ISN NO: 2347 – 3657
Volume 5, Issue 4, 2017

International Journal of Information Technology & Computer Engineering
ISN NO: 2347 – 3657
Volume 5, Issue 4, 2017

Management of Chickpea podborer, Helicoverpa armigera (Hubner) using HPR: A Review

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ABSTRACT

Legume pod borer, *Helicoverpa armigera* Hubner is the most important pest on wide variety of food, fibre, oilseed, fodder and horticultural crops. Enormous amount of loss has been reported in different crops worldwide. Apart from being highly polyphagous, *H. armigera* is widely adapted to feeding on various plant parts. However, damage to the reproductive parts particularly to flowers and developing seeds results in direct loss. Hence, the level of *H. armigera* infestation during the flowering and fruiting phase is widely used as the basis for assessment of loss, and to quantify the genotypic resistance to this insect. Varieties of chickpea showing varying degrees of resistance to *H. armigera* have been developed in India and some of these varieties have been used successfully by the farmers. Screening of more than 14800 germplasm accessions under natural infestation has resulted in the identification of 21 donors showing antixenosis, antibiosis and tolerance mechanism of resistance, and these sources can be used in breeding programmes. A high per cent of crude fibre and non reducing sugars and low per cent of starch have been found to be related with low incidence. Recent reports on significant variation in *H. armigera* gut proteinase inhibitors among chickpea genotypes escape insect attack or suffer less damage as compared to other genotypes because of phenological asynchrony. Deployment of *H. armigera*-resistant cultivars should be aimed at conservation of the natural enemies and minimizing the number of pesticide applications. Host plant resistance is compatible with other methods of insect control, exercises a constant and cumulative effect on insect populations over time and space, as no adverse effects on the environment, reduces the need to use pesticides, and involves no extra cost to the farmers.

Key words: Chickpea, Host plant, Management, Pod borer, Resistance, *Helicoverpa armigera*

Introduction

Insect pest problems in chickpea: Nearly 60 insect species are known to feed on chickpea, of which cutworms (black cutworm - *Agrotis ipsilon* Hufnagel), leaf feeding caterpillars (leaf caterpillar- *Spodoptera exigua* Hübner and hairy caterpillar- *Spilarctia obliqua* Walker), leaf miners (*Liriomyza cicerina* Rondani), aphids (*Aphis craccivora* Koch), pod borers (cotton bollworm - *H. armigera* and native budworm -*H. punctigera* Wallengren) and the bruchids (*Callosobruchus* spp.) are the major pests worldwide. The pod borer, *H. armigera* and aphids, *A. craccivora* (as a vector of chickpea stunt virus) are the major pests in the Indian subcontinent, while the leaf miner, *L. cicerina* is an important pest in the Mediterranean region. Bruchids, *Callosobruchus* spp. cause extensive losses in storage all over the world. Low to moderate levels of resistance have been identified in the germplasm, and a few improved varieties with resistance to pod borer and high grain yield have been developed.

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Germplasm accessions of the wild relatives of chickpea (*Cicer bijugum* , *C. judaicum* and *C. reticulatum*) have been used to increase the levels and diversify the bases of resistance to *H. armigera.* Efforts are also underway to utilize molecular techniques to increase the levels of resistance to pod borer. Synthetic insecticides, agronomic practices, nuclear polyhedrosis virus (NPV), entomopathogenic fungi, bacteria and natural plant products have been evaluated as components of pest management in chickpea'

Its significance as a pest is based on the peculiarities of its biology such as high mobility, polyphagy, high reproductive rate and diapause. Its preference for flowering / fruiting parts of high value crops such as cotton, vegetables, corn and pulsesconfers a high socio-economic cost to its depredations under subsistence farming in the tropics and subtropics. Agronomic factors such as high yielding varieties, increased use of irrigation and fertilizers and large scale planting of alternate crop hosts have contributed to increased severity of this pest (Reed and Pawar, 1982; Fitt, 1989). However, regional and local differences in host preference can give rise to differences in pest status on particular crops.

Distribution and extent of losses: *H. armigera* is widely distributed in Asia, Africa, Oceania and the Europe. Its outbreak/ damage has also been reported from Hungary (Szenasi and Mesozros., 1997), Sicily (Pinto *et al.,* 1997), Romania (Roman *et al.,* 1996), Slovakia (Gomboc 1999), Spain(Mejias *et al.,* 1998), Sweden (Palmqvist 1998), Switzerland (Hachler *et al.,* 1998) and the united kingdom (Howard 1998). Extensive damage by *Helicoverpa* has been reported on cotton, sunflower, chickpea, pigeonpea and vegetables. The damage to crops such as maize, sorghum and pulses can be quite severe in socio economic terms. Monetary losses result from the directreduction in yield and the cost of monitoring and control, particularly the cost of insecticides. In Australia, the cost of monitoring and control has been estimated to be A$25 million. In India, total losses in both pulses and cotton exceed $530 million per annum, and the insecticides applied for *Helicoverpa* control cost nearly $127.5 million on cotton and pulses. With this increased number of crop failures, greater insecticide use and development of resistance to insecticides (Dhingra *et al.,* 1988; Mc Caffery *et al.,* 1989), these figures may need to be revised upwards. The extent of losses in chickpea and pigeonpea has been estimated at over $645 million per annum in the semi arid tropics (ICRISAT 1992). In the tropics, total losses due to *Helicoverpa* on cotton, legumes, vegetables and cereals may exceed $ 2 billion and the cost of insecticides used *H. armigera* may be over $500 million.

Host range: Information on host plants of *Helicoverpa* and *Heliothis* species complex has been summarized by various workers (Fitt 1991; King 1994, Bai *et al.,* 1997; Mathews 1999). *H. armigera* is a major pest of cotton, pigeon pea, chickpea, sunflower, tomato, sorghum, pearl millet, groundnut, okra, fieldbeans, soybean, Lucerne, *Phaseolus* spp, lentil, tobacco, potato, maize, linseed, fruits, forest trees and a range of vegetable crops. A wide range of wild plant species support larval development of which important species in India include *Hibiscus* sp., *Acanthospermum* spp., *Datura* spp., *Gompherena celosioides;* and in Africa comprise of *Amaranthus* spp. *Cleome amaranthus* (grain amaranthus), Gomphrena, Acaypha (copperleaf), Hyposcyamus has been reported in *Lagacea mollis* (Aherkar *et al.*, 1999), *Canbis sativa* (Dippenaar *et al.,* 1996), sowthistle (*Sonchus oleracea*) (Gu and Walter, 1999), *Asparagus officinalis* (Kay and Hardy, 1999), Paulownia (Kumar and Ahmad, 1998), cape roosberry (*Physalis peruviana*) (Mehta *et al.,* 1996), striga spp. (Onu *et al.,* 1997), *Hyptis sauvelolons* and *Jatropa gossypiifloia* (Wilson, 1997) and *Lathyrus sativus* (Pophaly and Gupta, 1996).

Nature of damage and economic thresholds: In chickpea, the eggs are laid on leaves and young pods and the larvae initially feed on the young leaves and the larger larvae bore into the pods and consume the developing seeds. The larva also damages the fruiting bodies and leaves in several other crops.

Assessment of economic threshold: A first step in developing an IPM approach is to establish the economic threshold of thetarget pest. This may be defined as the number of insects per unit area or per plant above which a significant economic lossin crop yield will occur, with reference to timing in the crop season and stage of the insect life cycle. Odak and Thakur (1975) reported that more than 4 larvae m^{-2} in chickpea at flowering and early podding stages caused economic injury by decreasing grain yield by 2.4 g per

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10 plants. Sharma (1985) reported 1 larva m^{-1} row length as the economic threshold and injury level of *H. armigera* in chickpea.

Wightman *et al.* (1995) reported 9.7g per chickpea plant yield with no insect damage (multiplied by 130,000 plants ha^{-1} to obtain a seed yield of 1.26 t ha^{-1}). As per statistical calculations based on experimental data, the authors reportedthat the presence of one larva (second or third instar) per plant reduced chickpea grain yield to 8.9 g per plant or 1.16 t ha^{-1} (value Rs 7540 (when the market price in 1990 was Rs. 6500 t^{-1}), a cost equivalent of Rs 650 which is close to the cost of one *lannate* application. From these estimates, the authors developed a first working hypothesis: "if a farmer finds more than one larva per plant (the action threshold) during the podfilling stage and applies an insecticide, he would recover more than the cost from saved pods.

The economic threshold for bruchids in stored seeds is <1, as even the presence of one bruchid can result in complete infestation of all seeds in the container. Therefore, protective measures need to ensure complete exclusion of all bruchids in this situation. Thus, IPM with respect to bruchids differs from that applied to insect pests of the standing crop in that complete elimination of the pest is necessary.

Integrated pestmanagement

There are a range of potential options for managing *Helicoverpa* pod borer in chickpea. These are discussed below individually, prior to assessing how various options may best be combined into effective IPM packages.

Cultural practices of the crop and its environment

A number of cultural practices such as time of sowing, spacing, fertilizer application, deep ploughing, interculture and flooding have been reported to reduce the survival and damageby *Helicoverpa* spp. (Lal *et al.,*1985;Murray and Zalucki, 1990; Shanower *et al.,* 1998). Intercropping or strip-cropping with marigold, sunflower, linseed, mustard and coriander can minimize the extent of damage to the main crop. Strip-cropping also increases the efficiency of chemical control. Hand-pickingof large sized larvae can also be practiced to reduce *Helicoverpa*damage. However, the adoption of cultural practices depends on the crop husbandry practices in a particular agro-ecosystem. Rotations do not help manage these polyphagous and very mobile insects, although it has been noted that some crops (*e.g.* Lucerne) are more attractive to the moths, and susceptible crops should not be planted too close to the main crop. Habitat diversification to enhance pest control has been attempted in Australia. An area-wide population management strategy has been implemented in regions of Queensland and New South Wales to contain the size of the local *H. armigera* population, and chickpea trap crops have played an important role in this strategy (Ferguson and Miles, 2002; Murray *et al.,* 2005). Chickpea trap crops are planted after the commercial crops to attract *H. armigera* as they emerge from winter diapause. The emergence from diapause typically occurs when commercial chickpea has senesced and before summer crops (sorghum, cotton and mung bean) are attractive to moths (October to November). However, moths are diverted to weeds for oviposition (including wheat, *Triticum aestivum* L.) when they grow above the chickpea crop canopy (Sequeira *et al.,* 2001). Trap crops are managed in the same way as commercial crops, but destroyed by cultivation before larvae begin to pupate. The trap crops reduce the size of the local *H. armigera* population before it can infest summer crops and start to increase in size. As a result, the overall *H. armigera* pressure on summer crops is reduced, resulting in greater opportunity for the implementation of softer control options, reduced insecticide use and greater natural enemy activity.

Biological control: The influence of both biotic and abiotic factors on the seasonal abundance of *H. armigera* in relation to their natural enemies is poorly understood. The egg parasitoids*, Trichogramma* spp., are almost absent from chickpea ecosystem in India because of dense trichomes and their acidic exudates (Jalali *et al.,* 1988; Murray and Rynne, 1994; Romeis *et al.,* 1999). The ichneumonid, *Campoletis chlorideae* (Uchida), is probably the most important larval parasitoid on *H. armigera* in chickpea in India. *Carcelia illota* (Curran), *Goniophthalmus halli* Mesnil and *Palexorista laxa* (Curran) have also been reported to parasitize up to 54 per cent larvae on chickpea (Yadava *et al.,* 1991; King, 1994), although Bhatnagar *et al.* (1983)

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recorded only 3 per cent parasitism on chickpea. Predators such as *Chrysoperla* spp., *Nabis* spp., *Geocoris* spp., *Orius* spp. and *Polistes* spp. are the most common in India. Provision of bird perches or planting of tall crops that serve as resting sites for insectivorous birds such as myna anddrongo helps reduce the numbers of caterpillars.

The use of microbial pesticides including *H. armigera* nuclear polyhedrosis virus (HaNPV), entomopathogenic fungi, *Bt,* nematodes and natural plant products such as neem, custard apple and pongamia kernel extracts have shown some potentialto control *H. armigera* (Sharma, 2001). HaNPV has been reported to be a viable option to ontrol *H. armigera* in chickpea (Cherry *et al.,* 2000). Jaggery (0.5%), sucrose (0.5%), egg white (3%) and chickpea flour (1%) are effective in increasing the activity of HaNPV (Sonalkar *et al.,* 1998). In Australia, the efficacy of HaNPV in chickpea has been increased by the addition of milk powder, and more recently the additive Aminofeed (Anon., 2005). Spraying *Bt* formulations in the evening results in better control than spraying at other times of the day (Mahapatro and Gupta,1999). Entomopathogenic fungus*, Nomuraea rileyi* (Farlow) Samson (10^6 spores per ml), results in 90 -100 per cent larval mortality, while *Beauveriabassiana* (Balsamo) Vuillemin (2.68 x 10^7 spores per ml) resulted in 6 per cent damage in chickpea compared to 16.3 per cent damage in the untreated control plots. In Australia, specific control of *H. armigera* and *H. punctigera* on chickpea is being achieved using the commercially available HaNPV, with an additive that increases the level of control. Bt formulations are also used as a spray to control *Helicoverpa.* Different isolates of HaNPV have been characterized for their variation in the genetic makeup (Kambrekar *et al.,* 2005). Among the isolates screened, the HaNPV isolates collected from Coimbatore and Gulbarga have highest genetic variation. These isolates have been found very effective for the management of chickpea podborer both under laboratory and field conditions (Kambrekar *et al.,* 2009). The virulent isolates were also effective on the podborer on other host crops like tomato (Kambrekar, 2012a), pigeonpea (Kambrekar, 2009) and sunflower (Kambrekar, 2012b)under field condition in India.

Chemical control: Management of *Helicoverpa* in India and Australia in chickpea and other high - value crops relies heavily on insecticides. There is substantial literature on the comparative efficacy of different insecticides against *Helicoverpa.* Endosulfan, cypermethrin, fenvalerate, thiodicarb,profenophos, spinosad and indoxacarb have been found to be effective for *H. armigera* control on chickpea in Australia (Murray *et al.,* 2005). Spray initiation at 50 per cent flowering has been found to be most effective (Sharma, 2001). The appearance of insecticide resistance in *H. armigera*, but not in *H. punctigera* is considered to be related to the greater mobilityof the latter species (Maelzer and Zalucki, 2000). However, *H. armigera* populations in the northern region are largely resistant to pyrethroids, carbamates and organophosphates. Introduction of new chemistry, notably indoxacarb and spinosad, is being managed to minimize the development of resistance in *H. armigera* through a strategy that takes into account its use in all crops throughout the year (Murray *et al.,* 2005). Consequently, the use of indoxacarb in chickpea is limited to one application with a cut-off date for application to ensure one generation of *H. armigera* is not exposed to the product in any crop before the commencement of its use in summer crops (cotton and mung bean).

Biradar *et al.* (1998) reported that the treatment that received five sprays during both vegetative and reproductive phases *i.e.* at 15, 30, 45, 60 and 75 days after sowing recorded least podborer incidence (18.7%) by producing higher seed yield of 11.5 q/ha with 125.5 per cent increase over untreated check and thus avoiding the loss upto 55.7 per cent. The next best treatment was with three sprays given at reproductive phase (*i.e.* at 45, 60 and 75 days after sowing) with 21.5 per cent podborer incidence, 9.5 q/ha of seed yield and 86.3 per cent increase over the untreated check by avoiding the loss upto 46.3 per cent. Balikai *et al.* (2001) evaluated that quinalphos 25 EC (0.05%) when sprayed at 15-day intervals commencing at 50 per cent flowering found significantly superior over the untreated control with pod damage and yield of 19.6 per cent and 7.4 q ha^{-1} against the chickpea pod borer, *H. armigera* in chickpea cv. A-1.

Host plant resistance to legume pod borer, *Helicoverpa armigera*

The development of crop cultivars with resistance to insects has a great potential for integrated pest management, particularly under subsistence farming conditions in the developing countries (Sharma *et al.,* 1999). Many crop species possess some genetic variation, which can be exploited to produce varieties that are less susceptible to *H. armigera.* Breeding for resistance to insects has not been as rapidly accepted and developed, as is the case with disease resistant cultivars. This may be partly due to the relative ease with which insect control is achieved with use of insecticides. Another reason for slow progress in developing insect resistant cultivars has been the difficulties involved in ensuring adequate insect pressure for resistance screening. Insect rearing programmes are expensive, the technology development requires several years, and may not produce the behavioral or metabolic equivalent of an insect population in nature. However, with the development of insect resistance to insecticides, adverse effects of insecticides on natural enemies and public awareness of environmental pollution, there has been a renewed interest in the development of insect resistant cultivars. Establishment of International Agricultural Research Centres and collection and evaluation of crop germplasm for insect resistance have given a renewed impetus to the identification and use of HPR as an integral component of pest management worldwide. Host plant resistance along with biological and cultural control is a central component of any pest management strategy under subsistence farming conditions.

Resistance screening techniques

Development and standardization of resistance-screening techniques is the key for effective resistance-breeding program. Knowledge concerning the periods of maximum insect abundance and 'hotspots' is the first step to initiate work on resistance screening. Delayed plantings of crop and use of infester rows of susceptible cultivar of the same species or of different species can be used to increase the insect infestation under natural condition (Sharma *et al.,* 1992; Smith *et al.,* 1994;Kalode and Sharma 1995). Either the test material should be sown about 1-2 weeks later than the normal sowing time or thesowing time should be adjusted in such a manner that the mostsusceptible stage of the crop is exposed to maximum insect infestation. Generally, no insecticide should be applied in the insect screening nursery, but plant protection measures should be adopted, if necessary to control the other insects that interfere with screening for resistance to *H.armigera.* Screening for resistance to *H.armigera* under natural conditions is a long term process because of variation in insect population in space and time. As a result, it is difficult to identify reliable and stable and sources of resistance under natural infestation. This necessitates the need to develop techniques to screen for resistance to *H.armigera* under uniform insect pressure at the most susceptible stage of the crop.

Measurement of resistance

A part from being highly polyphagus, *H.armigera* is widely adapted to feeding on various plant parts such as leaves, tender shoots, flower buds, flowers and seeds. Damage to vegetative parts results in indirect loss, and is generally compensated as a result of re growth in the affected plants. However, damage to the reproductive parts particularly to flowers and developing seeds results in direct loss. Hence, the level of *Helicoverpa* infestation during the flowering and fruiting phase is widely used as the basis for assessment of loss, and to quantify the genotypic resistance to this insect. Numbers of fruiting bodiesand the extent of damage is the final outcome of complex interaction involving *Helicoverpa* and its host plants.

Percentage damage to the bolls, fruits, or pods is the most common parameter for determining the variation in genotypic susceptibility to *H. armigera*. However, this criterion often leadsto unreliable results due to variations in insect population, damage to the foliage (which is not reflected in the damage to the fruiting bodies), damage to flowers, dropping of reproductive pods as a result of early infestation and the genotypic ability to produce a second flush incase the first flush is lost due to *H. armigera* damage (at times the second flush may escape insect damage). To overcome these problems, the test material can be evaluated on a 1 to 9 damage rating scale, taking into consideration the extent of damage or recovery from damage during the vegetative stage (*ex:* in chickpea), numbers of fruiting bodies retained in plant, distribution of fruiting bodies throughout the plant canopy and the proportion of bolls, pods or fruits damaged by *H. armigera* (1=plants with little damage during the vegetative stage or showing good recovery from the damage, large number of fruiting bodies retained on the plants with uniform distribution throughout the canopy, and less than 10 per cent damage to the fruiting bodies and 9= plants with poor recovery from the damage, fewer fruiting bodies retained on the plant, uneven distribution of the fruiting bodies and >80 per cent of fruitingbodies damaged by the larvae).

A method of grading the test materials by using a 1 to 9 rating scale based on pod damage was suggested by Lateef and Reed (1995). Singh and Yadav (1999) proposed three parameters (relative pest pressure index, relative intensity of damage index and relative productivity index) to screen chickpea genotypes against *H. armigera.* The relative resistance is computed by using the data on mean number of healthy and damaged pods per plant instead of percent pod damage. This method takes into account the number of pods per plant, which is an important character in selecting chickpea genotypes for high productivity (Singh and Singh 1998). Considering total number of pods per plant and number of damaged pods, it is the number of healthy pods per plant that contributes to the productivity of genotypes, ex: genotypes such as P256 and bahar of chickpea and pigeon pea, respectively have been foundto be superior to others, by way of profuse podding and more number healthy pods per plant. But these genotypes, if considered on percentage pod damage basis would be inferior to those having less percentage pod damage, but too poor in podding. Genotypes with less number of pods also have a poor ability to compensate the loss due to insect damage. Since it is almost impossible to get a high level of resistance against
H. *armigera* in any legume crops, search for genotypes with recovery resistance through their ability to have more pods and recover from initial damage would be more rewarding. Productivity of such genotypes may be further improved by mitigating the loss as a result of pod borer damage through theuse of other control tactics.

Host plant resistance (HPR) in integrated pest management High levels of plant resistance are available against a few insect species only. However, very high levels of resistance are not the prerequisites for use of HPR in integrated pest management.Varieties with low to moderate levels of resistance or those which can avoid the pest damage can be deployed for pest management in combination with other components of pest management. Deployment of *Helicoverpa* resistant cultivars should be aimed at conservation of the natural enemies and minimizing the number of pesticide applications. Use of *Helicoverpa*-resistant cultivars will also improve the efficiency of other pest management practices, including the synthetic insecticides (Adkinson and Dyck, 1980; Panda and Khush, 1995). Host plant resistance can be used as a principal component of pest control, as an adjunct to cultural, biologicaland chemical control and as a check against the release of susceptible cultivars.

HPR as a principal method of insect control

HPR as a method of insect control has an important role to play in the context of IPM of *H.armigera* in different crops and cropping systems. Plant resistance as a method of pest control offers many advantages over other methods of pest management. However, there may be problems if we rely exclusively on host plant resistance for *Helicoverpa* control, eg: high levels of resistance may be associated with low yield potential or undesirable quality traits in some crops, and resistance may not be expressed in every environment whenever a variety is grown. Therefore, *Helicoverpa* resistant varieties have now been identified and deployed for the control of this insect worldwide (Painter, 1951; Maxwell and Jennings, 1980; Smith, 1989; Panda and Khush, 1995).

The mortality of larvae is nearly 15 per cent on ICCC 37 (susceptible variety), 35 per cent on ICCV 2 (moderately susceptible) and 40 per cent on ICC506EB (resistant). If we assume that there are 10 female moths per ha in the beginningof the season, then there will be 1919,14,063 moths in an area planted to a susceptible cultivar, ICCC37 as compared to 858,20,313 moths in the area planted to moderately resistant cultivar ICCV 2 and 675,00,000 moths in area planted to resistant cultivar, ICC 506EB. Based on rates of insect multiplication, there would be 2.84 and 1.27 times as many insects in areas

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planted to ICCC37 and ICCV2, respectively. Thus, even moderatelevels of plant resistance have a great influence on *Helicoverpa* populations, which is cumulative overtime. These models canalso explain the situations where *H.armigera* has become a serious problem with the introduction of newly developed high- yielding, but susceptible varieties.

Advantages of HPR in *Helicoverpa* management

Utilization of plant resistance as a control strategy has enormous practical relevance and additional emotional appeal (Davies, 1981). It is in this context that host plant resistance assumes a central role in our efforts to increase the production and productivity of crops. Plant resistance to insects is the backbone of any pest management system. Because:

- It is specific to the target pest or a group of pest, and generally has no adverse effects on the non target organisms;
- Effects of plant resistance on insect population density are cumulative over successive generations of the target pest because of reduced survival, delayed development and reduced fecundity
- Most of the insect-resistant varieties express moderate high levels of resistance to the *Helicoverpa* throughout the crop growing season-in contrast the pesticides have to be applied repeatedly to achieve satisfactory control ofpest populations;
- HPR is compatible with other methods of pest control, and also improves the efficiency of other methods of pest management;
- There are no harmful effects of HPR on non target organisms, humans and environment;
- It does not involve any costs to the farmer; and
- The farmers do not have to have any knowledge of application techniques.

Very high levels of resistance may neither be attainable nor required. A variety capable of reducing the pest population by50 per cent in each generation can be useful in reducing the pest damage below economic threshold within a few generations (Painter 1951). The cumulative and persistence effects of plant resistance are quite in contrast to the explosive effects of insecticides, where the insect population multiplies at a much faster rate after the insecticide application because of absence of natural enemies.

Limitations of HPR

Plant resistance is not a sole strategy for solving all the pest problems. Certain limitations and problems will always be set any insect control program and HPR is no exception. Development of plant verities resistant to insect to insect peststakes a long time. Some mechanisms of pant resistance may involve the diversion of some resources by the plant to extra structures or production of defense chemicals at the expense of other physiological processes including those contributing to yield (Mooney *et al.,* 1983). Although the concentration of defense chemicals responsible for resistance is low in plant tissues, the total amount per hectare may be high. The production cost of 34 kg of gossypol (which imparts resistance to *Heliothis / Helicoverpa* in cotton) in terms of glucose equivalent in cotton will be 70.7 kg of glucose ha (Mitra and Bhatia, 1982). Cost of resistance as well as the extent to which they can be modified by involving high costs cannot be modified. More information is needed on mechanisms of resistance, the genetic regulation of resistant traits, biochemicalpathways, and their physiological effect in different crops hosts of *Helicoverpa.* One might expect a negative correlation betweenthe potential yield of a cultivar and its level of resistance to the target pest. This is illustrated by the failure to evolve insect resistant varieties of soya bean, pigeon pea, chickpea, *etc.* The fundamental objective of breeding for *Helicoverpa* resistance in crop plants is to reduce the amount of pesticides needed to achieve satisfactory control of this pest, and an acceptable level of sustainable resistance, compatible with yield and qualityof the produce.

The chemical basis of plant resistance to insects at times can modify the toxicity of insecticides to insecticides to insects. e.g 2-tridecanone in wild tomato reduces the toxicity of carbaryl to *Heliothis* (Brattesten, 1988). Some plant defense chemicalsalso affect the food quality. Gossypol and related compounds that confer resistance to insect in cotton are toxic to non- ruminant vertebrates (Lambou *et al.,* 1966). Rutin, chlorogenic acid, tomatine and phenols have toxic effect on humans. Some of these compounds .may also be carcinogenic and mutagenic.Insect of chemicals in the soil may alter the nature of the rhizosphere. Therefore, all such interaction should be kept in mind while developing and deploying the insect resistant cultivar for pest management.

Future research needs

Screening of germplasm collection and their wild relatives to identify lines with stable and diverse mechanisms of resistance.

- An understanding of the mechanism that determine *Helicoverpa* movement / adaptation to different crop host and genotypes and an understanding of the mechanism and inheritance of resistance.
- Gene pyramiding to increase the levels and diversify the bases of resistance to *Helicoverpa* in different crops.
- Combining resistance to *Helicoverpa* with resistance to other important insect and diseases in a region.
- Identification of molecular markers and quantitative trait loci (QTL) in different crops, to gain an understanding of the number of genes and nature of gene action for resistance to *Helicoverpa.*
- Development of *Helicoverpa* resistant varieties through genetic transformation using genes with diverse mode of action.

Conclusion

Considerable progress has been made in developing techniques to screen for resistance to *H. armigera* under natural and artificial infestation. However, there is a need to establish insect rearing facilities at different research centers, and undertake multi locational testing of the identified sources and breeding materials to identify stable and diverse sources of resistance for use in crop improvement programs. Resistance to pod borer should be given as much emphasis as yield, to identify new varieties for cultivation by the farmers. Host plant resistance is compatible with other methods of insect control, exercises a constant and cumulative effect on insect populations over time and space, as no adverse effects on the environment, reduces the need to use pesticides, and involves no extra cost to the farmers. Host plant resistance to *Helicoverpa* can play an important role in pest management in different agro- ecosystems, and lead to sustainable crop production and environment conservation.

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