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(Prepared by T. L. Peever)

Pest Management in Chickpea

Chickpea is the third most important legume crop in the world, after dry bean and pea. It is cultivated in 42 countries in South Asia, North and Central America, the Mediterranean region, West Asia, and North and East Africa. In recent years, it has become an important crop in Australia, Canada, and the United States. Nearly 60 insect species are known to feed on chickpea. The important insect pests damaging chickpea in different regions are cutworms (black cutworm, *Agrotis ipsilon,* and turnip moth, *A. segetum*), leaf-feeding caterpillars (*Spodoptera exigua* and western yellow-striped armyworm, *S. praefica*), leafminers (*Liriomyza cicerina*), pea leaf weevil (*Sitona lineatus*), aphids (*Aphis craecivora*), pod borers (cotton bollworm, *Helicoverpa armigera,* and native budworm, *H. punctigera*), and bruchids (Chinese bruchid, *Callosobruchus chinensis*). Among these pests, the pod borer *H. armigera* and the aphid *A. craccivora* are the major pests of chickpea in the Indian subcontinent. In the Mediterranean region, the most important pest is the leafminer *L. cicerina. A. craccivora* is important as a vector of chickpea stunt disease, while *C. chinensis* is the most dominant pest species in storage.

Population Monitoring and Forecasting

Efforts have been made to develop a forecasting system, particularly for *H. armigera* in India. A rule of thumb has been developed to predict *H. armigera* populations using surplus/deficit rainfall in different months in southern India. A combination of surplus rains during the monsoon and deficit rainfall during November indicate low incidence, while deficit rains during the monsoon and surplus rains during November indicate severe attack. Additional information on November rainfall gives more precise information on the level of attack (low, moderate, or severe). In Australia, population monitoring with sex pheromone-baited traps is used to detect the onset of immigration or of emergence from local diapause. The abundance of *H. armigera* and *H. punctigera* as measured by light traps has shown that seasonal rainfall and pattern of crops grown locally give a reasonable prediction of the timing of population events and the size of subsequent generations. Timing of control is determined by field monitoring of larval densities in crops through the period of crop susceptibility. Control is recommended only when larval populations in crops at the postflowering stage exceed a threshold of two to four larvae per meter of row. There have been no efforts to study and develop population-prediction models for other insects infesting chickpea. There may be a need to know the conditions under which infestations of the leafminer *L. cicerina* cross economic thresholds and the climatic factors that can predict the onset of heavy infestations.

Host Plant Resistance

The development of chickpea cultivars resistant or tolerant to insects has a major potential for use in integrated pest management, particularly under subsistence farming conditions in developing countries. More than 14,000 chickpea germplasm accessions have been screened for resistance to *H. armigera* at ICRISAT in India under field conditions. Several accessions (ICC 506EB, ICC 10667, ICC 10619, ICC 4935, ICC 10243, ICCV 95992, and ICC 10817) with resistance have been identified, and cultivars such as ICCV 7, ICCV 10, and ICCL 86103 with moderate levels of resistance have been released. However, most of these lines are highly susceptible to Fusarium wilt. Therefore, concerted efforts are being made to break the linkage by raising a large population of crosses between lines with resistance to *H. armigera* and lines resistant to wilt.

Efforts are also currently underway at ICARDA to develop cultivars with resistance to the leafminer *L. cicerina.* Cultivars with low trichome density and those devoid of trichomes are highly susceptible to damage by the aphid *A. craccivora.* A number of genotypes/lines have been reported to be less susceptible to aphid damage. High levels of resistance have been observed in Desi chickpea to bruchids, *Callosobruchus* spp. Lines showing resistance to bruchids usually have small seeds with rough seed coats, which is not acceptable to consumers. Chickpea seed that is split for *dhal* is unattractive to ovipositing bruchid females, and therefore processing chickpeas into split peas or flour immediately after harvest can minimize losses caused by these pests.

Cultural Manipulation of the Crop and Its Environment

A number of cultural practices such as time of sowing, spacing, fertilizer application, deep plowing, interculture, and flooding have been documented by several workers to reduce insect damage. Intercropping or strip cropping with marigold, sunflower, linseed, mustard, and coriander can minimize the extent of *H. armigera* damage to the main crop. Strip cropping also increases the efficiency of chemical control. Large larvae can be handpicked to reduce pod borer damage. However, the adoption of cultural control depends on crop husbandry practices in a particular agroecosystem. Also, crop rotations do not help manage polyphagous and highly mobile insects such as *Helicoverpa/Heliothis* species, although it has been noted that some crops (e.g., alfalfa) are more attractive to the moths.

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* populations, and chickpea used as a trap crop plays an important role in this strategy. Trap crops are managed in the same way as commercial crops, but they are 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.

Plowing fields before planting and after harvest reduces damage by *Helicoverpa* spp. and the cutworm *A. ipsilon.* At times the plants are able to recover from foliar damage caused by these insects. The incidence of black aphid, *A. craccivora*, is greater under drought conditions and wide plant spacing. Early sowing leads to early canopy closure, which also helps to reduce the spread of viruses in chickpea. Therefore, early sowing and optimal planting densities can be used to minimize aphid infestation. Early-sown crops also escape leafminer damage in West Asia.

Biological Control

The importance of both biotic and abiotic factors on the seasonal abundance of *H. armigera* is poorly understood. Some parasitic wasps have been reported to avoid chickpea, probably because of its dense layer of trichomes and acidic exudates. The egg parasitoids *Trichogramma* spp. are almost absent from the chickpea ecosystem. The ichneumonid *Campoletis chlorideae* is probably the most important larval parasitoid of *H. armigera* on chickpea in India. *Carcelia illota*, *Goniophthalmus halli*, and *Palexorista laxa* have also been observed to parasitize 3–54% of the larvae on chickpea. Predators such as *Chrysopa* spp., *Chrysoperla* spp., *Nabis* spp., *Geocoris* spp., *Orius* spp., and *Polistes* spp. are the most common in India, attacking *Helicoverpa* spp. on chickpea and other crops. Provision of bird perches or planting of tall crops that serve as resting sites for insectivorous birds such as myna (*Acridotheres tristis*) and drongo (*Dicrurus macrocercus*) helps to reduce the numbers of caterpillars.

Braconid wasps such as *Microgaster* spp., *Bracon kitcheneri*, and *Fileanta ruficanda* parasitize larvae of the black cutworm, *A. ipsilon*, while *Broscus punctatus* and *Liogryllus bimaculatus* are common predators. A parasitic wasp, *Opius* sp., feeds on leafminer larvae in West Asia, but further research is required before this insect can be used for biological control in the field. Coccinellids and chrysopids are common aphid predators, while *Trixys indicus* and *Lipolexis scutellaris* are important parasitoids.

Biopesticides and Natural Plant Products

The use of microbial pathogens including *H. armigera* nuclear polyhedrosis virus (HaNPV), entomopathogenic fungi, *Bacillus thuringiensis* (*Bt*), nematodes, and natural plant products such as neem, custard apple, and karanj kernel extracts have shown some potential to control *H. armigera*. HaNPV is a viable option to control *H. armigera* in chickpea. Jaggery (0.5%), sucrose (0.5%), egg white (3%), robin blue (0.1%), and chickpea flour (1%) as well as milk powder and the additive Amino Feed are effective in increasing the efficacy of HaNPV. The entomopathogenic fungus *Nomuraea rileyi* (10^6 spores per milliliter) results in 90–100% larval mortality, while *Beauveria bassiana* (2.68×10^7 spores per milliliter) results in 6% damage in chickpea compared with 16.3% in control plots. Formulations of *Bt* used as sprays are effective to control *H. armigera* and the semilooper, *Autographa nigrisigna*. Spraying *Bt* formulations in the evening results in better control than spraying at other times of the day. Spraying with neem seed kernel extract (5%) is effective for controlling the leafminer, *L. cicerina*, but the persistence is limited.

Chemical Control

Management of *H. armigera* on chickpea and other high-value crops depends heavily on insecticides. Cypermethrin, profenophos, spinosad, methomyl, and indoxacarb are quite effective. Spray initiation at 50% flowering is most effective. Use of indoxacarb in chickpea in Australia is limited to one application with a cutoff date for application. This is to ensure that at least one generation of *H. armigera* is not exposed to the insecticide before the commencement of its use in summer crops such as cotton and mungbean.

Endosulfan dusts, sprays, or baits are effective for cutworm control. Generally, there is no need for aphid (*A. craccivora*) control on chickpea, but it may become necessary to prevent the spread of chickpea viruses. A number of insecticides such as methomyl, oxydemeton-methyl, and monocrotophos are effective on aphids. Endosulfan, dichlorvos, and malathion have been recommended for controlling the semilooper *A. nigrisignia*.

Integrated Pest Management (IPM)

The important insect pests damaging chickpea that need to be controlled during different stages of crop growth are cutworms (*A. ipsilon*), leaf-feeding caterpillars (*Spodoptera exigua*, *S. praefica*, *S. obliqua*, and *A. nigrisignia*), leafminers (*L. cicerina* and *L. congesta*), aphids (*A. craccivora*), pod borers (*H. armigera* and *H. punctigera*), and bruchids (*Callosobruchus* spp. and *Acanthoscelides obtectus*). Control measures for *H. armigera* and *H. punctigera* may be undertaken based on the number of moths caught in pheromone or light traps (five to 10 males per trap per day). Visual scouting and sweep nets can be used to obtain an estimate of insect infestations to decide on the need to initiate control measures. For pod borers, *Helicoverpa* spp., control measures may be undertaken when one egg per plant or two to three small larvae per meter row are observed.

Cultivars with resistance to pod borers, leafminers, and aphids have also been identified for use in IPM. Pod borer damage can be managed with cultural practices and handpicking of larvae.

Biopesticides and natural plant products can also be used in chickpea production early in the season when population densities are low. Application of these products allows for the buildup of natural populations of parasitoids for biological control. They can be used alone in rotation with insecticides or in combination with the insecticides. Several insecticides have been found to be effective for controlling insect damage in chickpea. Planting tall crops (such as sorghum, maize, or sunflower) that serve as bird perches or providing wooden perches attract insectivorous birds that feed on pod borer larvae. However, except for aphids, natural enemies are not very effective in reducing insect damage under field conditions.

Conclusions

Insect-resistant cultivars will form the backbone of integrated pest management in the future. The development and deployment of cultivars with resistance to insects will offer the advantage of allowing some degree of specificity so that pests, but not the beneficial organisms, are targeted. In order for pest-management programs to be effective, the following are needed: in-depth understanding of the population dynamics of insect pests to develop appropriate control strategies, a combination of resistance to insects with resistance to important diseases and with cold tolerance, utilization of wild chickpea relatives to diversify the genetic basis and thus increase levels of resistance to insect pests, identification of quantitative trait loci associated with resistance to insects, development of insect-resistant cultivars through genetic transformation using genes with diverse modes of action, and programs for insecticide-resistance management.

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Pest Management in Lentil

Lentil is an important pulse crop grown in Asia (India, Jordan, Lebanon, Syria, and Turkey), southern Europe, North and East Africa, North America, and the former Soviet Union. Poor crop management and abiotic and biotic stresses reduce grain yields. Among the biotic constraints, insect pests play a major role. About 36 insect pests have been reported to infest lentil under field and storage conditions, of which 21 have been reported from India. However, only a few of these are economically important and require control measures. The insect pests feeding on lentil under field conditions include aphids, bud weevils, cutworms, leaf weevils, lygus bugs, pod borers, stink bugs, and thrips. During storage, several species of seed beetles such as *Bruchus* spp. and *Callosobruchus* spp. cause severe damage. The pest status of each species varies greatly among regions. For example, *Aphis craccivora*, *Etiella zinckenella*, and *C. chinensis* have been reported as the major pests of lentil in India, while *Sitona crinitus*, *B. lentis*, and *E. zinckenella* have been identified as the most harmful pests of lentil in Turkey. Aphids (*Acyrthosiphon pisum* and *Aphis craccivora*), bruchid (*B. lentis*), thrips (*Thrips tabaci* and *T. angusticeps*), and leaf weevils (*S. lineatus*) are the key pests of lentil in Castilla La Mancha (central Spain). Lygus bugs are major pests of lentil in the Pacific Northwest of the United States.

Cultural Practices

The stem weevils, *Sitona* spp., emerge from the soil after aestivation, and hence crop rotation can reduce the likelihood of successful recolonization and subsequent infestation. Early sowing combined with weed control may provide partial control. Cultural control programs for lygus bugs are only partially effective because the target insect is supported by a continuity of plant hosts throughout its life cycle. Disturbing habitat by disking near fence rows and mowing roadsides can potentially lower lygus bug numbers but may also injure overwintering populations of beneficial insects. Flooding fields has been recommended as a control measure for the cutworm *Agrotis ipsilon*. Deep plowing of fields after crop harvest exposes the larvae and pupae to predators at the soil surface. Removing volunteer soybean plants from lentil crops is critical, since they serve as alternate hosts during the offseason.

Host Plant Resistance

Host plant resistance to aphids has potential for pest management in lentil. The cultivar Yerli Kirmizi shows reduced nodule feeding by *Sitona* spp. and increased seed yield over Sazak 91. However, no real sources of resistance to *Sitona* spp. have yet been found in lentil germplasm. Expression of the CryIII toxin in nodules has been shown to result in significant reduction in nodule damage by *Sitona* spp. on *Pisum sativum* and *Medicago sativa* and could be used as a component to produce *Sitona*-resistant lentil. Early-maturing and small-seeded genotypes of lentil are more susceptible to thrips in Bangladesh, but thrips in general are not major pests. Host plant resistance can also be used for the control of lima bean pod borer in lentil, since some variation in genotypic susceptibility has been reported. Short-duration genotypes generally suffer more damage from *E. zinckenella*. The lentil genotypes P 927, P 202, and LH 90-39 are resistant to damage, while LL 147 shows a tolerant reaction.

Biological Control

Aphids are attacked by a number of natural enemies, especially coccinellids, which may prevent rapid increase and reduce infestation levels. Lygus bugs have a few natural enemies, including a fairy wasp in the family Mymaridae that parasitizes the eggs. The parasitic wasp *Peristenus pallipes* attacks lygus nymphs, but its effectiveness is not well documented. One of the few parasitoids of lygus adults is a tachinid fly, *Alophorella* sp. Nabid plant bugs, big-eyed bugs, and spiders can also be used for biological control of this pest in lentil.

Biopesticides and Natural Plant Products

A water extract of *Melia azedarach* kernels at 50 g/L has been shown to significantly reduce *S. crinitus* adult damage on lentil leaves for 1 week and can be used for minimizing losses caused by lepidopteran pests.

Chemical Control

Insect damage in lentil, in general, is not high enough to warrant application of chemical insecticides. However, need-based application of insecticides may be undertaken under heavy insect infestation. In the event of severe aphid infestations before or at flowering, dimethoate is quite effective and may control aphids and lygus bugs at the same time. By controlling aphids, seed treatment with imidacloprid reduces *Bean leafroll virus* (BLRV), *Faba bean necrotic yellows virus* (FBNYV), and *Soybean dwarf virus* (SbDV) in faba bean and lentil. Seed treatment increases yields of susceptible lentil cultivars but not those of the resistant ones. The products with greatest potential for pest control on lentil include bifenthrin, cyfluthrin, imidacloprid, and λ-cyhalothrin. In addition, efforts are being made to develop thiomethoxam as a seed treatment for aphid control.

Carbofuran increases nodule mass by significantly reducing damage caused by *Sitona* spp. Chlorpyriphos (720 g a.i./ha), malathion (1,300 g a.i./ha), or oxydemeton-methyl (265 g a.i./ha) can also be applied in cases of severe weevil infestation. Yield increases resulting from application of carbofuran are generally higher in early- than in the late-sown crops. Seed treatment with furathiocarb effectively controls damage by *Sitona* spp., increases grain and straw yield, and is less disruptive to the environment than foliar insecticide sprays. Treatment for lygus bugs invariably takes place when treatment for pea aphid is made in the United States. This usually occurs at 50% bloom, and the rate of dimethoate used for aphid control is adequate for lygus control.

Cutworms can be controlled by broadcasting in the evening a poison bait (10 kg/ha) prepared with wheat bran, cotton, or groundnut cake and moistened with water and trichlofon, carbaryl, or parathion. Insecticides such as phosalone and carbaryl control thrips on lentil. Application of an insecticide for sucking insects (e.g., deltamethrin, malathion, dimethoate, or endosulfan) also provides good control of thrips. Control measures for *Helicoverpa/Heliothis*, *E. zincknella*, and *Cydia nigricans* are rarely needed. However, these insects directly affect the seeds