataticola* (dry root rot), *Sclerotium rolfsii* (collar rot), *Ascochyta fabae* f. sp. *lentis* (ascochyta blight), *Erysiphe polygoni* and *Leveillula taurica* (powdery mildew)
	Viruses	Luteoviruses (lentil yellows), Bean yellow mosaic virus (yellow mosaic), Cucumber mosaic virus
	Insects	*Callosobruchus chinensis* L., *C. maculates* Fab. (bruchids), *Aphis craccivora* (aphids), *Spodoptera exigua* Hubner (army worm), *Helicoverpa armigera* Hubner (pod borer),

Crop	Biotic constraint	Pest/Pathogen
Khesari (*Lathyrus Sativus* L.)	Fungi Insects	*Peronospora viciae* (downy mildew) *Aphis craccivora* (aphids)
Pea (*Pisum sativum* L.)	Fungi	*Rhizoctonia solani* (rhizoctonia seedling rot), *Pythium ultimum* (seedling rot), *Fusarium solani* f. sp. pisi (fusarium root rot), *Aphanomyces euteiches* (aphanomyces root rot), *Fusarium oxysporum* f. sp. *pisi* (fusarium wilt)
	Viruses Insects	Bean (pea) leaf roll virus (BLRV) *Acyrthosiphom pisum, Aphis pisum, Aphis craccivora* (aphids), *Phytomyza atricornis* Meig (leaf miner) *Helicoverpa armigera* (pod borer)
Fababean (*Vicia faba* L.)	Fungi	*Botrytis fabae* (chocolate spot) *Ascochyta fabae* (Ascochyta blight) Uromyces viciae-fabae (rust)

and fragile ecosystems with better water use efficiency in comparison to rice and wheat, can be included both in rainfed and irrigated RWCS. Additionally, pulses also contribute to soil fertility, offer great hope for diversification and reduce the use of chemical fertilizers in the RWCS. Extensive testing of various combinations revealed that rice-pulse and rice-oilseed/pulse rotations were more remunerative than rice-rice or rice-wheat cropping systems (Ali *et al.*, 2000). Identification of short-duration pulse varieties with resistance/tolerance to biotic stresses, desirable agronomic traits and cost-effective pest management strategies offers a tremendous potential for their inclusion in the RWCS.

Table 2: Major cropping systems including pulses in western IGP and eastern IGP

Western IGP	Eastern IGP
Pigeonpea-wheat	Rice-lentil/chickpea
Groundnut-wheat	Rice-groundnut
Rice-chickpea	Rice-mustard-urdbean/mungbean
Rice-mustard/potato-urdbean/mungbean	Groundnut-wheat

3. Biotic Constraints and their Management for Pulses Production in RWCS

Though there is a great demand, the large scale adoption of pulses in the RWCS of IGP is limited by several biotic stresses including diseases and insect-pests (Table 1). Some of these constraints are devastating and widespread, and several others are limited to a particular region (Table 3). The incidence and severity of diseases and insect pests are also influenced by some abiotic factors such as (a) hard and compact soil (due to puddling) leading to poor plant stand and crop establishment, (b) poor emergence and colonization by weak soil borne pathogens, (c) excessive moisture at the time of sowing resulting in slow initial growth and colonization by water loving fungi such *Phytophthora drechsleri* infection in pigeonpea, (d) terminal drought leading to the forced maturity and predisposition to infection by *Rhizoctonia bataticola* in chickpea and lentil, and wilt in chickpea *(Fusarium oxysporum)* and pigeonpea *(F. udum),* and (e) pre-harvest sprouting in high rainfall zones.

Strategies for improving pulse production in the RWCS depend on holistic and site-specific approaches. These approaches should mainly target at controlling diseases and pests by judicious use of host-plant resistance, pesticides and agronomic practices. Crop management options need (a) technologies to minimize the effect of puddling on pulse establishment and increase their productivity after rice, (b) sowing methods to

Table 3: Relative importance of biotic constraints affecting the production of chickpea and pigeonpea in the Indo-Gangetic Plains[1]

Constraint	Western IGP		Eastern IGP	
	Pigeonpea	Chickpea	Pigeonpea	Chickpea
Pod borer	+++	+++	+++	+++
Pod fly	++	+	++	-
Botrytis gray mold	+	+	++	+++
Ascochyta blight	-	+++	-	+
Phytophthora blight	+	-	++	-
Wilt	+++	+++	+++	+++
Nematodes	+	+	+	+

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

ensure optimum soil moisture for germination and crop establishment, (c) weed management in early stages of growth, (d) fertility and nutrient management including green manuring and organic matter recycling, (e) water management for rice to avoid moisture stress during early growth stages (seedling) of pulses (Ramakrishna *et al.*, 2000), and (f) seed treatment and foliar application of fungicides and insecticides for control of different fungal diseases and insect pests. A wide range of options are available for genetic improvement of pulses for their suitability and making them more competitive for inclusion in the RWCS. Improved plant type/architecture, tolerance to pre-harvest sprouting, early vigour, short duration, resistance or tolerance to major pests and diseases, and cold tolerance are some of the potential areas for genetic improvement. Finally, the genetically improved high yielding varieties need to be included in IPM packages to achieve competitive yields of pulses in the RWCS.

3.1 Biotic Constraints of Spring/Summer Season Pulses and their Management

Mungbean is an important summer pulse crop, with potential for expansion in the existing and new niches. Yield potential of mungbean is 3 tons ha^{-1}, but yields in farmers' fields remain 0.3-0.5 tons ha^{-1} being affected by several diseases and a few insect pests. The most important diseases and their management options are described as follows:

3.1.1 Fungal diseases: Cercospora leaf spot *(Pseudocercospora cruenta)* causes spots of varying sizes and shapes which are purplish at the beginning and later the center becomes grayish in colour leading to premature defoliation. The disease normally comes if the summer crop of mungbean receives rains during maturity. It affects the quality of the produce and hence fetches low price in the market. Foliar application of carbendazim @ 0.1% was economically effective in controlling the disease.

Powdery mildew *(Erysiphe polgoni)* commonly occurs in mungbean crop sown during Sep-Oct (after rice harvest) and was also observed in the summer-sown crop. Powdery masses of spores and mycelia are formed on the leaves which later turn dirty white, leading to defoliation in extreme cases. Like cercospora leaf spot this disease also affects the quality of the mungbean grains. The disease can be controlled by 2-3 foliar sprays of Tilt 250 ED®(0.1%), Thiovit 80WP® (0.2%), or Karathane® (0.1%) .

3.1.2 Viral disease: Yellow mosaic (mungbean yellow mosaic virus) is the most serious limiting factor in mungbean and urdbean cultivation in the IGP region. The disease can occur at any stage of crop growth, but yield losses are severe (up to 100%) when it occurs at an early stage. A mixture of irregular yellow and green patches on the leaves is the characteristic symptom of this disease. The pathogen is transmitted by whitefly *Bemisia tabaci* Genn. Foliar spraying of systemic insecticides such as aldicarb and formothion® was reported most effective in checking spread of the disease by controlling whitefly vector. High yielding mungbean genotypes MH 96-1, MH 96-2 and MH 96-3 are resistant to yellow mosaic, lodging and prolonged water logging at maturity and are suitable for summer/spring seasons (Dahiya and Yadav, 1999). Of the 200 germplasm lines screened, 169 were resistant to yellow mosaic and 21 were resistant to yellow mosaic, cercospora leaf spot and powdery mildew (Raje and Rao, 2002). These mungbean lines with multiple resistance need to be evaluated for their suitability at different locations in the RWCS.

3.2 Biotic Constraints of Rainy Season Pulses and their Management

Pigeonpea is the most common pulse crop grown in rainy season in rotation with rice/wheat in post-rainy season. Pigeonpea production is limited by different biotic constraints which are similar across the country. Pigeonpea yield is also limited by poor nodulation in farmers' fields. Some of the major biotic constraints of pigeonpea and their management options are as follows:

3.2.1 Fungal diseases: Of more than 60 identified pathogens of pigeonpea (Nene *et al.,* 1996), only a few are widely distributed in the IGP and are of economic importance. Wilt *(Fusarium udum),* and phytophthora blight *(Phytophthora drechsleri)* are economically important in the IGP of India. Phytophthora blight attacks and kills young plants of 1-7 weeks old. Yield losses are usually higher in short duration pigeonpea than in medium- and long-duration varieties. Fusarium wilt occurs in all growth stages, but more prevalent during flowering and podding. Long- and medium-duration types suffer more from wilt than short-duration types. Host plant resistance has been identified both for phytophthora blight and fusarium wilt. Seed dressing with Benlate T® at 3 g kg^{-1} seed is recommended for wilt control. For management of phytophthora blight, seed dressing with Ridomil MZ® at 3 g kg^{-1} seed followed by two foliar sprays at 15 day intervals starting from 15 days after germination is effective (Reddy *et al.,* 1993).

3.2.2 Insect Pests: The key pests of pigeonpea are pod borers *(Helicoverpa armigera, Maruca testulalis)* and pod fly *(Melanagromyza obtusa),* blister beetle *(Mylobris* spp.) and pod sucking bugs *(Clavigralla gibbosa, C. tomentosicollis).* The pod borers are omnipresent and cause substantial yield losses every year and are often the primary yield reducers. The damage caused by *H. armigera* in some locations in the IGP varied from 3% to 44% (Chauhan, 1992). In general, pod fly causes severe damage in the IGP. Others are occasional pests in specific locations and/or years. *H. armigera* can be effectively managed by the insecticides fenvalerate, monocrotophos and dimethoate (Singh, 2001). Biological control of *H. armigera* can be attempted by using *Trichogramma* spp., nuclear polyhedrosis virus (NPV) and neem extract.

3.2.3 Viral disease: Sterility mosaic (pigeonpea sterility mosaic virus) transmitted by the eriophyid mite *Aceria cajani* is a major viral disease of pigeonpea. Leaves of infected plants show a light and dark green mosaic pattern and fail to produce flowers or pods. Three medium-duration genotypes, MD-9109, MD-9110 and MD-9103 (Jain *et al.,* 1995), and eight early-maturing genotypes (Singh *et al.,* 1996) were resistant to both sterility mosaic and wilt. Seed dressing with 25% Furadan 3 G® or 10% aldicarb @ 3 g kg^{-1} seed followed by insecticidal control of the mite vector in the early stages of plant growth minimizes the incidence of sterility mosaic disease (Nene, 1995). Pigeonpea is also infected by bean yellow mosaic virus, and is often reported as sterility mosaic. The basic difference between these two viral diseases is that sterility mosaic infected plants fail to produce flower and pods.

3.2.4 Nematodes: The cyst nematode *Heterodera cajani* though reported from the RWCS is a minor constraint to pigeonpea production, and needs further monitoring. This nematode also attacks cowpea, horsegram, mungbean, urdbean and pea, the pulses commonly grown in the IGP. Little information is available on the control of this nematode and a few resistant sources have been identified (Siddiqui *et al.,* 1998; Devi, 1998). There is a need to explore greater use of these resistant sources in breeding programmes.

3.2.5 Weeds: Initial growth stages of pigeonpea are critical for weed competition and short-statured cultivars are more susceptible to weed competition than the tall cultivars. These weeds can cause yield losses up to 90%. Some of the common weeds of pigeonpea in the RWCS of the IGP and their management have been discussed by Chauhan (1990). One hand weeding and inter-culture at 30 days after sowing control majority of the early season weed flora. Herbicides such as pendimethalin, alachlor, and fluchloralin suppress weeds throughout the season and result in the increased grain yield (Ramakrishna and Tripathi, 1993).

3.3 Biotic Constraints of Post-rainy Season Pulses

Chickpea, lentil, lathyrus and pea are the pulses suitable for post-rainy season in the RWCS. Chickpea is sensitive to excessive soil moisture, high humidity, and cloudy and foggy weather which limit crop establishment, flower production, and fruit set and also increase severity of common soil-borne (root rots and wilts) and foliar diseases. Lentil is relatively tolerant to excess moisture and is preferred in soils with excess residual moisture. Management of the potential biotic and abiotic stresses of winter pulses is essential for increasing their productivity and competitiveness with wheat. Undoubtedly, inclusion of chickpea in the RWCS system is essential for the long-term sustainability and productivity of rice and wheat. Economically important biotic constraints that limit chickpea establishment and economically viable production are discussed here:

3.3.1 Diseases: Ascochyta blight (*Ascochyta rabiei*) and botrytis grey mould (*Botrytis cinerea*) are the two widespread and destructive diseases of chickpea in western and eastern parts of the IGP in India, respectively, and can cause up to 100% yield losses. Among the diseases of chickpea that infect root and stem base, wilt (*Fusarium oxysporum* f. sp. *ciceri*) is a serious disease and occurs at different growth stages. *F. oxysporum* is both seed- and soil-borne, and disease development is favoured by soil alkalinity and moisture stress. Dry root rot (*Rhizoctonia bataticola*), wet root rot (*R. solani*) and collar rot (*Sclerotium rolfsii*) are of sporadic occurrence and little is known about their economic importance, distribution, etiology, and management (Pande *et al.*, 2000). Fusarium wilt of pea and lentil, and downy mildew (*Peronospora viciae*) of lathyrus are the other major biotic constraints of winter pulses.

Effective control measures of these diseases include host plant resistance, adoption of cultural practices including sanitation, and use of fungicides for seed treatment and foliar application. The recommended fungicides for foliar application are Bordeaux mixture, wettable sulphur, zineb, ferbam, maneb, captan and chlorothalonil. Seed dressing with vinclozolin (Ronilan®) or carbendazim + Thiram® and foliar spray of carbendazim effectively prevent the seed- and air-borne infection of *B. cinerea*.

For management of fusarium wilt, seed dressing with Benlate T® (benomyl 30% + thiram 30%) @ 1.5 g kg^{-1} seed or Bavistin® (carbendazim) @ 2.5 g kg^{-1} seed is recommended to eliminate seed borne inoculum (Nene *et al.*, 1991). Use of the available host plant resistance in combination with seed dressing and sanitation appears to be the most effective control strategy for management of wilt.

3.3.2 Insect-pests: Pod borer (*Helicoverpa armigera*) is the key pest and causes economic losses to chickpea and some times to lentil throughout the IGP. Another insect pest that often attacks winter pulses is bruchid (*Callosobruchus chinensis*). It damages the matured crop both in the field and storage. Damage by the aphids, *Aphid craccivora* in lathyrus, and *A. pisum, A. craccivora* and *Acyrthosiphon pisum* sometimes results in economic yield losses.

Chemical control is effective in managing insect pests, but alternative measures are needed because of the high costs of insecticides and development of insecticide-tolerant pest populations. For subsistence farmers, mixed cropping of pulses with other crops, such as wheat and mustard, can help reduce losses. Biological control of *H. armigera* is possible using foliar sprays of NPV (Cowgill and Bhagwat, 1996) and 5% neem seed kernal extract (NSKE).

3.3.3 Nematodes: Nematode does not produce the characteristic symptoms on aerial parts but reduces plant vigour, delays flowering and induces early senescence-symptoms that are often confounded with poor soil nutrition. The two species of root-knot nematodes (*Meloidogyne incognita* and *M. javanica*) have been found to infect chickpea in the IGP in India. These nematodes interfere with nitrogen fixation and increase the incidence of Fusarium wilt in chickpea (Sharma *et al.*, 1994). The three polyphagous nematodes, cyst (*Heterodera* spp.), root-knot (*Meloidogyne* spp.), and reniform (*Rotylenchulus* spp.), have been found associated with chickpea cultivation, but *H. goettingiana* is the most harmful (Sikora and Greco, 1990). Yield losses due to nematode infection in lentil and lathyrus have not been established. Chemical control is effective against *Meloidogyne* spp., but is uneconomical in marginal farming systems.

3.3.4 Weeds: Late planting of chickpea in rice-chickpea sequential system exposes chickpea to greater weed competition. *Chenopodium album* L. (lamb's quarters) is a major weed of chickpea crop in the IGP and yield losses can be up to 40%. Lentil is a poor competitor with weed flora due to its slow growth during winter. Inadequate weed control may cause yield losses of 20-30% in lentil. The growth period during which weed competition is most deleterious was observed to be 30-60 days after sowing. Hand weeding around 30-45 days after sowing coupled with pre-emergence application of herbicides like pendimethalin or fluchloralin 1.0 kg a.i. ha^{-1} should be practiced. However, lentil is sensitive to herbicide toxicity than other pulses and herbicides should rarely be used (Singh and Singh, 1990).

4. Integrated Pest Management in Chickpea – A Case Study

Since none of the available management options is effective in controlling the major biotic constraints, integration of different available options is desirable to produce an economically viable pulse crop. An integrated pest management (IPM) technology for management of chickpea diseases and insect pests was developed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and National Center for Integrated Pest Management (NCIPM) for effective management of ascochyta blight, botrytis gray mould and pod borer in the IGP of India and Nepal. The IPM technology consisted of a combinational use of moderate levels of host plant resistance (such as Avarodhi), wider row spacing, seed dressing with Bavistin + Thiram (1:1) @ 3 g kg^{-1} seed, and need/weather-based foliar application of fungicide (Bavistin) and insecticide (monocrotophos). Selected farmers were educated on disease/pest identification and adoption of IPM by conducting farmers' orientation camps thrice during a crop season. The recommended technology resulted in an increase of grain yield by 96%-124% and net income by 100%-400%. The technology was successfully used in rehabilitating chickpea in the rice fallow lands of the IGP of Nepal and India.

5. Future Research Priorities

i. Integrated crop management (ICM) technologies should focus on the entire cropping system with emphasis on year-round and multi-year management of pest populations.

ii. There is a need to evaluate the changing scenario of diseases and pests in a crop sequence as a whole, and detailed information on the ecology, epidemiology and life cycle pattern of key pests is essential to develop, validate and promote cost-effective IPM technologies. Emerging geographic information system (GIS) and global positioning system (GPS) technologies should be utilized to obtain and analyze information on the occurrence and severity of different biotic stresses.

iii. Development of disease prediction models needs to be initiated. The precision and accuracy of these models need to be tested and validated at multilocation for future suitability.

iv. Standardized screening techniques should be adopted and practiced at different screening centers on a regional basis.

v. The potential of local antagonists and bio-agents should be tapped and the most suitable ones should be involved as components of IPM programmes.

vi. Crop-based pesticide application schedules against all biotic stresses should be developed. Though it is highly challenging, this aspect is needed by subsistence farmers of the IGP, especially to raise a profitable pulse crop in rice based cropping system. This needs to involve a multidisciplinary approach where chemicals applied to the pulses 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.

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