Lal, S. S., Yadava, C. P., Dias, C. A. R., and Nigam, R. 1989. Effect of planting density and chickpea cultivars on the infestation of black aphid, *Aphis craccivora* Koch. Madras Agric. J. 76:461-462.
Reed, W., Cardona, C., Sithanantham, S., and Lateef, S. S. 1987. The chickpea insect pests and their control. Pages 283-318 in: The Chickpea. M. C. Saxena and K. B. Singh, eds. CAB International, Wallingford, U.K.
Romeis, J., and Shanower, T. G. 1996. Arthropod natural enemies of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in India. Biocontrol Sci. Technol. 6:481-508.
Sharma, H. C., ed. 2005. *Heliothis/Helicoverpa* Management: Emerging Trends and Strategies for Future Research. Oxford and Ibh Publishing, New Delhi.
Sharma, H. C., and Ortiz, R. 2002. Host plant resistance to insects: An eco-friendly approach for pest management and environment conservation. J. Environ. Biol. 23:11-35.
Zalucki, M. P., and Furlong, M. J. 2005. Forecasting *Helicoverpa* populations in Australia: A comparison of regression based models and a bioclimatic based modeling approach. Insect Sci. 12:45-56.

(Prepared by H. C. Sharma, C. L. L. Gowda, G. V. Ranga Rao, M. K. Dhillon, and M. El Bouhssini)

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 and consequently yield, and insecticide application is occasionally necessary. Application of endosulfan, indoxacarb, methidathion, and deltamethrin at flowering or early pod setting is quite effective. Technologies for managing *H. armigera* with biopesticides such as *Bacillus thuringiensis*, *H. armigera* nuclear polyhedrosis virus, and neem seed kernel extract are also available and can be used as viable alternatives to synthetic insecticides.

Management of Insects in Storage

The most serious and frequently encountered insect pests of stored lentils are the bruchids *Callosobruchus chinensis*, *C. maculatus*, *Bruchus ervi*, and *B. lentis*. The grain should be dried to <12% moisture content and stored in a cool, dry place in airtight containers or sealed polyethylene bags, which can be kept under sunlight for 2–3 days to kill insects that have infested the seed before storage. A layer of neem leaves, wood ash, or dust can be spread on the top of the storage containers to minimize bruchid infestation. The grain may be split before storage (as *dhal*) to reduce the chances of infestation during storage. Infested seeds can be fumigated with phosphine before storage and should not be planted. Phosphine controls all insect stages, leaves no residue, and does not affect taste or germination. Application of two sprays (one before 50% flowering and the second 15 days later) of any contact insecticide provides adequate control from bruchid infestation in the field. Storage areas should be cleaned of all residues of earlier stored products and disinfested with malathion. Mixing seeds with olive oil and salt (5 ml and 20 g, respectively, per kilogram of seed) or neem seed oil (3 ml per kilogram of seed) provides good control for a period of 3–4 months. A dose of 1 kGy of gamma radiation kills *C. chinensis* within a week and is a suitable alternative control measure for *C. chinensis*. The dose is also sufficient for the management of other pests including *Tribolium castaneum* and *Rhizopertha dominica*. There are several other nonchemical approaches for controlling species of *Callosobruchus*. Neem is probably the most accepted alternative to fumigation and chemical control.

Selected References

Bragg, D., and Burns, J. W. 2001. Pea aphid and pea seed weevil control in dry field peas: Effects on yield and yield components from insecticide application timings. http://variety.wsu.edu/Updates/2001_Pea_Report.pdf.

El Damir, M., El Bouhssini, M., and Al Salti, M. N. 2000. Effect of *Melia azedarach* (L.) (Meliaceae) fruit extracts on *Sitona crinitus* (H.) (Coleoptera: Curculionidae) adults feeding. Arab J. Plant Prot. 18:64-67.

Islam, M. S., Solh, M. B., and Saxena, M. C. 1985. Effect of fertilization, inoculation, and carbofuran on nodulation, yield, and protein content of lentil [*Lens culinaris*]. LENS Newsl. 12:32-36.

Lal, S. S. 1992. Insect pest of lentil and their management: Review. Agric. Rev. 13:225-232.

Weigand, S., Lateef, S. S., El Din, N. E. S., Mahmoud, S. F., Ahmed, K., and Ali, K. 1994. Integrated control of insect pests of cool season food legumes. Pages 679-694 in: Expanding the Production and Use of Cool Season Food Legumes. Proc. Int. Food Legume Res. Conf. Pea, Lentil, Faba Bean, Chickpea, Grasspea, 2nd. F. J. Muehlbauer and W. J. Kaiser, eds. Kluwer Academic Publishers, Dordrecht, Netherlands.

(Prepared by H. C. Sharma, M. K. Dhillon, and M. El Bouhssini)