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## CHAPTER - 10

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# Pest Management in Grain Legumes: Potential and Limitations

H.C. Sharma<sup>\*1</sup>, Tamo Manuele<sup>2</sup>, Mustapha El Bouhssini<sup>3</sup> and  
GV Ranga Rao<sup>1</sup>

<sup>1</sup>International Crops Research Institute for the Semi-Arid Tropics (ICRISAT),  
Patancheru, 502 324, Telengana, India.

<sup>2</sup>International Institute of Tropical Agriculture, Benin.

<sup>3</sup>International Center for Agricultural Research in the Dry Areas (ICARDA),  
Rabat, Morocco.

\*Corresponding author: Email – [H.sharma@cgiar.org](mailto:H.sharma@cgiar.org)

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### 10.1 Introduction

Grain legumes such as chickpea, pigeonpea, cowpea, field pea, lentil, and Phaseolus beans are the principal source of dietary protein among vegetarians, and are an integral part of daily diet in several forms worldwide. They are an important component of cropping systems to maintain soil fertility because of their ability to fix atmospheric nitrogen, extract water and nutrients from the deeper layers of the soil as compared to cereals, and add organic matter into the soil through leaf drop. However, grain legumes are mainly grown under rainfed conditions and the productivity levels are quite low mainly because of severe losses due to insect pests and diseases. Average grain yield of pulses (0.86 t/ha) is only about one-fourth the average yields of cereals (3.54 t/ha). Production and productivity of grain legumes is constrained by several biotic and abiotic factors, and suffer an average of 31.9 to 69.6% loss in crop productivity due to insects, diseases, drought, weeds, and soil fertility. Pod borers (*Helicoverpa* and *Maruca*), Fusarium wilts, viral diseases, Ascochyta blight and Botrytis gray mold (Chen *et al.*, 2011).

## 10.2 Insect Pest Problems in Grain Legumes

Grain legumes are damaged by a large number of insect species under field conditions and in storage (Sharma *et al.*, 2010) (Table 10.1). Pod borers, *Helicoverpa armigera* (Hubner) and *H. punctigera* (Wallengren) are the most devastating pests of chickpea and pigeonpea in Asia, Africa, and Australia. The spotted pod borer, *Maruca vitrata* (Geyer), is a major pest of cowpea and pigeonpea (Sharma *et al.*, 1999). The pod fly, *Melanagromyza obtusa* Malloch causes extensive damage to pigeonpea in India. The leaf miner, *Liriomyza cicerina* (Rondani) is an important pest of chickpea in West Asia and North Africa (Weigand *et al.*, 1994). The spiny pod borer, *Etiella zinckenella* Treit. is a major pest of pigeonpea, field pea, and lentil.

**Table 10.1** : Important insect pests of grain legumes.

Common name	Scientific name	Distribution	Chick-pea	Pigeon-pea	Cow-pea	Field pea	Lentil	Phaseolus beans	Faba bean
Pod borers	<i>Helicoverpa armigera</i> (Hub.) <i>Helicoverpa punctigera</i> Wallengren	As, Af, Aus	xxx	xxx	x	xx	x	xx	
Spotted pod borer	<i>Maruca vitrata</i> (Geyer)	As, Af, Aus, Am	-	xxx	xxx	x	-	xxx	
Spiny pod borer	<i>Etiella zinckenella</i> Treit.	As, Af, Am	-	x	-	xxx	xx	-	
Pod fly	<i>Melana gomyza obtusa</i> Malloch	As, Aus	-	xxx	-	-	-	-	
Leaf miner	<i>Liriomyza cicerina</i> (Rondani)	As, Naf	xx	-	-	-	-	-	
Stem fly	<i>Ophiomyia phaseoli</i> Tryon		-	-	-	xx	-	xx	
Pod sucking bugs	<i>Clavigralla gibbosa</i> Spin. <i>Clavigralla tomentosicollis</i> (Stal.)	As, Af, Aus, Eu, Am	-	xx	xx	x	x	x	x
Pea and bean weevil	<i>Sitona</i> spp.	As, Naf, Am	-	-	-	xx	xx	xx	xx

Blister beetles	<i>Mylabris</i> spp.	As, Af	-	xx	x	-	-	xx	-
Aphids	<i>Aphis craccivora</i> Koch. <i>Acyrtosiphon pisum</i> Harris <i>Aphis fabae</i> (Scop.)	Ww	x	x	xx	xx	x xx	xx	xx
Whitefly	<i>Bemisia tabaci</i> Genn.	Ww	-	-	-	-	-	xx	
Defoliators	<i>Spodoptera litura</i> F., <i>S. exigua</i> * Hub., <i>Amsacta</i> spp., <i>Spilosoma obliqua</i> Walk.	As, Am*	-	x	x	x	x	x	
Leaf hoppers	<i>Empoasca kerri</i> Pruthi	As	-	x	x	x	x	xx	
Stem flies	<i>Ophiomyia phaseoli</i> Tryon.	As, Af, Aus, Eu	-	-	-	xxx	-	xx	
Thrips	<i>Caliothrips indicus</i> Bag. <i>Megaleurothrips usitatus</i> (Bag.)	Ww	-	x	x	x	-	xx	
Pea weevil	<i>Bruchus pisorum</i> L.	Ww	-	-	-	xx	-	-	
Bruchids	<i>Caloso bruchus chinensis</i> L.	Ww	xxx	xxx	xxx	xxx	xxx	xxx	xx

xxx = Highly important; xx = Moderately important; x = Occasional pest; - minor importance ; As = Asia; Naf = North Africa; Af – Africa; Am = Americas; Aus = Australia; Eu = Europe; and Ww = Worldwide distribution.

The aphid, *Aphis craccivora* Koch is a major pest of cowpea, field pea, faba bean, and *Phaseolus* beans, while *Aphis fabae* (Scop.) is a major pest of faba bean and *Phaseolus* beans. The pea aphid, *Acyrtosiphon pisum* Harris is a major pest of field pea and lentil. The cotton whitefly, *Bemisia tabaci* Genn. is an important pest of *Phaseolus* spp., black gram, and green gram. The defoliators [*Spodoptera litura* (Fab.) in Asia and *S. exigua* Hubner in Asia and North America, are occasional pests. Leafhoppers, *Empoasca* spp. cause economic damage in blackgram, greengram, and *Phaseolus* beans. Pod sucking bugs (*Clavigralla tomentosicollis* Stal., *C. gibbosa* Spin., *Nezara viridula* L. and *Bagrada hilaris* Burm.) are occasional pests, but extensive damage has been recorded in cowpea by *C. tomentosicollis* in Africa, and *C. gibbosa* in pigeonpea

in India. The pea and bean weevil, *Sitona lineatus* L. is a pest of field pea in the U.S. Pacific Northwest, and faba bean in North Africa and West Asia, while *S. crinitus* Herbst. is a pest of pea, lentil and other legumes in Asia and North Africa. The thrips, *Megaleurothrips usitatus* (Bagnall) in Asia, and *M. sjostedti* Trybom in Africa, and *Caliothrips indicus* Bag. cause extensive flower damage in food legumes. The bruchids, *Callosobruchus chinensis* L. and *C. maculatus* Fab. cause extensive losses in storage. The pea weevil, *Bruchus pisorum* L. is a major pest of field pea in most production areas (Clement *et al.*, 1999; Lal, 1987).

Losses due to insect pests vary across crops and regions (Table 10.2), and cause an average of 30% loss in India, which is valued at \$815 million, which at times could be 100% (Dhaliwal and Arora, 1994). In Africa, insect pests can be responsible for extensive damage (up to 100%) in cowpea. (Singh and Jackai, 1985), while in the U.S., the avoidable losses have been estimated at 40 to 45% (Javaid *et al.*, 2005). *Helicoverpa armigera* – the single largest yield reducing factor in food legumes, causes an estimated loss of over \$ 2 billion annually, despite over \$ 1 billion worth of insecticides used to control this pest (Sharma, 2005). In general, the estimates of yield losses vary from 5 to 10% in the temperate regions and 50 to 100% in the tropics (van Emden *et al.*, 1988). The avoidable losses in food legumes at current production levels of 60.45 million tonnes would be nearly 18.14 million tons (at an average loss of 30%), valued at nearly US\$ 10 billion (Sharma *et al.*, 2010).

**Table 10.2 :** Yield losses (%) due to major insect pests in grain legumes in different regions.

Crop/constraint	SA	ESA	WCA	WANA	LA
<b>Chickpea</b>					
<b>Insect pests:</b>	<b>26.0</b>	<b>20.0</b>	-	<b>20.0</b>	-
<i>Helicoverpa</i> *	18.0	15.0		12.0	
Leaf miner/aphids/cut worm	8.0	5.0		8.0	
<b>Common bean</b>					
<b>Insect pests:</b>	<b>25.0</b>	<b>20.0</b>	<b>20.0</b>	-	<b>28.0</b>
Bean fly/Apion	15.0	15.0	10.0	16.0	
Leaf hoppers/aphids	10.0	5.0	10.0	-	12.0
<b>Cowpea</b>					
<b>Insect pests:</b>	<b>25.0</b>	<b>25.0</b>	<b>22.0</b>	-	<b>26.0</b>
Flower thrips	5.0	5.0	8.0		7.0
Pod bugs	5.0	5.0	5.0		6.0
<i>Maruca</i> *	10.0	10.0	4.0		9.0
Aphids	5.0	5.0	5.0		4.0
<b>Faba bean</b>					
<b>Insect pests: Aphids</b>	<b>15.0</b>	<b>15.0</b>	-	<b>5.0</b>	-

<b>Lentil</b>					
<b>Insect pests:</b>	<b>12.0</b>	<b>15.0</b>		<b>20.0</b>	
Sitona weevil	5.0	10.0		15.0	
Aphids	7.0	5.0	-	5.0	-
<b>Pigeonpea</b>					
<b>Insect pests:</b>	<b>40.0</b>	<b>42.0</b>	-	-	-
<i>Helicoverpa/Maruca</i> *	20.0	20.0			
Pod fly	13.0	15.0			
Pod sucking bugs	7.0	7.0			
<b>Soybean</b>					
<b>Insect pests:</b>	<b>20.0</b>	<b>15.0</b>	<b>25.0</b>	-	<b>20.0</b>
Pod sucking bugs	5.0	5.0	5.0		5.0
Bean fly*	8.0	5.0	8.0		10.0
Leaf defoliators	7.0	5.0	12.0		5.0

SA = South Asia, ESA = East and southern Africa, WCA = West and central Africa, WANA = West Asia and North Africa, and LA = Latin America.

\*Have the potential to cause complete loss during outbreaks, which are quite frequent in the tropics.

Bruchids cause an average of 10 – 15% loss across crops/regions in storage.

Based on published information on percentage yield loss in different regions in various crops. Yield loss due to insect pests in a region has been computed as a percentage of total yield loss.

## 10.2.1 Pest management in grain legumes

### 10.2.1.1 Cultural practices

Early and timely planting is useful to avoid heavy insect damage in grain legumes. Early planting of chickpea in winter suffers less damage by the leaf miner, *L. cicerina* as compared to the spring-sown crop. The second generation of the leaf miner coincides with young, spring-sown chickpea plants (in contrast to the winter-sown crop); and hence, the higher level of infestation in spring-sown chickpea (Weigand *et al.* 1994; El Bouhssini *et al.* 2008a). However, early planting of chickpea suffers more damage in southern India because of high populations of *H. armigera*. Planting times might become more uncertain under climate change, *e.g.* during the 2009 rainy season, delay in the onset of monsoons by 30 days resulted in delayed plantings of pigeonpea, which was damaged by *H. armigera*, while heavy rains during August resulted in greater insect damage in soybean. Use of short-duration cultivars has often been used to avoid pest damage, but short-duration pigeonpea suffers greater damage by *M. vitrata* in southern India. Increased infestations of *Sitona crinitus* have

been observed in late sown lentil in Syria. Early harvesting of peas reduces the losses due to *B. pisorum* in Australia (Baker, 1990 a,b).

Deep ploughing of fields before planting and after crop harvest destroys the over-wintering population of *H. armigera* and soil inhabiting pests (Rummel and Neece, 1989; Fitt and Cotter, 2005). Irrigation or flooding of fields at the time of pupation reduces survival of *H. armigera*, and leads to decreased population densities in the following generation or season (Murray and Zalucki, 1990). During intercultural operations, birds such as common Myna (*Acridotheres tristis* L.), egrets (*Egretta* spp.), and drongos (*Dicrurus adsimilis* L.) follow the ploughshare to feed on insects that are exposed to the soil surface. Heavy fertilizer application results in luxuriant plant growth resulting in greater damage due to insect pests. Early termination of flowering and fruiting reduces the population carryover from one season to another, and also reduces the number of generations of *H. armigera* (Fitt, 1989), and has been used as one of the components for the management of this pest on cotton.

Intercropping chickpea with mustard, linseed, or safflower (Das, 1998), and pigeonpea with cowpea (Hegde and Lingappa, 1996) and sorghum (Mohammed and Rao, 1999) result in reduced damage by *H. armigera*. Intercropping can also be used as a means of encouraging the activity of natural enemies (Bhatnagar *et al.*, 1983). Trap crops and diversionary hosts have also been widely used to reduce the damage by *H. armigera* (Fitt, 1989). Marigold, sesame, sunflower, and carrots can be used as trap crops for *H. armigera*. In Australia, chickpea and pigeonpea are used as trap crops in cotton to reduce damage by *H. armigera*. Use of plant kairomones to lure *B. pisorum* (Clement *et al.*, 2000) and *H. armigera* (Rembold and Tober, 1985; Rembold *et al.*, 1990) into traps or toxin baits has also been suggested. Hand picking of the larvae, nipping the plant terminals with eggs, and shaking the plants to dislodge the larvae (particularly in pigeonpea) has been suggested to reduce *H. armigera* damage (Ranga Rao *et al.*, 2005). Bird perches can also be used to increase the predation by insectivorous birds such as myna and drongo. Egg masses and larvae of *S. litura* and *Amsacta* spp. can also be picked up by hand and destroyed. Although many crop management practices help to reduce pest incidence and yield loss in grain legumes, most of these practices need to be used in conjunction with other components of pest management in an integrated pest management program. The cultural practices have the advantage that they are compatible with all the other components of pest management in different combinations.

#### 10.2.1.2 Host plant resistance

Sources of resistance to insect pests have been identified, but have not been used extensively in breeding programs (Bhagwat *et al.*, 1995; Malhotra

*et al.*, 2007; Sharma *et al.*, 2010). Because of the lack of uniform insect infestations across seasons and difficulty in rearing some insect species, it has not been possible to make a rapid progress in developing insect resistant cultivars. Cultivars with resistance to insect pests have been identified in pigeonpea, chickpea, cowpea, black gram, green gram, and field pea (Singh, 1978; Parasai, 1996; Kalaria *et al.*, 1998; Das and Kataria, 1999; Jakai, 1990). However, the levels of resistance to some of the pests such as *H. armigera* are low to moderate. However, even low levels of resistance could be quite effective when deployed in combination with synthetic pesticides (Sharma and Pampapathy, 2004; El Bouhssini *et al.*, 2008 b). Cultivars with multiple-resistance to insects and dis-eases will be in greater demand in future because of the concerns associated with chemical control and environmental pollution. There is a need to break the linkage between insect resistance and susceptibility to diseases, *e.g.*, in chickpea and pigeonpea, *H. armigera*-resistant cultivars are susceptible to wilt (Sharma *et al.*, 2005a; Deshmukh *et al.*, 1996a,b).

Screening of over 15,000 accessions of chickpea and pigeonpea has led to identification of a few accessions with moderate levels of resistance to *H. armigera* (Lateef, 1985; Lateef and Pimbert, 1990, Lateef and Sachan, 1990 ). In lentil, genotypic differences for susceptibility to aphid (*A. craccivora*), pod borer (*E. zinkenella*), and seed weevil have been observed (Erskine *et al.*, 1994). Eight accessions of wild lentils have been identified to be resistant to *S. crinitus* (d'10 % nodule damage compared to >56% damage in accessions belonging to the cultivated species) (El Bouhssini *et al.*, 2008b). This was the first report on resistance against *Sitona* weevil in lentil. The resistant accession ILWL 245 belongs to the species *L. culinaris* Medikus subsp. *orientalis*, which is the progenitor of the cultivated lentil, and has crossability with the cultivated lentils. Sources of resistance to chickpea leaf miner have been identified, and used successfully in the breeding programs (Singh and Weigand, 1996; El Bouhssini *et al.*, 2008b; Malhotra *et al.*, 2007).

Development of cultivars with stable resistance to insect pests would provide an effective approach in pest management. However, it is not possible to develop cultivars with high levels of resistance to several key pest of grain legumes, particularly the pod borers as the levels of resistance in the cultivated germplasm are low to moderate. Therefore, efforts have to be made to introgress resistance genes either through wide hybridization from the wild relatives of these crops or insert exotic genes through genetic engineering to make host plant resistance a viable component of integrated pest management. Host plant resistance is compatible with all the other components of pest management, although pest resistant varieties at times may be incompatible with the natural enemies *e.g.*, varieties of chickpea and pigeonpea with glandular trichomes and long hairs or have indirect adverse effects through suboptimal prey.

### 10.2.1.3 Biological control

There is voluminous information on parasitism and to a lesser extent on predation of insect pests on different food legumes. The egg parasitoids, *Trichogramma* spp. and *Telenomus* spp. destroy large numbers of eggs of *H. armigera* and *H. punctigera*, but their activity levels are too low in chickpea and pigeonpea because of trichome exudates. The ichneumonid, *Campoletis chlorideae* Uchida is the most important larval parasitoid of *H. armigera* on chickpea in India (Pawar *et al.*, 1986). Tachinids parasitize late-instar *H. armigera* larvae, but result in little reduction in larval density. *Carcelia illota* (Curran), and to a lesser extent, *Goniophthalmus halli* Mesnil, and *Palexorista laxa* (Curran) parasitize up to 22% of *H. armigera* larvae on pigeonpea (Bhatnagar *et al.*, 1983), and up to 54% larvae in chickpea. There are a few reliable estimates of pre-pupal and pupal mortality of *H. armigera*. Prospects for biological control in cowpea have been summarized by Tamò *et al.* (2003, 2012). The pod borer *M. vitrata*, whose center of origin is the Tonkin region in South East Asia, has a much greater diversity of parasitoids in that region than in Africa (Long and Hoa, 2012). Of particular interest for redistribution in Africa is the ovo-larval parasitoid, *Phanerotoma philippinensis* Ashmead (and a complex of *Therophilus* species dominated by *T. javanus* (Bhat & Gupta), which has already been reported to control *M. vitrata* in Indonesia by Kalshoven and van der Vecht (1950). The parasitoid *Trichogrammatoidea eldanae* Viggiani attacking eggs of *M. vitrata* has been studied for its potential for augmentative releases (Tamò *et al.*, 2003). Inoculative releases of the parasitoid, *Ceranisus femoratus* Gahan against *M. sjostedti* were carried out in Benin, Ghana and Nigeria, leading to its establishment. In Benin, thrips population studies after releases indicated up to 43% reduction of larval abundance on selected leguminous wild host plants (Tamò *et al.*, 2012). Surveys to assess the impact of this parasitoid on overall reduction of thrips, and subsequent increase in cowpea yield, are currently on-going. In Syria, *Opius monilicornis* Fischer has been found to be the most effective parasitoid of chickpea leafminer, parasitising up to 70% of the larvae (Mardini *et al.*, 1999). The most common predators of insect pests of food legumes are *Chrysopa* spp., *Chrysoperla* spp., *Nabis* spp., *Geocoris* spp., *Orius* spp., *Polistes* spp., and species belonging to Pentatomidae, Reduviidae, Coccinellidae, Carabidae, Formicidae and Araneida (Zalucki *et al.*, 1986; van den Berg *et al.*, 1988; Romeis and Shanower, 1996; Sharma, 2001). Although effective in large numbers, the high cost of large-scale production precludes their economic use in biological control (King *et al.*, 1986).

Biological control is compatible with cultural practices and host plant resistance to insects, except in a few cases. However, parasitoids and predators are not compatible with synthetic pesticides. One of the major problems of



biological control is the lag time between release of natural enemies and their effect on bringing the pest populations below economic threshold levels. In addition, there are major issues related to their mass production and delivery system. As a result, the effects of biological control are not as distinct as that of synthetic insecticides. Once the natural enemies are established, they exercise a continuous and cumulative effect on pest populations. Since host plant resistance can have considerable influence on the activity and effectiveness of natural enemies, efforts should be made to identify crop cultivars that are compatible with the natural enemies of crops pests in different agro-eco-systems. Therefore, biological control has to be carefully knitted into the integrated pest management program in respective grain legume crops.

#### 10.2.1.4 Biopesticides

There is considerable information on entomophagous pathogens against pod borers, *H. armigera* and *H. punctigera*, although these tactics have not provided a viable alternative to synthetic insecticides. Spraying *Bacillus thuringiensis* (*Bt*) (Berliner) in the evenings results in better control than spraying at other times of the day (Mahapatro and Gupta, 1999). The entomopathogenic fungus *Nomuraea rileyi* (@  $10^6$  spores per ml) resulted in 90 to 100% larval mortality, while *Beauveria bassiana* (@  $2.68 \times 10^7$  spores per ml) resulted in 6% damage by *H. armigera* on chickpea compared to 16.3% damage in untreated control plots (Saxena and Ahmad, 1997). In Australia, a commercially available NPV has been tested on cotton, with an additive that increases the level of control. Neem and custard apple extracts, and neem and karanj (*Pongamia*) oil based formulations have also been recommended for the management of *H. armigera* (Ranga Rao *et al.*, 2005). Vegetable oils, neem oil and karanj oil provide effective protection against bruchid damage in pulses (Reddy *et al.*, 1996). Karanj oil, and leaf and seed extracts act as oviposition deterrents (Kumar and Singh, 2002). Neem oil has also been found to reduce chickpea leaf miner infestations, and has a less negative effect on the larval parasitoids (El Bouhssini *et al.*, 2008a).

A novel *Maruca vitrata* multi-nucleopolyhedrovirus (*MaviMNPV*) was reported for the first time from Taiwan (Lee *et al.*, 2007) as a specific entomopathogenic baculovirus, and subsequently introduced to West Africa for assessing its potential against local populations of *M. vitrata*. Experiments were carried out in Benin, Burkina Faso, Niger and Nigeria, yielding promising results (Tamò *et al.*, 2012). More recently, field trials to assess the performance of mixtures of botanical pesticides (Neem and Jatropha oil) and *MaviMNPV* indicated a synergistic effect, reducing not only the target *M. vitrata*, but also

aphids, and thrips populations (Sokame *et al.*, 2013). There is a need for a greater understanding of the effect of climate change on the efficacy and persistence of biopesticides for pest management. Biopesticides have given very impressive results under laboratory and greenhouse conditions. However, their effectiveness is not comparable to synthetic pesticides under field conditions as their efficacy often depends on environmental conditions. Biopesticides are compatible with cultural practices, host plant resistance, and synthetic pesticides, except in a few cases. One of the major problems of microbial pesticides is their slow rate of action. They often have short residual effect, and there are problems associated with quality control and delivery system.

#### 10.2.1.5 Chemical control

Management of insect pests in grain legumes relies heavily on insecticides, often to the exclusion of other methods. Control measures directed at adults, eggs, and neonate larvae are most effective in minimizing *H. armigera* damage. Spray decisions based on egg counts could destroy both invading adults and eggs, and leave a residue to kill future eggs and neonate larvae. Young larvae are difficult to find as they burrow into the flowers where they become less accessible to contact insecticides. As a result, it has not been possible to use economic thresholds for pest management. Spray initiation at 50% flowering has been found to be most effective (Singh and Gupta, 1997). As a result of heavy selection pressure, *H. armigera* has developed resistance to the major classes of insecticides, and it shown resistance to organo-chlorine, organophosphates, carbamates and synthetic pyrethroids in different parts of the world (Daly *et al.*, 1988; Gunning *et al.*, 1996; Armes *et al.*, 1996; Kranthi *et al.*, 2002; Ahmad *et al.*, 1997a,b; Burikam *et al.*, 1998). Insecticide resistance management strategies have been developed in several countries to prevent the development of resistance or to contain it. All strategies rely on a strict temporal restriction in the use of pyrethroids and their alteration with other insecticide groups to minimize selection for resistance (Sawicki and Denholm, 1987). Considerable information has also been generated on chemical control of *B. pisorum* in pea (Micheal *et al.*, 1990), *S. lineatus* and *A. fabae* in faba bean (Ward and Morse, 1995), and aphid vectors in lupins (Bwye *et al.*, 1997).

Chemical control is one of the most effective weapons for pest management. However, large-scale and repeated application of highly toxic insecticides leads to development of resistance, pesticide residues in the produce, and adverse effects on the natural enemies. Under heavy pest infestations, they are the only solution to provide an immediate relief from depredations of the pests. However, they must be used rationally, and timing of pesticide applications is most important

to derive the maximum benefit. They are compatible with other components of pest management, except the natural enemies.

#### 10.2.1.6 Transgenic resistance

Progress in developing transgenic plants of food legumes has been reviewed by Popelka *et al.* (2004). Efforts have been made to develop chickpea plants with *Bt* d-endotoxin genes for resistance to *H. armigera* (Kar *et al.*, 1997; Romeis *et al.*, 2004; Acharjee *et al.*, 2010). Transgenic pigeonpea plants with *cryIAb* and soybean trypsin inhibitor (SBTI) genes have been tested against *H. armigera* (Gopaldaswamy *et al.*, 2008). Transgenic chickpea and cowpea expressing cowpea trypsin inhibitor and  $\alpha$ -amylase inhibitor (Shade *et al.*, 1994; Schroeder *et al.*, 1995; Sarmah *et al.*, 2004; Luthi *et al.*, 2013) with resistance to bruchids has also been developed. Efforts are also underway to develop and test transgenic cowpea for resistance to spotted pod borer (Popelka *et al.*, 2004; Adesoye *et al.*, 2008), and test the transgenic plants under field conditions in West Africa (Higgins, 2007). Commercialization of transgenic plants with resistance to pod borers will revolutionize the production of chickpea, pigeonpea and cowpea, and provide a new tool for integrated pest management in grain legumes (Sharma, 2009).

Transgenic plants will provide one of the most effective weapons to tackle pest problems in grain legumes, particularly the pod borers, which are difficult to control even with insecticides. Since the level of host plant resistance in the cultivate germplasm are quite low, it is important to develop and deploy transgenic pulses with resistance to key pests. Since transgenic chickpea and cowpea are already available, efforts should be made to make this technology available to farmers in SAT Asia and Africa. Transgenic crops can be effectively deployed in combination with other components of pest management in an integrated pest management program, and we possibly can realize the similar gains in productivity as has been the case with transgenic cotton.

### 10.3 IPM-Omics

In recent years, genomic tools were applied to the study of pest populations for supporting development and deployment of IPM strategies (Agunbiade *et al.*, 2012a). This new systems approach in IPM, called IPM-omics, will be used to better guide *e.g.* releases of biological control agents suitable to specific populations of the target pest, and application of bio-pesticides. One practical application of IPM-omics is the recent study on the spatial genetic differentiation of *M. vitrata* in West Africa (Agunbiade *et al.*, 2012b). This study revealed genetically different populations based on limited gene-flow, possibly because of the South-North host switch during the rainy season as suggested by

Bottenberg *et al.*, 1997. On the deployment side, IPM-omics will provide scalable solutions, including the use of novel approaches in educational contents such as cellphone video animations (Bello-Bravo *et al.*, 2012). IPM-omics should also help in gene deployment strategies and target resistant varieties based on geographical distribution of virulent populations/biotypes.

#### 10.4 Conclusions

There is a need to gain a thorough understanding of the factors that lead to heavy losses in food legumes. Resistance genes from closely related wild relatives of grain legumes should also be utilized wherever possible. Genetically engineered plants with different insecticidal genes can also play a vital role in IPM. Cultural practices that reduce the intensity of insect pests are another important element of pest control. Diversified cropping systems that enhance the activity and abundance of natural enemies should be popularized among the farmers. Insecticides provide quick and effective pest control in food legumes. Neem seed kernel extract, *Bt*, and HaNPV have been recommended in many cases, but limitations on timely availability, quality control, and economic feasibility limit their use in pest management on a regular basis. There is a need for a greater understanding of the effect of climate change on the efficacy of natural enemies, host plant resistance to insects, biopesticides and synthetic insecticides, their persistence in the environment to develop effective strategies for pest management in grain legumes in future.

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