and intercropping could potentially reduce the intensity of *Helicoverpa* spp. Although the role of natural enemies as biological control agents is unclear, their impact could be improved by reducing pesticide applications and adopting cropping practices that encourage their activity. Most studies have shown that insecticide applications are more effective than neem kernel extracts, *Bt*, HaNPV, or augmentative releases of natural enemies. However, biopesticides and synthetic insecticides, applied alone, together, or in rotation, are effective for control of *Helicoverpa* spp. in chickpea. Moreover, scouting for eggs and young larvae is critical for initiating timely control measures. Insecticides with ovicidal or systemic action are effective against *Helicoverpa* spp. during the flowering stage. Finally, the development of transgenic plants with different insecticidal genes, molecular marker-assisted selection, and exploitation of the wild species of *Cicer* and *Lens* should be pursued to develop comprehensive programs for management of *Helicoverpa* spp. on chickpea and lentil.

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Thrips

Several species of thrips, including *Frankliniella occidentalis*, *Kakothrips robustus*, *Thrips angusticeps*, and *T. tabaci* (Thysanoptera: Thripidae), damage grain legumes, including lentil.

Geographic Distribution

F. occidentalis (Fig. 235) is commonly known as western flower thrips. The majority of the species in the genus *Frankliniella* are present in either North or South America, but a few are cosmopolitan. *F. schultzei* is known as cotton bud thrip and is important in Asia as a vector of *Tomato spotted wilt virus* (TSWV). *K. robustus* is known as pea thrips and is widely distributed in Europe. It attacks several crops such as horse bean, lathyrus, lucerne, and mustard in Bulgaria, the Czech Republic, Hungary, Poland, Romania, and Slovakia. *T. tabaci* and *T. angusticeps* are commonly known as onion or potato thrips. The genus *Thrips* comprises several hundred species, which are polyphagous and cosmopolitan in distribution. *T. tabaci* and *T. angusticeps* have been reported as key pests of lentil in central Spain.

Host Range

F. occidentalis is a polyphagous pest and has a wide host range including cereals, legumes, ornamentals, and fruit trees (citrus, grape, peach, plum, raspberry, strawberry, and others). This species is of worldwide importance as a vector of TSWV in a number of crops. *K. robustus* is polyphagous and infests a number of cultivated and weed hosts. *T. tabaci* and *T. angusticeps* infest banana, brassicas, cotton, cucurbits, gladiolus, mango, oil palm, onion, pea, tobacco, watermelon, and others. Besides infesting cultivated crops, these species also feed on several weed hosts. *T. tabaci* and *T. angusticeps* affect the productivity and quality of lentil seed in central Spain.

Nature of Damage

Most *Frankliniella* spp. prefer flowers (Fig. 236), but in the absence of flowers, they also feed on foliage (Fig. 237). When the populations of thrips are high, the growing points of the plants may blacken and wither. Feeding by thrips on young leaves results in silvery streaks on the opened leaves and distortion or curling of leaves. When infestation is severe, the leaf area is reduced, which indirectly affects photosynthesis and grain yield.

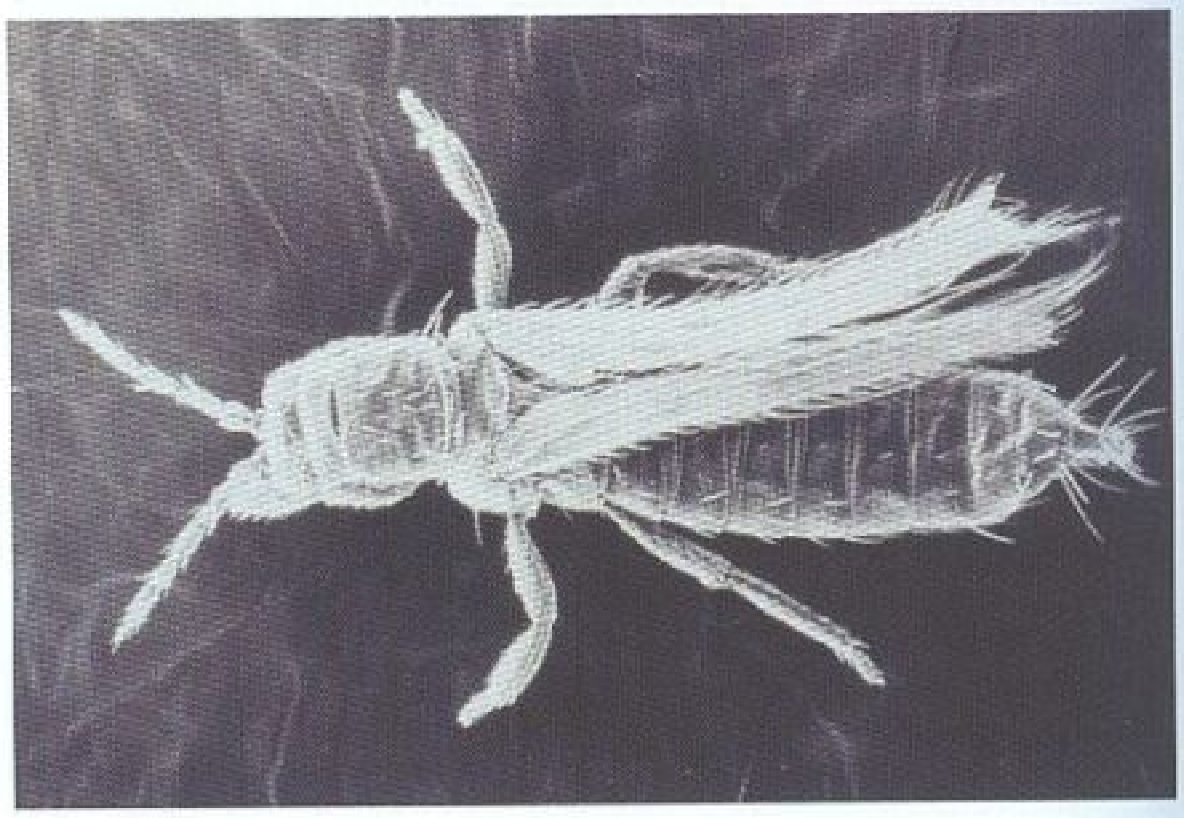

Fig. 235. *Frankliniella occidentalis* adult. (Courtesy ICRISAT)

Fig. 236. *Frankliniella occidentalis* feeding on flowers. (Courtesy ICRISAT)

Fig. 237. Foliar damage caused by thrips. (Courtesy ICRISAT)

Life Cycle

The life history of thrips involves an egg, two active larval instars that feed, followed by two (or three) relatively inactive pupal instars that probably do not feed, and the adults. One or both sexes may be wingless. In most phytophagous thrips, the eggs are inserted into the tissue of green plants. The males are generally haploid and derived from unfertilized eggs. Despite this sex-determination process known as haplodiploidy, many unrelated species have evolved the ability to reproduce in the absence of males. The cytological mechanisms involved are not fully understood, but parthenogenesis is important when the pest species are introduced to new areas. Sexual dimorphism is usually evident and is sometimes remarkable. Males of flower- and leaf-living species are usually smaller than the females, but males of fungus-feeding species are often much larger than females. Many phlaeothripid species produce different-sized morphs, with and without wings. These forms often exhibit bizarre patterns of allometric growth, particularly of the forelegs, and as a result, different morphs are considered to represent unrelated species. The adults and larvae of many species of thrips are found only in flowers, where they feed by sucking out the contents of pollen grains and probably the cell sap of other flower tissues around the bases of the anthers and on the developing fruits. Some flower-living species also feed on leaves, but most leaf-feeding species are restricted to leaves. Some thrips are associated with very young leaves, and these insects are often very small and active. Under optimal conditions, one generation may be completed in 12–15 days. *K. robustus* is known to have only one generation a year in England with an established diapause. Fully grown larvae usually enter the soil in mid summer, pupate early in the following spring, and emerge as adults in late spring. *T. tabaci* and *T. angusticeps* have one or two generations per year in temperate regions and undergo diapause. However, in the tropics, there are multiple generations per year and there is no diapause.

Management

Cultural practices. Agronomic practices such as adjusting planting date and sowing rate and intercropping play a significant role in suppressing thrips populations. Climatic conditions such as mild winters (night temperatures of 10–12°C, as in southern India), which are unfavorable to crops, are favorable to population buildup of thrips. Avoiding planting thrips-susceptible crops during the vulnerable phase helps to reduce the use of chemicals.

Host plant resistance. Resistant sources can play a significant role in the management of thrips in several crops. However, there is no information on host plant resistance to thrips in lentil.

Biological control. *Entomophthora* spp. epizootic on *T. tabaci* were reported in the Netherlands on eggplant in glasshouses. *E. parvispora* occurs widely throughout central and southern Europe. However, the fungus has not been successfully multiplied in vitro. Application of the nematode *Steinernema feltiae* against *F. occidentalis* decreased the thrips population but did not provide adequate control. Since natural biocontrol agents have not successfully kept the pest under manageable levels, it has been recommended that selective chemicals for the management of thrips be used. However, introduction of *Amblyseius* spp. shortly after thrips invasion in cucumber provided satisfactory control of *T. tabaci,* suggesting the feasibility of biocontrol.

Chemical control. Several researchers have shown efficient management of active thrips as well as populations in diapause by foliar and soil applications of insecticides. Systemic insecticides, such as dimethoate, monocrotophos, and imidacloprid, and insecticides with fumigant action, such as dichlorvos, have been found to be effective against a range of species. However, several thrips species have been reported to develop resistance to insecticides. There is a 30-fold increase in resistance to malathion and a 25-fold increase in resistance to dichlorvos in western flower thrips populations over the susceptible strain in the United Kingdom. There is no resistance in *F. occidentalis* to abamectin, methiocarb, and pyrazophos in Australia. However, buildup of resistance to chlorpyriphos, dichlorvos, and malathion has been recorded. Acephate, dimethoate, endosulfan, fipronil, methamidophos, methidathion, and spinosad are quite effective for controlling thrips. Resistance to imidacloprid, dimethoate, and thiamethoxam has been observed in *T. tabaci* in India.

Integrated pest management. Some strategies have been developed for the management of thrips on several crops. They include manipulating sowing dates, proper spacing, intercropping, utilizing resistant sources, use of biocontrol agents, disposal of plant residues, and need-based application of pesticides. However, most of these strategies are location specific.

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