CHAPTER 20

INSECT PESTS OF LENTIL AND THEIR MANAGEMENT

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Abstract: Lentil is one of the world's most important food plants and is particularly so in North Africa and South Asia and parts of North America, Europe and Australia. Consequently the crop is exposed to a broad spectrum of insect species in a wide variety of locations. The management of insect pests of the crop is crucial to optimizing production. The major insect pests of lentil in the field are aphids (*Aphis craccivora* & *Acyrthosiphon pisum*), leaf weevils (*Sitona* spp.), Lygus bugs, (*Lygus* spp.), and the Cutworm, (*Agrotis ipsilon*). Several other insect species are considered as minor field pests which are also noteworthy and include Thrips (*Thrips, Kakothrips,* & *Frankiniella*), Bud weevils (*Apion arrogans*), the pea moth, (*Cydia nigricana*), pod borers, (*Helicoverpa armigera* & *Heliothis* spp.), Lima-bean pod borer, (*Etiella zinckenella*), root aphids (*Smynthurodes betae*) and leaf miners (*Liriomyza* spp. and *Phytomyza* spp.). The most serious and frequently encountered insect pests of the stored grain are *Bruchus ervi* and *B. lentis* with *Callosobruchus chinensis* and *C. maculatus* also widespread. This chapter describes the morphology, lifecycle and crop damage caused by each of the insects pest species on lentil and provides detailed descriptions of management options for each species with references for each recommended action. For most insect species the use of pesticides is the primary management option. However, for some species, there are known sources of host plant resistance, as well as other integrated pest management options including biological control (e.g., beneficial insect predators and biological pesticides) and cultural practices, that can be used to help manage the pests and where known these are also described

1. INTRODUCTION

Lentil, *Lens culinaris* (Medikus) is an important pulse crop which is grown in North America, southern Europe, North Africa, West Asia (including Turkey), the former USSR countries of central Asia, and northern and central parts of India. In India, it is grown on about 1.29 million hectares with an average production of 0.5 million tones, and productivity level of 624 kg/ha (Yadava and Ahmad, 2000). Ethiopia contributes more than 66% of the area and about 60% of the production of lentil in sub-Saharan Africa (Bejiga et al., 2000). In North America where production is concentrated in Canada and Washington State (43% of US production) and yields of around 1300 kg Ha^{-1} $annum^{-1}$ are achieved, measures to control insect pests are effective and well established. Poor crop management and abiotic and biotic stresses reduce yields and are discussed in detail elsewhere in this book. Among the biotic constraints, insect pests play a major role in yield reduction. About three dozen insect pests have been reported to infest lentil under field and storage conditions (Hariri, 1981), out of which 21 species have been reported from India alone (Lal, 1992). However, only some of these are economically important, and require control measures. The field insect pests of note include aphids, *Sitona* weevils, *Lygus* and stinkbugs, cutworms, thrips, bud weevils, and pod borer. During storage, several species of seed beetles inlcuding *Bruchus* spp. and *Callosobruchus* spp. can cause severe damage. The pest status of each species largely depends on the location with different countries and regions reporting different insects. For example, *Aphis craccivora* Koch (Thakur et al., 1984), phycitid, *Etiella zinckenella* Treit. (Singh and Dhooria, 1971; Hammad, 1978) and bruchid, *Callosobruchus chinensis* Linn. (Staneva, 1982) have been reported as the major pests of lentil in India and *Sitona crinitus* Herbst, *Bruchus lentis* Froel., and *E. zinckenella* have been identified as the most important harmful insects of lentil in Turkey (Tamer et al., 1998). Whereas, aphids (*Acyrthosiphon pisum* Harris and *A. craccivora*), unvoluntine bruchid (*Bruchus lentis*), thrips (*Thrips tabaci* and *T. angusticeps*), and leaf weevils (*S. lineatus* L.) are the key pests of lentil in Castilla La Mancha (central Spain) (Perez Andueza et al., 2004) and Lygus bugs are major pests of lentils in the North West of North America. Each species or group of insects (usually related species or genera) are described along with information about biology, damage and control. Photographs are not presented of each pest insect species described since there are more than adequate insect image pages available on the world wide web.

2. MAJOR INSECT PESTS OF LENTIL

2.1. Aphids, *Aphis Craccivora & Acyrthosiphon Pisum*

Cowpea or groundnut aphid, *Aphis craccivora* Koch, and the pea aphid, *Acyrthosiphon pisum* Harris (Homoptera: Aphididae) are the major Hemipteran insect species of lentil in America, Europe, Africa, Australia, and Asia (Manero and L'Argentier 1987; Bejiga and Anbessa, 1993; Weigand et al., 1994; Muehlbauer, 1996; Yadava and Ahmad, 2000; Perez Andueza et al., 2004).

Aphis craccivora is small (2 mm long), soft-bodied, shiny and black, with dull greyish lightly powdered nymphs, and *A. pisum* is slightly larger at 3 to 4 mm long and green in color with characteristically long legs. It lives throughout the year without producing sexual forms. The alates (winged females) that are dispersed largely by wind, reproduce parthenogenetically producing viviparous colonies of apterae (wingless females), which later revert to winged forms for dispersion depending upon overcrowding and deterioration of the host plant. *A. pisum* generally take 9 to 11 days to reach the adult stage and then begins producing live young. An apterous female aphid contains the developing embryos of its grandchildren! This combination of the telescoping of generations and a very short life cycle leads to very rapid population increases under favorable conditions. *A. craccivora* and *A. pisum* are both polyphagous species, with a preference for herbaceous Leguminosae. They feed on the young shoots, leaves, inflorescences and fruits and, in herbaceous plants, also on the stems. Lentil is perhaps not the most suitable host for *A. craccivora* however since the net reproductive rate and post-reproductive period, adult longevity, survival, fecundity, and the lifespan were significantly longer on lentils than on other crops studied by Wale et al. (2000). Daily nymph production was significantly correlated with the minimum temperature on lentil. In autumn, changing photoperiod for *A. pisum* triggers the production of sexual males and females. After mating, the sexual female lays a few large, over-wintering eggs. Each egg hatches into a female nymph who is the first individual of a new clone.

Aphids damage lentil plants directly by feeding on them and more seriously transmit plant viruses. Both nymphs and adults suck the plant sap from the tender leaves, stems and pods, and mostly colonize on the young leaves and growing points, which become characteristically deformed. Host reaction to insect feeding are not characteristic but large populations on young plants can prevent their normal growth, affecting yield. The infestations of crops are always initiated by alate forms produced on preinfested plants. Yield can be drastically reduced, and if infestations are early and severe, plants can be killed, and the diseases transmitted by these aphids are covered elsewhere in this book. Of note however are Alfalfa and Cucumber mosaic viruses (CMV); diseases with broad host spectra that are serious problems in lentils (Latham et al., 2004) in Australia and CMV occurs frequently along with Pea seed-borne mosaic virus on lentils in Pakistan (Mammouk et al., 2001). While these viruses are transmitted via the seed (Latham and Jones, 2001; Jones and Coutts, 1996), the insects are by far the primary route for disease spread in the crop and thus a primary target for control. *Aphis craccivora* also transmits lentil tobacco streak virus (Lal, 1994). Aphids, leaf miners, and semi-loopers were the first dominant group of insect pests during the vegetative and flowering stages (Bhatnagar and Seghal, 1990).

Host plant resistance to bean aphid, *A. craccivora*, and biological control with predatory coccinellids has a potential scope for its management (Sharma and Yadav, 1993) but currently there are no alternative control measures or cultural practices for the management of aphids in lentils. While aphids are attacked by a number of natural enemies, coccinellids especially prevent their rapid reproduction rate and may reduce infestation levels sufficiently. In the event of severe infestations before or at flowering, aphids require control using chemical sprays the most widespread of which is dimethoate (various trade names at 0.5 kg. ha^{-1}) with 14 day PHI. Application in the US and Canada are usually made by air to 100% of the crop (Bragg and Burns, 2006) and subsequent losses to aphids are near 0%. Dimethoate is usually applied for aphids and *Lygus* bugs (discussed below) at the same time. A single spray should be enough for 3 weeks effective control but if reinfestation occurs before pod maturity a second spray may be given. Aphids may infest lentil fields only at a later stage of crop development (podding), where no spray is necessary. Other insecticides (e.g., fenvalerate, malathion, disulfoton, carbaryl, methomyl, methyl parathion, and endosulfan) are registered for control of pea aphid and have been tried by growers. However, none provide cost-effective control comparable to dimethoate. Efforts are, however, being invested in developing alternatives to dimethoate, which, like other organophosphates, is considered environmentally too hazardous (Bragg and Burns, 2001). Seed treatment with imidacloprid was shown to reduce Bean leaf roll virus (BLRV, family Luteoviridae), Faba bean necrotic yellows virus (FBNYV, genus Nanovirus) and Soybean dwarf virus (SbDV, family Luteoviridae) in faba bean and lentil, using artificial inoculation with the aphid vector, *Acyrthosiphon pisum* (Harris). The treatment increased yields of susceptible lentil varieties but not that of lentil varieties reported to be resistant (Makoouk and Kumari, 2001). The U.S. Dry Pea and Lentil Commission and the Washington State Commission on Pesticide Registration have funded research into environmentally more benign chemicals for the control of pea aphid in dry peas, which could translate to lentil. The products with greatest potential include bifenthrin, cyfluthrin, imidacloprid and lambda-cyhalothrin as floral applications made at 50 percent bloom. In addition there is research ongoing to develop thiomethoxam as a seed treatment for the United States and Canada (Bragg and Burns, 2001).

2.2. Leaf Weevils, *Sitona* spp.

Sitona crinitus Herbst (*Sitona macularius* Marsh.) (Coleoptera: Curculionidae) is one of the main insect species attacking lentil in southern Europe, North Africa, West Asia (Turkey, Syria, Lebanon, Jordan), and the former USSR (Solh et al., 1986; El Damir et al., 1999; Perez Andueza et al., 2004). Other related species that attack lentil include *S. lineatus* L. and *S. limosus* Rossi. The adult leaf weevils are distinguished by their grey-brown body (3–4 mm), a pronotum that has three longitudinal light lines and elytra that have three rows of dark and white spots. Females oviposit spherical yellow eggs, which become black with age. The larvae are white, with brown head capsules, and pupae are also white. Over-wintered adults of *S. crinitus* appear in late March and feed on young shoots and leaves (Kaya and Hincal, 1987), while the larvae appear when the climatic conditions are suitable, and have root nodules as food. Females of *S. lineatus* reportedly lived significantly longer than males when maintained as single reproductive pairs, but there were no significant differences between female and male lifespans when adults were kept in groups of 13 reproductive pairs (Schotzko and O'Keeffe, 1988). The spring migration state of the adults and the number of months spent in hibernal quiescence (dormancy) also had a significant effect on adult lifespan. In the Mediterranean region, where hot and dry summers prevail, the adults aestivate in the soil and start emerging in December/January (El Damir et al., 2001). Sometimes, the neonate adults have also been observed to emerge in May, where the lentil matures during this period, and might also feed little on other crops, but then enter the soil to aestivate until early winter. The adults of the previous generation will die in April/May. Thus, there is only one generation per year, and the adults live for almost one year. After mating the females oviposit eggs on the soil around the lentil plants or loosely on the leaves, which later fall to the ground and this can continue for several months with each female laying several hundreds of eggs. Temperature appears to be a critical factor in the emergence of the larvae from eggs and a study by El Damir et al. (2004) revealed that temperatures $< 10\,^{\circ}C$ induce quiescence in eggs of *S. crinitus*. When the larvae do hatch they move into the soil and infest the nodules of the plants and each larva may consume many nodules during development until pupation, which also occurs in the soil. The larval and pupal periods last for between 5–6 and 3–4 weeks, respectively, dependent on local climatic conditions, notably temperature.

While both the adults and larvae of *Sitona* sp. damage the crop, larvae are the main problematic stage. The adult weevils feed on the foliage in a characteristic manner, making semicircular notches from the leaf edges early in the season but this does not usually affect yield. If the insect populations are very high and the growth of the lentil seedlings is retarded by unfavorable environmental conditions then the plant can not compensate the damage to foliage quickly and the crop can consequently suffer economically important damage. The larvae of *Sitona* spp., however, feed on the root nodules and consequently are by far the most serious problem since this affects the capacity of the plant to fix N_2 (Solh et al., 1986). Nodule damage has also been reported to be significantly higher in early-sown than in late-sown lentils (Weigand et al., 1992) thus a late sown crop could lead to reduced damage through escape. Mineral nitrogen does not compensate for the damaged nodules, and fail to supplement fixed nitrogen for yield increase. In severe attacks the foliage can assume the yellow appearance like nitrogen deficiency characteristics. *Sitona crinitus*, *S. macularius*, and *Apion arrogans* are efficient vectors of broad bean stain comovirus (BBSV), while *S. limosus* transmit broad bean mottle bromovirus (BBMV) in lentil (Makkouk and Kumari, 1995) thus potentially pose an additional threat to crop security for farmers and emphasize the importance of managing this pest.

There is a significant and positive correlation between visual damage score and nodule damage by *Sitona* sp. ($r = 0.69$ and 0.75), where visual damage can help evaluate large numbers of genotypes for *Sitona* resistance at the same time under field conditions (El Damir et al., 1999) or determine levels of infestation. The white *Sitona* larvae inside the nodules or empty nodules can be found in uprooted lentil plants. Carbofuran and aldicarb reduce nodule damage significantly

(Solh et al., 1986), and yield increases due to carbofuran application are generally higher in early than in a late sown crop. Seeds of lentil can be treated with Promet^R (Furathiocarb) @ 12 ml/kg seed or granular insecticides may also be applied (e.g., Carbofuran) at planting. The use of carbofuran @ 1.5 kg a.i. ha^{-1} improved both nodulation and grain production (Islam and Afandi, 1982). Seed treatment with Promet (furathiocarb) effectively controls *Sitona*, increases grain and straw yields, and is less disruptive to the environment than insecticide sprays (Weigand et al., 1992, 1994). Rhizobial inoculation and phosphorus application increases lentil productivity in arid locations under Mediterranean environments (Al Karaki, 1996). If no preventive control is taken, and is observed with high infestation, Imidan^R (Phosmet) @ 1 kg a.i. ha^{-1} can be sprayed. This is, however, less effective than granular application and seed treatment. Carbofuran increases nodule mass by significantly reducing *Sitona* nodule damage, and seed protein content slightly, which increases overall protein yield (Islam et al., 1985). Alternatively, chlorpyriphos @ 720 g a.i. ha^{-1} or malathion @ 1 300 g a.i. ha^{-1}, or a systemic insecticide, oxydemeton methyl @ 265 g a.i. ha^{-1} can also be applied in cases of severe infestation (Erman et al., 2005). Application of oxydemeton methyl reduced 41.2 to 52.6 % damage on nodules, and increased seed yield (729 and 1461.6 kg/ha), biological yield (1825.5 to 3521.6 kg ha^{-1}), pods/plant (23.8 to 25.7), 1000-seed weight (47.7 to 48.4 g), plant height (26.1 to 30.0 cm), branches/plant (7.3 to 8.9), root dry weight/plant (0.106 to 0.136 g), and shoot dry weight/plant (0.859 to 1.056 g) over the unsprayed control. Cultivar, 'Yerli Kirmizi' showed low nodule feeding (0.8 to 1.9) by the Sitonid pest, and increased seed yield (712.6 to 1393.3 kg ha^{-1}) over 'Sazak 91 (537.4 to 1301.3 kg ha^{-1}). The water extract of *Melia azedarach* dry fruits extracts at 50 g l^{-1} significantly reduced *S. crinitus* adult damage on lentil leaves for one week (El Damir et al., 2000).

The weevils emerge from the soil after aestivation so crop rotation can reduce the likelihood of successful recolonisation and subsequent infestation to some extent. However, while crop rotation should be encouraged it should also be noted that *Sitona* weevils are strong fliers and can migrate considerable distances thus reinfestation from distance will also occur (Beniwal et al., 1993). Furthermore, weedy fields are more prone to *Sitona* damage so the concurrent management of weeds can help to reduce the problem of Sitonid weevils. Thus early sowing combined with the control of *Sitona* and weeds (cyanazine and pronamide), and P application gives higher net return with virtually no risk of economic loss to the farmer (Pala and Mazid, 1992: and elsewhere in this volume). Formononetin and associated metabolites in red clover act as chemical defenses against adult *S. lepidus* and the distribution of this pest in forage legumes could be manipulated through improvement in root health (Gerard et al., 2005). Isoflavonoid enzymes such as isoflavone reductase have the potential to be selected for high levels of these compounds for less susceptibility of lentils to *Sitona* (Robeson, 1978; Jung et al., 2000). However, no sources of resistance to *Sitona* have yet been found in the lentil germplasm (Erskine et al., 1994). The CryIII toxin expression in nodules resulted in significant reductions in nodule-feeding damage by *S. lineatus* on *Pisum* *sativum* and *S. hispidulus* on *Medicago sativa* (Bezdicek et al., 1994), and could be the new strategic component to produce *Sitona*-resistant lentils. However, since little progress has been made in this respect since then it is likely the technology is either unsuitable or not needed. Bt-toxins from the Centre for Legumes in Mediterranean Agriculture (CLIMA) collection have been used to screen adult insects and larvae of *Sitona* at ICARDA but the strains were only found effective against adult insects, not against larvae (Baum, 2000). There is presently no transgenic material available to or being used by farmers to manage *Sitona* weevils.

2.3. Lygus Bugs, *Lygus* spp.

Lygus bugs are a major pest in lentil production particularly in the North West of North America. In northern Idaho, more than 20 species of lygus bug have been identified on 70 species of plants with the most abundant being *L. hesperus* and *L. elisus*. The adult bugs are about 6 mm long, flattened, oval, and of various colors from pale green to yellowish brown. Lygus bugs survive the winter protected in ground litter, crop residues and buildings. They emerge soon after the snow melts in spring, and feed on winter annuals and the buds of flowering shrubs. Adults lay eggs in the spring and feed on various plants (Fuchs and Hirnyck, 2000). In Canada, over-wintering adults can be abundant in canola especially if the crops are in bud or flower and other hosts are not yet available. Eggs hatch into nymphs in about 10 days and reach maturity within one month and only a single generation develops on lentils. Immature *Lygus* bugs (nymphs) are light green and wingless. Several black spots, usually five, appear on their backs as they moult or mature through five instars before becoming adults. Wing buds are evident in fourth and fifth instars. In late summer, the new generation adults disperse from mature canola fields into later maturing hosts, such as alfalfa, and continue feeding until they migrate to over-wintering sites. In the South, the new generation adults first appear by about the end of June (Fuchs and Hirnyck, 2000, Bragg and Burns, 2000).

Finding *Lygus* successfully in the field is critical to prevent damage to the crop. Because lentils lie close to the ground sweeping with a net is an ineffective scouting practice and will often miss the presence of *Lygus*. Economic thresholds have been established for lygus bug control. When lentils are in bloom, and podding has begun, sweep nets can be used to determine quantity of adult bugs with 1 lygus bug for every 3 sweeps considered worthy of insecticide treatment. Close examination of the plants, however, is the only way to find *Lygus* bugs, which are usually found under the curly leaves of the lentil plants in the daytime, and rarely seen on the visible portions of the crop. Any presence of the bugs just before or during bloom justifies treatment according to the lentil industry (Fuchs and Hirnyck, 2000, Bragg and Burns, 2000). *Lygus* bugs pierce tender leaves, stems, buds, petioles, and developing seeds but are considered to be a serious pest of lentils primarily owing to the seed damage known as chalky spot syndrome which is characterized by pitted, crater-like depressions in the seed coat with or without a discolored chalky appearance. Chalky spot results in significant economic losses to the producer by reducing market price/value. Lentils with more than 3.5% chalky spot damage are graded and their value is discounted according to the level of the symptoms. Yield reduction due to either direct feeding or chalky spot can range up to 50%, and without control measures reductions in yield are about 30% (Fuchs and Hirnyck, 2000).

Lygus bugs have several natural control agents including a fairy wasp, in the family *Mymaridae*, that appears to remain unidentified according to the literature. It parasitizes the eggs of the bug (Jones, 1999). In addition a parasitic wasp, *Peristenus pallipes* attacks lygus nymphs but its effectiveness is not well documented (Baird, 2000). A European species, *P. digoneutis* has been introduced into alfalfa fields in eastern North America where it parasitizes about 40% of the tarnished plant bugs (Day and Mahr, 1999, Jones, 1999). One of the few parasitoids of lygus adults is a tachinid fly, *Alophorella sp.*, and nabid plant bugs, big-eyed bugs and spiders occasionally prey on young lygus bug nymphs. Cultural control programs for lygus bug are only partially effective because the target insect is supported by a variety of hosts. The continuity of plant hosts support lygus bugs throughout their life cycle. Disturbing habitat by disking near fencerows and mowing roadsides can potentially lower lygus bug numbers, but also will injure over-wintering populations of beneficial insects (Fuchs and Hirnyck, 2000). Treatment for *Lygus* bugs almost invariably takes place when treatment for pea aphid is carried out in North America to where its pest status is restricted. This usually occurs at 50 percent bloom, and the rate of dimethoate used for aphid control (0.5 lb a.i./ha) is adequate for *Lygus* control (Bragg and Burns, 2001).

2.4. The Cutworm, *Agrotis Ipsilon*

Agrotis ipsilon (Hufnagel) (Lepidoptera: Noctuidae) is a worldwide polyphagous pest, the larvae of which attack leaves, stems, and roots of many agricultural crops, including lentil although among leguminosae it is a more serious pest on soybean. It is also a pest on cauliflower, cotton, maize, strawberry, tomato and grapevine, which gives an indication of the breadth of its food source. The scientific name comes from the marking on the forewing of the adult, which resembles the Greek character ipsilon. The adult moths are grey-brown with a 40 mm wingspan, forewings are light brown, patterned with an ipsilon shape, and the hind wings are creamy white with brown edges. The females' lay over 1000 eggs in clutches of a dozen or so on leaves and even on soil. The eggs hatch after about 5 days (Beniwal et al., 1993). The young larvae, which like the adults are nocturnal, are green or greyish, becoming dark green or grey with age, and marked with two bright lines. Larvae remain below the surface of the ground, under clods of soil, or other shelters during the day. The first two larval stages feed on the foliage of the plant. The third and later stages often become cannibalistic and thus adopt solitary habits (Hill, 1983). They grow to as much as 50 mm in length when they can be found coiled round a damaged plant. Mature larvae bury deeply into the ground and pupate within cells, from which the adults emerge. Depending on the climate there might be one or several generations per year.

The older larvae cut the plant above the root crown. Most of the plant is not consumed after cutting, and larvae move to another plant leaving the earlier one to wither and dry. Some species feed on the upper leaves before moving to the soil surface. The abundance of *A. ipsilon* in some areas is partly affected by rainfall. In the drier areas (e.g., Syria) infestations are lower in years with high rainfall. In fact, flooding fields is recommended as a control measure in some cases. Deep ploughing of fields between crops turn up larvae and pupae to the soil surface making them susceptible to predators and sun. Weed hosts on outlying areas are often preferred sites of oviposition and serve as food for the cutworms in off-season. Cutworms are often difficult to control, especially when populations are epidemic in proportion. Large populations may cause severe crop damage with indications that the pest is the black cutworm. Unfortunately, by the time the pest is identified, the cutworms would have already developed into a life stage, which is not as susceptible to insecticides as the early larval stages. The sporadic nature of cutworm populations can make preventive treatments futile. And of course their soil-dwelling habits often beneath heavy foliage make control difficult with insecticides since they do not to reach the target (Hill, 1983). One way to control cutworms is to broadcast a poison bait prepared with wheat bran, cotton, or groundnut cake, moistened with water and trichlofon (Dipterex), carbaryl (Sevin) and Parathion @ 10 kg/ha in the evening (Bakr, 1994).

3. MINOR PESTS

3.1. Thrips, *Thrips, Kakothrips*, and *Frankiniella*

Thrips (*Thrips tabaci* Lindeman, and *T. angusticeps* Uzel) are the key pests of lentil in Castilla La Mancha (central Spain) (Perez Andueza et al., 2004), and Turkey (Tunc et al., 1999). However, several other species of thrips such as *Kakothrips robustus* (Uzel), *T. angusticeps*, and *Frankiniella* spp.. (Thysanoptera: Thripidae) have also been reported to infest lentil in most lentil-growing areas, but rarely cause serious damage (Beniwal et al., 1993). Thrips are minute (1 to 2 mm), elongate insects with four extremely slender wings in which the developmental stages resemble the adults, but are lighter coloured and wingless. Thrips attack leaves, flowers and pods by puncturing the plant organs and sucking up the sap, causing silvery blotches and dashes. As the attack increases the leaves and flowers become distorted and under heavy infestation can occasionally cause serious economic damage.

Removing volunteer soybean plants from the lentil crop is critical, since volunteer soybean plants have been reported to be the source for the thrips outbreak in lentil (Singh and Singh, 1994). Early maturing and small seeded genotypes of lentil have been reported to be more susceptible to thrips in Bangladesh (Sardar and Ahmad, 1991) but generally thrips are not a major field pest of lentil. Under greenhouse conditions thrips can appear in high numbers and cause severe damage on lentil plants grown for experimental purposes. Insecticides, Zolon, Nogos, and Sevin @ 0.025% effectively controls thrips in lentil (Sardar, 1990). Application of an insecticide for sucking insects (e.g., deltamethrin, malathion, dimethoate or endosulfan) will otherwise also provide good control (Beniwal et al., 1993).

3.2. The Bud Weevil, *Apion Arrogans*

Bud weevils infest several leguminous crops including lentil. Of particular relevance to the Mediterranean region is *Apion arrogans* Wenck. and *A. trifolii* (L.) from Europe, former USSR, and Southwest Asia. Adult *A. arrogans* weevils are about 3 mm long and the snout is characteristically longer than the body. The species also characteristically has long legs. The adults have dark blue elytra with black head, thorax, legs and abdomen. Larvae are yellow and legless. There is no published information on the life cycle of *A. arrogans*. Adult weevils feed on lentil leaves making small holes, but the main source of damage is caused by the larvae feeding on the buds and flowers whereby the ovules are destroyed (Beniwal et al., 1993). The bud weevil, *A. arrogans* has also been reported to transmit broad bean mottle virus (BBMV) in lentil (Makkouk and Kumari, 1989, 1995). Buds and flowers dry up and drop off. Inside the buds the larvae of *A. arrogans* can be found, which feeds on the developing seeds. Infestation levels are usually not high enough to warrant control measures, but in the occasional years when localized population densities are high methidathion at 0.5 kg a.i. ha^{-1} and monocrotophos at 2 ml L^{-1} can provide control.

3.3. The Pea Moth, *Cydia nigricana* (Fab.)

The pea moth is primarily a pest of field pea in North America, Europe and the Mediterranean, but it may also attack lentil. The adult is small compared to many Lepidoteran pests of Legumes (15 mm wingspan) and is brown with short, black and white lines along the front edge of the of the forewings. The larvae are pale off white with dark spots and short hairs and up to 12 mm long. The larvae over winter in a silk cocoon below the soil surface and pupate in spring. Adults appear at flowering and lay eggs on plants, after which larvae bore into the pods. Fully grown larvae drop to the soil to aestivate/hibernate (Beniwal et al., 1993). The larvae eat the seeds, and the damage often remains undetected until the pods are opened. Infestations are not severe enough to require control measures. However, since this insect directly affects the seeds and thus yield, insecticide application might be necessary sometimes. Sprays of methidathion (0.5 kg a.i./ha), deltamethrin (38 g a.i./ha), and endosulfan (6 ml/L) at the time of flowering/early pod setting can provide adequate control (Darty and Wimmer, 1983).

3.4. Pod Borers, *Helicoverpa armigera* (Hb.) & *Heliothis* spp. (Lepidoptera: Noctuidae)

Pod borers are arguably the most economically significant insect pest in the world owing to their widespread occurrence and broad spectrum of hosts. They are however only a minor pest of lentil in West Asia and the Indian subcontinent and do not present a serious threat to yield as they do in other crops such as chickpea (Stevenson et al., 2005). The adults are large and brown and up to 20 mm long, are active at night and lay hundreds of eggs singly on the underside of leaflets. Larvae can reach 40 mm, and have different and quite attractive coloration, but mostly green. Fully grown larvae, usually 6th instars drop to the soil to pupate. The larvae cause damage to the leaves with young instars scraping the surface of leaflets and feeding on flowers, while older larvae feed on foliage and more damagingly on pods. Control measures are rarely needed, however, as with *Cydia* spp. since this insect directly affects the seeds and consequently yield, insecticide application may occasionally be necessary using methidathion (Supracide^R @ 0.5 kg a.i./ha), deltamethrin (Decis @ 38 g a.i./ha) (Beniwal et al., 1993) and endosulfan (Thiodan 35 @ 3 ml/L) at the time of flowering/early pod-setting (Stevenson et al., 2005). Technologies for managing *H. armigera* with biopesticides such as *Helicoverpa armigera* Nucleopolyhedrosis Virus (HaNPV) are also proven and provide a viable alternative to chemical control strategies for this pest (Jayaraj et al., 1987, Cherry et al., 2000).

3.5. Lima-Bean Pod Borer, *Etiella Zinckenella* (Treit.) (Lepidoptera: Pyralidae)

The Lima-bean pod borer is an important insect pest of leguminous crops including lentil in USA, Europe, North and East Africa, Southwest Asia, India, and Pakistan. The mean egg, larval, pre-pupal and pupal life stage periods of *E. zinckenella* on lentil have been reported to be 5.4, 17.2, 2.3 and 13.8 days, respectively (Jaglan et al., 1995, 1996) and the fecundity per female is reportedly in the region of 60 eggs. The adult moths are 10 to 12 mm long with a wingspan of 22 to 28 mm. The forewings are brown-gray with a white anterior margin, while the hind wings are lighter. The larvae attain 10 to 12 mm length, and are greenish, with a brown line and head capsule. Mating takes place at night or in dark places, and females survive longer than males (Jaglan et al., 1995, 1996) albeit only for one week. Eggs are laid near the calyx of the flowers or on pods. The larval period lasts for 2 to 3 weeks after which the larvae pupate in the soil. Larvae are also known to diapause in winter. It completes 3 to 5 generations per year. The larvae feed on the soft green seeds in the pods even up to whole pod destruction but usually infestations rarely require control measures. Host plant resistance can contribute towards the pest management of *E. zinckenella* in lentil since some variation in infestations has been reported. For example, short duration genotypes have been reported to have higher larval population of *E. zinckenella* (Dashad et al., 2005). Minimum pod infestation was observed in LH 90–39, and was categorized as least susceptible (Jaglan et al., 1993), while LL 147 was considered tolerant to *E. zinckenella* damage (Brar et al., 1989). Short duration genotypes have been reported to have higher larval population of *E. zinckenella* (Dashad et al., 2005). Cultivars P 927 and P 202 proved to be resistant to the borer with a substantial increase of

52.9 and 43.5% yield over L 9–12, respectively (Chhabra and Kooner, 1970). Since this insect directly affects the seeds and thus yield, insecticide application might be necessary sometimes. Sprays of methidathion (Supracide[R] @ 0.5 kg a.i./ha), deltamethrin (Decis @ 38 g a.i./ha), endosulfan (Thiodan 35 @ 6 ml/L) at the time of flowering/early pod-setting can provide adequate control.

3.6. The Root Aphid, *Smynthurodes betae* Westwood (Homoptera: Aphididae)

Root aphids have been reported infesting lentil from Iran (Rezwani, 1995), Turkey and Syria (Bayaa et al., 1998). In some years yellow patches can be found in lentil fields that are caused by this and are visible as white woolly aphids on the roots. It is a heteroecious species with a 2-year cycle and forms yellowish to red galls on the primary host pistachio by rolling the leaf edge into a spindle near the leaf base. The root aphid is rarely regarded as economically important.

3.7. Leaf Miners, *Liriomyza* and *Phytomyza*

Several species of leaf miner such as, *Liriomyza* spp., *Phytomyza* spp. etc. (Diptera: Agromyzidae) have been reported occasionally as pests of lentil in West Asia, North Africa, and South America (Tamer et al., 1998, Weigand et al., 1994). *Liriomyza* spp. notably has attained a status as an important pest of lentil in Egypt (Ismail et al., 1995, Attia, 1997). The larvae feed inside the leaves and produce discoloured mines in which larvae can be seen during heavy infestations, the leaves are curved upward forming a cup shape, and sometimes lead to defoliation. The fully-grown larvae pupate in the soil and sometimes in the cup shaped leaves. The adult females lay eggs in the leaf tissues. Infestations are rarely heavy enough to warrant control measures.

4. STORAGE PEST INSECTS

The most serious and frequently encountered insect pests of stored lentils are *Bruchus ervi* Froel. (Coleoptera: Bruchidae), occurring in Europe, North Africa, and Southwest Asia; and *B. lentis* Fab., in the USA, Europe, North Africa, Southwest Asia, and India although other species do occur including *Callosobruchus chinensis* (L.), and cowpea seed beetle, *C. maculatus* (F.) (Coleoptera: Bruchidae). A 10 year study (1991–2000) of around 2517 samples of *Lens* spp. from over 40 countries that were processed for quarantine clearance at the National Bureau of Plant Genetic Resources, New Delhi, revealed through X-ray screening for infestations that one of these 4 species of bruchids occurred in about 30% of the samples. The studies also revealed the presence of *B. tristiculurs* Fahraeus, *Callosobruchus analis* (Fabr.) (Bhalla et al., 2004).

4.1. *Bruchus* spp.

B. ervi and *B. lentis* are both about 3 to 3.5 mm long and differ in that the elytra of the former are black with light brown hairs and whitish spots whereas *B. lentis* adults have dense and reddish grey hairs on the back, marked with several whitish spots. The larvae of both are light yellow with dark brown heads. The adults infest fields at flowering, where they feed on nectar and pollen. Yellow transparent eggs are oviposited on the young pods and upon hatching, the larvae penetrate the pod and feed on developing seeds. The larval period may last 6 weeks where upon the larvae eat an exit hole leaving only a thin circular window of epidermal membrane intact. After pupation the emerging adult opens this membrane and leaves the pod. Adults re-enter the seed or remain in other protected places for hibernation until the flowering the following season and some may remain in the dry seed until the seeds are planted. Thus there is only one generation per year and no eggs are laid on dry seeds, and there is no reproduction during storage. Fumigation of infested seeds with phosphine (Phostoxin) before storage can control infestations in the following crop. Every effort should be made to avoid planting infested seeds. Applications of two sprays (one before 50% flowering, and second 15 days later) of either of the insecticides, endosulfan (Thiodan 35) @ 4 ml/L, alpha capamethrin (Fasctac EC 10) @ 0.25 ml/L, or Methyl parathion (Metyphon EC 50) @ I ml/L, provide adequate control from lentil seed beetle (Beniwal et al., 1993).

4.2. *Callosobruchus* spp.

Both species of *Callosobruchus* are widespread, and have been reported from all continents with sub-tropical or tropical conditions (USA, Mediterranean, Asia, and Australia). The adults are similar in length to *Bruchus* but *C. chinensis* has characteristic triangular white spot at the base of the thorax, and elytra are rust coloured with two brown spots, while those of *C. maculatus* are black tipped with a large round spot. These species mainly occur in the stored seed but occasionally infest fields that are close to harvest. Although a pest of stored lentil *Callosobruchus* spp. prefer other legumes such as chickpeas and garden pea and this is attributed to the levels of moisture, proteins and phenols in the seed-coat (Bhattacharya and Banerjee, 2001). The eggs are laid on the seed coat with several eggs per seed and the emerging larvae hatch through the base of the egg and bore straight through the seed coat. The white larvae develop and pupate inside the seed with one generation complete in 3 to 4 weeks. Thus, these insects reproduce very rapidly and can consequently cause considerable damage to stored products including lentil.

Stores should be clean from all residues of earlier stored products and may be de-infested with malathion. The seed should also be free from straw, stones, pebbles, and flour and other implements such as threshers and vehicles should be properly cleaned. Stored seeds can be enclosed in polythene and fumigated with phospine (Phostoxine) which controls all insect stages, leaves no residue so is safe for seeds stored for food, and does not adversely affect taste or germination. Seeds stored for planting can also be treated with Actellic @ 4 to 10 ppm a.i. (0.5 g/kg seed) or malathion @ 10 ppm a.i., which will protect the seeds for several months. Mixing seeds with olive oil and salt (5 ml and 20 g/kg seed) or Neem seed oil (3 ml/kg seed) can provide adequate control for a period of 3 to 4 months (Beniwal et al., 1993). In addition, extracts of *Clerodendron siphonanthus* reportedly reduces the number of eggs laid on the seed surface of stored lentil and may provide an alternative pesticidal plant option for farmers (Pandey and Khan, 1998). *Callosobruchus chinensis* is also susceptible to biological control measures and specifically the parasitic wasp, *Dinarmus basalis* (Rond.), which can completely control the pest among red lentil when introduced at between 30 to 50 pairs in a 50 m^2 room depending on the time of year (Islam and Kabir, 1995). A dose of 1 kGy of gamma radiation completely killed *C. chinensis* within a week, and was indicated to be a suitable alternative control measure for *C. chinensis*. The dose was also sufficient for the management of other pests including *Tribolium castaneum* Herbst) and *Rhizopertha dominica* Fabricius (Roy and Prasad, 1993). There are countless other non chemical approaches for controlling species of *Callosobruchus* in the literature but most reports are on the control of *C. maculatus* infesting cowpea. Of all those reported, Neem is probably the most accepted alternative to fumigation and chemical control (Lale and Mustapha, 2000).

REFERENCES

Al Karaki, G. 1996. N Effects of phosphorus, *Rhizobium* and *Sitona* weevil control on seed growth, nodulation and yield of lentil under Mediterranean rainfed conditions. *Legume Research* 19: 201–210.

Attia, M.B. 1997. Ecological and control studies on the serpentine leaf miner, *Liriomyza trifolii*, Burgess, Diptera: Agromyzidae on lentil in Sharkia governorate, Egypt. *Minufiya Journal of Agricultural Research* 15: 1047–1057.

Baird, C.R. 2000. Using Parasites to Manage *Lygus* in the Pacific Northwest. Proceedings, Lygus Summit, 28 November 2000. Visalia, CA, University of CA Division of Agriculture and Natural Resources. http://www.uckac.edu/cottonipm/PDF_files/summit_papers/baird.pdf (accessed 17 August 2006)

Bakr, M.A. 1994. Plant protection of lentil in Bangladesh [*Lens culinaris*]. In: W. Erskine and M.C. Saxena (eds.), Lentil in South Asia, Proceedings of the Seminar on Lentil in South Asia, Indian Council of Agricultural Research, New Delhi, India: International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo (Syria), p. 177–186.

Baum, M. 2000. Pulse Transformation technology transfer. Unpublished report. http://www.aciar.gov.au/web.nsf/projectprint/ACIA-6SF23N?opendocument. Last accessed 17 August 2006.

Bayaa, B., Kumari, S.G., Akkaya, A., Erskine, W., Makkouk, K.M., Turk Z.O. and Zberk, I. 1998. Survey of major biotic stresses of lentil in South-East Anatolia, Turkey. *Phytopathologia Mediterranea* 37: 88–95.

Bejiga, G. and Anbessa, Y. 1993. Genetics and breeding research in lentil [*Lens culinaris*]. In: First National Cool-season Food Legumes Review Conference, 16–20 December, 1993, Addis Abeba, Ethiopia, South Africa.

Bejiga, G., Degago, Y. and Knight, R. 2000. Region 4: Sub-Sahara Africa. In: Linking research and marketing opportunities for pulses in the 21st Century, Proceedings of the Third International Food Legumes Research Conference, Adelaide, Australia, 22–26 September 1997. *Current Plant Science and Biotechnology in Agriculture* 34: 99–105. Kluwer Academic Publishers, Dordrecht, Netherlands.

Beniwal, S.P.S., Bayaa, B., Weigand, S., Makkouk K.H. and Saxena M.C. (1993) Field guide to lentil diseases and insect pests. http://www.icarda.org/Publications/Field_Guides/Lentil/Lentil.htm.

Bezdicek, D.F., Quinn, M.A., Forse, L., Beck, D.P., Weigand, S., Muehlbauer, F.J. (ed.) and Kaiser, W.J. 1994. Cloning *Bacillus thuringiensis* toxin genes for control of nodule-feeding insects. In: Expanding the production and use of cool season food legumes, Proceedings of the Second International Food Legume Research Conference on pea, lentil, faba bean, chickpea, and grasspea, Cairo, Egypt, 12–16 April 1992, pp. 738–752.

Bhalla, S., Kapur, M.L., Singh, C., Gupta, K., Kumar, N. and Lal, B. 2004. Interception of bruchids in imported lentil (Lens spp) germplasm. *Indian Journal of Agricultural Sciences* 74 (6): 332–333.

Bhatnagar, A. and Seghal, V.K. 1990. Incidence and seasonal occurrence of insect fauna associated with lentil crop in northern India. *Lens Newsletter* 17: 21–26.

Bhattacharya, B., Barik, A. and Banerjee, T.C. 2001. Bioenergetics and water balance in *Callosobruchus maculatus* (F.) (Coleoptera : Bruchidae) larval populations. *Oriental Insects* 37: 423–437.

Bragg, D. and Burns, J.W. 2000. Crop Profile for Lentil in Washington State. http://www.ipmcenters.org/cropprofiles/docs/WALentils.html (accessed 16 August 2006).

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 (accessed 16 August 2006).

Brar, J.S., Verma, M.M., Sandhu, T.S., Singh, B. and Gill, A.S. 1989. LL 147 variety of lentil (*Lens culinaris* L.). *Journal of Research, Punjab Agricultural University* 26: 170.

Cherry, A.C., Rabindra, R.J., Grzywacz, D., Kennedy and Sathiah, R. 2000. Field evaluation of *Helivoverpa armigera* – NPV formulations for control of chickpea pod borer, *H. armigera* (Hubn.) on chickpea (*Cicer arietinum* var Shoba) in Southern India. *Crop Protection* 19: 51–60.

Chhabra, K.S. and Kooner, B.S. 1970. Field resistance in some lentil cultivars against pod borer *Etiella zinckenella* Treit. *LENS Lentil Experimental News Service* (Canada) 7: 46–49.

Darty, J.M. and Wimmer, F. 1983. Lentil: Control of the pea midge and the peamoth (*Contarinia lentis*). *Phytoma* 347: 29–31.

Dashad, S.S., Kumar, Y. and Dahiya, B. 2005. Evaluation of small seeded lentil genotypes of different maturity groups against *Etiella zinckenella* Tr. *Research on Crops* 6: 332–336.

Day, W. and Mahr, S. 1998. *Peristenus digoneutis*, parasite of tarnished plant bug. *Midwest Biological Control News Online*. http://www.entomology.wisc.edu/mbcn/kyf510.html (17 August 2006).

El Damir, M., El Bouhssini, M. and Al Salti, M.N. 1999. A simple screening technique of lentil germplasm for resistance to *Sitona crinitus* H. (Coleoptera: Curculionidae) under artificial infestation. *Arab Journal of Plant Protection* 17: 33–35.

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 Journal of Plant Protection* 18: 64–67.

El Damir, M., Al-Salti, M.N. and El Bouhssini, M. 2001. Ecology and biology of *Sitona crinitus* H. in northern Syria. *Bassel Al-Assad Journal for Engineering Sciences* 14:109–119.

El Damir, M., El Bouhssini, M. and Al Salti, M.N. 2004. Embryo development and egg hatching of *Sitona crinitus* Herbst (Coleoptera: Curculionidae) under constant temperature regimes. *Pakistan Journal of Biological Sciences* 7(7): 1191–1193.

Erman, M., Yardm, E.N. and Kulaz, H. 2005. Effect of cultivars and insecticides on sitonid weevil, *Sitona crinitus* (Coleoptera: Curculionidae), and on yield, yield components and nodulation of lentil (*Lens culinaris*). *Indian Journal of Agricultural Sciences* 75: 204–206.

Erskine W, Tufail M, Russell A, Et Al. 1994. Current and Future Strategies in Breeding Lentil for Resistance to Biotic and Abiotic Stresses. *Euphytica* 73 (1–2): 127–135.

Fuchs, S.J. and Hirnyck, R.E. 2000. Crop Profile for Lentil in Idaho State. http://www.ipmcenters.org/cropprofiles/docs/IDlentils.html (accessed 17 August 2006).

Gerard, P.J., Crush, J.R. and Hackell, D.L. 2005. Interaction between *Sitona lepidus* and red clover lines selected for formononetin content. *Annals of Applied Biology* 147 (2): 173–181.

Grzywacz, D., Rabindra, R.J., Brown, M., Jones, K.A. and Parnell, M. 2002. The *Helicoverpa armigera* NPV production manual. NRI Report 2706, University of Grenwich. 130pp.

Hammad, S.M. 1978. Pests of grain legume and their control in Egypt. In: Pest of grain legumes: Ecology and control. Academic Press Inc., New York, pp. 135–137.

Hariri, G. 1981. Insect and other pests. In: C. Webs and G. Hawtin (eds.), Lentils. Commonwealth Agricultural Bureau, England, pp. 173–189.

Hill, D.S. 1983. *Agrotis ipsilon* (Hfn.). In: Agricultural Insect Pests of the Tropics and Their Control, 2nd Edition. Cambridge University Press, Cambridge, London, New York, New Rochelle, Melbourne, Sydney, pp. 357–358.

Islam, W. and Kabir, S.M.H. 1995. Biological-Control Potential of *Dinarmus-Basalis* (Rond) (Hymenoptera, Pteromalidae), A Larval-Pupal Ectoparasitoid of the Pulse Beetle, *Callosobruchus chinensis* (L). *Crop Protection* 14 (6): 439–443.

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 Newsletter* 12: 32–36.

Islam, R. and Afandi, F. 1982. Effect of some insecticides on nodulation and yield of two lentil cultivars. *Lentil Experimental News Service ICARDA (Syria)* 9: 24–25.

Ismail, I.I., Sharaf, E.I. and Din, A.A.A. 1995. Susceptibility of lentil varieties and strains to infestation with *Bemisia tabaci* Genn *Aphis craccivora* (Koch.) and *Liriomyza congesta* Becker in Egypt. *Zagazig Journal of Agricultural Research* 21: 269–277.

Jaglan, M.S., Sucheta, Khokhar, K.S. and Solanki, I.S. 1993. Screening lentil for susceptibility to *Etiella zinckenella* Treitschke infestation [*Lens culinaris*]. *Lens Newsletter* 20: 13–14.

Jaglan, M.S., Sucheta, Khokhar, K.S. and Kumar, S. 1995. Biology of lentil pod borer, *Etiella zinckenella* Treitschke on lentil and pea. *Annals of Biology*, Ludhiana 11: 224–228.

Jaglan, M.S., Sucheta and Khokhar, K.S. 1996. Lentil pod borer (*Etiella zinckenella* Treitschke), biology on lentil and pea. *Lens Newsletter* 23: 48–51.

Jayaraj, S., Rabindra, R.J. and Santharam, G. 1987. Control of *Heliothis armigera* (Hubner) on chickpea and lablab bean by nuclear polyhedrosis virus. *Indian Journal of Agricultural Science* 57: 738–741.

Jones, J. 1999. Lygus Bugs in Canola. Agdex 622–20. May 1999, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex741?opendocument (accessed 17 August 2006).

Jones, R.A.C. and Coutts, B.A. 1996. Alfalfa mosaic and cucumber mosaic virus infection in chickpea and lentil: incidence and seed transmission.*Annals* of Applied Biology 129: 491–506.

Jung, W., Yu, O., Lau, S.M.C., O'Keefe, D.P., Odell, J., Fader, G. and McGonigle, B. 2000. Identification and expression of isoflavone synthase, the key enzyme for biosynthesis of isoflavones in legumes. *Nature Biotechnology* 18 (2): 208–212.

Kaya, N. and Hincal, P. 1987. Population fluctuations and damage by the lentil leaf weevil (*Sitona crinitus* Herbst.) (Coleoptera: Curculionidae) in Denizli. Turkiye I. Entomoloji Kongresi Bildirileri, 13–16 Ekim, 1987, Ege Universitesi, Nornova, Izmir, pp. 259–266.

Lal, S.S. 1992. Insect pest of lentil and their management review. *Agricultural Review* 13: 225–232.

Lale, N.E.S. and Mustapha, A. 2000. Efficacy and acceptability of neem (*Azadirachta indica* A. Juss) seed oil and pirimiphos-methyl applied in three storage devices for the control of *Callosobruchus maculatus* (F.) (Coleoptera : Bruchidae). *Journal of Plant Diseases and Protection* 107 (4): 399–405.

Latham, L.J. and Jones, R.A.C. 2001. Alfalfa mosaic and pea seed-borne mosaic viruses in cool season crop, annual pasture, and forage legumes: susceptibility, sensitivity, and seed transmission. *Australian Journal of Agricultural Research* 52 (7): 771–790.

Latham, J.J., Jones, R.A.C. and Coutts, B.A. 2004. Yield losses caused by virus infection in four combinations of non-persistently aphid-transmitted virus and cool-season crop legume. *Australian Journal of Experimental Agriculture* 44 (1): 57–63.

Makkouk, K.M. and Kumari, S.G. 1989. *Apion arrogans*, a weevil vector of broad bean mottle virus [*Vicia faba*]. *Fabis Newsletter* 24: 26–27.

Makkouk, K.M. and Kumari, S.G. 1995. Transmission of broad bean stain comovirus and broad bean mottle bromovirus by weevils in Syria. *Journal of Plant Diseases and Protection* 102: 136–139.

Makkouk, K.M. and Kumari, S.G. 2001 Reduction of incidence of three persistently transmitted aphid-borne viruses affecting legume crops by seed-treatment with the insecticide imidacloprid (Gaucho (R)). *Crop Protection* 20: 433–437

Makkouk, K.M., Bashir, M., Jones, R.A.C. and Kumari, S.G. 2001. Survey for viruses in lentil and chickpea crops in Pakistan. *Journal of Plant Diseases and Protection* 108: 258–268.

Manero, E.A. de and L'Argentier, S.M. de. 1987. Aphididae and Thripidae injurious to lentil crop in the Jujuy Province. *Revista de Investigacion Centro de Investigaciones para la Regulacion de Poblaciones de Organismos Nocivos* 5: 17–26.

Muehlbauer, F.J. 1996. Advances in the production of cool season food legumes. *American Journal of Alternative Agriculture* (USA) 11: 71–76.

Pala, M. and Mazid, A. 1992. On-farm assessment of improved crop production practices in northwest Syria. 2. Lentil. *Experimental Agriculture* 28: 185–193.

Pandey, S.K. and Khan, M.B. 1998. Inhibitory effect of biopesticide on development of pulse weevil, *Callosobruchus chinensis* (L.) on lentil, *Lens esculentis* through injection method. *Journal of Advanced Zoology* 19: 94–98.

Perez Andueza, G., Mozos Pascual, M. de los and Portillo Rubio, M. 2004. Main pests of lentil (*Lens culinaris* Medikus) in Castilla La Mancha (central Spain): crop losses and influence on yield parameters. *Boletin de Sanidad Vegetal, Plagas* 30: 763–772.

Rezwani, A 1995. The sugar beet root aphids of Iran. *Journal of Entomological Society of Iran* 15: 45–51.

Robeson, D.J. 1978. Furanoacetylene And Isoflavonoid Phytoalexins in *Lens culinaris. Phytochemistry* 17 (4): 807–808.

Roy, M.K. and Prasad, H.H. 1993 Gamma-Radiation in the Control of Important Storage Pests of 3 Grain Legumes. *Journal of Food Science and Technology (Mysore)* 30 (4): 275–278.

Sardar, M.M.A. 1990. Insect pests reaction to various genotypes of lentil and bean and intervention of control tactics in Bangladesh. *Bangladesh Agricultural University Research Progress* (Bangladesh) 4: 8–14.

Sardar, M.M.A. and Ahmad, M. 1991. Genotypical evaluation of major pests on lentil and lablab bean in Bangladesh. *Bangladesh Agricultural University Research Progress* (Bangladesh) 5: 225–231.

Schotzko, D.J. and O'Keeffe, L.E. 1988. Effects of food type, duration of hibernal quiescence, and weevil density on longevity of *Sitona lineatus* (Coleoptera: Curculionidae). *Journal of Economic Entomology* 81: 1631–1636.

Sharma, R.P. and Yadav, R.P. 1993. Response of lentil varieties to the incidence of bean aphid (*Aphis craccivora* Koch.) and its predatory coccinellids. *Lens Newsletter* 20: 60–62.

Singh, H. and Dhooria, M.S. 1971. Bionomics of pea pod borer, *Etiella zinckenella* (Treit). *Indian Journal of Entomology* 33: 123–130.

Singh, K.J. and Singh, O.P. 1994. Role of volunteer soybean plants in the outbreak of thrips, *Megalurothrips distalis* (Karny), on lentil in India [*Lens culinaris*]. *Lens Newsletter* 21: 41–42.

Solh, M.B., Itani, H.M. and Kawar, N.S. 1986. The effect of *Sitona* weevil on nodulation and yield of lentils and the implication of certain control measures. *Lebanese Science Bulletin* 2: 17–27.

Staneva, E. 1982. Studies on the food plants of the cowpea weevil, *Callosobruchus maculates* F. (Coleoptera: Bruchidae). *Revista Zashchita* 19: 111–119.

Stevenson, P.C., Pande, S., Neupane, R.K., Chaudary, C.N., Bourai, V.A., Narayana Rao, J. and Grzywacz, D. 2005. The adoption of Integrated Crop Management Technologies for Chickpea by Poor Farmers in Nepal. pp. 135–142. In Pande, S., Stevenson P.C., Neupane, R.K. and Grzywacz, D. (Eds). Policy and strategy for increasing income and food security through improved crop management of chickpea in rice fallows in Asia. Summary of a NARC-ICRISAT-NRI Workshop, 17–18 November 2004, Kathmandu, Nepal. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 252 pp.

Tamer, A., Has, A., Aydemir, M. and Caliskaner, S. 1998. Faunistic survey studies on harmful and beneficial insects on food legumes (lentil, chickpea, bean) in Central Anatolia Region. *Bitki Koruma Bulteni* 38: 65–90.

Thakur, B.S., Verma, R., Patitunda, A. and Rawat, R.R. 1984. Chemical control of aphid, *Aphis craccivora* Koch on lentil. *Indian Journal of Entomology* 46: 103–105.

Tunc, I., Vierbergen, G. (ed.) and Tunccedilla, I. 1999. Thrips infestations on field crops in Turkey. In: Proceedings, Sixth International Symposium on Thysanoptera, 27 April-1 May, 1998, Akdeniz University, Antalya, Turkey. Akdeniz University, Faculty of Agriculture, Department of Plant Protection, Antalya, Turkey, pp. 145–150.

Wale, M., Jembere B. and Seyoum, E. 2000. Biology of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae) on cool-season legumes. *Insect Science and its Application* 20: 171–180.

Weigand, S., Lateef, S.S., El Din, N.E.S., Mahmoud, S.F., Ahmed, K., Ali, K., Muehlbauer, F.J. (ed.) and Kaiser, W.J. 1994. Integrated control of insect pests of cool season food legumes. In: Expanding the production and use of cool season food legumes, Proceedings of the Second International Food Legume Research Conference on pea, lentil, faba bean, chickpea, and grasspea, Cairo, Egypt, 12–16 April 1992, pp. 679–694. Kluwer Academic Publishers Group, Dordrecht, Netherlands.

Yadava, C.P. and Ahmad, R. 2000. Insect pests of lentil and their management. *Applied Entomology* 2: 82–95.