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Integrated Management of Insect Pests of Chickpea *Cicer arietinum* (L. Walp) in South Asian Countries: Present Status and Future Strategies – A Review

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Abstract.- This review and analysis has been focused on the major pulse chickpea *Cicer arietinum* L. Walp in order to provide discussion confined to only the major insect pests of this legume crop, those causing significant and frequent yield loss. Our intention is to bring forward and report the major efforts made in combating insect pest infesting chickpea in South and South-East Asia .The poor masses in South Asian part of the world can not afford animal protein, therefore, the only commodities which could supplement protein requirement in their diet are the only pulses which contains sufficient amount of proteins and falls within purchasing capability of poor people. In author's view, an ever-growing population needs at least a proportionate increase in consumption of vegetable protein, and other nutritional requirements provided by food legumes including chickpea so as to balance a cereal-based diet. Scientists working in various institutions in this region undertook extensive studies and research to develop Integrated Pest Management (IPM) and Integrated Crop Management (ICM) in order to reduce chickpea grain yield losses. This review highlights the IPM efforts on the use of Chemicals, eco-friendly approaches (use of natural pathogens, plants materials, agronomic practices and insect parasitoids etc.). Thus insect pest management options are viewed from a systems perspective to the farming enterprise. Examples of successful IPM approaches operating in farmers' fields have been sought, for their possible extrapolation to other situations. Admittedly, there are few examples of direct farmer involvement in evolution of IPM packages for food legume crops including chickpea. However, we do recognize the need to involve farmers themselves in the evolution and evaluation of IPM strategies and we hope that this assembly of information relating to IPM of chickpea will facilitate increased farmer-participatory IPM activities.

Keywords: Integrated pest management, integrated crop management, South Asia, natural pathogens, agronomic practices, *Cicer arietinum*

INTRODUCTION

Chickpea, *Cicer arietinum* L. Walp is an important grain legume crop of South Asia, with the region accounting for about 87% of the world area of the crop. The crop is normally grown rainfed in the postrainy season (Oct-Mar) of the subtropics of South Asia with minimal inputs of fertilizer or pesticides. Chickpea is normally grown with and is being increasingly relegated to marginal lands, due to its displacement from irrigated and better water-endowed lands by higher and more stable yielding crops such as wheat (Kelley *et al.*, 2000). The major constraints leading to low and unstable yields of chickpea are drought stress, foliar diseases (*e.g.* ascochyta blight caused by *Ascochyta rabiei* (Pass.) Labr.

Chickpea can be host to a wide range of

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insect pests (Reed *et al.,* 1987; Ranga Rao and Shanower, 1999) but acid exudation from above-ground plant parts probably acts as a partial deterrent to many of these (Reed *et al.,* 1987). By far the most economically important insect pest of chickpea is the pod borer, *Helicoverpa armigera* Huebn. Substantial yield losses due to this pest have been reported across South Asia. For example, in various chickpea growing areas of India, yield losses in particular fields or plots in the range of 10-85% have been documented (Reed, 1983; Ahmed, 1984; Lal *et al.*, 1985; Das, 1987; Qadeer and Singh, 1989; Yadava and Lal, 1997). In Bangladesh and Nepal, chickpea pod damage due to *Helicoverpa* pod borer in unprotected farmers' fields has been in the range of 5-15% in recent seasons (Musa, 2000; Pande and Narayana Rao, 2000). In Northern Pakistan, up to 90% pod damage due to *H. armigera* has been recorded in unprotected chickpea fields (Ahmed *et al.,* 1986; Anonymous, 1987a; Anonymous, 1998a). Crop rotation, introduction of new varieties or crops, land reclamation, use of irrigation and fertilizer have helped to increase populations of polyphagous insect pests such as *H. armigera* (Rivnay, 1962; Talhouk, 1969; Elmosa, 1981; Hariri, 1981; White, 1987). Irrigation schemes create new habitats that promote migratory process in some insect species, the populations of which usually build up and migrate to areas that were otherwise beyond their reach (Bhatnagar 1987). Large scale cultivation of cotton in India and Pakistan and pigeonpea in south and central India, these crops being preferred hosts of *H. armigera*, has further aggravated the pest situation in general due to population build-up and shifts of the pest from one host to another.

Large scale cultivation of cotton and pigeonpea (preferred hosts of *H. armigera*) in south and central India has further aggravated the pest situation in general due to population shifts of the pest from one host to another host. In Pakistan, during chickpea season 2001-2002, an out break of *H. armigera* was reported by farmers growing chickpea near cotton areas (Anonymous, 2002).

Incidence of semilooper, *Autographa nigrisigna* (Wlk.) and acridid *Chrotogonus trachypterus* (Blanchard) and an arctiid *Spilosoma obliqua* (Walker) as pests of minor importance on chickpea in India and Pakistan was reported by (Lal *et al.,* 1981; Mahmood and Shah, 1984; Anonymous, 1984a; Mahmood *et al.,* 1987; Deka *et al.*, 1987b). In southwest Asia, the leafminer, *Liriomyza cicerina* (Rondani) on chickpea has also been reported (Hariri, 1979; Pimbert, 1990).

The next most important insect pest of stored chickpea is the grain weevil, or bruchid (*Callosobruchus maculatus* F.), which attacks stored grain. Losses can be total in infected seed containers. Ahmed *et al.* (1989a, 1993, 1991) and Afzal *et al.* (1987) reported genetic parameters of resistance in chickppea, stating that number of bruchid holes is a better indicator of seed resistance. Although other insect pests may be of local and intermittent occurrence, [*e.g. Aphis craccivora* (Koch), *Agrotis ipsilon* (Hufnagel), *Autographa nigrisigna* (Walker)] (Reed *et al.,* 1987; Ranga Rao and Shanover, 1999) extent of economic loss caused by them is relatively minor and sporadic, and implementation of control measures is probably not warranted. In view of the dangers of indiscriminant use of chemical insecticides, as outlined in the introduction, it is necessary that environment friendly insect management techniques be adopted for staple food crops such as chickpea, as a matter of urgency.

This research review collates and assesses recent advances on potential components for an IPM approach for chickpea in South Asia, concentrating on pod borer and bruchids as the major insect pests. We have particularly attempted to identify IPM approaches, involving appropriate combination of IPM components, which have immediate relevance in the chickpea fields of resource-poor farmers of the region, due to the imminent threat of inappropriate use of chemical pesticides on this crop.

MAJOR ADVANCES AND DISCOVERIES IN MANAGEMENT OF CHICKPEA INSECT PESTS

Assessment of economic threshold

A first step in developing an IPM approach is to establish the economic threshold of the target pest. This may be defined as the number of insects per unit area or per plant above which a significant economic loss in 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 10 plants. Sharma (1985) reported 1 larva m^{-1} row length as the economic threshold and injury level of *H. armigera* in chickpea.

In an attempt to establish threshold levels for chickpea, Ahmed *et al.* (1985) observed that chickpea yield in the control plot with no insect damage (approximately 1,66,000 plants ha^{-1}) was 1.38 t ha^{-1}. At the early podding stage of chickpea, presence of two larvae (third instar) per plant reduced chickpea grain yield by 0.189 t ha^{-1}. At 1985 grain price of Rs. 3,250 t^{-1}, the yield loss was Rs. 614 ha^{-1}. The cost of one application of insecticide (Nogos) was Rs 485, thus the cost:benefit ratio was 1:1.25, indicating profitability for the farmer if control measures were taken.

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 reported that 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 pod filling stage and applies an insecticide he should 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.

Pest prediction and monitoring

Insect pest management strategies need to be based on sound knowledge and understanding of insect populations and their fluctuations over years with respect to adult emergence, larval population, number of generations during crop seasons and the influence of environmental factors. With these objectives, extensive studies on populations of *H. armigera* using pheromone traps were undertaken from the 1983-84 to the 1997-98 chickpea season at National Agricultural Research Center (NARC), Islamabad, Pakistan (Ahmed, 1984; Ahmed *et al.*, 1985; Afzal *et al.*, 1985; Ahmed *et al.*, 1987; Malik, 1987; Anonymous, 1984a, 1986, 1987a, 1988a, 1989a, 1990, 1993, 1995, 1996; Jan *et al.*, 1988; Chaudhary *et al.*, 1995; Ahmed, 1999. Ahmed *et al.*, 2000a,b; Ahmed *et al.*, 2012).

Dent, (1985) reported population studies of *Helicoverpa armigera* through pheromone trap catches and larval counts (from 1981-1984) 3 consecutive chickpea seasons at ICRISAT, India. In India, at ICRISAT entomologists conducted extensive studies on the development of pheromone trap to monitor *H. armigera* populations in collaboration with the entomologists of various National Agricultural Research Institution in the region (Nesbitt *et al.*, 1980; Pawar and Reed, 1984; Pawar *et al.*, 1984; Lal *et al.*, 1985; Pawar *et al.*, 1988; Qadeer and Singh, 1989; Yadava and Lal, 1988). At ICRISAT, India, Das *et al.* (1997) subjected pheromone trap population and weather data (from 1981-1988) to statistical analysis to develop regression models and revealed that a significant relationship existed between the amount of pre-monsoon (1-22 standard week) rainfall (X_1) and post monsoon (43-52 weeks) pest population (Y_1), which can be described by the equation $Y_1 = 786+17.7354X_1$, R^2=0.9041 for forecasting *H. armigera* population.

Patil and Kulkarni (1997) reported maximum trap catch population of *Helicoverpa armigera* during October to December from 1987 to 1995 with peak populations in 50th standard week at Raichur, India. The authors also observed highly significant negative correlation between trap catch populations and maximum and minimum temperature and rainfall.

Integrated pest management

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

Host plant resistance

Host plant resistance (HPR) presents an ideal means of combating *Helicoverpa* pod borer. There is evidence of reasonable levels of HPR in chickpea but its effective deployment on a large scale in farmers' fields is yet to be accomplished. Since the 1970s, ICRISAT has facilitated attempts to identify chickpea genotypes with usable levels of HPR in South Asia, mainly through development of standardized field screening techniques and distribution of International Chickpea *Helicoverpa* Resistance Nurseries (ICHRN) (Nene and Kanwar 1988). Collaboration between ICRISAT and the All India Coordinated Pulse Improvement Project (AICPIP), after years of evaluation under diverse agro-ecological conditions in India, has identified the genotypes ICC 506, ICC 738, ICCX 730008, ICC 6663, ICC 10817, PDE 5, PDE 2, ICC 10667, ICC 10619, ICC 10613, ICC 86111, ICC 93215, ICC 93216, ICCL 79048, ICCV 7, L 2793(C235), var.6591, 7-6, LBG 3, PDG 92-2, Pant CE 1, Pant CE 2, JG 897, JG322, Chaffa, ICCV 10 and JG 934 as showing either resistance, promising tolerance, or at least reduced susceptibility to *Helicoverpa* pod borer (Anonymous, 1981, 1982b, 1983b, 1984b, 1985b, 1988b, 1989b; Gowda *et al.*, 1983; Lateef, 1985; Ujagir and Khare, 1987, 1988; Sachan, 1990; Lateef and Pimbert, 1990; Pimbert, 1990; Lateef and Sachan, 1990; Singh *et al.*, 1990; Ahmed *et al.*, 1990; Anonymous, 1997; Bhatnagar and Rao, 1997; Gumber *et al.*, 2001; Bhatt and Patel, 2001).

In Myanmar, at the Agricultural Research Institute, Yazin, ICHRNs were evaluated during 1987-88 and 1988-89 seasons at different locations, and the genotypes ICCX 730008-8-1-IP-BP and ICC 506 showed relatively less pod-borer damage (Ahmed *et al.*, 1990). In Nepal, Thakur (1998) screened 52 chickpea genotypes for three successive years under mild to heavy natural infestation of *H. armigera* and reported that chickpea genotypes ICCX 860043-BP, ICCX 900239-BP, ICCV 95991, ICCV 88102 and GLK 88341 gave highest grain yields. In Pakistan, ICHRN (desi short, medium and long duration) was evaluated at Agriculture Research Station, Karak, North-West Frontier Province and genotypes ICC 4935-E2795, ICCX 730020-11-1, and ICC 10243 were found promising (Ahmed *et al.*, 1990).

However, although promising levels of HPR to *Helicoverpa* have been found in chickpea, the trait has not been adequately exploited in breeding programs in South Asia to the point of developing varieties carrying HPR along with an appropriate combination of other desirable traits. A possible reason for this is the association of HPR to *Helicoverpa* with several undesirable traits such as small seed size and susceptibility to *Fusarium* wilt (Reed *et al.*, 1987).

Recent advances in development of transgenic plants, whereby genes conferring specific resistance to insect pests can be inserted into otherwise acceptable varieties, offers further scope for developing chickpea varieties with substantially enhanced HPR against *Helicoverpa*. In recent years there has been a flurry of research activity in incorporation of genes encoding internal synthesis of compounds with insecticidal properties in a wide range of crop species (Sharma *et al.*, 2000). Prominent among such genes are the delta endotoxin encoding genes derived from the soil bacterium *Bacillus thuringiensis* (*Bt*). These have been expressed in various crop plants with promising results, mainly in terms of a need for less chemical pesticide use. Transgenic cotton, maize, tobacco, rice, potato, etc. carrying *Bt* genes are being commercially cultivated in the USA,

Having options to use a range of insecticidal compounds is necessary due to the problem of build-up of insect resistance to particular compounds; the same problem as occurs with regular application of particular chemical insecticides. For example, the efficacy of *Bt* in leaf and squares of cotton in northern China was high during the second generation of the predating insect, *H. armigera*, but declined in the third and fourth generations (Yang *et al.*, 1996). The surviving third and fourth generation larvae, after feeding on flowers of *Bt* cotton, fed on the bolls until pupation, which could cause selection in the field populations of *H. armigera*. The increase in resistance was 7.1-fold after 17 generations of selection in the laboratory, with an average mortality of 67.2% for each generation. The resistance grade of *Bt* cotton declined from high resistance against a non-selected population to medium levels of resistance against the selected population, indicating a potential problem of development of resistance in insects to *Bt* cotton.

As an additional requirement to prevent

build-up of insect resistance, it is necessary to grow refugia of susceptible crop varieties adjacent to the transgenic crop, further complicating matters, especially for resource poor farmers. Further complications in the use of transgenic crops with insect resistance occur if secondary pests are not controlled in the absence of sprays for the major pests, the need to control secondary pests through chemical sprays will kill the natural enemies and thus offset one of the advantages of transgenics, sprayed fields are adjacent to transgenic fields and if insect migration reduces the effectiveness of transgenics (Sharma *et al.,* 2000). In South Asian countries, the debate on regulation and official release of transgenic plants is still on-going, with the prospect of official sanction for their commercial cultivation seemingly well into the future.

There appear to be considerable genotypic differences in the extent to which chickpea seed can be infested and damaged by bruchids. Types with large, yellow seed with a smooth seed coat were more severely damaged than small brown seeds with a hard seed coat. (Rai and Singh, 1989). In India, Pant G-112, K 901 and G 130 showed relatively less bruchid damage (Pandya and Pandey, 1980; Rai and Singh, 1989).

Therefore, there appears to be sufficient genetic variation in response to bruchid attack to warrant breeding for bruchid resistance. However, there is little likelihood of this occurring because bruchid resistance is not likely to rate very highly among the list of objectives in any breeding program and because there are effective alternative control measures available.

Cultural control

Detailed knowledge of the life cycle of an insect pest, and how it is affected by the environment, gives scope for adjustment of cultural practices of a crop so as to lessen the effect of the pest. In northern India, larval peaks of *H. armigera* occur during 10-16 standard weeks and hence early sowing (in October) or use of short duration chickpea cultivars should permit crop maturity before peak pest load (Lal and Sachan,1987; Yadava and Lal, 1990). Plant spacing also affects incidence of *H. armigera* damage. In general, denser plant population favors increased pod damage, per plant and per unit area (Reed *et al.,* 1987; Naresh *et al.,* 1989; Begum *et al.,* 1992). However, higher plant densities may not necessarily result in yield loss due to compensation in total pod number per unit area at higher density (Sithanantham and Reed, 1979; Pimbert, 1990). In any case, farmers have limited ability to manipulate plant population due to such factors as unreliable seed viability, seedling diseases and adverse soil physical conditions at crop establishment.

Intercropping of chickpea with certain crops has been shown to reduce damage by *Helicoverpa* pod borer. This may be a result of the companion crop harboring higher numbers of natural enemies or non-preference for egg laying by *H. armigera* in a field containing the intercrop. By concealing a plant among other species, which do not offer the same kind of stimuli, it should be possible to reduce the efficiency of the pest's host seeking behavior and interfere with its population development and survival (Pimbert, 1990).

Mehta *et al.* (1989) studied the effect of intercropping mustard, wheat, barley, lentil and linseed with chickpea and concluded that intercropping generally delayed the appearance of major pests of chickpea and reduced their incidence, particularly the linseed intercrop, while the incidence of pests with the lentil intercrop was highest. Chickpea intercropped with mustard in North-east Plains Zone, and chickpea intercropped with safflower or linseed in the Peninsular Zone of India, have been found highly attractive in comparison with sole crops (Chandra, 1987). Wheat, coriander, safflower and sunflower intercropped with chickpea considerably decreased pod borer damage (5-6%) as compared to 16% pod damage in a sole crop (Anonymous, 1997). Lal, (1990) concluded that intercropping of chickpea with mustard, linseed, wheat, barley resulted in low pod borer damage. Das *et al.* (1997) reported chickpea intercropping with wheat and mustard with a row ratio of 2:1 harbored 25% and 14% less larval population of *H. armigera* at 50% flowering and 50% podding stage, respectively, in comparison with the sole crop. They further showed that intercropping of chickpea with coriander with a row ratio of 2:2 harbored significantly lower larval population and was economically more profitable as compared to a sole crop; a row ratio of 8:2 had intermediate values.

Farmers' decisions on cultural practices to follow for chickpea are normally guided by factors other than eventual minimization of *Helicoverpa* damage. Intercropping seems the most practical recommendation for minimizing infestation as it also provides other advantages, such as minimization of foliar disease incidence, crop diversification, insurance against failure of one crop in a mixture or intercrop and a higher land equivalent ratio. Avoidance of a dense canopy in chickpea is beneficial for both foliar disease control and build-up of *Helicoverpa* larvae.

A cultural, non-chemical, method for prevention of bruchid damage during seed storage is mixing of seeds with sand in a sealed container (AM Musa, Rajshahi, Bangladesh, personal communication). After sun drying of seed for at least 5 hours, and ensuring absence of bruchids from the dried seed, seed is placed on a layer of sand at the bottom of the container. Alternate layers of seed and sand are placed and the container shaken to fill the air spaces between seeds. When the container is full, a complete layer of sand is placed on the top before the container is sealed. Even if bruchids can later enter the container they are physically hindered and hence repelled from reaching the seed. Seed stored in this way would be suitable for human consumption, after sieving away the sand, whereas this would not be so if it were stored using chemicals.

BIOLOGICAL CONTROL

Under an ecologically balanced situation, a species considered as a "pest" normally has one or more natural enemies preying on it. As mentioned earlier, pest outbreaks can be induced by application of chemicals more injurious to the natural enemies than the pest. Thus a major consideration in any IPM endeavor is how to enhance activity of natural enemies so as to restrict pest damage below or near economic threshhold levels, and certainly to avoid any action that would jeopardize the activity of natural enemies. Effective enhancement of natural enemies requires a thorough understanding of their biology and interaction with the target pest organism. For management of *Helicoverpa* in chickpea, and other crops that it attacks, potential natural enemies whose activity can be enhanced range from viruses to higher animal.

Viruses

Most natural populations of *Helicoverpa armigera*, and also of other lepidopteran species, have at least some degree of infection by species-specific nuclear polyhedrosis viruses (NPVs). If the degree of NPV infection can be enhanced then the *Helicoverpa* larval population can be decimated, without deleterious effects on any other organisms. In India, scientists have done extensive studies on evaluation of NPVs and developed technologies for successful application of indigenous NPV preparations to combat *H. armigera* infesting chickpea. Thakur (1998) applied an NPV preparation @ 1.5 ml l^{-1} and obtained 586 kg ha^{-1} grain yield, not significantly different from that with a chemical insecticide (Deltamethrin 2.8 EC applied @ 1.0 ml l^{-1}) (685 kg ha^{-1}) but significantly more than an unsprayed control (330.0 kg ha^{-1}). Sharma *et al.* (1997) reported high *H. armigera* larval mortality in bio-agent and chemical insecticide treatments. NPV@ 300 LE ha^{-1} caused 78.7% reduction in larval population, resulting in 10.0% pod damage and high grain yield (1.86 t ha^{-1}), whereas the chemical insecticide Endosulfan 35 EC @ 1200 ml ha^{-1} caused a 70.9% reduction in larval population, resulting in 11.2% pod damage and 1.86 t ha^{-1} grain yield. Many other workers in India have applied of NPV and reported significant reductions in *H. armigera* larval population and accordingly less pod damage in chickpea, as compared to chemical insecticides and control treatments (Jayaraj *et al.*, 1987; Pawar *et al.*, 1987; Narayana, 1980; Anonymous, 1983b, 1982a; Chandra, 1987; Rabindra and Jayaraj, 1988; Balasubramaniam *et al.*, 1989).

Bacteria

In the developed world, use of *Bacillus thuringiensis* (*Bt*) based microbial insecticides have become an integral part of IPM approaches, particularly because these preparations provide an environmentally suitable alternative to the generally hazardous broad-spectrum chemical insecticides. These bacterial insecticides, like NPV, target specific insects but do not affect beneficial organisms (e.g. parasitoids and predators). With the development of more effective *Bt* strains and improved commercial formulations, these insect pathogens are gaining increasing international support for use against agricultural insect pests. The efficacy of *Bt*, which can be enhanced by incorporation of suitable quantities of acids, salts, oils, adjuvants, thuringiensin (-exotoxin of *Bt*) and chemical insecticides, against lepidoteran pests including *H. armigera* has been demonstrated (Salama, 1984; Salama *et al*., 1986; Morris, 1988; Karel and Shoonhoven, 1986; Ahmed *et al.,* 1989b, 1990; Khalique and Ahmed, 2001b).

In Pakistan, extensive studies were conducted on evaluation of bio-efficacy of some indigenous and exotic strains of *B. thuringiensis* and commercial preparations (Anonymous, 1978; 1982a; 1989a; 1989b; 1990; Khalique *et al.,* 1982b, 1989; Ahmed *et al.,* 1990, 1994, 1998; Khalique and Ahmed, 2001a,b). This resulted in the development of a package of *Bt* application technology for management of *H. armigera* infesting chickpea. Application of DiPel 2X and DiPel ES @ 1.6 kg ha^{-1} and 1.5 l ha^{-1}, respectively, at early stages of crop infestation (1^{st}, 2^{nd} and 3^{rd} instar larval infestation) with at least 2 applications at 7 days interval resulted in significant increases in yield of chickpea as compared to controls (Ahmed *et al.*, 1994; Ahmed, 1999; Ahmed and Khalique, 2012).

At Pantnagar, Durgapur, Sehore, Rahuri, Bangalore, and Dulbarga, in India, preparations of *Bt* based insecticides, Biobit, Delfin and DiPel together with NPV, showed minimum pod damage (4.2 to 16.7%) as compared to the control (12.4 to 38.6%) (Anonymous, 1997). It appears that *Bt* based insecticides can be made effective IPM tools in the South Asian countries if an awareness is developed among farmers about the critical time and method for their safe application.

Parasitoids

Where chemical insecticides are not used, various parasitoids can be found parasitizing eggs and larvae of *H. armigera* infesting chickpea. These natural enemies can often maintain *H. armigera* populations at sub-threshhold levels. In Bangladesh, Nepal, Pakistan and India, it is estimated that less than 10% of farmers currently use chemical insecticides on chickpea, which provides scope for evaluation, utilization and enhancement of effective *H. armigera* parasitoids. Pawar *et al.* (1986) reported 31.4% parasitism of *H. armigera* larvae by *Campoletis chlorideae* (Uchida), an ichneumonid, in chickpea at ICRISAT, India. In Bihar state of India, 14.3 to 58.0% parasitism of *H. armigera* larvae by *C. chlorideae* was observed in chickpea fields (Prasad and Chand 1986). In Maharashtra state of India, 14.7% parasitism by *C. chlorideae* on *H. armigera* larvae was observed in a chickpea field (Bilapati *et al.,* 1988).

In Pakistan, extensive studies on parasitism of *H. armigera* larvae on chickpea by *C. chlorideae* have been undertaken (Ahmed, 1984; Ahmed *et al.,* 1986; 1987; 1989b). A mean level of 46.5% parasitism was observed at the early stage of the crop (from mid-Oct to Nov). In a laboratory evaluation, 31.0 to 50.0% parasitism on *H. armigera* larvae was observed from the 1^{st} to the 4^{th} generation of this parasitoid. Studies on host age susceptibility, with the aim of mass culturing *C. chlorideae,* indicated that 1-5 day old host larvae (1^{st} to 2^{nd} instar) were more susceptible to parasitism (48-59%) than older larvae (Anonymous, 1987a; 1988a; Ahmed *et al.,* 1990). Laboratory studies indicated that *C. chlorideae* do not lose vigor or effectiveness as parasites after successive generations maintained in the laboratory (Ahmed *et al.,* 1987; Anonymous, 1985a).

Fortunately, *C. chlorideae* is the only parasitoid capable of parasitizing hosts in the presence of acid exudates, as produced by chickpea foliage, and could prove to be effective in suppressing the host population of *H. armigera* on chickpea crops if economical methods for mass culturing and field application of this parasitoid are evolved.

Scientists in Pakistan (Ahmed *et al.,* 1986) carried out extensive studies in order to evaluate effectiveness of *C. chlorideae* in parasitizing its host *H. armigera* through successive generation (4 generations) of the parasite, they observed 45.95% parasitism by the 1^{st} generation adults of parasitoid (711 larvae parasitised out of 1724 1^{st} instar larvae exposed to 1^{st} generation parasitism), 30.90% parasitism by the 2^{nd} generation adults of parasitoid (737 larvae parasitised out of 2376 1^{st} instar larvae exposed to 2^{nd} generation parasitism), 52.30% parasitism by the 3^{rd} generation adults of parasitoid

(880 larvae parasitised out of 1660 1st instar larvae exposed to 3rd generation parasitism) and 52.53% parasitism by the 4th generation adults of parasitoid (67 larvae parasitised out of 120 1st instar larvae exposed to 1st generation parasitism). They further reported that male and female emergence ratios of parasitoid from 1st to 4th successive generations were 1.3:1, 2.1:1, 2.9:1 and 20:0 (in this case no female emerged) respectively

In the meantime, however, it is recommended that every endeavor should be made to encourage natural populations of parasitoids. The most obvious way of achieving this is avoidance, to the extent possible, of application of chemical insecticides in and around chickpea crops. Mixed cropping or intercropping with crops such as mustard or linseed should enhance natural *C. chlorideae* populations and thus minimize pod borer damage (Pimbert, 1990).

Another potentially effective parasitoid of *H. armigera* on chickpea is *Trichogramma* spp., small wasps which attack *H. armigera* eggs (Van der Maesen, 1972; Reed *et al.,* 1987). However, acid exudation from chickpea foliage discourages activity of this parasitoid (Rembold and Winter, 1982; Rembold *et al.*, 1990). At Nagpur, India, Kulat *et al.* (1999) conducted experiment and reported that after four releases of 100,000 *Trichogramma chilonis* ha^{-1} none of the 1763 *H. armigera* eggs collected from chickpea during the growing seasons of 1994-96 were found parasitized. The authors attributed the failure in parasitism to either the dry environment or discouragement of the parasite by acidic secretion of the chickpea plants.

Predators

Various insectivorous birds have long been observed to be effective predators of *H. armigera* larvae. Activity of these birds can be enhanced, and more birds attracted, by placing bird perches in chickpea fields. However, it should be checked that the birds so attracted do not include those which damage chickpea pods themselves. Branches of bamboo make effective bird perches as secondary branches emerge at almost right angles from the main stem, providing convenient perches on bamboo stems inserted into the soil. Use of bird perches is an extremely low cost but potentially effective means of *H. armigera* control, worthy of inclusion in most IPM packages. Managed foraging by domestic poultry, at least near homesteads, can also assist in control of pod borer. In low income rural areas in South Asia where chickpea is grown, children can effectively collect *H. armigera* larvae from chickpea and then destroy them; modest payment can be given for this task (C. Johansen, personal observation in Bangladesh).

Botanical pesticides

Dating from traditional practices, various plant extracts have shown insecticidal properties and can be used effectively on field crops. The most well-known and commonly used is azadirachtin isolated from the seed, wood, bark, leaves and fruits of the neem tree (*Azadirachta indica*). Azadirachtin has both anti-feedent and growth retarding properties and can lead to death at one or the other stage in the life cycle probably by interfering with the neuroendocrine control of metamarphosis in insects (Roy and Dureja, 1998). In 1993, some cotton farmers in Yeotimal district of Maharashtra state of India were able to manage *Helicoverpa* pod borer by spraying chilly plus garlic extract. Later, this method was successfully applied to control *Helicoverpa* pod borer on chickpea and pigeonpea. A botanical pesticide method for management of *Helicoverpa armigera* on cotton was successfully implemented in farmers' fields of two villages (Sadya Tanda and Wanaparthy) in Warangal District, Andhra Pradesh, India in 1997 which in the authors' opinion can also be used to manage this pest infesting chickpea (Anonymous,1998b).

Authors Chari, *et al.* (1998) observed that the net profit in eco-friendly modules at both the villages was as good as in pesticide loaded module. They further stated that grain yield of chickpea varied considerably due to soil heterogeneity and outbreak of *Helicoverpa* during 1997-98.

In Pakistan, research on evaluation of NSKE against major lepidopterans e.g. *H. armigera, Pectinophora gossypiella* and *Earias* spp. pests of cotton and other high value crops has resulted in the development a registered product named NIMBOKILL 60 EC and this neem product is available in the market at a competitive rate as an IPM tool.

Various plant extracts have also been successfully used to protect stored chickpea seed from bruchids. Treatment of seed with mustard oil at the rate of 7.5-10.0 ml kg^{-1} seed can be used to protect certain desi chickpea varieties (CM-72, NEC-138-2, C-141, HG-202-6-1 and ICCL-11514) for more than five months against attack of *C. chinensis* (Khalique *et al.*, 1988). Chaudhary (1990) reported that neem, groundnut, castor (*Ricinus communis*), soybean and sesame oils at 0.5 and 1.0 ml 100 g^{-1} of chickpea seed reduced damage by *C. chinensis*. Weigand and Tahhan (1990) observed 90% protection of chickpea seed for 4 months following treatment with olive oil + salt.

CHEMICAL PESTICIDES

The thrust of this treatise is to promote minimal use of chemical pesticides in chickpea and other food legumes. Nevertheless, it is recognized that immediate implementation of ideal IPM packages is not possible throughout South Asia and that chemical pesticides are still required as a last resort to control severe pod borer infestation. The earlier mentioned promising biological and botanical pesticide may not be available or their use not yet properly evaluated and standardized for particular situations and locations. If chemical pesticides are to be employed, their use needs to be determined by actual need, based on regular scouting of the crop for eggs and small larvae. Only if threshold levels are being approached should application of these chemicals proceed. Preference should be given to need-based use of chemicals which can effectively target the pest without adversely affecting other organisms. The type of chemical pesticide used should be rotated, preferably on a regional basis rather than a farm basis if this can be organized among neighboring farmers, so as to minimize development of insect resistance to particular pesticides. Detailed consideration should be given to safe means of handling and application of chemical pesticides to the crop, and whether they would leave toxic residues for subsequent human or animal consumption.

Excessive and indiscriminate use of chemical pesticide usually gives rise to development of resistance to insecticides in the insect pests which becomes an severe problem in the developing countries (South Asian) due to unawareness of the farming communities to handle insecticides resistance problems. Over the past 20 years, due to Many workers have reported development of resistance in *H. armigera* to a number of chemical insecticides groups (pyrethroids, carbamates, chlorinated hydrocarbon, organophosphates) (Schulten, 1987, McCaffery *et al*., 1989).

In the region, a number of chemical insecticides (Endosulfan 35 EC, Quinolphos dust 1.5%, Quinolphos 20 EC, Quinolphos 20 AF. Curacron ' 60 SL, Nuvacron 100 SL, Kanodane 1.3% D, Kanodane 20 EC Polytrin-C 44 EC, Ripcord 10 EC, Baythroid , Sherpa , fenvelerate 20 EC, Deltamethrin 2.5 EC Dimecron 60 SL, Carbicron , Aldrin , Nexagon and lannate etc.) applied at various dosages and times have been used on chickpea for effective control of *H. armigera*, *Autographa nigrisigna* and *Liriomyza cecirina* (Sanap and Deshmukh, 1987; Thakur *et al.*, 1988; Dethe and Kale, 1991; Yasin, 1986; Pawar, 1984; Wightman *et al.*, 1995; Sehgal, 1990; Sehgal and Ujagir, 1990; Chauhan and Ombir, 1989; Khalique *et al.*, 1985; Mahmood and Shah, 1984; Mahmood *et al.*, 1987; Weigand *et al.*, 1987; Pawar *et al.*, 1993; Ujagir *et al.*, 1997).

Deltaphos 3 EC, Profenofos 50 EC and Polytrin 44 EC were found most effective against *H. armigera* and the mean pod damage under these treatment was 9-10% as against 25% in control plots (Anonymous, 1997). Chauhan (1990) recommended timely need based application of endosulfan 0.07%, fenvalrate0.008% or cypermethrin 0.006% at the podding stage of the crop.

For storage of seed only, and not storage for grain consumption, various fumigant chemicals can be placed in sealed containers with the seed for protection against bruchids. Use of naphthalene balls is safest, cheapest and most convenient; one ball (about 1 g) is added for every kg of seed (Musa, 1998). Fumigants commonly used for dis-infestation of grain storage/godown is phosphine (PH_3) gas which is produced on the spot from a solid compound, Aluminum phosphide commonly available in the region under different trade names (in Pakistan, it is available as Celphos/Agtoxin/ phostoxin tablet). The recommended use of these tablets under completely air-tight containers/stores/ godown is @ 45 tablet (each tablet weighing 3.0 g) per 1000 cubic feet space.

In Pakistan, At National Agricultural Research Center, Islamabad, the first author has been using a technique to fumigate pulses grain kept in 100 Kg seed capacity jute bag. The technique involves the use of thick polythene sheet wrapped around 7 bags (700 kg seed stack) in a way to make it air tight and 2 agtoxin tablet were placed in the polythene sheet enclosure. This technique worked and the experimental seed can be stored without bruchid infestation for more than 6 to 7 months (until next sowing season).

SAFE METHODS OF HANDLING AND APPLICATION OF INSECTICIDES

It is commonly observed during insecticide application on a crop that farmers do not adopt necessary technical precautionary measures in order to prevent health hazards. As a matter of fact insecticides application is serious business and if precautionary measures are not adopted, it can result in serious illness of the applicator. In every instance of insecticide application, the applicator should ensure that: (i) The insecticide to be used must be effective having least mammalian toxicity; (ii) Persons engaged in pesticide operation must be properly supervised and protected; (iii) Recommended rate of insecticides should be applied with the help of proper application technology and always read the label on the container; (iv) Handle insecticide containers carefully and if container leaks or spills, decontaminate the area by washing with soap; (v) Avoid insecticide storage near food or drinking water; (vi) Do not rub eyes or touch the mouth while applying insecticides and thoroughly wash face and hand with soap after application and before eating, drinking, and smoking or using the toilet; (vii) Do not allow the victim of insecticide poisoning to drive home unattended; (viii) If intoxication occur due to direct or indirect contact with insecticide, the patient should immediately be taken to the nearest doctor for medical advice and treatment.

DISPOSAL OF INSECTICIDE CONTAINERS

Potential contamination of ground and surface water occurs if used containers are left unattended lying near the wells, streams and in areas with high water table. This negligence may be dangerous to members of public, fish, other forms of life and especially to the children playing with the used containers. The best methods used for the disposal of empty insecticide containers is to crush/break them first and then bury the containers on the user’s own farm.

Insecticide storage at farm level

Insecticides should always be stored in cool, dry, locked, well ventilated areas without drains. They should be kept away from food and drinking water used for human and animal consumption. It is necessary that all the insecticides should be kept in their original containers. Insecticide store should display a sign “Chemical Storage –Warning— Authorised persons only” visible on the side of entrance leading into the storage.

PRACTICAL IPM PACKAGES

Chickpea pod borer (Helicoverpa armigera)

While the above-mentioned IPM components targeting *Helicoverpa* pod borer have been developed and evaluated in small plot field trials, usually on research stations, their evaluation on an operational scale in farmers’ fields is not often reported. Further, field evaluations have usually been confined to one component, and a maximum of two (Anonymous, 1997), whereas the ultimate objective of IPM should be to assemble multiple defenses against an insect pest. This is particularly important in the case of such a polyphagous and mobile pest as *Helicoverpa*. Various combinations of IPM components have been proposed, as described below, but have rarely been tested, as a package, for their effectiveness and economic benefit on an operational scale in fields of resource-poor farmers. This task is indeed complex to implement and statistically analyze. Additionally, when agronomic packages are being developed and evaluated, it is not just IPM components that are of interest but other cultural practices that would favor higher yields and stability of yield. Therefore, when improved agronomic packages are evaluated, they are usually in the form of integrated crop management (ICM) packages, which would contain one or more IPM components along with other recommended cultural practices (Pande and Narayana Rao, 2000).

In Bangladesh and Nepal, chickpea production has been declining during the last decade, mainly because of epidemics of Botrytis gray mold (BGM). However, it is possible to manage this disease in farmers' fields (Pande and Narayana Rao, 2000), and if this is successfully done the next most important threat to chickpea yield is pod borer. Existing recommendations on pod borer control of chickpea in these countries refer almost exclusively to spraying of chemical pesticides, such as monocrotophos and endosulphan, at early podding stages (Rehman, 1999). However, from the foregoing it is desirable to minimize this component of IPM and maximize use of more bio-friendly alternatives. To the authors' knowledge no such IPM packages for chickpea in Nepal or Bangladesh have been evolved or systematically evaluated in farmers' field situations. We can only therefore propose suitable IPM procedures for possible future on-farm testing, based on recent experience and observations in these countries. Components of a package would therefore comprise:

1. To the extent possible, sow chickpea as a mixed crop with crops like mustard, linseed or coriander, to maximize non-preference for *Helicoverpa* egg laying and harboring of natural enemies, like *C. chlorideae*. Such mixed cropping is also a strategy to minimize BGM infestation, and is feasible as cultivation of these crops is non-mechanized in Bangladesh and Nepal. As earlier mentioned, farmers' decisions about mixed cropping or intercropping are determined by factors given greater priority than IPM considerations and such "ideal" mixtures may be more fortuitous than planned. Nevertheless, if chickpea is to be monocropped, then every attempt should be made to mix chickpea fields with fields of other crops, rather than have large contiguous blocks of chickpea. However, in difficult soil conditions like in the Barind Tract of Bangladesh (Musa *et al.,* 2001), there are few alternative cropping options to chickpea.
2. Farmers should be trained in monitoring of *Helicoverpa* infestation so as to effectively use insecticide. Small larvae (up to 3rd instar) cause characteristic scarring of leaves, providing an indication of where to search for them in the canopy. Effectiveness of all insecticides decreases with larval size and so timely spraying of small larvae is necessary. A threshold level of one larva of 1^{st} or 2^{nd} instar per plant could be taken as critical for insecticide application.
3. Use insecticide if the threshold level is breached. Although use of biological and botanical insecticides is much more desirable than use of chemical ones, unfortunately development and field testing of the former in Bangladesh and Nepal has not progressed to the stage where they can be confidently recommended. Thus reliance on chemical insecticides remains necessary. Use of one chemical (e.g. endosulphan) for the first spray but of another chemical if further sprays are necessary is recommended to minimize build-up of insecticide resistance. Such a regime should be applied across as wide an area as is possible to arrange. Training in safe handling, and correct application methods of the insecticides used would generally be required. However, such use of chemicals should only be considered as an interim measure until effective biological and botanical insecticides can be recommended for general use; which may take at least another three seasons or so.
4. If threshold levels are approached then bird perches should be placed at regular intervals across the field, for example a 10 x 10 m grid. However, it needs to be checked that the attracted birds are themselves not damaging pods.
5. In the chickpea growing areas of Bangladesh and Nepal it is feasible to mobilize children to hand-pick larvae and destroy them should insecticide application not be effective or when there is serious infestation, particularly if some remuneration is offered.

It is proposed that an IPM package along the lines suggested above should be tested on an operational scale in farmers' fields, to quantify its effectiveness. Such IPM plots should be grown adjacent to plots without IPM treatments but otherwise treated identically to the IPM plots, with at least five such paired comparisons at a given location (*e.g.* village). Cultural practices other than IPM components should be optimum for chickpea in the target regions, *e.g.* Botrytus grey mold (BGM) control to ensure a reasonable pod load for *Helicoverpa* to attack. Such trials should be farmer implemented, to test whether farmers can effectively apply the suggested practices and to obtain feedback on any problems arising in doing so.

In Pakistan, there is a currently recommended Integrated Crop Management (ICM) package for chickpea including some IPM components for management of *Helicoverpa* (Ahmed, 1999; Anonymous, 2002). The IPM components are:

1. Timely sowing, in October and up to mid-November, so as to prevent delayed podding into the period when pod borer infestation is most likely (mid-April in northern Punjab province).
2. Application of chemical insecticides when *Helicoverpa* starts infesting the crop at the flower initiation stage. The presence of two 2nd instar (5-6 mm larval size)/plant warrants insecticide application, as follows: (i) Karate 2.5 EC @ 750 ml/ha mixed in 200 liters of water should be sprayed when 2nd instar larvae are found to be infesting the crop, or (ii) Thiodan 35 EC @ 3.0 liter/ha mixed in 200 liters of water can also used to spray the crop for effectively control the pest at 50% flowering of the crop, or (iii) Match [an Insect Growth Inhibitor (IGI)] @ 1.8 liter/ha mixed in 200 liters of water can also be sprayed to achieve good control of the pest at the initial infestation stage of the crop.

   The insecticidal spray can be repeated after 12 to 15 days if insect infestation is still present.
3. Although farmers usually grow chickpea as a sole crop, it is recommended that the chickpea be strip cropped with wheat, linseed, mustard or coriander. A strip of 1.5 m of each crop can be alternated. This practice encourages the natural enemies to parasitise the pest.

An example from India includes several IPM components in a general ICM package recommended for chickpea, developed by Excel Industries (Pawar, 1998). The IPM components are:

1. Use of *Helicoverpa* tolerant chickpea varieties wherever available and acceptable to farmers.
2. Need-based application of: Spray Endocel 35 EC 1.0 liter + Heliocel (NPV) 250 ml/ha at later stages (flowering and podding). If *Helicoverpa* still remain, then repeat NPV@ 500 ml/ha, but normally this should not be necessary.
3. Strip cropping with mustard or coriander, in alternate 1.5 m strips, to encourage natural enemies of *Helicoverpa*.

Bruchids

In Bangladesh, effective control of bruchids in storage of chickpea seed can be obtained through the following procedure (Musa, 1998): (i) Drying of threshed seed in bright sunlight for 5-7 hr; (ii) Inspection of seed for absence of bruchids immediately prior to packing for storage; (iii) Place seed in a polythene bag with 1g (= 1 ball) naphthalene kg^{-1} seed, and seal the bag; (iv) Place the bag in a vermin-proof container; (v) Store the container above ground level in a dry and airy location.

Variations on this method, such as use of mustard or neem oil instead of naphthalene, are also effective (Rahman, 1999). For storage of chickpea grain (i.e. seed intended for human consumption), naphthalene, other chemical fumigants/repellents and oils should be avoided as they impart an undesirable taste to the grain. In this case the sand storage method, as described in the “cultural practices” section can be used.

RECOMMENDATIONS FOR FUTURE STRATEGY

In most chickpea growing areas of South Asia, chickpea cultivation is in transition, from essentially a subsistence crop to a commercial crop. It is also moving into new areas, such as in peninsular India and the Barind of Bangladesh. Thus increased use of inputs directed towards chickpea cultivation is becoming more common. Despite considerable research having been done on bio-friendly alternatives for control of *Helicoverpa* pod borer, chemical insecticides remain the mainstay of defense against this pest. Thus cultivation of the chickpea crop is threatened by all of the hazards experienced in other crops where use of chemical insecticides has got out of hand. Following are some suggestions to avoid these hazards.

An immediate priority is to scale up testing of bio-friendly IPM packages to on-farm situations, such that alternatives to reliance on chemical insecticides alone can be demonstrated to chickpea growers. Emphasis needs to be given to weaning off chemicals in favor of the bio-friendly alternatives. The IPM farmer field school approach used initially for rice would seem an ideal approach to follow in this regard. This will permit farmers to learn more about the ecology of pod borer and its natural enemies and thereby provide a sound base for a bio-friendly strategy. However, it is inevitable that chemical insecticides will play a crucial role in pod borer control of chickpea for several years to come. Therefore intensive training in proper use of these chemicals should be an integral part of such field schools, along with gradual introduction of bio-friendly methods. Nevertheless, farmer training in IPM should not be isolated from introduction of other desirable cultural practices; it should form part of the overall ICM methodology.

There is obviously more research required to make some of the bio-friendly IPM components more "farmer-friendly". For example, improved quality control and its monitoring is needed for effective and large scale use of NPV by farmers. Further ecological studies are needed on natural enemies of *Helicoverpa* in and around chickpea fields, to improve understanding of how to enhance them. Such studies should be participatory with farmers as they will ultimately be benefited by learning how to recognize and enhance them. Ecological studies on a broader scale are also needed to be better able to predict pod borer infestation of chickpea. Such factors as infestation on crops preceding chickpea, both where the chickpea is cultivated as well as in other areas, and weather influences are worthy of more critical analysis.

In view of the substantial genotypic differences in HPR of chickpea to *Helicoverpa* pod borer, recognized over two decades ago, efforts should be renewed and redoubled to develop otherwise acceptable varieties carrying substantial levels of HPR. It is suggested that this could be most quickly done using conventional plant breeding methods but by maintaining HPR as a major criterion in selection of progeny. Various problems associated with the "apparent quick-fix" option of developing transgenic plants with *Helicoverpa* resistance would probably render this only a long-term possibility. Use of genetic markers could theoretically hasten the conventional breeding process, but only if unambiguous markers for resistance are already available for use. A need to establish such markers may lengthen the time required to reach a finished product, as insect resistance is likely to be under complex genetic control thus complicating unambiguous identification of markers.

To minimize bruchid damage to stored chickpea, the major requirement is large-scale farmer training in the cultural techniques already established as effective.

CURRENT DEBATES AND SIGNIFICANT GAPS IN THE RESEARCH

Therefore, this review and analysis focuses on the major pulse chickpea. Similarly, to provide focus, discussion is confined to only the major insect pests of this legume crop, those causing significant and frequent yield losses.

In author's view, an ever-growing population needs at least a proportionate increase in consumption of vegetable protein, and other nutritional requirements provided by food legumes including chickpea, so as to balance a cereal-based diet. Enhanced intake of animal-derived protein, as an alternative to vegetable protein, is increasingly difficult for poorer sections of the community, due to relatively rapid increases in prices of animal products. The increasing demand for cereal grains is exacerbating problems associated with a trend towards monocropping of cereals. Diversification of cereal-dominant cropping systems is necessary to break pest, disease and weed cycles and prevent deterioration of soil physical and chemical properties. Chickpea among legumes is particularly suitable candidates for crop diversification in cereal-based systems due to their ability to replenish the soil with fixed atmospheric nitrogen and organic matter and because they normally do not host the major pests and diseases affecting cereal crops.

Insect pests are important yield reducers of chickpea (although stored seed of this crop is regularly damaged by *Callosobruchus* spp.; the considerations involved in control of this pest equally apply to other pulses as well.

The "modern agriculture" approach, dating from the "green revolution" in the 1960s in the South and South-East Asia region, has been to apply chemical insecticides when it is perceived that presence of insects on a crop is likely to reduce crop yield. However, previous experience with liberal use of pesticides on cereal and various high value field crops (e.g. cotton) presents a warning that this scenario should not be repeated with chickpea.

Hazards posed by even "normal" use of chemical insecticides on crops are elaborated in http//www.toxictrail.org. These compounds pose at least some toxicity hazard to humans if appropriate, indeed strict, handling precautions are not taken. Such precautions are difficult to expect among the rural poor, where literacy levels are low, insecticide containers are often labeled in foreign languages in any case, and other sources of information on safe use of pesticides are not readily available. It is estimated that 25 million farmers in Asia are currently suffering from visible symptoms of chemical pesticide poisoning. Regular use of a chemical insecticide induces build-up of resistance to that chemical in the target insect. For example, *Helicoverpa armigera*, the polyphagous pod borer that is a major enemy of chickpea discussed here, has developed over 100- to 1000-fold resistance to several pyrethroid insecticides (Pawar 1998). Increased insecticide resistance of the pest results in decreasing effectiveness of the insecticide, decreasing returns to investment in pest control by the farmer and use of higher and more frequent doses of chemicals with consequent increased health hazards to those handling them (Georghiou and Mellon, 1983; Metcalf, 1983; Sehulten, 1987; Dhingra *et al*., 1988; McCaffery *et al*., 1989; Ahmad *et al*., 1994; Armes and Panday, 1995; Srivastava, 1995).

However, there are eco-friendly and effective alternatives to the use of chemical pesticides alone in control of major insect pests of chickpea. It is ironic that several of these were practiced by farmers of the region before the widespread availability of chemical pesticides; it now seems necessary to relearn about some of these alternatives. However, it is sometimes argued that these traditional methods were associated with a low-input, low-output subsistence agriculture and are therefore not relevant to present day requirements of high yields, even from the fields of resource-poor farmers. It is argued that they can be of relevance in a crop management package aimed at high and stable yields, and are indeed necessary if the chemical pesticide trap is to be avoided. A first lesson to learn from traditional agriculture is to understand the local ecology, so as to be able to identify vulnerable phases in a pest's life cycle and thus target these. The key to a "modern" agriculture capable of meeting the food needs of the region without unduly damaging the resource base is indeed a better understanding of ecological consequences of any crop production techniques.

The major objective of this review is to examine which eco-friendly components of insect management can be deployed in an integrated pest management (IPM) package suitable for maximum production of chickpea. Although there are many definitions of IPM, for the purpose of this review it is defined as an optimum combination of pest management methods implemented in farmers' fields that will minimize economic yield loss of a crop caused by an insect pest or range of pests without resulting in toxic effects on other organisms or otherwise causing an ecological imbalance that would eventually reduce crop yield potential. Early attempts at IPM took the form of a top-down approach whereby a package of IPM components was assembled by scientists and then recommended to farmers (Kogan, 1998). A realization that farmers need to understand the ecology of the situation before they can realistically implement IPM lead to more recent concepts of farmer participation in problem diagnosis and development of location-specific IPM solutions (Kogan, 1998).

The authors consider that the first consideration in eco-friendly insect pest management is exploitation of any host plant resistance (HPR) to the particular pest. The current and potential value of this approach for chickpea has not been fully exploited, however, entomologists and breeders in International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), India, where continued efforts were made from 1983 to 1995 and as a result developed a number of moderately resistant chickpea genotypes. The ICRISAT has distributed these genotypes to collaborating countries in the South Asia but results were not found encouraging due to disease attack on these genotypes.

The scope for HPR has been increased by the advent of transgenic plants with particular, targeted resistances, and this is examined for its prospects for use in an IPM package for chickpea and other legumes crops. Various crop cultural practices that may affect insect pest damage have been assessed with various degrees of success. Options for biological control and use of “natural”, biological pesticides have also been evaluated e. g. If the above eco-friendly methods prove inadequate to effectively control a major pest, then it may be necessary to resort to use of chemical insecticides; in this case the precautions to be taken for their effective and safe use are specified.

Most of the research on individual components of a potential IPM package for the target crop like chickpea and other food legumes has been done in isolation from other components, whether on research stations or in farmers’ fields. If an ecological approach to insect management is to be followed then it is likely, and logical, that a combination of several of these components will be necessary. Thus this review attempts to identify optimum combinations of potential components of IPM that would be most relevant to apply in the fields of resource poor farmers growing chickpea. It is recognized that optimum components of IPM also need to be compatible with the other agronomic components of an integrated crop management (ICM) package. Thus insect pest management options are viewed from a systems perspective to the farming enterprise. Examples of successful IPM approaches operating in farmers’ fields have been sought, for their possible extrapolation to other situations. Admittedly, there are few examples of direct farmer involvement in evolution of IPM packages for food legume crops including chickpea, as currently advocated (Ooi 1999). However, it is generarelly cognized that the need to involve farmers themselves in the evolution and evaluation of IPM strategies and hope that this assembly of information relating to IPM of chickpea will facilitate increased farmer-participatory IPM activities.

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