DISSERTATION

INTEGRATED PEST MANAGEMENT STUDIES OF THE INSECTS AFFECTING OILSEED BRASSICAS IN COLORADO

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY NIHAT DEMIREL ENTITLED INTEGRATED PEST MANAGEMENT STUDIES OF THE INSECTS AFFECTING OILSEED BRASSICAS IN COLORADO BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF SCIENCE.

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ABSTRACT OF DISSERTATION

INTEGRATED PEST MANAGEMENT STUDIES OF THE INSECTS AFFECTING OILSEED BRASSICAS IN COLORADO

Early evaluation of canola and other oilseed brassicas as potential crops for Colorado indicated several insects as potentially limiting to production - false chinch bug (FCB), *Nysius raphanus* Howard, western black flea beetle (WBFB), *Phyllotreta pusilla* Horn, and various *Lygus* spp., notably pale legume bug (PLB), *L. elisus* Van Duzee. Studies were conducted to assist in development of pest management systems for these potential insect pests of Colorado oilseed brassica production.

Sampling of vegetation outside of canola indicated that winter annual weeds, particularly flixweeds (*Descurainia* spp.), were important in early season population development of FCB and WBFB. Spring populations of *Lygus* spp. were greatest in alfalfa, with or without flixweed. Trapping studies with FCB and its tachinid parasitoid, *Phasia occidentis* (Walker), indicated that yellow was most attractive to FCB and blue to the parasitoid. Both species showed attraction to traps baited with oilseed extracts. Surveys of *Lygus* nymphs resulted in recoveries of braconid parasitoid *Leiophron uniformis* (Gahan) from all sites in eastern Colorado but from none in western Colorado. Average percent parasitism was 5.5 and 7.6 percent in 2001 and 2002 collections, respectively. The three *Lygus* species were present in 2002 collections were *L. elisus* (58.4%), *L. hesperus* Knight (29.3%), and *L. lineolaris* (Palisot de Beauvois) (12.3%).

Action threshold studies involved artificial infestation of bagged flowering and pod branches of canola (heads). FCB was more damaging when infestations occurred at early flower stage compared to later, early pod stage of plant growth. On average 10% yield loss occurred with infestations of 12.8 FCB/'head' at early flower stage; 39.7 FCB/'head' at early pod stage. Similar PLB studies with indicated this species was more damaging to crop, causing 10% yield loss with 3.3 PLB/'head' at early flowering stage; 8.7 PLB/'head' at early pod stage. Evaluations of host plant resistance among oilseed brassicas indicated FCB showed strong feeding preference for older plants compared to seedlings. Spring mustard W1-23 was cultivar consistently least preferred by FCB. Spring mustard ZEM 1 supported the greatest number of WBFB while W1-23 had lowest numbers of WBFB. Other least preferred cultivars were spring canolas Helios, Sterling, and Alto.

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I am deeply dedicated this work to my family, my father, Okkes Demirel, and my mother, Meryem Demirel, and my brothers, Veli, Mustafa, Hidayet, my sisters, Cennet and Turkan Demirel.

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WESTERN BLACK FLEA BEETLES STUDIES

GENERAL OBJECTIVES OF THESE STUDIES

Oilseed brassica crops have been cultivated for several thousand years, with origins in Asia. They are broadly adapted to cooler climates and have been grown in Europe since at least the 13th century. Presently oilseed brassicas, primarily canola, constitute over 1/8 of the vegetable oils produced worldwide. Furthermore they have shown the greatest increased percentage in production among oilseed crops in the past two decades, largely due to their very low percentage of saturated fats. Canola also works well in some production systems, often as a rotational crop with wheat.

Most North American production of canola occurs in the Prairie Provinces and the upper tier states of Minnesota, North Dakota, and Montana. Limited production has occurred in Colorado, which during a brief period in the late 1980s had nearly 5000 acres in cultivation, largely centered in the San Luis Valley. Since that peak period Colorado production has been greatly reduced due to economics (e.g., proximity to processing facilities), excessive summer temperatures - and some serious insect problems.

In Colorado, the insect complexes associated with canola have sometimes been similar to those in northern production areas, but with some differences. For example, *Lygus* spp. are generally recognized as important pests in Canada and the northern US as well Colorado. However, the species are different with *L. elisus* predominant in Colorado and *L. lineolaris* in northern areas. Similarly the flea beetle of primary concern in NA canola production is *Phyllotreta cruciferae*, whereas *P. pusilla* is associated with the crop in

Colorado. There are also key pests unique to Colorado production, notably the false chinch bug (*Nysius raphanus*).

The overall objective of this research is to develop components necessary to an Integrated Pest Management Program (IPM) for insects affecting oilseed brassica crops grown in the southern production area of Colorado.

Within the broad objective specific studies address the components. These include: establishment of economic injury levels, evaluation of sampling methods, life history study, and evaluation of pest management tactics (chemical, biological, cultural controls). These were conducted for the three key pests of canola grown in Colorado: false chinch bug (*N. raphanus*), western black flea beetle (*P. pusilla*), and the pale legume bug (*L. elisus*). A single study was also conducted on cabbage aphid (*Brevicoyne brassicae*), which occurs as a pest of canola throughout North America, but has yet caused little injury to this crop in Colorado.

FALSE CHINCH BUG STUDIES

CHAPTER I

FALSE CHINCH BUG LITERATURE REVIEW

INTRODUCTION

Seed bugs of genus *Nysius* (Hemiptera: Lygaeidae) are found in semiarid regions throughout temperate areas of the world. Sweet (2000) recognized several *Nysius* spp. as being important agricultural pests, including *N. clevelandensis* Evans, *N. ericae* Schilling, *N. huttoni* Buchanan-White, *N. plebeius* Distant, *N. vinitor* Bergroth, *N. niger* Baker and *N. raphanus* Howard. The latter two are known from North America and with the generally applied common names northern false chinch bug and false chinch bug, respectively.

The false chinch bug, *Nysius raphanus,* was originally described by Howard (1872) who termed it the 'radish bug'. The original description, in part, follows:

> "Radish bug's body is long, with numerous short hairs; head and thorax cinerous: Scutel is blackish. Antennae pubescent, four-jointed, chestnut brown, first and third joints about equal length, second, long as first and third, last, longer and thicker than third. Hemelytra semi-transparent punctured, with brown nervures, outside at base hairs, interior terminal."

N. raphanus is generally considered the most serious pest among North America species of *Nysius* (Ashlock 1977, Sweet 2000), although Capinera (2002) suggests *N. niger* may be of greater importance. That there is some debate on this subject is in no small part due to considerable confusion as to the proper identity of *Nysius* in much of the early literature. For example, Milliken (1918) misidentified *N. raphanus* as *N. ericae*, a European species (Sweet 2000) that closely resembles *N. raphanus* (Barber 1947a). *N. raphanus* apparently has also been misidentified in literature as *N. angustatus* Uhler. In a 2000 revision, Sweet (2000) concluded that many of the past records involving reports of past injury by *Nysius* spp. in North America are "hopelessly confused".

HOST RANGE AND PLANT INJURY

The false chinch bug is a general feeder with preference for plants in the Chenopodiaceae and Brassicaceae (Howard 1872, Knowlton 1934, Smith 1942a, Knowlton and Wood 1943, Wene 1953, Leigh 1961, Tappan 1970, Sweet 2000, Capinera 2002). A wide range of vegetable crops have been reported injured including lettuce, potato, carrot, celery, carrots, radish, cabbage, cauliflower, mustard, turnip, broccoli, and some cucurbits. False chinch bug has been damaging to most of the major field and forage crops including cotton, corn, alfalfa, flax, oats, wheat, sugarbeets, sorghum, sunflower and tobacco. Fruit crops reported to be damaged include strawberry, raspberry and grapes. All of the oil seed brassicas (canola, rape, Indian mustard) may be damaged (Sweet 2000), although mention of the species was reglected in the review by Lamb (1989) of insect pests of oilseed brassica crops.

A very large number of weeds have been reported to host *N. raphanus* (Knowlton 1934, Knowlton and Wood 1943, Leigh 1961, Barnes 1970, Tappan 1970). These are summarized in Table 1.1.

Table 1.1. Weed species reported to host false chinch bug, *N. raphanus*.

Common Name	Scientific Name	Family
Pigweeds	*Amaranthus* spp.	Amaranthaceae
Spiny amaranth	*Amaranthus spinosus* L.	Amaranthaceae
Common ragweed	*Ambrosia artemisiifolia* L.	Asteraceae
Cocklebur	*Xanthium pensylvanicum* Wallr.	Asteraceae
Mustards	*Brassica* spp.	Brassicaceae
Flixweed	*Descurainia sophia* (L.) Webb. ex Prantl.	Brassicaceae
Tansy mustard	*Descurainia pinnata* (Walt.) Britt.	Brassicaceae
Shepherd's purse, Medic	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae
London rocket	*Sisymbrium irio* L.	Brassicaceae
Peppergrass	*Lepidium nitidium* Nutt.	Brassicaceae
Virginia pepperweed	*Lepidium virginicum* L.	Brassicaceae
Russian thistle	*Salsola iberica* Sennen & Pau	Chenopodiaceae
Kochia	*Kochia scoparia* (L.) Schrader	Chnopodiaceae
Saltbush	*Atriplex* spp.	Chenopodiaceae
Lambsquarters	*Chenopodium album* L.	Chenopodiaceae
Jerusalem oak	*Chenopodium botrys* L.	Chenopodiaceae
Thyme-leaved spurge	*Chamaesyce serpyllifolia* L.	Euphorbiaceae
Carpet-weed	*Mollugo verticillata* L.	Molluginaceae
Crowfootgrass	*Dactyloctenium aegyptium* (L.) P. Beauv.	Poaceae
Strong-scented love grass	*Eragrostis minor* Host	Poaceae
Crabgrass	*Digitaria sanguinalis* (L.) Scop.	Poaceae
Barnyardgrass	*Echinochloa crus-galli* (L.) Beauv.	Poaceae
Goosegrass	*Eleusine indica* (L.) Gaertn	Poaceae
Johnsongrass	*Sorghum halepense* (L.) Pers.	Poaceae
Bermudagrass	*Cynodon dactylon* (L.) Pers.	Poaceae
Pennsylvania smartweed	*Polygonum pennsylvanicum* L.	Polygonaceae
Black nightshade	*Solanum nigrum* L.	Solanaceae

Scientific and common names (Fischer et al. 1990, Randall 2002).

Injury is caused from removal of sap, which is sucked from plants while feeding. Individual insects cause little damage but large aggregations frequently occur on single plants or in small areas of the field. Heavily infested plants can show symptoms of severe wilting and sometimes are killed (Howard 1872, Milliken 1918, Knowlton 1934, Smith 1942a, Leigh 1961, Wood and Starks 1972, Byers 1973, Young and Teetes 1977).

Wood and Starks (1972) reported that the false chinch bug cause significant injury on the head of the sorghum plants. They feed on developing seed causing smaller, lighter distorted seed (Young and Teetes 1977). Actual yield loss occurred only when more than 200 bugs per head were present, resulting in damage to 23 percent of the seed. The damaged seed can become infected with a fungus (*Alternaria* sp.) that causes the seed to turn black and results in further deterioration of quality (Young and Teetes 1977).

LIFE HISTORY

Knowlton (1934) reported that all stages (eggs, nymphs and adult) of false chinch bug could survive the winter under favorable conditions in Northern Utah. However, others report that the sole overwintering stage is the adult (Barnes 1970, Byers 1973, Sweet 2000) under protective debris or rubbish.

Both males and females are produced, the males being perceptibly smaller than the female (Milliken 1918). Eggs are about 1.5 mm long and 0.4 mm wide and translucent pinkish white color. They have been observed to be laid in many sites including loose soil, among clods or rubbish, among petals of a composite flower (e.g., great-flowered gaillardia, *Gaillardia pulchella* Foug.), between the glumes in grasses (e.g., strong-scented love grass, *Eragrostis minor* Host), among the clustered parts of plants such as thyme-leaved spurge (*Chamaesyce serpyllifolia* (Pers.)) and carpet-weed (*Mollugo verticillata* L.); and among the down from cottonwood (*Populus* spp.) (Milliken 1918).

There are five nymphal stages (Howard 1872) and the nymphs are grayish with reddish-brown abdomens (Knowlton and Wood 1943). Milliken (1918) noted that at

Garden City, Kansas, with an average temperature of 26.5 C, eggs hatched in about 4 days, the average nymphal period was 20.4 days, and the average time from oviposition to maturity was 24.4 days. In Wichita, Kansas with an average temperature of 23.8 C eggs hatched in 3.5 days, and the average nymphal period was 20.7 days for a period from oviposition to maturity of 24.2 days. Capinera (2002) reported that one generation could be completed in about 29 days under favorable weather conditions.

False chinch bug is multivoltine and the number of generations produced per year varies with location and weather (Burgess and Weegar 1986). In Utah false chinch bug has three to five generations under favorable temperature conditions (Knowlton 1934).

Early season populations of false chinch bug appear on different weed species. Leigh (1961) reported *Sisymbrium irio* L., *Capsella bursa pastoris* (L.) Medik., and *Lepidium nitidium* Nutt., to be important early season hosts. Barnes (1970) also reported *Sisymbrium irio* L., an introduced European species, was important in supporting false chinch bug prior to movement in vineyards. Capinera (2002) also commented on the importance of weeds prior to dispersal to nearby crops.

Outbreaks of false chinch bugs on crops are usually associated with drought. Large numbers move from drying weed hosts in early to mid-summer into irrigated fields (Knowlton 1934, Leigh 1961). For example, seedling cotton is damaged as false chinch bugs migrate from wild weed species to cotton in mid-May and cause significant damage to the crop at that time (Leigh 1961). Heavy rains are also reported to cause significant mortality of false chinch bug (Howard 1872).

In the morning, while the dew is on the plants, they are found concealed in the shriveled up leaves, and are rather sluggish (Howard 1872). Leigh (1961) also reported these insects remain hidden beneath clods or trash through the night and during the mid-day period when temperatures are high. They may be observed feeding on the plants during midmorning and late afternoon. Strong winds cause the bugs to seek cover. During periods of hiding, feeding may continue on the stems at and beneath the ground level (Leigh 1961). Aggregation behavior with this species is commonly observed (Knowlton 1934, Smith 1942a, Leigh 1961).

NATURAL ENEMIES

Two species of tachinids have been reared from false chinch bug - *Hyalomya aldrichii* Townsend (Clancy and Pierce 1966) and *Phasia occidentis* Walker (Milliken and Wadley 1923, Brooks 1945). The primary record for *H. aldrichii* was the report by Clancy and Pierce (1966) who noted 9 percent parasitism of female false chinch bugs in midspring collections in southern California.

P. occidentis is the species most commonly reared from the High Plains (Milliken and Wadley 1923, Brooks 1945). Milliken and Wadley (1923) observed 7.7 percent parasitism with females much more frequently parasitized than the males. Adults of *P. occidentis* have a short, broad body and the abdomen is oval and flattened, particularly in the male. Wings are variable and may be broad or narrow (Brooks 1945).

Oviposition has not been observed but Milliken and Wadley (1923) reported that it is probable that the fly deposits an egg on the body of the host, and larvae on hatching bore into the host. The larva of *P. occidentis* lives in the abdominal cavity of *N. raphanus*. In the earlier stages of parasitism infested females cannot be distinguished from gravid females. Upon emergence the former host has a shrunken and empty abdomen. Pupation occurs off the host. Copulation occurs within a few hours after emergence and adults have been maintained in colonies for seven days, following emergence from the pupa. The life cycle requires about 25 days to complete, and in this respect bears a close relationship to the habits of it FCB the host.

Common predators of false chinch bug include *Geocoris* spp. and *Nabis* spp. (Clancy and Pierce 1966). In addition, *N. raphanus* (=*Nysius ericae*) specimens were recognized in stomachs of 46 species of birds (Knowlton and Wood 1943).

PHYSICAL CONTROL

Previous studies by Al-Doghairi (2000) indicated that yellow cups baited with canola oil caught false chinch bugs. Pivnick et al. (1991) reported that the northern false chinch bug, *Nysius niger*, is attracted to mustard oils with a specific side-chain structure. The compound ethyl ICB (4-isothiocyanatobutyrate), placed in rubber septa attached to boll weevil traps, was most attractive. However, no further development has occurred to develop traps for monitoring or management of *Nysius* spp.

CULTURAL CONTROL

The primary cultural control involves management of weed hosts (Capinera 2002). Barnes (1970) suggested management of London rocket, an early season weed host, is important in preventing later FCB migrations into adjacent crops. In Colorado winter annual mustards, such as flixweed, appear to be similarly important wild host plants for false chinch bug during the early spring.

CHEMICAL CONTROL

False chinch bug has been controlled with foliar applications of insecticides (Capinera 2002). Spot treatments often are the best approach because FCB tends to be highly aggregated on some plants or some places of the field (Young and Teetes 1977).

Very few published insecticide trials have included false chinch bug. The earliest reported trials to control false chinch bug involved dust formulations of heptachlor, aldrin, toxaphane, and endrin, all of which resulted in effective control for the false chinch bug (Wene 1958). In addition, five percent malathion and 0.1 percent impregnated pyrethrum dust also provided control.

Leigh (1961) conducted two different trials under field and laboratory conditions. In field experiments endrin and heptachlor gave satisfactory control, while Sevin (1-naphthyl methylcarbamate) was relatively ineffective. In laboratory trials, malathion was the most effective compound. Dieldrin, endrin, and trichlorf were about equally effective against for false chinch bug, while toxaphene and DDT were relatively ineffective.

Far more studies have been conducted on other lygeaids, notably chinch bugs (*Blissus* spp.). For example, foliar applications of ethyl parathion, carbaryl, carbofuran, and Penncap M (encapsulated methyl parathion) significantly reduced numbers of *B. leucopterus leucopterus* (Say) on sorghum (Wilde and Morgan 1978, Mize et al. 1980, Bauernfeind 1987). Post emergence application of phorate granules and chlorpyrifos spray to corn reduced chinch bugs over 90 percent in one experiment during the first week (Peters 1983). However, carbofuran and carbaryl sprays were less effective in wheat (Peters 1983). The best control of *B. l. leucopterus* on wheat was obtained with phorate granules with ca. 58 percent control (Peters 1983).

Bauernfeind (1987) also reported that treatments of fenvalerate, parathion, endrin and chlorpyrifos provided acceptable kill (at least 90 percent population reduction) within the first 24 h after their application. More recent studies done by Castro and Riley (1999) found effective control with cyfluthrin (Baythroid), deltamethrin (Decis), carbofuran (Furadan 4F), lambda cyhalothrin (Karate), chlorpyrifos (Lorsban 4EC) and fipronil (Regent 2.5EC).

Sears et al. (1980) reported that a number of the insecticides were evaluated over a 5-year period for control of hairy chinch bug, *Blissus leucopterus hirtus* Montandon. They concluded that diazinon at 2-4 kg AI/ha and chlorpyrifos provided the most consistent control. Carbaryl, Aspon and methidathion were effective at higher tested rates, while chlordane was ineffective. Also the best time of treatment was early in the season when most of the hairy chinch bugs were in the 3rd instar. This gave better control than application made to later stages.

The southern chinch bug, *B. insularis*, also is an important pest of turfgrass in the southern United States (Sweet 2000). Propoxur and two pyrethroids (fenvalerate, permethrin) provided good control of southern chinch bug populations on lawns (Reinert 1982). Nagata and Cherry (1999) reported that survival of different life stages of the southern chinch bug measured after insecticidal applications of acephate, chlorpyrifos and lambda-cyhalothrin. Adults and nymphs were killed with all three insecticides sprayed at recommended field rates. Nagata et al. (2002) also reported on insecticidal treatments made using chlorpyrifos for control of southern chinch bugs.

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CHAPTER II

DEVELOPMENT OF ACTION THRESHOLDS FOR FALSE CHINCH BUG, *NYSIUS RAPHANUS* (Howard) (HEMIPTERA: LYGEAIDAE), AFFECTING SPRING CANOLA

INTRODUCTION

The false chinch bug (FCB), *Nysius raphanus* (Howard), originally described from Kansas by Howard (1872), is the most serious pest among North America species of *Nysius* (Ashlock 1977, Sweet 2000). In addition, many of the early papers referring to *N. ericae* were in error and described damage attributable to *N. raphanus* (Sweet 2000). False chinch bug has a broad host range but prefers plants of the Brassicaceae (Howard 1872, Knowlton 1934, Sweet 2000, Capinera 2002) and can be a key pest of oilseed brassicas grown in Colorado (Al-Doghairi 2000, personal communication Steve Stadelmaier, Cargill Oilseed Research, Ft. Collins, CO). Plant damage usually results when masses congregate upon plants and feed, causing wilting (Howard 1872, Knowlton 1934, Knowlton and Wood 1943, Leigh 1961, Wood and Starks 1972, Byers 1973, Young and Teetes 1977). Population increase in canola can also lead to increased problems in subsequently seeded crops (Buntin et al. 2002).

Quantifying damage potential of an insect pest is critical to development of integrated pest management programs (Pedigo 1999, Cramer 2000, Thacker 2002). Wood and Stark (1972) studied FCB injury potential to sorghum, but to date there is apparently no published research quantifying crop loss by any North American *Nysius* species to any oilseed crop. Action thresholds have been proposed for the related rutherglen bug (*N. vinitor* Bergroth) on canola in Australia (Anonymous 2003). The purpose of this research was to better determine the relationship of FCB infestation on yield of canola at both early flower (stage 4.2) and pod stages (stage 5.2) (Harper and Berkenkamp 1975).

MATERIALS AND METHODS

False Chinch Bug Action Threshold Trials, 2001. Trials were conducted at the Colorado State University Horticulture Research Center in Ft. Collins, Colorado. Plots were established by seeding on 26 April to double-row beds at 76-cm row spacing. In the first trial seven different spring canola (*Brassica napus* L.) cultivars were included: Hyola, Excel, Apollo, Helios, Alto, Defender, and 46A65. A second trial replicated five cultivars: Hyola, Excel, Apollo, Defender, and 46A65. Plot areas consisted of 2 beds, 6-m long. These were then subdivided in half. Northwest and southeast 3-m sections of bed were used in trials with FCB infestation at the early flower stage and early pod stage, respectively.

Experimental design was randomized complete block design with 4 replications. One variable consisted of introducing different numbers of FCB into bagged heads at two different plant growth stages. Bags were placed over flowering and pod branches of the plants that were selected of approximately similar size. For convenience of discussion these bagged branches will subsequently be termed “heads”. Prior to any treatment, in each plot five canola heads were selected of approximately equal size. Four of these were bagged with the latter one serving as a non-bagged control. The bags used were of 12-cm x 20-cm polypropylene mesh (Applied Extrusion Technologies, Specialty Nets & Nonwovens, Middletown, Delaware) primarily used for confining heads during plant breeding. The bags were snuggly fastened to the stem with a twist-tie.

Four different levels of FCB were introduced into the bagged heads - 0, 10, 20, 40/head. These were field-collected adults collected 1 to 2 days prior to infestation and maintained in a holding cage. They were then aspirated into individual vials for introduction into the bagged head.

Introduction of FCB occurred at two plant growth stages. The early flowering stage was comparable to Stage 4.2 described by Harper and Berkenkamp (1975), when there are many flowers opened and lower pods are elongating. These plants were bagged 6 July and FCB introduced into the bags 11 July. Infestations were also made at the early pod stage, comparable to stage 5.2, with the seeds in lower pods green (Harper and Berkenkamp 1975). These plants were bagged 25 July and FCB introduced into the bags 26 July.

No insecticides were used on plots after infestations. A 10 May application of carbaryl was used to control western black flea beetles, *Phyllotreta pusilla* (Horn) that potentially affect seedling stages. The second insecticide application, involving imidacloprid, was done prior to bagging, 30 June, to control cabbage aphid, *Brevicoryne brassicae* (L.).

All plots were harvested 24 August. The entire heads were cut, with the bag intact and hung for drying. The pods were then crushed to release the seeds and separated from other debris by use of sieves.

An additional trial was conducted at the Cargill Oilseed Research Center in Ft. Collins on the cultivar IMC204. Plots were established by seeding to double-row beds at 76-cm row spacing. Individual plots were 6-m long and arranged in a randomized complete block design. The trials consisted of 10 replications and five treatments - 0 FCB (bagged control), 10 FCB, 20 FCB, and 40 FCB/head along with a non-bagged control. Infestation at the early flower stage occurred June 28 and at the early pod stage on July 11. The trial was harvested August 16 in a manner similar to the above-described trial. Data were analyzed using Least Significant Difference (LSD) and Regression Analysis (SAS Institute 1990).

False Chinch Bug Action Threshold Trials, 2002. Trials were again conducted at the Colorado State University Horticulture Research Center. Plots were established by direct seeding April 3. Plot size was two 2-row beds, 3-m in length.

The first trial consisted of six different spring canola cultivars: Apollo, Hyola, Helios, Excel, IMC205, and 46A65. The second trial repeated four of these: Apollo, Hyola, Excel, and 46A65. Plot design was similar to that of 2001. The third trial repeated two different spring canola cultivars, IMC204 and IMC205. Pesticide use on the plots consisted of a pre-emergence application of trifluralin for weed control and a single 10 May carbaryl application for control of western black flea beetle.

Bagging of heads for the early flower stage trial was done on 19 June; field collected FCB were introduced into bags 25 June. For evaluations during the early pod stage, canola heads were covered with bags on 15 July and FCB introduced 17 July. Bagging of heads and management of plots was similar to that of 2001.

All plots were harvested 21 August. At this time the heads were cut and maintained within the bag and hung for drying. When dry, pods were crushed to release the seeds and separated from other debris by use of sieves. After this procedure, the seed was further cleaned using Agriculex CB-1 (column blower) to sort out seed from plant debris. Data were analyzed using Least Significant Difference (LSD) and Regression Analysis (SAS Institute 1990).

RESULTS AND DISCUSSION

False Chinch Bug Action Threshold Trials, 2001. Among the tested varieties there was a range in yield loss from FCB infestation during the early flower stage (Table 2. 1). The cultivar Excel had greatest yield reductions, sustaining significant yield loss from all treatments (10, 20, 40 FCB/head) when infested at early flower stages (*F=4.01*, *P=0.0457*). The cultivars Helios and Defender had yield reductions from infestation levels of 20, and 40 FCB/head (*F=3.97*, *P=0.0469*; *F=3.60*, *P=0.0589*, respectively). However, the cultivars of Alto and 46A65 had no significant yield reduction from any FCB infestation treatment that applied at early flower stages (*F=0.67*, *P=0.5935*; *F=1.23*, *P=0.3556*, respectively). Combining all cultivars in the first trial, yields were reduced 43, 68, and 69 percent with infestations of 10, 20, and 40 FCB/head, respectively, compared to the 0 FCB/head control (*F=12.01*, *P=0.0001*) (Table 2. 1).

In the second trial, run concurrently, 10 and 20 FCB/head caused significant yield reductions on the cultivar Apollo at early flower stage (*F=2.61*, *P=0.1154*) (Table 2. 4). Significant yield reductions were also recorded on Defender, 46A65, and Hyola with the highest FCB infestations (*F=4.14*, *P=0.0422*; *F=3.15*, *P=0.0790*; *F=2.41*, *P=0.1345*, respectively). Unlike Trial 1, Excel showed no yield reduction from any FCB infestation (*F=0.40*, *P=0.7538*). When all cultivars were combined yield reductions averaged 26, 58, and 55 percent with infestations of 10, 20 and 40 FCB/head (F=*5.77*, *P=0.0013*).

In the third trial, at the Cargill Oilseed Research Center, 20 FCB infestation treatments resulted in significant yield loss, compared to the 0 FCB/head control, on the cultivar IMC204 (*F=0.18*, *P=0.9063*) (Table 2. 7).

Generally there was lower yield response from FCB infestation at the pod stage of growth. No significant yield reductions occurred from infestations of 10 FCB/head (*F=3.01*, *P=0.0335*) (Table 2. 2). Yield reductions did occur on Apollo, Helios, and Excel with 20 FCB/head at the early pod stage (*F=5.92*, *P=0.0163*; *F=3.18*, *P= 0.0777*; *F=2.31*, *P=0.1447*, respectively). No significant yield reductions occurred from any FCB infestation to the cultivars 46A65, Alto, and Defender (*F=0.32*, *P=0.8133*; *F=1.37*, *P=0.3144*; *F=1.83*, *P=0.2122*, respectively). Overall yield reductions among all combined cultivars were 26 percent with 20 FCB/head, and 23 percent with 40FCB/head, compared with the 0 FCB/head control (*F=3.01*, *P=0.0335*).

In the second trial yield reduction at early pod stages of canola occurred on the cultivars of Apollo, and 46A65 with 10 FCB/head (*F=2.65*, *P=0.1124*; *F=2.14*, *P=0.1655*, respectively) (Table 2. 5). Yield losses occurred at 20 FCB/head on Excel (*F=5.44*, *P=0.0207*), and at 40 FCB/head with all cultivars except 46A65 (*F=2.15*, *P=0.1640*; *F=5.44*, *P=0.0207*; *F=1.89*, *P=0.2010*; *F=2.65*, *P=0.1124;* *F=2.14*, *P=0.1655*, respectively). Yield losses from infestations of 40 FCB/head also occurred on IMC204 in the third trial (*F= 2.44*, *P=0.0856*) Table 2. 7).

The effect of bagging heads did not appear to greatly affect yields. Comparison of bagged heads containing no added false chinch bugs and non-bagged controls showed no yield effects during early flower stage trials (Tables 2. 3, 2. 6, 2. 8). Yields were significantly reduced in the non-bagged controls with one cultivar (Excel) in both trials. In addition, yield was reduced in the non-bagged control with the cultivar IMC204 during an early pod stage trial (Table 2. 8)

False Chinch Bug Action Threshold Trials, 2002: Overall, effects from FCB infestation were lower in all 2002 trials, compared to 2001. Infestations during early flowering produced some significant yield reductions in the first trial (*F=5.12, P=0.0029*) (Table 2. 9). Greatest effects occurred on IMC205, which sustained yield loss at 10 FCB/head (*F=2.75, P=0.1038*). Average yield reduction of all cultivars combined were 31, 51, and 68 percent with infestations of 10, 20, and 40 FCB/head (*F=5.12, P=0.0029*). However, there were no significant yield losses from FCB infestation during early flowering in the second trial (*F=0.44, P=0.7243*) (Table 2. 12). In the third trial yield losses occurred only with 40 FCB on the cultivar IMC204 (*F=3.21, P=0.0758*) (Table 2. 15).

Infestations at early pod growth stage produced significant yield reductions in only one cultivar in one trial (*F=0.42, P=0.7400*; *F=0.33, P=0.8056*; *F=0.56, P=0.6466*, respectively) (Tables 2. 10, 2. 13, 2. 16). Helios had significant yield reduction with 20 FCB/head compared with the 0 FCB/head control (*F=2.65, P=0.1121*) (Table 2. 10).

There were minimal yield effects resulting from bagging (Tables 2. 11, 2. 14). In the first trial yield of Helios was lower on the non-bagged control, compared to the 0 FCB/head bagged treatment. Hyola had significantly lower yields in the second trial on bagged plants.

Yields varied greatly among the conducted trials making it difficult to compare the effects of different FCB infestations on yield. To develop such comparisons calculations were made of the number of FCB required to produce 10 percent yield loss. This was done by use of the slope of the yield loss (in grams)/FCB in the formula (Y/10)/(-S), where Y = average yield of the uninfested check and S is the slope. In all five trials where there was a negative relationship of yield with increasing FCB infestation a determination of numbers of FCB/head required to cause 10 percent yield loss could be established (Table 2. 18). This could not be done with the third 2001 trial (Table 2. 7), which involved only a single cultivar and did not sustain yield loss.

With these comparisions FCB was consistently established to be more damaging following infestations that occurred at early flowering compared to early pod stage. Number of FCB required causing 10 percent yield loss at early flowering stage infestation in the five trials ranged from 4.8-39.4 FCB/head (avg. 12.8). At early pod stage 10 percent yield loss resulted from average FCB infestations of 15.4-109.8 (avg. 39.7).

There have been no previous FCB damage assessment trials on canola although some work has been done on other crops. Young and Teetes (1977) reported that FCB feeding on developing sorghum seed caused smaller and lighter distorted seed. Actual yield loss occurred only when 200 bugs per head damaged 23 percent of the seed. The point of equal compensatory effect occurred at 14 percent damaged seed or approximately 140 bugs per head. Damage resulted from sucking juices from the immature developing grains. Damaged seed was also more commonly infected with a fungus (*Alternaria* sp.) that causes the seed to turn black and results in further deterioration of quality.

The studies reported here do demonstrate that *N. raphanus* can significantly affect yield of canola. In Australia, the related species *Nysius vinitor* (rutherglen bug) similarly feeds on pods and is reported to potentially reduce pod set, fill and seed quality. Action thresholds proposed for *N. vinitor* are 10 adults or 20 nymphs per plant, more if moisture is not limiting (Anonymous 2003). These numbers seem a bit conservative for FCB. In these studies 10 percent yield loss occurred on average with 12.8 FCB/head during early flowering stage infestations. Since the 'heads' used in these trials typically involved less than half of the reproductive area of the plant a threshold of closer to 25 FCB/plant or more seems more appropriate for FCB.

However, growth stage of canola can also modify effects of FCB damage potential. Plants are typically most heavily infested by FCB at pod fill and plants are consistently less susceptible to FCB than infetations that occur earlier during early flowering (Table 2.18). Action thresholds used for FCB in canola should reflect plant growth stage. With an average of 39.7 FCB/head required to cause 10 percent yield loss during early pod infestations, an action threshold substantially higher than that proposed for *N. vinitor* seems appropriate, perhaps closer to 80 FCB/plant.

Cultivar responses to FCB may also be incorporated into FCB action thresholds. However, in these studies all nine tested cultivars sustained yield loss in at least one trial at some FCB infestation level. Variation between trials was substantial but it appears that a significant level of resistance to FCB injury did not occur among the tested cultivars.

Table 2. 1. Yield (g. /head) of Seven Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Flower Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
Hyola	1.30 a	0.86 ab	0.40 ab	0.22 b	- 0.02660
Helios	1.49 a	1.41 ab	0.07 c	0.23 bc	- 0.03585
Excel	1.37 a	0.49 b	0.38 b	0.41 b	- 0.01995
Defender	2.32 a	0.92 b	0.66 b	0.62 b	- 0.03636
Apollo	0.78 a	0.11 c	0.68 ab	0.17 bc	- 0.01028
Alto	1.42 a	0.87 a	0.77 a	0.80 a	- 0.01296
46A65	0.87 a	0.82 a	0.11 a	0.49 a	- 0.01159
AVERAGE	1.36	0.78	0.44	0.42	- 0.02194

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 2. Yield (g. /head) of Seven Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Pod Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	No. False Chinch Bugs/Head[1]				
Cultivars	0 FCB	10 FCB	20 FCB	40 FCB	Slope
Hyola	6.56 a	6.77 a	4.10 b	3.75 b	- 0.08124
Helios	7.65 a	7.49 a	5.45 b	6.00 ab	- 0.04747
Excel	7.33 a	6.50 ab	4.50 b	6.16 ab	- 0.03104
Defender	7.61 a	5.33 a	4.88 a	5.46 a	- 0.04345
Apollo	5.71 a	5.17 ab	3.90 bc	2.68 c	- 0.07826
Alto	4.89 a	3.28 a	5.65 a	6.05 a	0.04577
46A65	3.87 a	3.67 a	3.49 a	3.14 a	- 0.01831
AVERAGE	6.23	5.46	4.57	4.75	- 0.03629

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 3. Yield (g. /head)[1] of Seven Canola Cultivars Bagged and Non-bagged for False Chinch Bugs (FCB) during the Early Flower and Pod Stages. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 FCB	Non-bagged	0 FCB	Non-bagged
Hyola	1.30 a	2.85 a	6.56 a	6.57 a
Helios	1.49 a	2.87 a	7.65 a	6.86 a
Excel	1.37 a	1.68 a	7.33 a	3.03 b
Defender	2.32 a	3.35 a	7.61 a	4.62 a
Apollo	0.78 a	1.97 a	5.71 a	3.42 a
Alto	1.42 a	4.30 a	4.89 a	4.71 a
46A65	0.87 a	4.73 a	3.87 a	5.23 a

[1] At each growth stage, means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 2. 4. Yield (g. /head) of Five Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Flower Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
Hyola	1.99 a	1.12 ab	0.79 ab	0.60 b	- 0.03154
Excel	1.97 a	2.18 a	1.35 a	1.49 a	- 0.01594
Defender	2.69 a	1.72 ab	0.89 b	0.89 b	- 0.04298
Apollo	1.45 a	0.41 b	0.42 b	0.70 ab	- 0.01329
46A65	1.38 ab	1.59 a	0.54 b	0.60 b	- 0.02425
AVERAGE	1.90	1.40	0.80	0.86	- 0.02560

[1] Means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 2. 5. Yield (g. /head) of Five Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Pod Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
Hyola	6.74 a	4.65 ab	4.92 ab	4.19 b	- 0.05291
Excel	9.19 a	7.34 ab	5.73 b	6.37 b	- 0.06646
Defender	8.63 a	5.41 ab	7.76 ab	5.05 b	- 0.06706
Apollo	7.80 a	4.28 b	6.28 ab	4.43 b	- 0.06096
46A65	4.52 ab	2.43 b	4.73 a	4.09 ab	0.00743
AVERAGE	7.38	4.82	5.88	4.83	-0.04799

[1] Means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 2. 6. Yield (g. /head)[1] of Five Canola Cultivars Bagged and Non-bagged for False Chinch Bugs (FCB) during the Early Flower and Pod Stages. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 FCB	Non-bagged	0 FCB	Non-bagged
Hyola	1.99 a	5.48 a	6.74 a	5.25 a
Excel	1.97 a	4.62 a	9.19 a	5.52 b
Defender	2.69 a	4.88 a	8.63 a	7.14 a
Apollo	1.45 a	4.51 a	7.80 a	5.26 a
46A65	1.38 a	4.69 a	4.52 a	5.80 a

[1] At each growth stage, means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 2. 7. Yield (g. /head) of the Canola Cultivar IMC204 Bagged and Non-bagged during the Early Flower and Pod Stage. Trial Three, Cargill Oilseed Research Center, Ft. Collins, CO, 2001.

		No. False Chinch Bugs/Head[1]				
Cultivars	Stages	O FCB	10 FCB	20 FCB	40 FCB	Slope
IMC204	Flower	2.39 a	2.13 a	2.10 a	1.99 a	0.00045
IMC204	Pod	7.52 a	6.72 ab	7.05 ab	5.66 b	- 0.03738

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 8. Yield (g. /head) of the Canola Cultivar IMC204 Bagged and Non-bagged during the Early Flower and Pod Stage. Trial Three, Cargill Oilseed Research Center, Ft. Collins, CO, 2001.

Cultivars	Stages	O FCB	Non-bagged
IMC204	Flower	2.39 a	2.82 a
IMC204	Pod	7.52 a	4.05 b

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 9. Yield (g. /head) of Six Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Flower Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
46A65	1.90 a	1.36 a	0.65 a	1.09 a	- 0.01992
Helios	7.30 a	3.34 ab	1.77 b	2.78 ab	- 0.09816
Apollo	0.76 a	0.55 ab	0.19 ab	0.05 b	- 0.01821
Hyola	3.47 a	5.14 a	4.33 a	0.97 b	- 0.07611
Excel	2.28 a	2.53 a	1.71 a	0.78 a	- 0.04239
IMC205	3.40 a	0.34 b	0.71 ab	0.44 b	- 0.05745
AVERAGE	3.19	2.21	1.56	1.02	- 0.05204

[1] Means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 2. 10. Yield (g. /head) of Six Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Pod Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
46A65	6.11 a	4.69 a	4.16 a	4.91 a	- 0.00788
Helios	9.12 a	7.28 ab	4.42 b	7.55 ab	- 0.03794
Apollo	4.08 a	4.06 a	3.25 a	3.54 a	- 0.01599
Hyola	5.30 a	5.83 a	5.02 a	4.01 a	- 0.03839
Excel	5.59 a	5.21 a	4.16 a	4.76 a	- 0.02226
IMC205	5.68 a	3.88 a	3.32 a	4.37 a	- 0.02504
AVERAGE	5.98	5.16	4.06	4.86	-0.024583

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 11. Yield (g. /head)[1] of Six Canola Cultivars Bagged and Non-bagged for False Chinch Bugs (FCB) during the Early Flower and Early Pod Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 FCB	Non-bagged	0 FCB	Non-bagged
46A65	1.90 a	2.93 a	6.11 a	3.96 b
Helios	7.30 a	0.82 b	9.12 a	7.03 a
Apollo	0.76 a	1.47 a	4.08 a	2.36 a
Hyola	3.47 a	1.92 a	5.30 a	3.78 b
Excel	2.28 a	2.96 a	5.59 a	1.90 b
IMC205	3.40 a	1.50 a	5.68 a	3.30 b

[1] At each growth stage, means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 12. Yield (g. /head) of Four Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Flower Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
46A65	5.71 a	3.64 a	3.11 a	2.69 a	-0.06740
Apollo	3.80 a	2.78 a	2.99 a	2.31 a	-0.03209
Excel	2.26 b	4.11 ab	6.80 a	4.90 ab	0.06502
Hyola	4.19 a	5.19 a	5.27 a	4.17 a	-0.00596
AVERAGE	3.99	3.93	4.54	3.52	-0.01011

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 13. Yield (g. /head) of Four Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Pod Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
46A65	7.61 a	7.64 a	8.16 a	6.78 a	-0.01990
Apollo	6.14 a	6.85 a	7.19 a	6.59 a	0.00858
Excel	7.74 a	7.60 a	8.95 a	7.90 a	0.00851
Hyola	6.68 a	6.74 a	7.74 a	7.69 a	0.02844
AVERAGE	7.04	7.21	8.01	7.24	0.00641

[1] Means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 2. 14. Yield (g. /head)[1] of Four Canola Cultivars Bagged and Non-bagged for False Chinch Bugs (FCB) during the Early Flower and Early Pod Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 FCB	Non-bagged	0 FCB	Non-bagged
46A65	5.71 a	6.23 a	7.61 a	6.60 a
Apollo	3.80 a	1.68 a	6.14 a	5.77 a
Excel	2.26 a	2.81 a	7.74 a	4.87 a
Hyola	4.19 b	8.54 a	6.68 a	5.16 a

[1] At each growth stage, means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 15. Yield (g. /head) of Two Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Flower Stage. Trial Three, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
IMC204	1.57 ab	1.99 a	0.44 b	0.24 b	-0.04122
IMC205	3.27 a	1.68 a	1.33 a	0.68 a	-0.05861

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 16. Yield (g. /head) of Two Canola Cultivars Bagged and Infested with Different Numbers of False Chinch Bugs (FCB) during the Early Pod Stage. Trial Three, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. False Chinch Bugs/Head[1]				
Cultivars	O FCB	10 FCB	20 FCB	40 FCB	Slope
IMC204	3.23 a	2.35 a	2.39 a	2.49 a	- 0.01377
IMC205	5.47 a	4.62 a	4.11 a	4.81 a	- 0.01355

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 2. 17. Yield (g. /head)[1] of Two Canola Cultivars Bagged and Non-bagged during the Early Flower and Early Pod Stage. Trial Three, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 FCB	Non-bagged	0 FCB	Non-bagged
IMC204	1.57 a	4.24 a	3.23 a	2.23 a
IMC205	3.27 a	2.00 a	5.47 a	4.26 a

[1] At each growth stage, means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 2.18. Summary of yield loss relationship between false chinch bug (FCB) and canola seed weight, 2001-2002.

Trial[1]	Year	Growth Stage[2]	Yield (g.)/ 0 FCB/head	Average Slope	FCB to Produce 10% Yield Loss[3]
HFRC, Trial One	2001	EF	1.36	-0.02194	6.2
HFRC, Trial One	2001	EP	6.23	-0.03629	17.2
HFRC, Trial Two	2001	EF	1.90	-0.02560	7.4
HFRC, Trial Two	2001	EP	7.38	-0.04799	15.4
CORC, Trial Three	2001	EF	2.39	0.00045	----
CORC, Trial Three	2001	EP	7.52	-0.03738	20.1
HFRC, Trial One	2002	EF	3.19	-0.05204	6.1
HFRC, Trial One	2002	EP	5.98	-0.02458	24.3
HFRC, Trial Two	2002	EF	3.99	-0.01011	39.4
HFRC, Trial Two	2002	EP	7.04	-0.00641	109.8
CORC, Trial Three	2002	EF	2.42	-0.04991	4.8
CORC, Trial Three	2002	EP	4.35	-0.01366	31.8

[1] HFRC - Colorado State University Horticulture Field Research Center; CORC - Cargill Oilseed Research Center.

[2] Early flower stage (EF) and Early pod stage (EP).

[3] Number of FCB estimated to cause 10% yield loss calculated by (Y/10)/(- S), where Y = yield (g.) and S is the slope of yield loss (g.) per FCB/canola head.

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CHAPTER III

EVALUATION OF SPRING CANOLAS AND MUSTARDS OF VARYING AGE FOR RELATIVE PREFERENCE BY FALSE CHINCH BUGS, *NYSIUS RAPHANUS* (HOWARD)

INTRODUCTION

The false chinch bug (FCB), *Nysius raphanus* (Howard), is a general feeder with a decided preference for brassicas (Howard 1872, Knowlton 1934, Wene 1953, Wene 1958, Sweet 2000). Damage can occur at all growth stages but is most damaging at seedling stages (Smith 1942, Tappan 1970) and, particularly, following flowering and during seed-pod development (personal observations). FCB is a key pest of canola grown in Colorado (Al-Doghairi 2000). During outbreaks large aggregations can occur on plants causing wilting and sometimes death of plants (Knowlton 1934).

Host plant preference is potential management tactic in development of IPM systems (Norris et al. 2003). An evaluation of FCB susceptibility among oilseed brassicas has not previously been published. The purpose of this study was to make preliminary evaluation of resistance present in commercially available oilseed canola and mustard.

MATERIALS AND METHODS

Trials were conducted during 2000 at Colorado State University, Ft. Collins, CO. Included were mixtures of 11 different *Brassica* cultivars including seven spring canolas, *Brassica napus* cvs. Alto, Sterling, Helios, Westar, CO1, IMC01, and Springfield, a winter canola, *Brassica napus* cv. Casino, a winter mustard, *Brassica juncea* cv. Debut, and two spring mustards, *Brassica juncea* cvs. ZEM 1, and W1-23.

A separate variable was age of the plants. Seedling stages were evaluated beginning at 15 days after seeding (DAS). Older plants were first evaluated at 45 days following seeding. Replications consisted of randomly placing a single equal-aged plant of each cultivar within a 61-cm high x 61-cm long x 37-cm wide cage and subsequently introducing 100 field collected false chinch bug adults. Each of the cages contained plants of two different growth stages (15 days after seeding; 45 days after seeding). Experimental design was randomized complete block with five replications.

There were three separate runs of the trial each conducted under identical conditions. The first trial took place from 16 to 22 August; the second trial from 25 to 31 August; the final trial from 7 to 11 September. In each trial count of the numbers of false chinch bugs per plant were made at 24-hr intervals. Data analyses were done using Student-Newman-Keuls (SNK) (SAS Institute 1990).

RESULTS AND DISCUSSION

Overall, FCB showed strong feeding preference for older plants ($F= 19.81$, $P=0.0001$; $F=38.52$, $P=0.0001$; $F=35.28$, $P=0.0001$, respectively) (Tables 3. 1, 3. 2, 3. 3). Average FCB numbers on 45-day old plants was 46-82 percent greater than on 15-day old plants among the three trials ($F=19.81$, $P=0.0001$; $F=1.94$, $P=0.0400$; $F=38.52$, $P=0.0001$; $F=2.18$, $P=0.0194$; $F=35.28$, $P=0.0001$; $F=3.40$, $P=0.0004$, respectively) (Tables 3. 1, 3. 2, 3. 3). Cultivars that had the greatest difference in numbers between 15 DAS and 45 DAS were ZEM1, Debut and CO1 ($F=112.07$, $P=0.0001$; $F=20.36$, $P=0.0001$; $F=64.44$, $P=0.0001$; $F=130.63$, $P=0.0001$; $F= 81.57$, $P=0.0001$; $F=99.36$, *P=0.0001*; *F=82.93*, *P=0.0001*; *F=18.67*, *P=0.0001*; *F=47.90*, *P=0.0001*, respectively) (Tables 3. 1, 3. 2, 3. 3). Cultivars that showed least differences due to age in the three trials were Helios, Alto, and W1-23 (*F=0.51*, *P=0.4782*; *F=10.61*, *P=0.0019*; *F=0.03*, *P= 0.8615*; *F=0.11*, *P=0.7415*; *F=0.27*, *P=0.6040*; *F=9.58*, *P=0.0034*; *F=1.01*, *P=0.3218*; *F=71.60*, *P=0.0001*; *F=7.39*, *P=0.0103*, respectively) (Tables 3. 1, 3. 2, 3. 3).

Few differences in susceptibility were evident in seedling age plants. In one trial the cultivars Alto, and CO1 each hosted significantly higher FCB numbers/plant. However, such differences were neither consistent nor repeated.

Significant differences were observed among older (45-day) plants. The spring mustard cultivar ZEM-1 consistently supported highest numbers of FCB/plant (*F=112.07*, *P=0.0001*; *F=130.63*, *P=0.0001*; *F=82.93*, *P=0.0001*, respectively) (Tables 3. 1, 3. 2, 3. 3). Other cultivars showing high FCB preference included the winter mustard Debut (*F=81.57*, *P=0.0001*) (Table 3. 2), and spring canola CO1 (*F=64.44*, *P=0.0001*; *F=99.36*, *P=0.0001*, respectively) (Table 3. 1, 3. 2).

Some older cultivars were little infested by FCB. The spring mustard cultivar W1-23 and spring canola cultivar Helios were most consistent in this regard, supporting 17 percent and 17 percent the number of FCB/plant on the most heavily infested spring mustard (ZEM-1) and spring canola (CO1) cultivars. In addition, the cultivar W1-23 also showed resistance to western black flea beetle (Chapter 12), suggesting this may be a source of multiple pest resistance.

Table 3. 1. Average number of false chinch bugs on canolas and mustards of two different ages. First run of a laboratory choice experiment.

Cultivar	Type[1]	DAS[2]	FCB/Plant[3] 1 DAT	2 DAT	3 DAT	4 DAT	5 DAT	6 DAT	Average
W1-23	SM	15	1.4 a	3.4 a	6.4 a	5.2 a	5.2 a	1.4 a	3.8 a
ZEM 1	SM	15	2.0 a	0.4 a	3.2 a	3.8 a	2.6 a	0.8 a	2.1 a
Debut	WM	15	1.8 a	1.2 a	3.2 a	2.4 a	3.4 a	1.0 a	2.2 a
Casino	WC	15	2.2 a	2.0 a	5.4 a	4.4 a	5.0 a	1.2 a	3.4 a
CO1	SC	15	0.4 a	0.4 a	3.0 a	3.0 a	2.2 a	0.8 a	1.6 a
IMCO1	SC	15	1.2 a	1.2 a	1.8 a	1.8 a	3.6 a	0.6 a	1.7 a
Alto	SC	15	1.0 a	3.6 a	2.8 a	8.2 a	5.2 a	2.8 a	3.9 a
Helios	SC	15	0.6 a	1.4 a	4.0 a	2.2 a	5.8 a	1.2 a	2.5 a
Sterling	SC	15	0.2 a	3.0 a	4.0 a	3.2 a	4.2 a	3.4 a	3.3 a
Westar	SC	15	0.2 a	1.2 a	2.4 a	6.8 a	2.8 a	0.2 a	2.3 a
Springfield	SC	15	0.2 a	1.2 a	3.6 a	4.2 a	4.4 a	5.6 a	3.2 a
W1-23	SM	45	1.6 c	3.4 b	6.2 bcd	5.2 bcd	5.0 b	0.6 c	3.7 cd
ZEM 1	SM	45	13.2 a	10.4 a	14.2 a	11.0 abc	10.6 ab	8.6 a	11.3 a
Debut	WM	45	0.6 c	5.8 ab	12.6 ab	12.6 ab	17.0 a	2.4 bc	8.5 b
Casino	WC	45	1.0 c	2.0 b	3.0 d	4.8 bcd	5.0 b	4.6 abc	3.4 cd
CO1	SC	45	6.4 b	8.8 a	11.6 abc	15.4 a	15.8 a	7.2 ab	10.9 a
IMCO1	SC	45	1.6 c	1.4 b	9.2 abcd	3.8 cd	13.0 a	2.6 bc	5.3 c
Alto	SC	45	1.2 c	1.0 b	1.4 d	2.6 cd	3.6 b	0.6 c	1.7 d
Helios	SC	45	0.4 c	0.6 b	4.8 cd	2.2 d	3.4 b	0.8 c	2.0 cd
Sterling	SC	45	0.6 c	1.0 b	3.6 d	7.4 bcd	5.8 b	2.8 bc	3.5 cd
Westar	SC	45	0.8 c	2.6 b	6.2 bcd	5.2 bcd	4.8 b	0.2 c	3.3 cd
Springfield	SC	45	0.4 c	1.2 b	2.2 d	1.8 d	2.6 b	2.0 bc	1.7 d

[1] WM = Winter mustard; SM = Spring mustard; WC = Winter canola; SC = Spring canola

[2] DAS - Days after seeding. Age of the plant at the initiation of the evaluation. DAT - Days after treatment. Evaluation made subsequent to infestation with false chinch bug.

[3] Numbers within a column of the same seeding date that are followed by the same letter are not significantly different (P>0.05) by SNK.

Table 3. 2. Average number of false chinch bugs on canolas and mustards of two different ages. Second run of a laboratory choice experiment.

Cultivar	Type[1]	DAS[2]	FCB/Plant[3]					
			1 DAT	2 DAT	3 DAT	4 DAT	5 DAT	Average
W1-23	SM	15	1.0 a	0.8 a	0.6 a	0.6 a	1.4 a	0.9 a
ZEM 1	SM	15	0.8 a	0.8 a	0.8 a	0.8 a	0.6 a	0.8 a
Debut	WM	15	1.4 a	2.6 a	2.0 a	4.2 a	3.0 a	2.6 a
Casino	WC	15	2.2 a	3.0 a	2.0 a	1.4 a	1.0 a	1.9 a
CO1	SC	15	1.2 a	2.2 a	1.2 a	1.4 a	1.2 a	1.4 a
IMCO1	SC	15	0.8 a	1.6 a	2.8 a	2.6 a	2.8 a	1.7 a
Alto	SC	15	2.6 a	4.4 a	1.4 a	2.2 a	1.0 a	2.3 a
Helios	SC	15	2.2 a	2.2 a	2.6 a	3.0 a	2.0 a	2.4 a
Sterling	SC	15	1.2 a	1.6 a	0.6 a	1.4 a	1.0 a	1.2 a
Westar	SC	15	0.4 a	2.8 a	2.6 a	2.8 a	0.6 a	1.8 a
Springfield	SC	15	0.6 a	1.4 a	1.0 a	0.0 a	1.2 a	0.8 a
W1-23	SM	45	0.8 b	1.8 c	2.2 c	2.2 b	7.8 b	3.0 c
ZEM 1	SM	45	14.8 a	15.6 ab	27.0 a	10.0 b	12.4 b	16.7 a
Debut	WM	45	8.8 ab	17.6 a	17.0 ab	21.2 a	24.8 a	15.2 a
Casino	WC	45	1.0 b	1.8 c	1.2 c	2.6 b	9.8 b	2.7 c
CO1	SC	45	15.6 a	15.0 ab	18.2 ab	15.0 ab	13.8 b	15.8 a
IMCO1	SC	45	1.0 b	1.8 c	1.4 c	3.4 b	3.0 b	2.1 c
Alto	SC	45	1.2 b	3.2 c	3.4 c	3.6 b	3.0 b	2.9 c
Helios	SC	45	0.6 b	3.8 c	3.4 c	1.6 b	3.4 b	2.2 c
Sterling	SC	45	0.8 b	10.2 abc	5.8 c	2.0 b	2.2 b	4.2 c
Westar	SC	45	2.0 b	4.8 bc	4.8 c	3.4 b	4.2 b	2.6 c
Springfield	SC	45	13.6 a	9.4 abc	12.6 bc	10.4 b	13.4 b	9.1 b

[1] WM = Winter mustard; SM = Spring mustard; WC = Winter canola; SC = Spring canola

[2] DAS - Days after seeding. Age of the plant at the initiation of the evaluation. DAT - Days after treatment. Evaluation made subsequent to infestation with false chinch bug.

[3] Numbers within a column of the same seeding date that are followed by the same letter are not significantly different (P>0.05) by SNK.

Table 3. 3. Average number of false chinch bugs on canolas and mustards of two different ages. Third run of a laboratory choice experiment.

Cultivar	Type[1]	DAS[2]	FCB/Plant [3] 1 DAT	2 DAT	3 DAT	4 DAT	Average
W1-23	SM	15	0.4 a	0.4 a	0.8 a	1.8 ab	0.9 b
ZEM 1	SM	15	1.0 a	1.2 a	1.0 a	2.2 ab	1.4 ab
Debut	WM	15	0.0 a	0.2 a	1.2 a	2.0 ab	0.9 b
Casino	WC	15	1.6 a	1.6 a	2.2 a	1.0 ab	1.6 ab
CO1	SC	15	1.4 a	1.6 a	3.6 a	3.4 a	2.5 a
IMCO1	SC	15	0.4 a	0.0 a	0.2 a	1.6 ab	0.6 b
Alto	SC	15	0.8 a	0.4 a	0.8 a	1.8 ab	1.0 b
Helios	SC	15	0.4 a	0.8 a	1.4 a	2.4 ab	1.3 b
Sterling	SC	15	1.0 a	0.8 a	0.6 a	1.4 ab	1.0 b
Westar	SC	15	1.0 a	1.0 a	0.8 a	1.0 ab	1.0 b
Springfield	SC	15	0.4 a	0.6 a	0.4 a	0.6 b	0.5 b
W1-23	SM	45	0.6 b	4.0 bc	1.6 bc	2.6 c	2.2 d
ZEM 1	SM	45	29.0 a	23.0 a	22.8 a	19.8 a	23.7 a
Debut	WM	45	1.0 b	7.4 bc	11.6 b	3.8 c	6.0 c
Casino	WC	45	1.2 b	1.2 c	0.6 c	1.8 c	1.2 d
CO1	SC	45	6.6 b	10.4 b	9.4 bc	8.6 bc	8.8 b
IMCO1	SC	45	8.4 b	12.6 b	10.4 bc	10.0 bc	10.4 b
Alto	SC	45	7.8 b	12.4 b	9.4 bc	11.0 bc	10.2 b
Helios	SC	45	1.2 b	1.4 c	1.2 bc	3.0 c	1.7 d
Sterling	SC	45	1.0 b	0.6 c	1.8 bc	2.2 c	1.4 d
Westar	SC	45	3.8 b	7.0 bc	5.4 bc	3.6 c	5.0 c
Springfield	SC	45	8.9 b	11.8 b	1.8 bc	13.2 b	11.0 b

[1] WM = Winter mustard; SM = Spring mustard; WC = Winter canola; SC = Spring canola

[2] DAS - Days after seeding. Age of the plant at the initiation of the evaluation. DAT - Days after treatment. Evaluation made subsequent to infestation with false chinch bug.

[3] Numbers within a column of the same seeding date that are followed by the same letter are not significantly different (P>0.05) by SNK.

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CHAPTER IV

RELATIVE ATTRACTION OF FALSE CHINCH BUG, *NYSIUS RAPHANUS* (HOWARD) AND ITS TACHINID PARASITIOD, *PHASIA OCCIDENTIS* (WALKER), TO CANOLA AND MUSTARD COMPOUNDS

INTRODUCTION

The false chinch bug, *Nysius raphanus* (Howard), is the most serious pest among North America species of *Nysius* spp. (Ashlock 1977, Sweet 2000). It has a wide host range but is particularly damaging to crucifers and a key pest of canola grown in Colorado (Al-Doghairi 2000).

Some previous trapping studies involving the brassica-feeding western black flea beetle, *Phyllotreta pusilla* (Horn), incidentally captured false chinch bugs (Al-Doghairi 2000). These observations were suggestive that yellow was attractive. Also trials involving traps baited with canola oil or allyl isothiocyanate showed indications of increased FCB attraction. On the basis of this, expanded trials were indicated to better identify traps specifically effective for FCB capture.

Mustard oils and allyl isothiocyanate, used in the preliminary studies, are among the secondary compounds common to Brassicaceae (Feeny 1977, Aliabadi and Whitman 2001). Such secondary compounds are also sometimes utilized in host finding by parasitoids of phytophagous insects (Titayavan and Altieri 1990, Tumlinson et al. 1993, Vaughn et al. 1996, Rose et al. 1998, Bradburne and Mithen 2000, Turlings et al. 2000). The key FCB parasitoid recovered in Colorado is a tachinid, *Phasia* (= *Phorantha*) *occidentis* (Walker) (Milliken and Wadley 1923, Brooks 1945). Therefore, during FCB trapping trials concurrent observations on *P. occidentis* were also recorded.

MATERIALS AND METHODS

All trials were conducted during late summer, 2000 at either of two locations. The first was at the Cargill Oilseed Research Center in Ft. Collins, CO where canola was the predominant crop surrounding the trapping study. The second site was within a Napa cabbage field in an organic vegetable farm (Grant Family Farms (GFF) in Waverly, CO.

In the first trial at the Cargill site, 266 ml golden yellow drinking plastic cups were used as the traps. The test treatments were poured into the base of the cup and the inner rim of the cup was coated with Tanglefoot^R. Tested treatments included raw canola seed oil (1 ml/cup), raw mustard seed oil (1 ml/cup), a combination of mustard and canola oil (0.5 ml + 0.5 ml/cup), water (10 ml) and 2 fresh canola pods, polypropylene glycol antifreeze (10 ml/cup), and water (10 ml/cup). The traps were attached to electric fence posts 38 cm above ground and spaced at 3-m intervals along the edge of a canola field. Plot design was a randomized complete block with four replications. The first trial was established 16 July and concluded at 5 days.

The second trial was conducted 15-20 September. Insects were captured on yellow sticky Apple Maggot No-Bait traps (Trece Inc., Salinas, CA). Treatments (1 ml mustard oil, 1 ml canola oil) were smeared directly on the surface of the trap and an unbaited trap served as a control. The yellow sticky traps were attached by small size nail on the stake that were all on single 38 cm x 38 cm stake formed into a cross, each separated 9 cm from the adjacent trap. Traps were arranged in random order on the stake and stakes were separated by 12-m spacing.

Plot design was randomized complete design with four replications. At the GFF site three different trials were concurrently conducted from 1 August to 7 August. All were arranged as a randomized completed design with four replications. The same basic 266 ml cups described above were used as the trap but color was also involved in treatments, with either golden yellow and dark blue used in the studies. Treatments included the canola oil, mustard oil, and mustard oil and canola mixtures described above. In addition a ground mustard seed (Frontier of Natural Products, Fort Collins, CO) was included as a treatment. Finally, an extract of crushed canola seed pods was prepared. This was done by crushing fresh pods and then concentrating the juice by freeze-drying. The ground mustard seed was applied at a 1 mg/cup; all liquid treatments at 1 ml/cup.

Yellow-colored cups were used in the first trial, blue-colored cups in the second, and a comparison of yellow vs. blue was done in the third trial. The golden yellow and blue cups were placed on a 38 cm x 38 cm wooden stake cross, the cups separated by 9 cm along the horizontal. Stakes containing the cups were separated by 11-m spacing. Plot design was randomized completed design with four replications. Data for all trials were analyzed using Least Significant Difference (LSD) (SAS Institute 1990).

RESULTS AND DISCUSSION

In the first trial (Table 4. 1), yellow cups baited with raw canola oil, raw mustard and combinations of the two caught significantly higher numbers of false chinch bugs compared to water and polypropylene glycol controls ($F=5.12$, $P=0.0062$). Mustard oil and canola oil also showed significant attractiveness in the second trial, conducted at the Cargill Oilseed Research Center ($F=5.82$, $P=0.0394$) (Table 4. 2). Attraction also occurred with extracts of freeze-dried canola seed pods (Table 4. 3), but not with extracts of dried mustard seed ($F=1.85$, $P=0.1840$). Canola and mustard oils baited with yellow color cups caught significantly more false chinch bug comparing to mustard oil baited with blue color cups (*F= 3.41*, *P= 0.0668*) (Table 4. 5)

These data are consistent with the preliminary observations of Al-Doghairi (2000) who caught significantly higher numbers of false chinch bugs on yellow sticky traps baited with canola oil. Previous studies by Pivnick et al. (1991) reported that the northern false chinch bug, *Nysius niger* Baker, is attracted to mustard oils with a specific side-chain structure. The compound ethyl ICB (4-isothiocyanatobutyrate), placed in rubber septa attached to boll weevil traps, was most attractive. Al-Doghairi (2000) also reported that yellow cup traps with baits, presented in film canisters containing allyl isothiocyanate (AITC), caught significantly more false chinch bugs than yellow cups baited with water (control). These specific compounds can be difficult to handle, because of potential injury they can cause upon contact or inhalation. The data from this trial suggest that relatively crude extracts of oilseed canola or mustard, as well as dried canola seed pod extracts, can also be used to effectively increase FCB capture at traps. In addition to ease of handling, these latter materials are cheap and readily available.

The use of canola oil baits also increased capture of *Phasia occidentis* (*F=1.93*, *P=0.1495*; *F=1.78*, *P=0.1969*; *F=5.65*, *P=0.0086*, respectively) (Tables 4. 1, 4. 3, 4. 4). Previous research by Pinvick (1993) had established that some hymenopterous parasitoids associated with *Brassica*-feeding insects also showed attraction to mustard oil compounds. The braconid parasitoid, *Meteorus leviventris,* was caught in highest numbers on traps baited with AITC. Response was related to the rate with higher captures at traps releasing 4 mg/day compared to 40 mg/day. Later studies by Murchie et al. (1997) reported that traps baited with 2-phenylethyl isothiocyanate caught more males and females of *Platygaster subuliformis* than traps baited with allyl isothiocyanate or unbaited traps.

The data from this study appear to be the first showing that secondary host plant compounds can increase captures of tachinids. When incorporated into traps the use of appropriate colors can further increase effectiveness of traps (Chapter 5). For example, the use of blue significantly increased capture of *P. occidentis* compared to yellow in traps baited with canola oil ($F=2.51, P=0.1249$) (Table 4. 5).

Table 4. 1. Capture of false chinch bugs (*Nysius raphanus*) and its associated tachinid parasitoid (*Phasia occidentis*) in yellow cup traps baited with different mustard and canola compounds. Trial 1, Cargill Oilseed Research Center, Ft. Collins, CO. 16-21 July, 2000.

Tested Compound and Volume/Trap	*N. raphanus*/ Cup[a]	*P. occidentis*/ Cup[a]
Canola oil (1 ml)	717.5 a	9.8 a
Mustard oil + Canola oil (0.5 ml + 0.5 ml)	672.0 a	4.3 b
Mustard oil (1 ml)	647.8 a	4.3 b
Water (10 ml) + 2 Canola pods	442.3 ab	5.3 ab
Polypropylene glycol (10 ml)	301.0 b	4.3 b
Water Check (10 ml)	180.8 b	4.3 b

[a] Means within a column not followed by the same letter are significantly different ($P > 0.05$) by LSD.

Table 4. 2. Capture of false chinch bugs (*Nysius raphanus*) on yellow sticky traps baited with canola or mustard oils. Trial 2, Cargill Oilseed Research Center, Ft. Collins, CO. 15-20 September, 2000.

Tested Compound and Volume/Trap	*N. raphanus*/Trap[a]
Mustard oil (1 ml)	262.3 a
Canola oil (1 ml)	212.8 ab
Yellow sticky trap control	123.8 b

[a] Means within a column not followed by the same letter are significantly different (P> 0.05) by LSD.

Table 4. 3. Capture of false chinch bugs (*Nysius raphanus*) and its associated tachinid parasitoid (*Phasia occidentis*) in yellow cup traps baited with different mustard and canola compounds. Trial 1, Grant Family Farms, Waverly, CO. 1-7 August, 2000.

Tested Compound and Amount/Trap	*N. raphanus*/ Cup[a]	*P. occidentis*/ Cup[a]
Canola oil (1 ml)	27.8 ab	2.3 a
Mustard oil (1 ml)	28.0 ab	0.3 b
Crushed freeze-dried canola pods extract (1 ml)	30.5 a	0.8 ab
Ground mustard seed (1 mg)	24.5 ab	1.3 ab
Water check (10 ml)	17.0 b	1.0 ab

[a] Means within a column not followed by the same letter are significantly different ($P > 0.05$) by LSD.

Table 4. 4. Capture of false chinch bugs and its associated tachinid parasitoid (*Phasia occidentis*) in blue cup traps baited with different mustard and canola compounds. Trial 2, Grant Family Farms, Waverly, CO. 1-7 August, 2000.

Tested Compound and Amount/Trap	*N. raphanus*/ Cup[a]	*P. occidentis*/ Cup[a]
Mustard oil + Canola oil (0.5 ml+ 0.5 ml)	49.5 a	1.8 bc
Canola oil (1 ml)	48.3 a	2.8 ab
Mustard oil (1 ml)	46.5 a	4.3 a
Ground mustard seed (1 mg)	20.5 b	1.0 c
Water check (10 ml)	28.5 ab	2.0 bc

[a] Means within a column not followed by the same letter are significantly different (P> 0.05) by LSD.

Table 4. 5. Capture of false chinch bugs and its associated tachinid parasitoid (*Phasia occidentis*) in blue and yellow cup traps baited with different mustard and canola compounds. Trial 3, Grant Family Farms, Waverly, CO. 1-7 August, 2000.

Bait[a]	Trap Color	*N. raphanus*/ Cup[b]	*P. occidentis*/ Cup[b]
Canola oil (1 ml)	Yellow	69.5 a	3.5 b
Mustard oil (1 ml)	Yellow	65.0 a	3.5 b
Canola oil (1 ml)	Blue	52.5 ab	7.0 a
Mustard oil (1 ml)	Blue	45.8 b	5.0 ab

[a] All traps were baited with 1 ml, placed in a 38 cm above ground.

[b] Means within a column not followed by the same letter are significantly different (P>0.05) by LSD.

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CHAPTER V

EVALUATION OF COLOR TRAPS FOR MONITORING FALSE CHINCH BUG, *NYSIUS RAPHANUS* (HOWARD), WITH NOTES ON CAPTURES OF ITS ASSOCIATED TACHINHID PARASITIOD, *PHASIA OCCIDENTIS* (WALKER)

INTRODUCTION

The false chinch bug, *Nysius raphanus* (Howard), is a very common insect of the High Plains States. Originally described from Kansas by Howard (1872), it is the most serious pest among North America species of *Nysius,* although erroneously identified as *N. ericae* in many early papers (Ashlock 1977, Sweet 2000). False chinch bug has a wide host range but is particularly damaging to brassicas and is a key pest of canola grown in Colorado (Al-Doghairi 2000). Large aggregations can occur on plants and heavily attacked plants may badly wilt and often fail to recover (Knowlton 1934, Smith 1942, Leigh 1961).

The previous studies conducted by Al-Doghairi (2000) reported that yellow colored traps were attractive to false chinch bug. Furthermore, yellow traps baited with allyl isothiocyanate caught significantly more false chinch bugs than yellow color cup traps baited with water (as control).

The most common parasitoid associated with false chinch bug is the tachinid *Phasia* (= *Phorantha*) *occidentis* (Walker) (Milliken and Wadley 1923, Brooks 1945). Parasitism is almost entirely confined to the females of *Nysius*. It has commonly been recovered incidentally during recent Colorado studies but its occurrence has not been quantified.

To assist field studies of false chinch bug development an effective monitoring trap is desirable. These studies were established to determine the relative attractiveness of color in trap design. Furthermore, observations were made on attraction to color by *P. occidentis*, as this species is potentially important as a biological control agent for false chinch bug and few studies exist on the color attraction of tachinids.

MATERIALS AND METHODS

All trapping studies were conducted during the summer of 2000. The initial trials were conducted at the Cargill Oilseed Research Center in Ft. Collins and involved use of 8-cm x 13-cm colored sticky traps placed on wood stake crosses with the horizontal bar 60-cm above the ground. Traps were spaced 6-m apart within a canola field. In the first trial trapping was conducted over a 7 day period, from 5 to 12 July, and evaluated the colors yellow, blue, neon yellow, neon green, neon pink and orange. In the second trial trapping was repeated during two intervals; the first running from 16 July to 21 July, the second from 18 July to 23 July. Neon orange, silver and white were added to the second trial and orange was dropped. Experimental design was randomized complete design with 4 replications and consisted of the eight color treatments.

Two additional trapping experiments were conducted during the same season at the Horticulture Field Research Center North of Ft. Collins, CO. Trap design, trap placement and experimental design were similar to the above-described trapping experiments. In the first trial eight color treatments and trapping occurred within a canola field from 7 to 14 July. Because of the response to silver in this trial a subsequent series of traps were evaluated, including aluminum. This last trial was conducted between 14 and 21 July. Data were analyzed using Student-Newman-Keuls (SNK) (SAS Institute 1990).

RESULTS AND DISCUSSION

In the first trial (Table 5. 1) greatest numbers of false chinch bugs were caught on yellow sticky traps (*F=18.33, P=0.0001*). During the subsequent trial (Table 5. 2) the yellow sticky colored traps again caught the highest number of false chinch bug in both trial runs (*F=17.63, P=0.0001*; *F=21.60, P=0.0001*, respectively). Previous studies (Al-Doghairi 2000) also indicated yellow colors were preferred by false chinch bug. Significantly higher numbers of false chinch bug adults were caught on blue colored traps compared to the various neon colored and white traps (*F=17.63, P=0.0001*; *F=21.60, P=0.0001*, respectively) (Table 5. 2).

Much lower numbers of false chinch bugs were captured during the trials at the Horticulture Field Research, due to low population density of false chinch bugs (Tables 5. 3, 5. 4). Although yellow traps had the highest captures, results were not significant (*F=1.98, P=0.1065*; *F=2.42, P=0.0551*, respectively). Silver had the second highest capture in the first trial and captures at aluminum traps in the final study were suggestive that such shiny surfaces may also be useful in future trap modifications.

Yellow was not an attractive color for *P. occidentis*. However, blue was significantly more attractive than all other tested colors and captured 9.2X as many as the yellow in the four trap periods where they were both included (*F=13.64, P=0.0001*; *F=7.98, P=0.0001*; *F=6.40, P=0.0004*; *F=1.29, P=0.3047*, respectively) (Tables 5. 1, 5. 2, 5. 3).

Previous studies have reported different species of tachinds captured on yellow color traps. Buriff and Davis (1974) reported incidental capture of tachinids during studies of apple maggot, *Rhagoletis pomonella* (Wash). A total of 378 tachinids, primarily *Archytas apicifer* (Walker) and *A. californiae* (Walker), were captured on yellow sticky panels. The use of sticky colored-panels also was suggested by Burk (1982) as a useful way of obtaining specimens of certain tachinids, specifically *Euphasiopteryx ochracea* (Bigot 1889). The data from these studies suggest that the color blue would be far superior to standard yellow traps where surveying tachinids.

Table 5. 1. Capture of false chinch bug and its associated tachinid parasitoid (*Phasia occidentis*) on different colored sticky traps. Cargill Oilseed Research Center, Ft. Collins, CO, 5-12 July, 2000.

Trap color	False chinch bugs/trap[a]	*P.occidentis*/trap[a]
Yellow	316.3 a	0.3 b
Blue	130.8 b	9.8 a
Neon Yellow	55.5 b	0.5 b
Neon Green	45.3 b	0.3 b
Neon Pink	26.8 b	0.3 b
Orange	39.3 b	0.5 b

[a] Average of four replications. Means within a column not followed by the same letter are significantly different ($P > 0.05$) by SNK.

Table 5. 2. Capture of false chinch bug and its associated tachinid parasitoid (*Phasia occidentis*) on different colored sticky traps, Trial 2. Cargill Oilseed Research Center, Ft. Collins, CO, 16-21 and 18-23 July, 2000.

	False chinch bugs/trap[a]		*P. occidentis*/trap[a]	
Trap Color	16-21 Jul	18-23 Jul	16-21 Jul	18-23 Jul
Yellow	137.5 a	181.0 a	3.0 b	3.5 b
Blue	78.3 b	131.8 b	22.5 a	31.0 a
Neon Green	34.5 c	19.3 c	5.5 b	3.3 b
Neon Yellow	28.5 c	25.3 c	5.8 b	6.5 b
Neon Orange	22.3 c	26.3 c	10.3 b	7.8 b
Neon Pink	22.8 c	33.5 c	4.5 b	12.3 b
White	18.0 c	32.8 c	5.0 b	12.0 b
Silver	18.0 c	23.3 c	7.3 b	11.3 b

[a]Average of four replications. Means within a column not followed by the same letter are significantly different ($P > 0.05$) by SNK.

Table 5. 3. Capture of false chinch bug and its associated tachinid parasitoid (*Phasia occidentis*) on different colored sticky traps, Trial 3. Colorado State University Horticultural Field Center, Ft. Collins, CO, 7-14 July, 2000.

Trap color	False chinch bugs/trap[a]	*P. occidentis*/trap[a]
Yellow	8.0 a	0.3 a
Silver	5.3 a	0.3 a
White	4.8 a	0.0 a
Blue	3.5 a	1.0 a
Orange	1.3 a	0.0 a
Neon Yellow	3.3 a	0.5 a
Neon Pink	3.0 a	0.5 a
Neon Green	2.0 a	0.5 a

[a]Average of four replications. Means within a column not followed by the same letter are significantly different ($P > 0.05$) by SNK.

Table 5. 4. Capture of false chinch bug and its associated tachinid parasitoid (*Phasia occidentis*) on different colored sticky traps, Trial 4. Colorado State University Horticultural Field Center, Ft. Collins, CO, 14-21 July, 2000.

Trap color	False chinch bugs/trap[a]	*P. occidentis*/trap[a]
Yellow	37.0 a	1.5 a
Aluminum foil - shiny side	20.3 a	0.5 a
Aluminum foil - dull side	18.3 a	0.8 a
White	11.0 a	0.5 a
Neon Green	11.0 a	1.3 a
Neon Yellow	8.8 a	1.0 a
Silver	10.0 a	1.3 a
Orange	9.0 a	2.0 a

[a]Average of four replications. Means within a column not followed by the same letter are significantly different ($P > 0.05$) by SNK.

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CHAPTER VI

PERMETHRIN TREATMENT OF POLLINATION BAGS AS A PROTECTANT FROM FALSE CHINCH BUG, *NYSIUS RAPHANUS* (HOWARD) (HEMIPTERA: LYGAEIDAE), INJURY TO CANOLA

INTRODUCTION

False chinch bug (FCB), *Nysius raphanus* (Howard), is a seriously damaging pest of crucifers and a key pest of canola grown in Colorado (Al-Doghairi 2000). One particular problem associated with production of the crop often develops during breeding (personal observation Steve Stadelmaier, Cargill Oilseed Research Center, Ft. Collins, Colorado). Typically during this process canola heads are covered to control pollination. However, the bagged heads are often attractive to FCB, which may aggregate in large masses. Such aggregation behavior of false chinch bug has been often reported by (Howard 1872, Knowlton 1934, Knowlton and Wood 1943, Leigh 1961). Feeding through the mesh bags can occur, with effects on canola yield that have not previously been documented.

Since early studies by Wene (1958) and Leigh (1961) there have been few, if any, published FCB insecticide evaluations. For this study, the use of pyrethrins and permethrin to protect bagged canola heads were considered because of their low toxicity (Thomson 1998, Muller 2000, Ware 2000), a significant consideration where bags are to be handled. Furthermore, they show repellent as well as insecticidal activity, features desirable in preventing the aggregation of false chinch bugs on bagged canola heads. Pyrethrins are botanical insecticides, which have contact and stomach-poison activity, rapid knock-down effects on many insects, and has repellency to many insects (Thomson 1998, Muller 2000, Ware 2000). Permethrin has similar properties, with some repellent effect and is considerably more persistent.

MATERIALS AND METHODS

All studies were conducted during July 2001 within canola fields located in Larimer County, CO. The primary research site was the Colorado State University Horticulture Field Research Center (HFRC), north of Ft. Collins. One trial was also conducted at the Cargill Oilseed Research Center (CORC) in east Ft. Collins.

Trials involved polypropylene mesh bags (Applied Extrusion Technologies, Specialty Nets and Nonwovens, Middletown, Delaware) used in plant breeding to exclude pollinating insects. The bags were 16-cm x 18 cm, of tight mesh, and were cinched at the bottom of by use of a plastic twist-tie around the stalk. Bags were placed over flowering branches of the plants that were selected of approximately similar size. For convenience of discussion these bagged branches will subsequently be termed "heads".

Preliminary Post-bagging Treatment Trial. Trials were conducted at the HFRC site on spring canola seeded 26 April. All treatments were located in a single row and individual plots consisted of a single bagged head. Experimental design was randomized complete block with four replications. For three treatments 40 field-collected FCB adults were placed into the bags; the fourth did not have any FCB introduced to serve as a control for determining effects of prior FCB infestation on subsequent infestation. Insecticides were applied to bags 19 July, as a wetting mist of either a 0.1 percent solution of pyrethrins (Spectracide and Vegetable Insect Spray[R]) or a 0.01 percent solution of permethrin (Bug Stop Concentrate[R]). The mesh bags were placed on plants approximately 6 hours after application, allowing sufficient time for air drying. Evaluations were made by counting all FCB that had aggregated on bags on two different dates, 23 July, and 31 July.

Pre-bagging Treatment Trial. Trials were established to evaluate the effectiveness of a pre-bagging permethrin application on false chinch bug on two cultivars of canola (cv. Hyola and Defender) seeded 14 May at the HFRC site. Each treatment consisted of 10 bags, arranged along a single canola bed in randomized complete block design. Permethrin was applied as a prebagging treatment on 17 July at 0.01 percent concentration. Bags were then placed on the plants 19 July. A second permethrin application was made 31 July on bags in situ. Evaluations of FCB on bags were made July 23, 31, and August 3. Plots were taken to yield and harvested 24 August.

Post-bagging Treatment Trials. Two parallel trials were conducted to reevaluate the effect of in situ post-bagging permethrin treatment on false chinch bug aggregation on pollination bags and subsequent effects on yield. Trials at the HFRC site involved a 14 May planting of the canola cultivar 'Defender' and involved ten individually bagged heads/treatment. Trials at the CORC site utilized 16 April-seeded planting of the cultivar 'IMC205' and included twenty replications. Canola heads were bagged at both sites on 19 July. Two post-bagging applications of a 0.01 percent permethrin spray were made to wet the bags - a 19 July treatment immediately after bagging and a second 31 July treatment. Counts of false chinch bugs on bags were made on three dates at each site. Plots were taken to harvest and yield determined 16 August. Data from all trials were analyzed using Least Significant Difference (LSD) (SAS Institute 1990).

RESULTS AND DISCUSSION

High numbers of FCB were observed to aggregate on bags surrounding canola heads. Permethrin provided excellent control of FCB on bags through 4 days following application ($F=18.27$, $P=0.0004$) (Table 6. 1). Pyrethrins were not effective on 31-July ($F=2.11$, $P=0.1695$). Numbers of FCB on untreated bags did not significantly differ depending on whether 40 FCB had been previously introduced into each head suggesting that prior presence of FCB did not substantially contribute to subsequent FCB aggregation on the bags.

Permethrin also provided good control of FCB on bags with prebagging treatment both Hyola and Defender at 4, 12 and 15 DAT ($F=8.07$, $P=0.0194$; $F=10.12$, $P=0.0112$; $F=10.32$, $P=0.0106$; $F=6.71$, $P=0.0292$; $F=2.00$, $P=0.1913$; $F=15.43$, $P=0.0035$, respectively) (Table 6. 2). In addition, such treatments provided large increases in yield of heads that were covered with bags 79 percent for Defender and 32 percent for Hyola ($F=15.43$, $P=0.0035$; $F=5.54$, $P=0.0431$, respectively) (Table 6. 2). In the last trials, permethrin again provided excellent control of FCB on bags with post bagging applications on the cultivar Defender and IMC205 at all evaluation dates ($F=13.15$, $P=0.0055$; $F=20.37$, $P=0.0015$; $F=500.9$, $P=0.0001$; $F=6.44$, $P=0.0201$; $F=5.38$, $P=0.0317$; $F=5.33$, $P=0.0324$, respectively) (Table 6. 3). These in situ applications resulted in 72 percent higher yield with the cultivar Defender, and 25 percent with IMC205 ($F=136.6$, $P=0.0001$; $F=10.23$, $P=0.0047$, respectively).

In conclusion, both pretreatment and post treatment with permethrin of bags covering canola heads can suppress FCB for at least 4 days. Although there are no previous reports documenting the potential of *N. raphanus* to affect canola yield, nor was FCB included in the review of insects affecting oilseed *Brassica* by Lamb (1989), these studies clearly indicate that they can be very damaging, at least when massed on bagged heads as commonly occurs during breeding trials. Permethrin treatment of bags used in control breeding of the crop can have substantial positive effects on yield of spring canola where FCB is present.

Table 6. 1. Number of false chinch bugs (FCB) on pollination bags placed on spring canola 'heads'. Bags were treated with insecticides and/or received infestation of false bugs within the bag 19 July 2001. Colorado State University Horticulture Field Research Center, Ft. Collins, Colorado.

Treatment (concentration)	FCB/bag	FCB/bagged head[a]	
		23 Jul	31 Jul
Permethrin (0.01 %)	40	1.5 c	51.0 b
Pyrethrins (0.01 %)	40	29.5 b	95.0 a
No insecticide	40	92.3 ab	78.3 ab
No insecticide	0	249.5 a	80.0 ab

[a]Numbers within a column not followed by the same letter are significantly different (P > 0.05) by LSD.

Table 6. 2. False chinch bugs (FCB) on bagged 'heads' of two spring canola cultivars ('Hyola', 'Defender') and yield. Bags were treated with permethrin 19 July 2001, prior to placement on the plant. Horticulture Field Research Center, Ft. Collins, Colorado.

Cultivar	Bag treatment (concentration)[a]	FCB/bagged/head[b]			Yield (g./head)
		23 Jul	31 Jul	3 Aug	
Hyola	Permethrin (0.01%)	0.4 b	4.7 b	14.3 b	9.6 a
Hyola	Untreated Check	75.4 a	87.2 a	99.4 a	6.5 b
Defender	Permethrin (0.01%)	1.1 b	28.7 b	34.7 b	11.7 a
Defender	Untreated Check	197.9 a	63.3 a	67.2 a	2.4 b

[a] Permethrin was applied 19 July at 0.01% concentration to wetting prior to bagging plants. A second permethrin application was made 31 Jul to bags in situ following FCB evaluation.

[b] Numbers within a column for each cultivar not followed by the same letter are significantly different ($P > 0.05$) by LSD.

Table 6. 3. False chinch bugs (FCB) on bagged 'heads' of spring canola cultivars ('Defender') and yield. Bags were treated with permethrin 19 July 2001. Horticulture Field Research Center (HFRC) and Cargill Oilseed Research Center (CORC), Ft. Collins, Colorado.

Cultivar [a]	Bag treatment (concentration)[b]	FCB/bagged head[c] 23 Jul	31/30 Jul	3/6 Aug	Yield (g./head)
Defender	Permethrin (0.01 %)	1.8 b	1.8 b	7.6 b	15.1 a
Defender	Untreated Check	201.2 a	116.4 a	85.0 a	4.3 b
IMC205	Permethrin (0.01 %)	2.7 b	15.6 b	18.1 b	7.6 a
IMC205	Untreated Check	12.2 a	36.2 a	31.6 a	5.7 b

[a] Plots involving cv. Defender conducted at HFRC site; cv. IMC205 at CORC site.

[b] Bags sprayed with permethrin 19 July, immediately following initial bagging. A second application was made 31 July, after the FCB counts were made.

[c] Where two dates are listed the first was at the HFRC site; second at CORC site. Numbers within a column not followed by the same letter are significantly different ($P > 0.05$) by LSD.

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LYGUS BUG STUDIES

CHAPTER VII

LYGUS BUG LITERATURE REVIEW

INTRODUCTION

The genus *Lygus* Hahn (Hemiptera: Miridae), variously known as plant bugs *Capsids* or *Blindwanzen*, includes important pests of cultivated and non-cultivated hosts in the United States (Schuh and Slater 1995, Wheeler 2000, Wheeler 2001). Worldwide 43 species are described with 34 present in the United States (Table 7. 1) (Kelton 1975, Loan and Shaw 1987). Twenty-two of these are reported from Colorado (Table 7. 1) (Kelton 1975).

Table 7. 1. North American *Lygus* (Kelton 1975). Those indicated with * are known from Colorado.

Lygus abroniae Van Duzee	*Lygus aeratus* Knight
**Lygus atriflavus* Knight	*Lygus atritibialis* Knight
**Lygus borealis* (Kelton)	*Lygus bradleyi* Knight
**Lygus ceanothi* Knight	**Lygus columbensis* Knight
**Lygus convexicollis* Reuter	**Lygus desertinus* Knight
**Lygus elisus* Van Duzee	**Lygus hesperus* Knight
**Lygus humeralis* Knight	**Lygus lineolaris* (Palisot de Beauvois)
Lygus mexicanus Kelton	**Lygus nigropallidus* Knight
**Lygus nubilatus* Knight	**Lygus nubilus* Van Duzee
Lygus oregonae Knight	**Lygus perplexus* Stanger
**Lygus plagiatus* (Uhler)	**Lygus potentillae* Kelton
**Lygus ravus* Stanger	**Lygus robustus* (Uhler)
Lygus rolfsi Knight	*Lygus rubroclarus* Knight
Lygus rubrosignatus Knight	**Lygus rufidorsus* (Kelton)
**Lygus shulli* Knight	*Lygus solidaginis* (Kelton)
Lygus striatus Knight	**Lygus unctuosus* (Kelton)
Lygus vanduzeei Knight	**Lygus varius* Knight

Three of these have formal common names recognized by the Entomological Society of America (Anonymous 1989) - *L. lineolaris* (tarnished plant bug), *L. hesperus* (western tarnished plant bug), and *L. elisus* (pale legume bug). All three are very common species in Colorado (Kelton 1975).

Description of *L. hesperus*, originally described from California (Kelton 1975). Kelton (1975) is as follows: "Pronotum of western tarnished plant bugs are usually green, outer half of callus, spot behind callus, and spot at basal angle, black. In additions, mesoscutum is black and scutellum is yellow, two median dashes at base, black. Hemelytron is yellowish green, apical half of corium often reddish". *L. hesperus* is widely distributed in the western United States. It is commonly found with *L. elisus* and *L. lineolaris* in agricultural areas and is confined to relatively low altitudes of the Rocky Mountain regions.

L. elisus, also originally described from California, can be described as follows (Kelton 1975): "Pronotum are pale green, spot behind each callus black. Mesoscutum is black. Scutellum is green, two median dashes at base, and often lateral lines, black. Hemelytron is pale green". *L. lineolaris* was originally described from the Eastern United States and well known as the most common and widely distributed *Lygus* species of North America (Kelton 1975). Its description by Kelton (1975) follows: "Pronotum is yellowish brown to reddish brown: outer callus, two dots or rays behinds, black. Mesoscutum is black, lateral margins reddish. Scutellum is yellowish, two median and lateral lines, black or reddish. Hemelytron is reddish brown".

In surveys of *Lygus* associated with oilseed brassicas, Leferink (1991) reported that *L. lineolaris* made up the highest population density with 82.9 and 55.2 percent in two years of Alberta, Canada surveys. *L. borealis* and *L. desertinus* comprised the great majority of the remaining species. Butts and Lamb (1991) found *L. elisus* the most abundant *Lygus* species in oilseed rape during four years of sampling in Alberta. In some contrast, Leferink and Gerber (1997) found *L. lineolaris* was to be the dominant species in all seeding in southern Manitoba, making up 55.2 percent of pooled adult samples. *Lygus elisus* was second in abundance (37.1 percent) and *L. borealis* was the least abundant (7.7 percent).

HOST RANGE

All species of *Lygus* are plant feeders; they will also attack smaller and less active insects for food (Kelton 1975). Most *Lygus* species occur on a wide range of herbaceous plants, shrubs, and trees (Kelton 1975, Wheeler 2000) although some species have a single host plant or are restricted to a group of related plants. Several *Lygus* species are well known as economic crop pests, colonizing fruit trees and nursery stock in orchards, all types of vegetable crops, alfalfa and clover hay or seed crops, cotton and tobacco crops, and commercial flower crops (Kelton 1975).

Tarnished plant bug (TPB), *L. lineolaris*, is extremely polyphagous, feeding and breeding on a great variety of plants. Recorded host plants included 328 classified to species or subspecies and 57 identified only to genus (Young 1986). Host plants occur among 55 plant families in 30 of the 70 orders of angiosperms in North America. At least 130 economically important plants have recorded as tarnished plant bug host plants, including apple, apricot, cherry, grape, peach, pear, plum, quince, asters, carnations, chrysanthemums, dahlias, marigolds, peonies, and roses, beans, beets, cabbage, celery, carrots, cucumbers, peas, potatoes, lettuce, and turnips, alfalfa, clover, tobacco, cotton, blackberries, raspberries, currants, and strawberries (Kelton 1975).

Pale legume bug, *L. elisus*, is an important pest of alfalfa seed and hay (Kelton 1975, Fye 1982, Schwartz and Foottit 1992), oilseed brassicas (Kelton 1975, Schwartz and Foottit 1992, Timlick et al. 1993), vegetable crops, cotton, and fruit trees (Kelton 1975). Pale legume bug has been reported to feed on 17 different families of plants including Apiaceae, Asteraceae, Brassicaceae, Caprifoliaceae, Caryophyllaceae, Chenopodiaceae, Fabaceae, Hypericaceae, Lamiaceae, Onagraceae, Polygonaceae, Rhamnaceae, Rosaceae, Scophulariaceae, Solanaceae, Urticaceae (Schwartz and Foottit 1992), and Compositae (Fye 1982).

Among the Brassicaceae recorded host plants are: *Brassica campestris* L., *B. napus* L. (Butts and Lamb 1991, Schwartz and Foottit 1992, Timlick et al. 1993, Leferink and Gerber 1997), *B. oleracea* L., *B. juncea* (L.) Czern., *Sinapis alba* L., *S. arvensis* L.(Schwartz and Foottit 1992), *Capsella bursa-pastoris* (L.) Medik. (shepard's purse), *Cardaria draba* (L.) Desv. (hoary cress), *Descurainia sophia* (L.) Webb ex Prantl. (flixweed), *Sisymbrium altissimum* L. (tumble mustard), *Lepdium latifolium* L. (perennial pepperweed) (Fye 1982, Schwartz and Foottit 1992), *L. perfoliatum* L., (Schwartz and Foottit 1992) and *Chorispora tenella* (Pall.) DC. (blue mustard) (Fye 1982). Important hosts in the Chenopodiaceae include *Chenopodium album* L. (lambsquarters), *C. botrys* L., *Kochia scoparia* (L.) Schrad. (kochia) (Fye 1982, Schwartz and Foottit 1992), *Beta vulgaris* L., *Salsola kali* L., (Schwartz and Foottit 1992), and *Salsola iberica* auct. (Russian thistle) (Fye 1982), Amaranthaceae, *Amaranthus retroflexus* L. (pigweed) (Fye 1982, Schwartz and Foottit 1992).

Common composite family hosts are *Ambrosia artemisiifolia* L. (ragweed), *Centaurea repens* L. (Russian knapweed), *Cirsium arvense* (L.) Scop. (Canada thistle), *Conyza canadensis* (L.) Cronquist (horseweed), *Helianthus annuus* L. (sunflower), *Iva xanthifolia* Nutt. (marsh-elder), and *Solidago* spp. (goldenrod) (Fye 1982).

The other *Lygus* species common in Colorado is the western tarnished plant bug, *L. hesperus*. *L. hesperus* is a pest of alfalfa seed and hay, cotton, fruit and vegetable crops. It also feeds on a great variety of weeds and other herbaceous plants (Kelton 1975). Populations predominate on volunteer alfalfa and red clover (Fye 1982).

DAMAGE

Most *Lygus* species are oligophagous and some become plant pests due to their habit of feeding on new growth and reproductive parts (Kelton 1975, Loan and Shaw 1987, Henry and Lattin 1987, Schuh and Slater 1995, Wheeler 2000, Nordlund 2000). Both nymphs and adults feed preferentially on either the plant's meristematic tissue or on the developing reproductive organs (Strong 1970, Layton 2000, Wheeler 2000). Feeding is accompanied by injection of salivary enzymes into the plants and further damage results from the disruptive effects of these digestive enzymes on the plant tissues (Layton 2000). Strong (1970) reported that injury caused by *Lygus* is due to the salivary enzyme polygalacturonase, which rapidly digests any tissue the insect feeds on. Symptoms range from local lesions at feeding sites to systemic effects such as growth and differentiation disorders (Wheeler 2000). If the feeding site happens to be an area of hormone production, catfacing, blasting, abscission, or deformation occurs. Effects on seeds include embryoless or shriveled seeds (Strong 1970).

Butts and Lamb (1990) described the visible injuries by *Lygus* to the oilseed brassicas, *Brassica napus* and *B. campestris*. Lesions develop on the surfaces of stems, buds, flowers and pods around the feeding site. Buds and flowers may abscise ('blasting') and seeds collapse. *Lygus* damage to buds and flowers usually results in a net reduction in the yield of canola seed, even though the plants compensate to some extent by replacing lost buds and flowers. Plants did not compensate for seeds that collapsed as a result of feeding. Symptoms of *Lygus* injury to seeds are more distinct than those for bud injuries because the feeding puncture is often preserved in the seed coat. Damaged seeds may be classified as being punctured, seeds with a feeding puncture but no obvious collapse of the seed coats, partially collapsed, seeds that collapsed only in the area immediately surrounding the feeding puncture, and collapsed, seeds that collapsed to the extent that little more than seed coats remained (Butts and Lamb 1990, Turnock et al. 1995).

Oilseed pods caged with *Lygus* suffered a higher seed loss but did not produce a significantly different number of seeds than pods with low levels of injury. The total weight of seed produced per pod was negatively related to the percentage of seeds blasted by *Lygus* for both *B. napus* and *B. campestris*. When *Lygus* feeding blasted 10 percent of the seeds, the loss in weight of seed produced per pod was about 11 percent, showing that pods had little or no ability to compensate the weight of seeds for the loss of seeds (Butts and Lamb 1990). Butts and Lamb (1991) reported that a survey of commercial fields showed that 6 percent of canola seed in some regions was destroyed by *Lygus* bugs, on average, and that in some fields > 20 percent of seed was destroyed.

LIFE HISTORY

Most *Lygus* species are multivoltine (Kelton 1975, Henry and Lattin 1987, Layton 2000) and all *Lygus* species overwinter as adults (Kelton 1975, Layton 2000, Wheeler 2000). Kelton (1975) described adults as usually seeking shelter in the litter close to the host plant or migrating to a more suitable cover away from the host plant. The hibernating adults emerge in the spring and feed on the tender shoots and buds. After mating females lay eggs in the stems of the host plant throughout spring and summer. The eggs incubate for 10-14 days prior to hatch. Nymphs pass through five instars completing development in approximately 30-45 days (Kelton 1975).

In oilseed brassica crops, *Lygus* densities vary between plant growth stages (Timlick et al. 1993, Gerber and Wise 1995, Leferink and Gerber 1997, Wise and Lamb 1998a,b). *Lygus* bug populations are significantly higher during early flower and pod stages of canola (Leferink 1991, Timlick et al. 1993, Gerber and Wise 1995, Leferink and Gerber 1997, Wise and Lamb (1998a,b). Leferink (1991), sampling *L. lineolaris*, *L. borealis* and *L. desertinus* in canola, first observed adult *Lygus* at the beginning of flowering stages. Population density peaked during pod stages of canola. Timlick et al. (1993) reported that adults of both *L. lineolaris* and *L. elisus* reached a peak during the flowering of the host (growth stages 4.1-4.4), declined, and then peaked again in the pod stages (growth stages 5.3-5.4). *Lygus* populations normally are the highest after flowering when nymphs are present and pods are developing. Wise and Lamb (1998a) also reported that the highest plant bug densities occurred as pods developed, at growth stages 5.1 or later in the untreated check plots of each test. In Manitoba, canola is usually colonized by the second generation of *L. lineolaris* that is produced during the season and completes one generation on the crop (Gerber and Wise 1995). Second-generation nymphs first appear at the flowering stages of the canola crop and adult *Lygus* populations reached the highest level during early pod stages (Leferink and Gerber 1997).

NATURAL ENEMIES

The natural enemies of *Lygus* species have summarized by Clancy and Pierce (1966) and, more recently, by Ruberson and Williams (2000). Primary parasites of *Lygus* include several species each of Mymaridae (from eggs), Braconidae (mainly from nymphs), and Tachinidae (from adults) (Clancy and Pierce 1966, Loan 1974a,b, Marsh 1979). Additional parasitoids occur within Ichneumonidae, Scelionidae and the entomopathogenic nematodes.

Among the Hymenoptera, the most important are the egg parasitoids of the family Mymaridae. These include *Anaphes iole* Girault, *A. ovijentatus* (Crosby and Leonard), *Polynema pratensiphagum* Walley and *Erythmelus miridiphagus* Dozier (Clancy and Pierce 1966, Streams et al. 1968, Sillings and Broersma 1974, Jackson and Graham 1983, Udayagiri et al. 2000, Ruberson and Williams 2000, Smith and Nordlund 2000).

Clancy and Pierce (1966) reported that eggs of *L. hesperus* in alfalfa are commonly attacked by *A. ovijentatus*. In 50 samples from 14 California counties egg parasitization averaged 46.6 percent. Sillings and Broersma (1974) reported *A. ovijentatus* parasitized up to 85 percent of *Lygus* eggs in alfalfa. Jackson and Graham (1983) reported that four of the most important pest species of *Lygus* - *L. hesperus*, *L. lineolaris*, *L. elisus*, and *L. desertinus* - were all heavily parasitized by *A. ovijentatus*. They also mentioned that under laboratory conditions *L. desertinus* was the most suitable host, whereas *L. elisus* was the least suitable.

The related egg parasitoid, *A. iole*, is sometimes used in biological control release programs for *Lygus* management. Udayagiri et al. (2000) released 15,000 *A. iole* in acresized plots every week at three sites in strawberries grown on the central coast in California. They observed a 64 percent suppression of *L. hesperus*, which is important pest of strawberry. This compared very favorably to chemical control, with which growers achieved only 44.7 percent *L. hesperus* reduction. Smith and Nordlund (2000) reported that *A. iole* are candidates for use in augmentation programs of biological control, as a component of area wide IPM for *Lygus* species management.

Within the Braconidae two important genera of the tribe *Euphorini* attack different *Lygus* species in the United States - *Leiophron* Nees and *Peristenus* Foerster (Marsh 1979). Loan (1974a) reviewed the genera, describing 31 new species, 11 in *Leiophron* and 20 in *Peristenus*. The basic life cycle outline for both *Leiophron* and *Peristenus* has been described by Loan (1980, 1983). Adult parasitoids emerge April-May. Females usually parasitize instar I and II nymphs. Mature parasitoid larvae emerge from mature nymphs or adults in May-July. They spin a cocoon in soil, under bark or similar protected locations. Pupation and transformation to the adult stage occurs within the cocoon and overwintering stages are diapausing adults in the cocoon.

The known North America species of *Leiophron* are specific parasites of Miridae (Clancy and Pierce 1966, Loan 1974a, Loan 1974b, Marsh 1979, Loan and Shaw 1987, Ruberson and Williams 2000). The most important species of the genus *Leiophron* that attack *Lygus* include *L. uniformis* (Gahan) (Clancy and Pierce 1966, Loan 1974a, Marsh 1979, Graham et al. 1986, Hedlund and Graham 1987, Day 1987, Debolt 1989, Smith and Nordlund 2000), *L. pallipes* Curtis (Loan 1965, Clancy and Pierce 1966, Streams et al. 1968), and *L. pseudopallipes* Loan (Loan 1970).

L. uniformis is an important internal parasitoid of the nymphs of *L. elisus*, *L. hesperus*, and *L. lineolaris* in the United States (Clancy and Pierce 1966, Loan 1974a, Marsh 1979, Graham et al. 1986, Hedlund and Graham 1987, Day 1987, Debolt 1989). *L. uniformis* females will attempt to oviposit in all nymphal instars of *L. hesperus* (Debolt

1981) but prefer earliest instars (Loan 1974a, Loan 1980, Debolt 1981, Loan 1983, Loan and Shaw 1987). During oviposition the female pounces upon the host, curls her abdomen beneath its body, and quickly inserts an egg by means of the very short ovipositor (Clancy and Pierce 1966). The entire act is completed in a few seconds, and the parasite may attack several nymphs in rapid succession. At maturity the larva bores through the host integument and drops to the ground, where it spins a white elongated oval cocoon with irregular longitudinal corrugations (Clancy and Pierce 1966). Parasite larvae emerge from host instars III-V (Debolt 1981), usually instar V (Sillings and Broersma 1974, Loan and Shaw 1987). In the laboratory pupal cocoons were observed 10-12 days after oviposition (Clancy and Pierce 1966). *L. uniformis* is reported multivoltine (Loan 1980, Loan 1983, Day 1987, Day et al. 1998, Ruberson and Williams 2000).

Leiophron pallipes also attacks *Lygus* species (Loan 1965, Clancy and Pierce 1966, Streams et al. 1968), including *L. hesperus* and *L. elisus*. Loan (1965) described that a single egg of *L. pallipes* is deposited in the haemocoel of a mirid nymph. Of the five nymphal instars of the host usually instars II and III were attacked. Development of *L. pallipes* in the field, from egg to emerged larva, was five to six weeks, based on dissections and rearing. *L. pallipes* consistently emerged from instar V nymphs. The seasonal development of *L. pallipes* is closely related to the life cycles of the host mirids (Loan 1965). Loan (1970) also described as new species *L. pseudopallipes* and *Euphoriana lygivora*, which are recorded as parasites of *L. lineolaris*.

The known North America species of *Peristenus* are also specific parasites of Miridae (Clancy and Pierce 1966, Loan 1974a, Loan 1974b, Marsh 1979, Loan and Shaw 1987, Ruberson and Williams 2000). *Peristenus* species are the most commonly reared native parasitoids of nymphal and adult *Lygus* spp in the United States (Ruberson and Williams 2000). The most important species of the genus *Peristenus* are *P. pallipes* (Curtis). *P. pseudopallipes* (Loan), *P. stygicus* Loan, *P. digoneutis* Loan, *P. rubricollis*

(Thompson), *P. stenodemae* Loan and *P. nigricarpus* (Szepligeti) (Loan and Pawinska 1973, Hormchan 1977, Smith and Nordlund 2000, Ruberson and Williams 2000). *Peristenus* spp. oviposit in first, second, and third instar nymphs of mirids, mainly *Lygus* spp. (Brindley 1939).

P. stygicus was recovered from a mirid, *Polymerus unifasciatus* (F.), in western Turkey (Drea et al. 1973). Hormchan (1977) later reported *P. stygicus, P. rubricollis, P. digoneutis*, and *P. pallipes* in Mississippi. *P. stygicus* is common species that have several generations per year (Drea et al. 1973, Van Steenwyk and Stern 1976, Hormchan 1977, Van Steenwyk and Stern 1977). *P. stygius* attacks instars I-IV of *L. lineolaris*, with earlier instars being more susceptible to parasitization (Hormchan (1977). In addition to *L. lineolaris*, *P. stygicus* successfully parasitized *L. hesperus* and *L. seriatus*, all abundant and economically important pests of cotton in Texas (Porter 1979). Additional mirid hosts reported by Hedlund and Graham (1987) include *L. rugulipennis* (F.), *Polymerus unifasciatus* (F.), and *Adelphocoris lineolatus* (L.).

Females usually laid one egg per host. The mature larva left the host and formed a cocoon in the substrate. Females attempted to oviposit in all instars but fecundity and reproductive longevity of *P. stygicus* was significantly reduced as the host age increased from instar I to V (Van Steenwyk and Stern 1976). Thirteen percent parasitism was reported by the first generation of *P. stygicus* Hormchan (1977).

P. pallipes is a common parasite of the tarnished plant bug, *L. lineolaris* (Hormchan 1977). In addition, *P. pallipes* attacks *L. elisus*, and *L. hesperus* (Marsh 1979). *P. pallipes* and *P. pseudopallipes* were important *L. lineolaris* parasitoids in both alfalfa fields and in areas of uncut weeds (Lim and Stewart 1976).

The most important tachinid parasitoids of *Lygus* are *Phasia* (=*Alophorella*) *aeneoventris* (Williston), *P. fumosa* (Coquillett), *P. pulverea* (Coquillett), and *P. robertsonii*

(Townsend) (Ruberson and Williams 2000). *P. robertsonii* has only been reported to parasitize adult adult *Lygus*, the remaining species attack both nymphs and adults.

Predators of *Lygus* are found within the orders Hemiptera, Neuroptera (Clancy and Pierce 1966, Smith and Nordlund 2000), and Coleoptera (Clancy and Pierce 1966). Predatory Hemiptera are particularly important, including the lygaeids *Geocoris punctipes* (Say), *G. pallens* (Stal), and *G. bullatus* (Say), anthocorids *Orius insidiosus* (Say) and *O. tristicolor* (White), nabids, *Nabis alternatus* (Parshley), reduviids, *Z. renardii* Kolenati, *Sinea confusa* Caudell, and the pentatomid, *Podisus maculiventris* (Say) (Ruberson and Williams 2000). In laboratory studies both eggs and nymphs of *L. hesperus* were readily attacked by *Geocoris* adults. *Lygus* nymphs were consumed by *Nabis* adults and nymphs (Clancy and Pierce 1966, Propp 1982, Ruberson and Williams 2000). Within the Neuroptera, *Chrysoperla* larvae fed on nymphs of *Lygus* (Smith and Nordlund 2000).

Liu et al. (2002) tested the pathogenicity of 32 fungal isolates from the genera *Beauveria*, *Verticillium*, *Paecilomyces*, *Metarhizium*, *Mariannaea*, and *Hirsutella* to instar II *L. lineolaris* under laboratory conditions. Several genera of these entomopathogenic fungi showed promise as microbial control agents against *L. lineolaris*. *Hirsutella* sp., *B. bassiana*, *M. anisopliae*, and *V. psalliotiae* produced average mortality levels in *L. lineolaris* of > 80 percent. In addition, among the *P. fumosoroseus* and *P. farinosus* isolates, 56-62 percent mortality was obtained. Mortality rates of < 40 percent occurred in the *Mariannaea* sp. and *V. lecanii* isolates (Liu et al. 2002).

The fungal pathogen, *Beauveria bassiana,* may have particular potential for management at early-season populations of *Lygus* species in crop systems (Steinkraus and Tugwell 1997, Ruberson and Williams 2000, Liu et al. 2002). *L. lineolaris* nymphs and adults were highly susceptible to *B. bassiana* ARSEF 3769 in the laboratory (Steinkraus and Tugwell 1997). They reported 97.9 percent mortality at 5 days after treatment in *L. lineolaris* adults when the commercial *B. bassiana* product Mycotol (280 g per ha) and imidacloprid (50 g a.i. per ha) were applied together. This compared to 67.3 percent mortality from application of imidacloprid alone (50 g a.i. per ha), 52 percent by Mycotol alone (280 g per ha), and 7.6 percent and 13.6 percent mortality in the control. Six days after treatment, mortality from the Mycotol application was higher (83.9 percent) than imidacloprid alone (67.3 percent) (Steinkraus and Tugwell 1997).

Mermithid nematodes also commonly parasitize *Lygus* species (Ruberson and Williams 2000, Wheeler 2000, Wheeler 2001).

CHEMICAL CONTROL

Because *Lygus* spp. can be important pests on such a wide range of crops there have been a great many chemical trials conducted for their control. Most of these have involved *L. lineolaris*, the tarnished plant bug and the history of insecticide use against this insect was recently reviewed by Scott and Snodgrass (2000). In cotton, Lygus was often controlled incidentally by applications made against other pests. Early insecticides used on the crop with activity against tarnished plant bug included calcium arsenate, Paris green, and sulphur. In the 1940s the predominant treatments were mixtures such as chlorinated camphene + sulphur, DDT + sulphur, and benzene hexachloride + sulphur were used to control tarnished plant bugs. Chlorinated hydrocarbons such as dieldrin, endrin, strobane, and toxaphene were used in cotton for tarnished plant bug control into the 1960s. Later there was more dependence on organophosphates, such as malathion and trichlorfon (Leigh et al. 1977), and carbamates (Scott and Snodgrass 2000).

This, in turn, was followed by pyrethroids. Pree (1985) reported that cypermethrin was more toxic to *L. lineolaris* adults than permethrin, fenvalerate, dimethoate, ethyl parathion, azinphosmethyl, phosmet, DDT and endosulfan insecticides in both laboratory and field studies trials. Overall, pyrethroids were more toxic than other groups of insecticides. Scott and Snodgrass (2000) reported that newer chemistry (imidacloprid, fipronil, thiamethoxam) also is highly effective against tarnished plant bug.

Insecticides have been used effectively to control *Lygus* damage in canola. Butts and Lamb (1991) reported that applications of deltamethrin applied for control of *Lygus* at the early pod stage increased yield by 11-35 percent in five tests. Leferink and Gerber (1997) found that optimal application time was early pod development and *Lygus* populations were high. Yield response from insecticide application to canola was estimated by Wise and Lamb (1999b) to be 0.007 t/ha per plant bug per 10 sweeps when sampled at the end of flowering or the beginning of pod formation. An insecticide application at the end of flowering (growth stage 4.4) or when pods began to develop (growth stage 5.1) always resulted in higher yields in the treated plots than in the untreated ones (Wise and Lamb 1998b).

CULTURAL CONTROL

A wide variety of cultural control methods have been attempted for control of *Lygus* in various crops. Stewart and Layton (2000) described several methods applicable to *Lygus* management on cotton. These included host plant resistance (transgenic or nectariless cotton cultivators that are resistant to *Lygus* species), cotton and alfalfa intercropping, use of trap crops such as kenaf (*Hibiscus canabinus* L.) and redwoot pigweed (*Amaranthus retroflexus* L.), and destruction or management of non-crop host plants.

Developing *Lygus* resistance in oilseed mustards has not been attempted but host plant evaluations have been made among Brassicaceae. Bodnaryk (1996) reported that adult *L. lineolaris* fed 5-10 times less frequently on seeds within pods of white mustard, *Sinapis alba* L., than on seed within pods of canola in no-choice feeding tests in the laboratory. The presence of long, sharp spines (trichomes) on pods of *S. alba* did not account for all of the difference in feeding. Feeding on shaved pods of *S. alba* was only twofold higher than on unshaved control.

Robbins et al. (2000) reported that the most important off-field hosts, which could influence Lygus numbers in cotton, were species of fleabane, *Erigeron* spp. Fleabane can support high tarnished plant bug numbers during the time cotton begins to produce fruit, in June and July. Nonselective management (mowing or use of an herbicide that kill broadleaf weeds) of these wild hosts to reduce tarnished plant bug numbers was tested in one small study. Although *Erigeron* is not a common species in Colorado, other non-crop hosts may be important (Fye 1982). This includes alfalfa, which is well documented as an important breeding source of *Lygus* (Sevacherian and Stern 1974, 1975). Furthermore, manipulations of alfalfa through strip harvest have also been shown to prevent migration of *Lygus* to adjacent crops (Stern et al. 1964, Stewart and Layton 2000).

Rhainds et al. (2001) reported that reflective mulch may suppress incidence of damage by tarnished plant bug both directly, by reducing number of nymphs per flower cluster, and indirectly, by enhancing productivity of strawberry plants. White sticky color traps have also been proposed for suppression of *Lygus* damage to strawberry (Rancourt et al. 2000). However, use of these methods in oilseed brassicas likely would not be compatible with production or cost effective.

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CHAPTER VIII

DEVELOPMENT OF ACTION THRESHOLDS FOR PALE LEGUME BUG, *LYGUS ELISUS* (Van Duzee) (HEMIPTERA: MIRIDAE), AFFECTING SPRING CANOLA

INTRODUCTION

The genus *Lygus* Hahn (Hemiptera: Miridae) includes important pests of a wide variety of cultivated and non-cultivated host plants (Schuh and Slater 1995, Wheeler 2000, Wheeler 2001). Worldwide there are 43 species of *Lygus*, 34 of which are present in the United States (Kelton 1975, Loan and Shaw 1987). Twenty-two *Lygus* species have been recorded in Colorado (Kelton 1975). Among the most economically important species of *Lygus* bugs are the western tarnished plant bug, *Lygus hesperus* Knight, pale legume bug (PLB), *Lygus elisus* Van Duzee, and tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), all of which are very common species in Colorado.

Lygus are highly mobile, multivoltine, oligophagous, and some become pests due to their habit of feeding on new growth and reproductive parts (Kelton 1975, Loan and Shaw 1987, Henry and Lattin 1987, Schuh and Slater 1995, Wheeler 2000). All pest species of *Lygus* share a common characteristic of feeding preferentially on either the meristematic tissue or on the developing reproductive organs (Strong 1970, Layton 2000, Wheeler 2000, Wheeler 2001). As they feed they inject the salivary enzyme polygalacturonase, which rapidly digests any tissue around the feeding site (Strong 1970, Layton 2000). When such feeding occurs at a site of hormone production a variety of secondary disorders can result including catfacing, blasting, abscission, and deformation.

Lygus are important pests of oilseed brassicas (Kelton 1975, Schwartz and Foottit 1992, Schuh and Slater 1995) feeding primarily on buds, flowers, pods and seeds (Lamb 1989). Visible injuries to *B. napus* L. (canola, rape) and *B. campestris* L. (oilseed mustard) appear as surface lesions and can cause buds and flowers to abscise and seeds to collapse. *Lygus* damage to buds and flowers usually results in a net reduction in the yield of canola seed, although the plants compensate to some extent by replacing lost buds and flowers (Butts and Lamb 1990). In a survey of commercial fields in Alberta, *Lygus* bugs destroyed an average of 6 percent of the canola seed in some regions with some fields sustaining seed losses of > 20 percent. In Manitoba, Leferink (1991) sampled *L. lineolaris*, *L. borealis* (Knight) and *L. desertinus* (Knight) in canola and observed that adults first appeared at the beginning of flowering stages and population density reached the highest level during pod development.

Central to optimally managing insects with an Integrated Pest Management approach is determining the damage potential of different pest populations. These are commonly presented as economic thresholds (ET), described as the pest population density at which a tactic should be initiated in order to stop the pest density from reaching the economic injury level (EIL) (Pedigo et al. 1986, Dent 2000, Pedigo 2002, Norris et al. 2003). Economic thresholds have been proposed for *Lygus* in canola. Butts and Lamb (1991b) reported on yield losses associated with various levels of *Lygus*, as determined by sweep net sampling. Plant growth stage was a factor with greatest losses occurring with *Lygus* infestations present during the early pod stage. Wise and Lamb (1998a) proposed an economic threshold of 15 plant bugs per 10 sweeps in canola at the end of flowering or at the beginning of pod formation, based on crop prices and control cost from 1989 to 1992.

At slightly later stages of plant growth their proposed economic threshold in canola was 20 plant bugs per 10 sweeps.

The pale legume bug (PLB), *L. elisus*, is widely distributed throughout the prairie-parkland and the Rocky Mountain regions of North America (Kelton 1975). Butts and Lamb (1991a) found it to be the most common *Lygus* species associated with canola in the Prairie Provinces and it is also usually the most common species in northeastern Colorado. In canola, *L. elisus* reaches peak populations during the flowering of the host (growth stages 4.1-4.4) of Harper and Berkenkamp (1975) declines, and then peaks again in the pod stages (growth stages 5.3-5.4) (Timlick et al. 1993).

This study seeks to determine the specific effect of *L. elisus* to spring canola under conditions of controlled infestation at different plant growth stages. This can allow concurrent evaluations of *L. elisus* damage to different cultivars. It can also allow comparison of damage potential to other species that can affect the crop at the same time, such as the false chinch bug, *Nysius raphanus* Howard.

MATERIALS AND METHODS

Lygus Action Threshold Trials, 2001. Trials were conducted at the Colorado State University Horticulture Research Center in Ft. Collins, Colorado. Plots were established by seeding on 26 April to double-row beds at 76-cm row spacing. In the first trial seven different spring canola (*Brassica napus* L.) cultivars were included: Hyola, Excel, Apollo, Helios, Alto, Defender, and 46A65. A second trial replicated five cultivars: Hyola, Excel, Apollo, Defender, and 46A65. Plot areas consisted of 2 beds, 6-m long. These were then subdivided in half. Northeast and southwest 3-m sections of bed were used in *L. elisus* bug infestation at the early flower stage and early pod stage, respectively. The remaining two sections were used in concurrent trials with false chinch bug (Chapter 2).

Experimental design was randomized complete block design with 4 replications. One variable consisted of introducing different numbers of *L. elisus* into bagged heads at two different plant growth stages. Bags were placed over flowering and pod branches of the plants that were selected of approximately similar size. For convenience of discussion these bagged branches will subsequently be termed " heads". Prior to any treatment, in each plot five canola heads were selected of approximately equal size. Four of these were bagged with the latter one serving as a non-bagged control. The bags used were of 12-cm x 20-cm polypropylene mesh (Applied Extrusion Technologies, Specialty Nets & Nonwovens, Middletown, Delaware) primarily used for confining heads during plant breeding. The bags were snuggly fastened to the stem with a twist-tie.

Four different levels of *L. elisus* (PLB) were introduced into the bagged heads - 0, 2, 8, 16/head. These were field-collected adults collected 1 to 2 days prior to infestation and maintained in a holding cage. They were then aspirated into individual vials for introduction into the bagged head.

Introduction of *L. elisus* occurred at two plant growth stages. The early flowering stage was comparable to Stage 4.2 described by (Harper and Berkenkamp 1975), when there are many flowers opened and lower pods are elongating. These plants were bagged 6 July and *L. elisus* was introduced into the bags 11 July. Infestations were also made at the early pod stage, comparable to Stage 5.2, with the seeds in lower pods green (Harper and Berkenkamp 1975). These plants were bagged 25 July and *L. elisus* introduced into the bags 26 July.

No insecticides were used on plots after infestations. A 10 May application of carbaryl was used to control western black flea beetles, *Phyllotreta pusilla* (Horn), which potentially affect seedling stages. The second insecticide application, involving imidacloprid, was done prior to bagging, 30 June, to control cabbage aphid, *Brevicoryne brassicae* (L.).

All plots were harvested 24 August. The entire heads were cut, with the bag intact and hung for drying. The pods were then crushed to release the seeds and separated from other debris by use of sieves.

An additional trial was conducted at the Cargill Oilseed Research Center in Ft. Collins on the cultivar IMC204. Plots were established by seeding to double-row beds at 76-cm row spacing. Individual plots were 6-m long and arranged in a randomized completed block design. The trials consisted of 10 replications and five treatments - 0 PLB (bagged control), 2 PLB, 8 PLB, and 16 PLB/head along with a non-bagged control. Infestation at the early flower stage occurred June 28 and at the early pod stage on July 11. The trial was harvested August 16 in a manner similar to the above-described trial. Data were analyzed using Least Significant Difference (LSD) and Regression Analysis (SAS Institute 1990).

Lygus Bug Action Threshold Trials, 2002. Trials were again conducted at the Colorado State University Horticulture Research Center. Plots were established by direct seeding April 3. Plot size was two 2-row beds, 3-m in length.

The first trial consisted of six different spring canola cultivars: Apollo, Hyola, Helios, Excel, IMC205, and 46A65. The second trial repeated four of these: Apollo, Hyola, Excel, and 46A65. Plot design was similar to that of 2001. The third trial repeated two different spring canola cultivars, IMC204, and IMC205. Pesticide use on the plots consisted of a pre-emergence application of trifluralin (Treflan) for weed control and a single 10 May carbaryl application for control of western black flea beetle.

Bagging of heads for the early flower stage trial was done on 23 June; field collected *L. elisus* were introduced into bags 25 June. For evaluations during the early pod stage, canola heads were covered with bags on 14 July and *L. elisus* bugs were introduced 17 July. Bagging of heads and management of plots was similar to that of 2001.

All plots were harvested 21 August. At this time the heads were cut and maintained within the bag and hung for drying. When dry, pods were crushed to release the seeds and separated from other debris by use of sieves. After this procedure, the seed was further cleaned using Agriculex CB-1 (column blower) to sort out seed from plant debris. Data were analyzed using Least Significant Difference (LSD) and Regression Analysis (SAS Institute 1990).

RESULTS AND DISCUSSION

In the 2001 trials significant yield reductions occurred on all cultivars ($F=12.18$, $P=0.0001$; $F=7.88$, $P=0.0001$; $F=4.56$, $P=0.0140$, respectively) (Tables 8. 1, 8. 4, 8. 7). In the first trial, four of these (Defender, Hyola, Alto, and Apollo) sustained significant yield loss at the lowest level of infestation (2 PLB/head) during early flower ($F=35.49$, $P=0.0001$; $F=4.51$, $P=0.0340$; $F=11.97$, $P=0.0017$; $F=5.30$, $P=0.0223$, respectively) (Table 8. 1). Two the remaining cultivars (Helios, and 46A65) showed significant yield reductions at 8 PLB/head and one (Excel) did not have significant yield reductions until introduction of 16 PLB/head ($F=2.88$, $P=0.0955$; $F=2.08$, $P=0.1727$; $F=2.29$, $P=0.1467$, respectively). However, Hyola, along with Excel, Defender, and Apollo, showed significant yield reductions at 2 PLB/head in the second trial (*F=3.17, P=0.0783*; *F=17.42, P=0.0004*; *F=4.26, P=0.0393*; *F=3.28, P=0.0727*, respectively) (Table 8. 4). IMC204 showed significant yield reductions at 16 PLB/head (*F=4.56, P=0.0140*) (Table 8. 7).

Such dramatic effects on yield following *L. elisus* infestation at early flowering were not repeated in 2002 (*F=2.26, P=0.0870*; *F=0.93, P=0.4321*; *F=0.75, P=0.5331*, respectively) (Tables 8. 9, 8. 12, 8. 15). Only one cultivar (Excel) in one trial showed significant yield suppression, at infestation of 8 PLB/head (*F=2.46, P=0.1292*) (Table 8. 12).

Overall yield effects were less following PLB infestation at the later, early pod stage. Only one cultivar (Alto) in one 2001 trial (Table 8. 2) incurred significant yield losses with infestations of 2 PLB/head (*F=12.67, P=0.001*). With few exceptions, yield reductions observed during 2001 only resulted from infestations at the highest level, 16 PLB/head (*F=3.88, P=0.0494*; *F=4.17, P=0.0416*; *F=2.98, P=0.0887*; *F=2.17, P=0.1614*; *F=2.79, P=0.1016*; *F=12.67, P=0.001*; *F=7.63, P=0.0077*; *F=4.23, P=0.0400*; *F=5.32, P=0.0220*; *F=3.78, P=0.0525*; *F=3.59, P=0.0594*; *F=1.56, P=0.2225*, respectively) (Tables 8. 2, 8. 5, 8. 7). In 2002 trials significant yield reductions only occurred on one cultivar (46A65) when infested at the highest level (*F=3.94, P=0.0477*) (Table 8. 13).

Artifacts associated with the study technique of bagged heads may be a factor in the responses observed from *L. elisus* infestation. Interplot variability was very high in these studies, which can obscure significant differences. Bagging can interfere with pollination, although spring canola is largely self-pollinated. Furthermore, the presence of bags on canola heads often makes them particularly attractive to false chinch bug, which may mass on bagged heads (Chapter 6). However, comparison of the non-bagged heads with bagged heads where no *L. elisus* (0 PLB) were introduced (Tables 8. 3, 8. 6, 8. 8, 8. 11, 8. 14, 8. 17) suggests that there was little effect on yield from bagging.

In the report of Butts and Lamb (1991b) highest loss from a mixed population of *Lygus* occurred at densities of 52 *Lygus* bugs per 10 sweeps at the early pod stages. Moreover, when densities at this stage were 1-5 *Lygus* bugs per 10 sweeps, yield losses of 14 to 18 percent were observed. Wise and Lamb (1998a, 1998b) proposed an economic threshold of 15 *Lygus*/10 sweeps in canola at the end of flowering or at the beginning of pod formation. Wise and Lamb (1998a) reported that an insecticide application at the end of flowering (growth stage 4.4) or when pods began to develop (growth stage 5.1) always resulted in higher yields in the treated plots than in the untreated ones.

These previous efforts at establishing economic thresholds for *Lygus* on canola used sweep net sampling of field populations. A condition with the artificial infestation of bagged heads of this study is not strictly comparable. However, low populations (2 PLB/head) of *L. elisus* were able to significantly reduce yields in some cultivars at early flowering in the 2001 trials. This suggests that relatively low numbers of *L. elisus* at this growth stage can similarly affect canola yields as do mixed *Lygus* spp. infestations used in earlier studies.

Turnock et al. (1995) had reported that that incidence of collapsed seeds increased by 1.5 percent for each *Lygus* bug per sweep. However, the effect of increasing *L. elisus* numbers/head did not decrease yields in a strictly linear fashion. For example, averaged across all three 2001 trials the average yield reduction was 51.1, 63.8, and 65.8 percent for heads infested at 2 PLB, 8 PLB, and 16 PLB at early flower stages ($F=12.18$, $P=0.0001$; $F=7.88$, $P=0.0001$; $F=4.56$, $P=0.0140$, respectively) (Tables 8. 1, 8. 4, 8. 7).

More direct correlations occurred at early pod stage infestation. Averaged across all three 2001 trials the average yield reduction was 14.9, 24.1, and 47.3 percent for heads infested at 2 PLB, 8 PLB, and 16 PLB at early pod stages ($F=13.97$, $P=0.0001$; $F=10.16$, $P=0.0001$; $F=1.56$, $P=0.2225$, respectively) (Tables 8. 2, 8. 5, 8. 7). Overall yield reduction among all combined cultivars were 33 percent with 8PLB/head, and 49 percent with 16 PLB/head at early flower stages in the first trials in 2002 ($F=2.26$, $P=0.0870$) (Table 8. 9). However, there were no significant yield reduction occurred at early pod stages in first trial during this period ($F=0.14$, $P=0.9377$) (Table 8. 10). In the second trials, overall yield reduction was 21 percent with 8PLB/head, and 27 percent with 16PLB/head at early flower stages ($F=0.93$, $P=0.4321$) (Table 8. 12). Averaged yield reduction of all cultivars combined was 16 percent with 16PLB/head at early pod stages in 2002 ($F=0.65$, $P=0.5841$) (Table 8. 13). Butts and Lamb (1990) reported that total weight of seed produced per pod was negatively related to the percentage of seeds blasted by *Lygus*. When *Lygus* blasted 10 percent of the seeds, the loss in weight of seed produced per pod was about 11 percent, showing that pods had little or no ability to compensate the weight of seeds for the loss of seeds. Such direct correlation of increasing *L. elisus* and yield loss was not consistently observed. Instead of there often appeared to be a plateau of yield loss at higher *L. elisus* densities.

Yields varied greatly among these reported trials making it difficult to compare the effects of different PLB infestations on yield. To develop such comparisons calculations were made of the number of PLB required to produce 10 percent yield loss.

This was done by use of the slope of the yield loss (in grams)/PLB in the formula (Y/10)/(-S), where Y = average yield of the uninfested check and S is the slope. In all five trials where there was a negative relationship of yield with increasing PLB infestation a determination of numbers of FCB/head required to cause 10 percent yield loss could be established (Table 8. 18). This could not be done with the third 2002 trial (Table 8. 16), where there was not a relationship of yield loss with increased PLB infestation.

The proposed economic threshold of Wise and Lamb (1998a) was raised to 20 plant bugs per 10 sweeps at growth stage 5.2. In these studies (Table 8. 18) comparisions of 10 percent yield loss occurred with infestations of 3.1-5.6 PLB/head (avg. 3.3) with early flowering stage infestations, and 3.4-19.0 PLB/head (avg. 8.72) at early pod stage infestations. However, differences in effect of growth stage only occurred during 2002. Effects on yield of PLB infestation at early flowering were identifical to infestation at early pod stage in 2001 trials. Leferink and Gerber (1997) decided that the best application of insecticides for *Lygus* bugs on canola was early pod development (growth stages 5.1-5.2) if *Lygus* populations are high.

During this study nine canola cultivars were included in at least one trial. All of them, with the exception of IMC205, which was included only in 2002, showed significant yield loss from *L. elisus* infestation in at least one trial. This suggests that there is likely little resistance to *Lygus* injury among canola cultivars.

Table 8. 1. Yield (g. /head) of Seven Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Flower Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
Hyola	2.12 a	0.60 b	0.72 b	0.54 b	- 0.06677
Helios	3.47 a	1.17 ab	0.86 b	0.73 b	- 0.12669
Excel	1.50 a	0.73 ab	0.90 ab	0.59 b	- 0.03919
Defender	1.01 a	0.17 bc	0.33 b	0.10 c	- 0.03806
Apollo	0.85 a	0.35 b	0.13 b	0.37 b	- 0.02201
Alto	1.45 a	0.46 b	0.67 b	0.36 b	- 0.04559
46A65	1.19 a	0.86 ab	0.40 b	0.57 ab	- 0.03609
AVERAGE	1.66	0.62	0.57	0.47	-0. 05349

[1]Means followed by the same letter in a row do not differ significantly (P> 0.05, LSD).

Table 8. 2. Yield (g. /head) of Seven Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Pod Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
Hyola	4.97 ab	6.27 a	4.76 ab	3.36 b	- 0.13854
Helios	7.45 a	4.87 ab	3.44 b	4.42 b	- 0.14928
Excel	5.88 a	3.63 ab	5.52 ab	2.78 b	- 0.12790
Defender	7.30 a	5.02 ab	5.77 ab	3.93 b	- 0.15515
Apollo	5.34 a	4.43 ab	2.41 ab	1.51 b	- 0.23645
Alto	7.24 a	4.21 b	3.33 b	3.23 b	- 0.19552
46A65	5.72 a	5.69 a	3.58 b	2.86 b	- 0.19540
AVERAGE	6.27	4.87	4.16	3.16	-0.17118

[1]Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8. 3. Yield (g. /head)[1] of Seven Canola Cultivars Bagged and Non-bagged for *Lygus elisus* (PLB) during the Early Flower and Pod Stages. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 PLB	Non-bagged	0 PLB	Non-bagged
Hyola	2.12 a	2.08 a	4.97 a	5.16 a
Helios	3.47 a	4.64 a	7.45 a	5.13 a
Excel	1.50 a	2.80 a	5.88 a	1.77 b
Defender	1.01 b	2.00 a	7.30 a	4.60 a
Apollo	0.85 a	1.60 a	5.34 a	3.74 a
Alto	1.45 a	2.63 a	7.24 a	2.89 b
46A65	1.19 a	0.99 a	5.72 a	5.20 a

[1] For each plant growth stage, means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 8. 4. Yield (g. /head) of Five Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Flower Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
Hyola	3.16 a	1.71 b	1.49 b	1.61 b	- 0.06932
Excel	4.15 a	1.65 b	1.23 b	1.10 b	- 0.14246
Defender	2.81 a	1.03 b	1.02 b	1.09 b	- 0.07075
Apollo	5.16 a	2.14 b	1.78 b	1.62 b	- 0.16199
46A65	1.70 a	1.37 ab	0.33 b	0.89 ab	- 0.05335
AVERAGE	3.40	1.58	1.17	1.26	- 0.09957

[1] Means followed by the same letter in a row do not differ significantly (P> 0.05, LSD).

Table 8. 5. Yield (g. /head) of Five Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Pod Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
Hyola	6.10 a	6.53 a	5.42 a	4.47 a	- 0.11940
Excel	7.33 a	8.31 a	6.88 ab	4.02 b	- 0.23577
Defender	6.13 a	5.76 a	5.30 a	2.05 b	- 0.24740
Apollo	5.60 a	4.78 ab	5.29 a	2.59 b	- 0.16370
46A65	5.85 a	4.16 ab	4.45 ab	2.73 b	- 0.15597
AVERAGE	6.20	5.91	5.47	3.17	-0.18445

[1] Means followed by the same letter in a row do not differ significantly (P> 0.05, LSD).

Table 8. 6. Yield (g. /head)[1] of Five Canola Cultivars Bagged and Non-bagged for *Lygus elisus* (PLB) during the Early Flower and Pod Stages. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2001.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 PLB	Non-bagged	0 PLB	Non-bagged
Hyola	3.16 a	4.13 a	6.10 a	7.39 a
Excel	4.15 a	5.95 a	7.33 a	7.52 a
Defender	2.81 a	4.34 a	6.13 a	4.14 a
Apollo	5.16 a	4.35 a	5.60 a	3.27 a
46A65	1.70 b	3.51 a	5.85 a	5.80 a

[1] For each plant growth stage, means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 8. 7. Yield (g. /head) of IMC204 Canola Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Flower and Pod Stages. Trial Three, Cargill Oilseed Research Center, Ft. Collins, CO, 2001.

		No. *Lygus elisus*/Head[1]				
Cultivars	Growth Stage	O PLB	2 PLB	8 PLB	16 PLB	Slope
IMC204	Flower	1.95 ab	2.72 a	1.18 bc	0.86 c	- 0.09645
IMC204	Pod	6.21 a	5.38 ab	5.42 ab	4.80 b	- 0.11879

[1]Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8. 8. Yield (g. /head) of IMC204 Canola bagged and Non-bagged for *Lygus elisus* (PLB) during the Early Flower and Pod Stages. Trial Three, Cargill Oilseed Research Center, Ft. Collins, CO, 2001.

		No. *Lygus elisus*/Head[1]		
Cultivars	Growth Stage	O PLB	Non-bagged	Slope
IMC204	Flower	1. 95 a	1.86 a	- 0.11879
IMC204	Pod	6.21 a	3.24 b	- 3.14800

[1]Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8. 9. Yield (g. /head) of Six Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Flower Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
46A65	1.20 a	2.02 a	1.36 a	0.47 a	- 0.06684
Apollo	1.40 a	0.99 a	0.86 a	0.48 a	- 0.04956
Excel	1.00 a	0.92 a	0.64 a	0.90 a	- 0.00717
Helios	4.35 a	3.95 a	2.04 a	1.25 a	- 0.20028
Hyola	1.57 a	2.15 a	0.75 a	0.59 a	- 0.08465
IMC205	0.31 a	2.12 a	1.52 a	1.73 a	0.04619
AVERAGE	1.64	2.03	1.20	0.90	-0.06039

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8. 10. Yield (g. /head) of Six Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Pod Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
46A65	4.53 a	3.34 a	5.03 a	4.06 a	0.01019
Apollo	2.81 a	2.51 a	2.75 a	2.35 a	- 0.02055
Excel	5.27 a	6.03 a	4.00 a	4.43 a	- 0.08576
Helios	8.12 a	7.92 a	7.74 a	7.95 a	- 0.00835
Hyola	3.96 a	4.19 a	2.29 a	3.60 a	- 0.04483
IMC205	2.85 a	3.45 a	3.85 a	3.05 a	0.00459
AVERAGE	4.59	4.57	4.28	4.24	-0.02412

[1]Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8. 11. Yield (g. /head)[1] of Six Canola Cultivars Bagged and Non-bagged for *Lygus elisus* (PLB) during the Early Flower and Pod Stage. Trial One, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 PLB	Non-bagged	0 PLB	Non-bagged
46A65	1.19 a	1.69 a	4.53 a	2.22 b
Apollo	1.40 a	2.27 a	2.81 a	1.96 b
Excel	1.00 a	2.72 a	5.27 a	2.77 a
Helios	4.35 a	2.02 a	8.12 a	0.96 b
Hyola	1.57 a	1.79 a	3.96 a	2.95 a
IMC205	0.31 b	3.66 a	2.85 a	2.37 a

[1] For each plant growth stage, means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 8. 12. Yield (g. /head) of Four Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Flower Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
46A65	5.05 a	4.05 a	5.73 a	3.77 a	- 0.04268
Apollo	3.16 a	2.77 a	1.57 a	1.74 a	- 0.09120
Excel	5.73 a	5.20 ab	2.26 b	2.91 ab	- 0.19136
Hyola	5.26 a	6.91 a	5.64 a	5.65 a	- 0.02068
AVERAGE	4.80	4.73	3.80	3.52	- 0.08648

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8.13. Yield (g. /head) of Four Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Pod Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
46A65	10.41 a	8.12 ab	9.09 a	5.32 b	- 0.25792
Apollo	4.36 a	4.38 a	5.06 a	3.81 a	- 0.02759
Excel	6.75 a	8.96 a	8.22 a	7.69 a	0.00752
Hyola	7.13 a	5.53 a	6.66 a	7.18 a	0.04467
AVERAGE	7.16	6.75	7.26	6.00	-0.05833

[1] Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8. 14. Yield (g. /head)[1] of Four Canola Cultivars Bagged and Non-bagged for *Lygus elisus* (PLB) during the Early Flower and Pod Stage. Trial Two, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 PLB	Non-bagged	0 PLB	Non-bagged
46A65	5.05 a	6.23 a	10.41 a	6.60 a
Apollo	3.16 a	3.53 a	4.36 a	4.34 a
Excel	5.73 a	3.85 a	6.75 a	5.86 a
Hyola	5.26 a	6.07 a	7.13 a	6.65 a

[1] For each plant growth stage, means followed by the same letter in a row do not differ significantly ($P > 0.05$, LSD).

Table 8. 15. Yield (g. /head) of Two Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Flower Stage. Trial Three, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
IMC204	3.21 a	2.89 a	1.73 a	2.06 a	- 0.07582
IMC205	1.45 a	2.45 a	2.02 a	0.26 a	- 0.09629

[1]Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8. 16. Yield (g. /head) of Two Canola Cultivars Bagged and Infested with Different Numbers of *Lygus elisus* (PLB) during the Early Pod Stage. Trial Three, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	No. *Lygus elisus*/Head[1]				
Cultivars	O PLB	2 PLB	8 PLB	16 PLB	Slope
IMC204	2.14 a	2.99 a	3.15 a	3.41 a	0.06327
IMC205	4.31 a	3.41 a	3.32 a	3.14 a	- 0.05535

[1]Means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8. 17. Yield (g. /head)[1] of Two Canola Cultivars Bagged and Non-bagged for *Lygus elisus* (PLB) during the Early Flower and Early Pod Stage. Trial Three, Horticulture Field Research Center, Ft. Collins, CO, 2002.

	Early Flower Stage		Early Pod Stage	
Cultivars	0 PLB	Non-bagged	0 PLB	Non-bagged
IMC204	3.22 a	2.52 a	2.14 a	2.67 a
IMC205	1.45 a	2.55 a	4.32 a	4.45 a

[1] For each plant growth stage, means followed by the same letter in a row do not differ significantly (P > 0.05, LSD).

Table 8.18. Summary of yield loss relationship between pale legume bug (PLB) and canola seed weight, 2001-2002.

Trial[1]	Year	Growth Stage[2]	Yield (g.)/ 0 PLB/head	Average Slope	PLB to Produce 10% Yield Loss[3]
HFRC, Trial One	2001	EF	1.66	-0.05349	3.1
HFRC, Trial One	2001	EP	6.27	-0.17118	3.7
HFRC, Trial Two	2001	EF	3.40	-0.09957	3.4
HFRC, Trial Two	2001	EP	6.20	-0.18445	3.4
CORC, Trial Three	2001	EF	1.95	-0.09645	2.0
CORC, Trial Three	2001	EP	6.21	-0.11879	5.2
HFRC, Trial One	2002	EF	1.64	-0.06039	2.6
HFRC, Trial One	2002	EP	4.59	-0.02412	19.0
HFRC, Trial Two	2002	EF	4.80	-0.08648	5.6
HFRC, Trial Two	2002	EP	7.16	-0.05833	12.3
CORC, Trial Three	2002	EF	2.33	-0.08606	2.7
CORC, Trial Three	2002	EP	4.35	0.00396	----

[1] HFRC - Colorado State University Horticulture Field Research Center; CORC - Cargill Oilseed Research Center.

[2] Early flower stages (EF) and early pod stages (EP).

[3] Number of PLB estimated to cause 10% yield loss calculated by (Y/10)/(- S), where Y = yield (g.) and S is the slope of yield loss (g.) per PLB/canola head.

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CHAPTER VIV

SURVEY OF *LYGUS* SPP. AND AN ASSOCIATED PARASITOID, *LEIOPHRON UNIFORMIS* (GAHAN) (HYMENOPTERA: BRACONIDAE), IN COLORADO

INTRODUCTION

The genus *Lygus* Hahn (Hemiptera: Miridae) includes important pests of cultivated and non-cultivated hosts in the United States (Schuh et al. 1995, Wheeler 2000). Worldwide there are 43 known species of *Lygus* (Kelton 1975) with 34 present in the United States (Kelton 1975, Loan and Shaw 1987). Some *Lygus* spp. are highly mobile, multivoltine, and oligophagous and some become pests due to their habit of feeding on new growth and reproductive parts (Kelton, 1975, Henry and Lattin 1987).

Three *Lygus* species are important pests in cultivated crops and non-cultivated habitats in Colorado: *L. lineolaris* (Palisot de Beauvois), known as the tarnished plant bug; *L. hesperus* Knight, the western tarnished plant bug; and *L. elisus* Van Duzee, the pale legume bug. Known parasites of *Lygus* include several species each of Mymaridae from eggs, Braconidae mainly from nymphs, and Tachinidae from adults (Clancy and Pierce 1966). Members of the genus *Leiophron* Nees (Hymenoptera: Braconidae, Euphorinae) attacks nymphal stages of *Lygus* (Clancy and Pierce 1966, Capek 1970, Loan 1974, Marsh 1979, Day 1987, Loan and Shaw 1987, Jackson and Debolt 1990, Ruberson and Williams 2000).

Leiophron uniformis (Gahan) is important internal parasitoid of the nymphs of *L. elisus*, *L. hesperus*, and *L. lineolaris* in the United States (Clancy and Pierce 1966, Loan 1974, Marsh 1979, Graham et al. 1986, Day 1987, Debolt 1989). *L. uniformis* adults overwinter inside a cocoon among soil, under tree bark (Loan 1974, Loan 1983, Loan and Shaw 1987) or in other protected sites, emerging in April to May (Loan 1983). *L. uniformis* females will attempt to oviposit in all nymphal instars of *L. hesperus* (Debolt 1981) but prefer earliest instars (Loan 1974, Loan 1980, Debolt 1981, Loan 1983, Loan and Shaw 1987).

During oviposition the female pounces upon the host, curls her abdomen beneath its body, and quickly inserts an egg by means of the very short ovipositor (Clancy and Pierce 1966). The entire act is completed in a few seconds, and the parasite may attack several nymphs in rapid succession. At maturity the larva bores through the host integument and drops to the ground, where it spins a white elongated oval cocoon with irregular longitudinal corrugations (Clancy and Pierce 1966). Parasite larvae emerge from nymphs III-V (Debolt 1981), usually instar V (Sillings et al. 1974, Loan and Shaw 1987). In the laboratory pupal cocoons were observed 10-12 days after oviposition (Clancy and Pierce 1966). Elsewhere, *Leiophron uniformis* is reported multivoltine (Loan 1980, Loan 1983, Day 1987, Day et al. 1998, Ruberson and Williams 2000).

The primary purpose of this study was to determine seasonal occurrence of *L. uniformis* on *Lygus* species present in Colorado and to observe influences of cultivated hosts and non-cultivated hosts on parasitism incidence. A secondary objective was to better document the relative occurrence of *Lygus* spp. in the state and to note host associations.

MATERIALS AND METHODS

2001 Collections. Eleven Colorado sites were sampled during 2001, in Larimer (7 sites), Weld (2 sites), and Mesa (2 sites) counties (Table 9. 3). A total of 50 samples were taken from June 14 to August 15, 2001 (Table 9. 1). Field sampling involved using of a standard 15-in diameter sweep-net. The number of sweeps varied between sites, with sufficient number made to acquire a sample of *Lygus* nymphs for rearing. *Lygus* nymphs were aspirated and transferred to a cardboard ice-cream container with some host plant material for transfer back to the lab.

A variety of vegetation types were sampled including roadsides and fields, primarily containing flixweed (*Descurainia sophia* (L.) Webb ex Prantl, alfalfa (*Medicago sativa* L.), and canola (*Brassica napus* L.). Scientific and common names of predominant vegetations were identified using (Fischer et al. 1990, Randall 2002). Most samples were taken from alfalfa (41 samples, involving 558 *Lygus* nymphs) followed by flixweed (7 samples, totaling 179 nymphs). Based on concurrent adult collections, the great majority of the *Lygus* spp. present was *L. elisus*; a small percentage of the adult insects were *L. lineolaris*.

Nymphs were reared within cardboard ice-cream containers, modified to have a mesh-covered opening cut into the top. The nymphs were provided green bean pods and a small piece of cotton wick slightly moistened with water. All samples were checked daily for evidence of parasitoid emergence from nymphs. Emerged parasitoids were promptly transferred to individual glass vials to prevent predation and allow for adult emergence.

2002 Collections. Sampling was expanded during 2002. Sampling was initiated 29 May and continued through 8 October (Table 9. 1). The areas of surveys were also expanded to include sites in Larimer (14), Weld (32), Morgan (23), Logan (20), Mesa (5), Delta (7), Montrose (17), Pueblo (2), and Alamosa (7) counties (Table 9. 3). In total, 257 site visits were made. Samples were taken from a mixture of vegetation sites. Cropland involved in the study primarily involved monocultures of alfalfa or canola. Relatively pure stands of flixweed and alfalfa stands heavily infested with flixweed were sampled, particularly early in the season when flixweed is actively growing and flowering. Other sites sampled later in the season included alfalfa and various summer annual weeds including kochia (*Kochia scoparia* (L.) Schrad.), lambsquarters (*Chenopodium album* L.), and redroot pigweed (*Amaranthus retroflexus* L.). Indentifications of scientific and common names of predominant vegetations have been produced by Fischer et al. (1990), and Randall (2002).

After transfer back to the laboratory, the *Lygus* nymphs were aspirated and transferred to Petri dishes for further rearing. A piece of filter paper was placed on the bottom and moistened cotton wick was provided for to increase humidity and provide a secondary water source; fresh green bean pods were provided for food. No more than twenty nymphs were placed in each rearing dish. Cultures were checked daily and parasitoids that had emerged were immediately transferred to individual vials for rearing. Parasitoids that died were preserved in alcohol. Notes were maintained on all insects that died for unknown causes, were parasitized or which made it to the adult stage.

RESULTS AND DISCUSSION

A total of 776 nymphs from 50 different samples were collected during 2001 sampling. *Leiophron uniformis* (Gahan) emerged from a total of 43 nymphs for an overall parasitism of 5.5 percent (Tables 9. 1, 9. 2, 9. 3). In 2002, 3046 nymphs were collected from 257 samples. There was a large percent of mortality from unknown causes (e.g., cannibalism, injury during collection). Of those that survived 144 parasitoids emerged and 1745 *Lygus* made it to the adult stage for overall parasitism of 7.6 percent (Tables 9. 1, 9. 2, 9. 3).

These levels of parasitism are similar to those reported elsewhere. Averaged monthly parasitization of *L. elisus* and *L. hesperus* by *L.* (=*Euphoriana*) *uniformis* observed by Clancy and Pierce (1966) in alfalfa remained below 2 percent in May, June and July then increased to 7.2 percent in August. Graham et al. (1986) reported maximum parasitism of 10.6 percent on July at Tucson and 11.0 percent at Yuma.

In this study, parasites were recovered in June and July but not in August sampling during 2001 (Table 9. 1). More extended sampling occurred in 2002 and parasitism was observed in all months from May through October, peaking at over 34 percent in August (Table 9. 1).

Loan (1983) reported emergence of Euphorine (=*Leiophron*) parasites in May, early June, late June, early July and August. Clancy and Pierce (1966) observed *L. uniformis* parasitism of 7.2 percent in August among a mixed population of *L. elisus* and *L. hesperus*. This increased to 11.0 percent in September and dropped to 5.7 percent in October. Parasitism of 4.0 and 9.5 percent was reported by Graham et al. (1986) in September at Tucson and Yuma, respectively. In Colorado surveys during 2002, percentage parasitism continued to exceed 6 percent in September and in October. Such an extended period of activity strongly supports a multivoltine life cycle in Colorado.

Sampling of different *Lygus* hosts indicated that parasitism by *L. uniformis* occurred in alfalfa, flixweed, alfalfa/flixweed mixtures, kochia, lambsquarters, and canola (Table 9. 2). The highest percentage parasitism occurred in canola during 2002 sampling (11.8 percent) and *L. uniformis* was recovered from 1 or 5 Lygus nymphs collected during 2001. Parasitism in alfalfa, the most intensively sampled crop, was 4.1 and 10.9 percent in the two years (Table 9. 2). This compares closely to the 11 percent parasitism of *L. lineolaris* in the alfalfa-grass fields reported by Day (1999). Graham et al. (1986) sampled *Lygus* in alfalfa, cotton, grain sorghum, guayule, and a number of weed hosts in southern Arizona and found parasitism by *L. uniformis* most consistently in nymphs collected from alfalfa. Jackson and Debolt (1990) speculated parasitism might increase 60-70 percent if hay cutting is delayed for seed.

Substantial parasitism of *Lygus* by *L. uniformis* also occurred in many non-cultivated plantings. During 2002, parasitism in flixweed was 2.2 percent, kochia 6.6 percent, and lambsquarters 9.7 percent (Table 9. 2). No parasites were recovered from *Lygus* collected in a relatively small number of samples from redroot pigweed. Clancy and Pierce (1966) noticed increasing *L. uniformis* parasitism of *Lygus elisus* on *Chenopodium* weed species from spring to midsummer. Grahan et al. (1986) first recovered *L. uniformis*-parasitized nymphs from *Chenopodium* in April at Tucson, Yuma, and Gila Bend. The levels of parasitism on *Lygus* from *Chenopodium* plants were somewhat higher than on alfalfa: 28.6 percent in July in Yuma, 14.3 percent in April at Gila Bend, and 10 percent in August at Benson.

In 2001 and 2002 sampling period, *L. uniformis* was recovered from Larimer, Weld, Morgan, Logan, and Pueblo counties (Table 9. 3). However, recoveries of *L. uniformis* did not occur in collections from Mesa, Delta, Montrose, and Alamosa counties. The highest percent of *L. uniformis* was recovered in Larimer County in 2001 (Table 9. 3). In 2002, the highest percent of *L. uniformis* was recovered from Pueblo county, followed Morgan, Larimer, Weld countries.

A breakdown of the 1745 *Lygus* species collected in 2002 and reared to the adult stage indicated three species present; *L. elisus*, *L. hesperus*, and *L. lineolaris* (Tables 9. 4, 9. 5). *Lygus elisus* was recovered in highest numbers at 58.4 percent of the total. *Lygus hesperus* was the second most abundant species in sampling (29.3 percent) followed by *L. lineolaris* (12.3 percent).

The highest population of *L. elisus* occurred during the early season and comprised 98.0 and 89.2 percent of all *Lygus* collected in May, and June sampling, respectively (Table 9. 4). At this time *L. elisus* was found mainly on flixweed and in alfalfa/flixweed mixtures, the plantings most commonly sampled during that period of the season (Table 9. 5). Fye (1982) reports *L. elisus* as the predominate species on weedy crucifers, chenopods, kochia, and pigweeds. Schwartz et al. (1992) reported *L. elisus* from 16 different families including Brassicaceae (*Brassica campestris*, *Brassica napus*, *Descurainia sophia*) Chenopodiaceae (*Amaranthus retroflexus*, *Chenopodium album*, *Kochia scoparia*) and Fabaceae, with alfalfa being the most important host. In this survey (Table 9. 5) *L. elisus* was observed to commonly utilize both weedy hosts and the cultivated hosts alfalfa and canola.

Lygus hesperus tended to occur in higher percentage later in the season becoming the predominant *Lygus* species recovered during October and September (Table 9. 4). It was the species most commonly recovered from lambsquarters (87.8 percent), kochia (80.3 percent), canola (57.3 percent) and redroot pigweed (47.4 percent) (Table 9. 5). It was also abundant in alfalfa and comprised 21 percent of the total *Lygus* recovered from that crop.

Lygus lineolaris was the species recovered in lowest numbers during 2002 sampling (Tables 9. 4, 9. 5). Snodgrass et al. (1984) reported highest populations of *L. lineolaris* during May, and June and again during September, and October. In this study greatest recoveries were populations occurred on July, and October, with none collected in August samples (Table 9. 4).

Lygus lineolaris is an extremely polyphagous insect having over 300-recorded hosts (Schwartz et al. 1992). In this study the highest percentage of *L. lineolaris* was found in collections of the two cultivated crops alfalfa (22.3 percent) and canola (18.0 percent) (Table 9. 5). Leferink and Gerber (1997) reported *L. lineolaris* as the dominant species in canola, followed by *L. elisus*. In canola (Timlick et al. (1993) observed *Lygus* populations to reach a peak during the flowering of the host, decline then peak again in the pod stages. *L. lineolaris* is well documented as a pest of alfalfa (Kelton 1975), the plant sampled most intensively late in the season this survey.

Table 9. 1. *Lygus* spp. nymph collections and subsequent parasitism by *Leiophron uniformis*, arranged by collection date, 2001-2002.

Collection Month	No. Samples	No. Nymphs	Unknown Mortality	No. Adults	No. Parasitized (Percent)[a]
		2002 Sampling			
May	6	359	59	300	2 (0.7)
June	91	746	253	493	24 (4.6)
July	71	853	444	409	75 (15.5)
August	20	153	136	17	9 (34.6)
September	60	861	378	483	31 (6.0)
October	9	74	31	43	3 (6.5)
		2001 Sampling			
June	19	434	-------	-----------	22 (5.1)
July	15	195	-------	-----------	21 (10.8)
August	16	147	-------	-----------	0 (0.00)
Total (2002)	257	3046	1301	1745	144 (7.6)
Total (2001)	50	776	------	-----	43 (5.5)

[a] Parasitism percentage in 2002 excluded nymphs that died from unknown causes. Parasitism percentage in 2001 based on all nymphs collected.

Table 9. 2. *Lygus* spp. nymph collections and subsequent parasitism by *Leiophron uniformis*, arranged by vegetation at collection site, 2001-2002.

Predominant Vegetation	No. Samples	No. Nymphs	Unknown Mortality	No. Adults	No. Parasitized (Percent)[a]
		2002 Sampling			
Alfalfa	141	1466	766	700	86 (10.9)
Flixweed	40	522	126	396	9 (2.2)
Alfalfa/Flixweed	18	244	60	184	3 (1.6)
Kochia	22	263	106	157	11 (6.6)
Lambsquarters	19	278	139	139	15 (9.7)
Canola	13	243	93	150	20 (11.8)
Redroot pigweed	4	30	11	19	0 (0.00)
		2001 Sampling			
Alfalfa	41	558	------	------	23 (4.12)
Flixweed	7	179	------	------	19 (10.6)
Canola	1	5	------	------	1 (20.0)
Sunflower	1	34	------	------	0 (0.0)
Total (2002)	257	3046	1301	1745	144 (7.6)
Total (2001)	50	776	-----	------	43 (5.5)

[a] Parasitism percentage in 2002 excluded nymphs that died from unknown causes. Parasitism percentage in 2001 based on all nymphs collected.

Table 9. 3. *Lygus* spp. nymph collections and subsequent parasitism by *Leiophron uniformis*, arranged by sampling location, 2001-2002.

Colorado County	No. Sites	No. Samples	No. Nymphs	Unknown Mortality	No. Adults	No. Parasitized (Percent)[a]
		2002 Sampling				
Larimer	14	84	1267	531	741	68 (8.4)
Weld	32	70	964	378	587	47 (7.4)
Morgan	23	43	346	163	183	22 (10.7)
Logan	20	22	172	61	111	4 (3.5)
Mesa	5	5	40	15	21	0 (0.0)
Delta	7	7	40	35	5	0 (0.0)
Montrose	17	17	146	95	49	0 (0.0)
Pueblo	2	2	21	12	9	3 (25)
Alamosa	7	7	50	11	39	0 (0.0)
		2001 Sampling				
Larimer	7	33	579	-------	--------	42 (7.3)
Weld	2	7	85	-------	--------	1 (1.2)
Mesa	2	10	112	-------	--------	0 (0.0)
Total (2002)	127	257	3046	1301	1745	144 (7.6)
Total (2001)	11	50	776	-----	-----	43 (5.5)

[a] Parasitism percentage in 2002 excluded nymphs that died from unknown causes. Parasitism percentage in 2001 based on all nymphs collected.

Table 9. 4. *Lygus* spp. collected during 2002 surveys, arranged by date of collection.

Collection Month	No. Samples	No. Adults Reared	No. Identified to Species (%)		
			L. elisus	*L. hesperus*	*L. lineolaris*
May	6	300	294 (98.0)	4 (1.3)	2 (0.7)
June	91	493	440 (89.2)	36 (7.3)	17 (3.4)
July	71	409	197 (48.2)	98 (24.0)	114 (27.9)
August	20	17	11 (64.7)	6 (35.3)	0 (0.0)
September	60	483	77 (15.9)	337 (69.8)	69 (14.3)
October	9	43	0 (0.0)	31 (72.1)	12 (27.9)
Total	257	1745	1019 (58.4)	512 (29.3)	214 (12.3)

Table 9. 5. *Lygus* spp. collected during 2002 surveys, arranged by vegetation at collection site.

Predominant Vegetation	No. Samples	No. Adults Reared	No. Identified to Species (%)		
			L. elisus	*L. hesperus*	*L. lineolaris*
Alfalfa	141	700	397 (56.7)	147 (21.0)	156 (22.3)
Flixweed	40	396	383 (96.7)	9 (2.3)	4 (1.0)
Alfalfa/Flixweed	18	184	165 (89.7)	13 (7.1)	6 (3.3)
Kochia	22	157	22 (14.0)	126 (80.3)	9 (5.7)
Lambsquarters	19	139	7 (5.0)	122 (87.8)	10 (7.2)
Canola	13	150	37 (24.7)	86 (57.3)	27 (18.0)
Redroot pigweed	4	19	8 (42.1)	9 (47.4)	2 (10.5)
Total	257	1745	1019 (58.4)	512 (29.3)	214 (12.3)

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WESTERN BLACK FLEA BEETLE STUDIES

CHAPTER X

WESTERN BLACK FLEA BEETLE LITERATURE REVIEW

INTRODUCTION

The genus *Phyllotreta* (Coleoptera: Chrysomelidae/Alticinae) is one of the largest and most economically important groups of flea beetles. Worldwide there are 150 known species of *Phyllotreta* with 48 of them generally distributed in America north of Mexico (Edward et al. 2002). The genus contains several important agricultural pest species that mainly attack brassicas (Chittenden 1909, Chittenden and Marsh 1920, Newton 1928). Among the pest species are *P. nigripes* F., *P. consobrina* Curt, *P. punctulata* Marsh, *P. atra* Payk, *P. cruciferae* Goeze (Newton 1928, Hicks 1972, Burgess 1977a, Lamb and Turnock 1982, Lamb 1983, Vincent and Stewart 1984, Palaniswamy and Lamb 1992), *P. diademata* Foudr., *P. vittula* Redt., *P. undulata* Kutsch., *P. nemorum* L., *P. flexuosa* Ill., *P. ochripes* Curt., *P. sinuate* Steph., *P. tetrastigmata* Com., *P. exclamationis* Thunb. (Newton 1928), *P. pusilla* Horn (Chittenden, 1909, Chittenden and Marsh 1920), *P. striolata* (F.) (Hicks 1972, Burgess 1977a, Lamb and Turnock 1982, Lamb 1983, Vincent and Stewart 1984, Palaniswamy and Lamb 1992), *P. albionica* (Lec.), *P. robusta* LeConte, (Burgess 1977a) and *P. bipustulata* (F.) (Vincent and Stewart 1984).

Recorded from Colorado are *P. pusilla*, *P. lewisii* (Crotch), and *P. zimmermanni* (Crotch), based on records at the C.P. Museum of Arthropod Diversity. Four *Phyllotreta* spp. have established common names by the Entomological Society of America: *P. armoraciae*, horseradish flea beetle; *P. pusilla*, western black flea beetle; *P. ramosa*, western striped flea beetle; and *P. striolata*, striped flea beetle (Anonymous 1989). Keys to

Phyllotreta have been produced by Arnett (1960), Downie and Arnett (1996), and Edward et al. (2002).

The most severe pests of oilseed *Brassica* cultivars in Europe and North America are *P. cruciferae*, *P. striolata*, *P. undulata* (Lamb 1989) and *P. pusilla* (Chittenden and Marsh 1920, Al-Doghairi 2000). The latter, known as the western black flea beetle (WBFB) is a key pest of brassicas plants grown in Colorado (Chittenden and Marsh 1920, Al-Doghairi 2000). Its range includes a broad area of the western US including New Mexico, Arizona, Wyoming, Nebraska, Oklahoma, and Kansas (Chittenden and Marsh 1920). In attempts to develop oilseed brassica crops in Colorado, WBFB has proved to be a key pest capable of severely damaging crops (Whitney Cranshaw, Colorado State University, personal observation).

The following is a description of *P. pusilla*, provided by Chittenden and Marsh (1920): "shining metallic copper in color, approximately 2.9 mm in length. The body is elongate oval, and much flattened. Antennae are slender and the same as in both sexes. Head scarcely is visibly punctate. Thorax less than twice as wide as long, widest at middle, sides actuate, apex slightly narrower than base, disc convex, surface shining, the punctures moderate, closely placed, but not convex. Elytra wider than the thorax, humeri obtuse, punctuations coarser than that of the thorax, closely placed, very little finer near the apex, but less dense, surface shining. Body beneath and legs piceous, abdomen is sparsely punctate. The femor of hind legs are strongly developed, fitting insect for jumping up, especially when they are disturbed".

DAMAGE

WBFB damage to plants is almost entirely due to adult feeding; larval feeding on roots is considered negligible (Chittenden and Marsh 1920, Al-Doghairi 2000). Chewing of adult *Phyllotreta* often produces "pit-like holes" or "shot-holes" of the leaf interior, although they may also chew along leaf margins, on stems and seed-pods (Chittenden and Marsh 1920, Burgess 1977a, Lamb 1988, Al-Doghairi 2000). Most damage usually occurs during the period of seedling growth, during the first few weeks after emergence (Turnock 1982, Lamb 1984). Plants are frequently killed, causing poor stand establishment. Surviving plants with early season damage show delayed development, uneven height and maturity, reduced seed yield and raise chlorophyll content of seed (Osgood 1975, Lamb 1984, Bracken and Bucher 1986).

Brassica cultivars are important crops of the oil seed industry and the most widely grown of these in North America is canola, *Brassica napus* L.. Canola (a contraction of Canadian Oil-Seed Low Acid) was developed in the 1970s by a plant-breeding program designed to develop cultivars of oilseed rape with low levels of glucosinolates and erucic acid (Fahey et al. 2000). Canola seed contains about 40 percent oil and by regulation this oil must contain < 2 percent erucic acid (Shahidi 1990, Fahey et al. 2000). All currently registered varieties of canola and oilseed rape are susceptible to attack by flea beetles (Gavloski et al. 2000).

WBFB injury occurs at several periods during the season (Chittenden and Marsh 1920, Newton 1928). Initial injuries result from the overwintered flea beetles. These are present by the end of April or during May and continue until June. Most seedling injuries result from this overwintered population. Serious injury can also result from adults of the first generation, present in June and July, although most plants are well established and not as susceptible to effects of seedling injuries. Brown et al. (1999) reported that uncontrolled infestation reduce seed yield of canola species by 37 and 32 percent in *Brassica napus* L. and *Brassica rapa* L., respectively. Cosmetic injuries by WBFB can occur throughout the growing season on leafy brassicas such as mustard greens and arugala.

Severity of WBFB damage can be strongly influenced by weather (Burgess 1977a, Turnock 1982, Lamb and Turnock 1982). In years with hot, dry spring weather, weedy hosts are scarce and high temperature encourages rapid movements of the beetles. In addition, high temperatures can stress brassicas making them more susceptible to damage. In contrast, cool, moist weather encourages plant growth and enables crops to pass quickly through the early susceptible stage (Burgess 1977a, Turnock 1982).

HOST RANGE

WBFB has a wide host range. Although primarily associated with crucifer plants several other families are incidentally damaged by adult feeding (Table 10.1) (Chittenden 1909, Chittenden and Marsh 1920, Al-Doghairi 2000, and personal observations).

Table 10. 1. Plants Reported Damaged by Western Black flea Beetle Feeding.

Family	Scientific Name	Common Names
Brassicaceae	*Armoracia rusticana* P. Gaertn., B. Mey. & Scherb.	Horseradish
	Brassica rapa L.	Turnip, Chinese cabbage, pak choi
	Brassica napus L.	Canola, rape, rutabaga
	Brassica oleracea L.	Broccoli, Brussels sprout, Cabbage, Cauliflower, Collards, kale
	Brassica juncea (L.) Czern.	Mustard greens
	Cleome serrulata Pursh	Rocky Mountain bee plant
	Descurainia pinnata (Wait.) Britt.	Tansymustard
	Descurainia sophia (L.) Webb. ex Prantl.	Flixweed
	Iberis spp.	Candytuft
	Lepidium spp.	Peppergrass, pepperwort
	Lobularia maritima (L.) Desv.	Sweet alyssum
	Nasturtium officinale R. Br.	Watercress
	Raphanus sativus L.	Radish
	Rorippa spp.	Yellow cress
	Sisymbrium spp.	Hedge mustard
Chenopodiaceae	*Beta vulgaris* L.	Beet
Solanaceae	*Lycopersicon esculentum* Mill.	Tomato
	Solanum tuberosum L.	Potato
Fabaceae	*Pisum sativum* L.	Pea
	Phaseolus vulgaris L.	Common bean
Apiaceae	*Daucus carota* L.	Wild carrot

Scientific and common names (Randall 2002).

Brassica plants, including those that are WBFB hosts, typically contain the secondary compounds glucosinolates (Feeny 1977, Benn 1977, Sang et al. 1984, Metcalf

1987, Hopkins et al. 1998, Fahey et al. 2000, Renwick 2002). Glucosinolates are present in sixteen families of dicotyledonous angiosperms (Fahey et al. 2000) and serve as stimulants for oviposition or feeding. Volatile products from their hydrolysis also are attractants for several insect species (Renwick 2002). The most studied of these are isothiocyanates, often referred to as mustard oils, which act as attractants and stimulants for several specialist insects that feed on brassica plants (Renwick 2002).

Secondary compounds of Brassicaceae can be important feeding stimulants. Hicks (1974) reported that addition of sinigrin (mustard oil glucosides or allyl isothiocyanate) to bean leaves could result in feeding by *P. cruciferae* on bean, a non-host. Feeding increased on bean leaves as the sinigrin concentration in the leaves was increased. The amount of feeding increased with sinigrin concentration up to a maximum of 3.0 percent (45,900 ppm) sinigrin, but dropped off drastically at 4.0 percent (61,200 ppm) sinigrin. In addition, Altieri and Schmidt (1986) mentioned that allyl isothiocyanate-treated plants proved to be more attractive than plants treated wild mustard extracts. Collard plants sprayed with wild mustard extracts, and especially with allyl isothiocyanate emulsions, proved to be more attractive to flea beetles than collard plants sprayed with water.

LIFE HISTORY

Basic outline of the life history of WBFB was presented by Chittenden and Marsh (1920), who studied the insect in the Arkansas Valley of Colorado. WBFB overwinters as adults under clods of earth, dead leaves, or other rubbish. Mating occurs during May and June. Females deposit their eggs in cracks in soil about roots of host plants usually winter mustards. Females begin egg lying as early as middle of April and continue into early September. The eggs are light yellow, glisten, are of oval form, and about 0.5 mm in length.

Emerging larvae are thread-like in appearance. They are uniformly white except for the head sclerites, the legs and a chitinized area on the caudal abdominal segment, which are pale chestnut brown. Larvae feed by chewing roots and roots hairs. The pupa is halticine-form, approximately the same size as adult and entirely white. The entire life cycle takes approximately about 30 days in June and July (Chittenden and Marsh 1920). Apparently three generations are normally produced annually in the Arkansas Valley with population peaks becoming indistinct by midsummer.

NATURAL ENEMIES

Microctonus pusillae Muesebeck (misidentified, as *Perilitus epitricis* Vier by Chittenden and Marsh (1920) is the only hymenopterous parasitoid associated with *P. pusilla* (Muesebeck 1936, Krombein et al. 1979). *M. pusillae* is a parasitoid of the adult stage with larvae apparently emerging through the abdomen and under the elytra. The larva spins a light gray cocoon in which it transforms to pupa. Chittenden and Marsh (1920) reported *M. pusillae* as most abundant from late June to late July. The greatest percentage of observed beetle parasitism was 16 percent.

Wylie and Loan (1984) surveyed natural enemies of flea beetles, *Phyllotreta* spp., in southern Manitoba. They recovered six euphorines (Braconidae): *Townesilitus psylliodis* (Loan), *Microctonus punctulatae* sp.n., *Microctonus pusillae* Muesebeck, *Microctonus vittatae* Muesebeck, *Microctonus zimmermanni* sp.n., and *Townesilitus bicolor* (Wesm.). Only *M. vittatae* was commonly recovered from their sampling. Two species, *M.*

punctulatae and *T. psylliodis*, were reported to overwinter there only in *Psylloides punctulata*, the hop flea beetle.

Females of the two-euphorine genera have different oviposition behaviors as well as distinctive morphological characters. Females of *Townesilitus* fly onto their hosts and oviposit only into the abdomen. *Microctonus* species stand beside the beetle and oviposit into the head, thorax, or abdomen.

Microctonus vittatae is the best studied of these flea beetle parasitoids. It is a thelyotokous species with males being exceedingly rare (Smith and Peterson 1950). *Phyllotreta striolata* is the primary host (Smith and Peterson 1950, Wylie 1980a,b, Wylie 1982, Wylie and Loan 1984, Wylie 1985), and it is also recovered from *P. bipustulata*, *P. zimmermanni* (Smith and Peterson 1950), and *P. cruciferae* (Wylie 1980a,b, Wylie 1982, Wylie and Loan 1984, Wylie 1985). Females of several successive overlapping generations are present each year from late May or early June until October (Wylie 1980b).

Fertile eggs appear to be oviposited sometimes within a few minutes after emergence of wasps from cocoons (Smith and Peterson 1950). Eggs are usually inserted into the thoracic region of the beetle. A single larva develops in each host, and full-grown larvae force their way out of the caudal end of their hosts, invariably killing the beetles. Shortly thereafter they spin white silken cocoons. The entire life history of parasitoid may be completed in 18 to 20 days. Incidence of parasitism by *M. vittatae* in *P. striolata* averaged of 46.4 percent over a 3 year studied reported by Smith and Peterson (1950).

Females of a European parasite, *Microctonus bicolor*, oviposit into the abdomen of the host (Wylie and Loan 1984). Development time, from oviposition to larval emergence, was 3-4 weeks, and adults emerge approximately 2 weeks later. In tests of host range in

Manitoba *M. bicolor* oviposited readily in *Phyllotreta striolata* and occasionally in *P. cruciferae*, but not in *Psylliodes punctulata*. Wylie and Loan (1984) concluded that *Microctonus bicolor* is unlikely to provide economic control of *P. cruciferae*, which is the most important of the oilseed brassica flea beetles in the southern part of the Prairie Provinces. In addition, Wylie (1983) reported that *M. bicolor* could readily parasitize WBFB.

Predation of flea beetles is less commonly reported on *Phyllotreta* spp. Burgess (1977b) observed predation of *P. striolata* in western Canada by the big-eyed bug, *Geocoris bullatus* (Say), but concluded it was only an incidental predator of adults. Burgess (1980) also observed some predation of *P. cruciferae* adults by green lacewing larvae, *Chrysoperla carnea* (Stephens) and by the nabid *Nabis alternatus* (Parshley) in mustard fields (Burgess 1982). The nabid *Nabicula americolimbata* (Carayon) and the pentatomid spined soldier bug, *Podisus maculiventris* (Say), were observed feeding on the adult flea beetles of the genus *Phyllotreta* (Culliney 1986). In addition, the field cricket, *Gryllus pennsylvanicus* Burmeister, feeds on *P. cruciferae* adults and could be an effective predator in the field conditions (Burgess and Hinks 1987).

Birds also commonly consume WBFB. Chittenden and Marsh (1920) reported 12 bird species observed to feed on the insect including the common and Texas nighthawks, white-throated swift, horned lark, starling, song sparrow, chipping sparrow, tree swallow, and marsh wren.

Another WBFB biological control agent identified by Chittenden and Marsh (1920) are entomopathogenic nematodes. Those observed from *P. pusilla* were not identified but were about 0.6 mm in length and were found in populations of 200 to 500 nematodes/beetle.

MANAGEMENT-CHEMICAL CONTROL

In one of the earliest chemical control trials for *Phyllotreta* McGregor and Stringham (1977) tested granules containing 5 percent carbofuran at seeding. Yield losses of 17 and 26 percent occurred on unprotected *Brassica napus* L. and *B. campestris* L., respectively, compared to plants treated with carborfuran. Visible damage was also reduced on all three *Brassica* spp. in the trial - *B. napus*, *B. campestris* and *B. juncea*. Lamb (1984) tested planting time treatments of carbofuran and lindane applied against a *Phyllotreta* species on canola. They found carbofuran granules to protect plants for two weeks. Lindane provided protection for only one week after seedling.

Weiss et al. (1991) tested foliar applications of permethrin, endosulfan, esfenvalerate, and malathion for control of *P. cruciferae* on canola. Carbaryl was the most effective insecticide, followed by permethrin, endosulfan, esfenvalerate, and malathion. Carbaryl produced 95 percent mortality up to 1.82 days after application; permethrin, esfenvalerate, and endosulfan produced 95 percent mortalities at 1.67, 1.25 and 1.13 days after application. However, Al-Doghairi (2000) reported that endosulfan (Thiodan) and esfenvalerate (Asana) were considerably more effective at controlling *P. pusilla* than were imidacloprid (Provado), carbaryl (Sevin), fipronil (Agenda), lambdacyhalothrin (Warrior), cypermethrin (Mustang and Ammo), permethrin (Ambush), and methomyl (Lannate).

Microbial and plant derived pesticides are also alternatives that have been tested against some flea beetles. One of these is azadirachtin, extracted from seeds of the neem tree, *Azadirachta indica*, a plant widely grown throughout tropical and subtropical Asia, Africa, Australia, and Central and South America (Ermel 1995, Schmutterer 1995). Azadirachtin is a very complex tetranortriterpenoid (Ascher 1993, Schmutterer 1995) and acts as a repellent, antifeedant (Saxena 1995, Copping and Menn 2000), oviposition deterrent, growth-retardant, molt-inhibitor, and sterilant (Schmutterer 1988, Schmutterer 1995, Schmutterer and Wilps 1995, Immaraju 1998). Azadirachtin has shown activity against a wide range of insects including members of the orders Isoptera, Orthoptera, Thysanoptera, Hemiptera, Homoptera, Hymenoptera, Coleoptera, Lepidoptera (Schmutterer 1995).

Previous studies have indicated that neem products decreased significantly population density of *P. cruciferae*, *P. downsei*, *P. striolata* (Schmutterer and Singh 1995), and *P. pusilla* Horn (Al-Doghairi 2000). Al-Doghairi (2000), using the formulations Margosan-O[R] and Azatin[R], concluded that they could be effective alternatives to synthetic insecticides for control of western cabbage flea beetle on brassica crops. Palaniswamy and Wise (1994) conducted a trial with three neem-based formulations that were tested to determine their repellent and feeding deterrent effects on flea beetle (*P. cruciferae*) on canola. At concentrations ranging from 0.05 to 12 percent concentrate, Safer's Neem Insecticide[R] was more effective than were RD-9 Repelin[R] or Margosan-O in decreasing plant damage through a higher beetle mortality and repellency in laboratory and field studies. RD-9 Repelin showed repellency for 1-2 days at 12 percent concentration and for 6 hours at 1.2 and 6 percent concentrations. Decrease in feeding injury in neem-treated seedlings was attributable largely to the repellent effects of neem products. In addition, Hot Pepper Wax[R] and horticultural oil (SunSpray[R]) have also had some demonstrated repellent effect on WBFB (Al-Doghairi 2000).

Spinosad is a recently developed insecticide derived from the actinomycete *Saccharopolyspora spinosa* Mertz & Yao. (Bret et al.1997, Thompson and Hutchins 1999, Copping and Menn 2000, Thompson et al. 2000). The primary insecticidal components are known as spinosyns, with the common formulation consisting of spinosyn A and spinosyn D (Bret et al. 1997, Thompson and Hutchins 1999, Sparks et al. 2001). Spinosad provides effective control of different pests in the insect orders Lepidoptera, Diptera (Thompson et al. 1997, Thompson et al. 2000, Sparks et al. 2001) and Thysanoptera (Copping and Menn 2000, Thompson et al. 2000). Spinosad is also effective against some Coleoptera (elm leaf beetle, willow leaf beetles, Colorado potato beetle) (Bret et al. 1997) and Orthoptera (migratory grasshopper) (Demirel 1998). Spinosad has also been tested against the flea beetle *Epitrix fuscula* Crotch and provided control comparable to carbamate and pyrethroid insecticides, ca. 90 percent control at six days (McLeod et al. 2002).

MANAGEMENT-TRAPPING

Trapping and mulches have been used to control western black flea beetle on cultivated crops. Color traps can be used for different purposes such as monitoring population density of insect species and to provide direct control different insects species on cultivated crops (Hicks 1972, Vincent and Stewart 1985, Al-Doghairi 2000). There have been several studies of response by *Phyllotreta* to colored traps. Al-Doghairi (2000) found Saturn green and Saturn yellow traps attracted significantly more WBFB than transparent traps. Yellow traps were found attractive to *P. cruciferae* and *P. striolata* by (Hicks 1972). Vincent and Stewart (1985) found the white and yellow traps captured significantly more adult *P. striolata* than green and red traps.

The combination of color with attractant compounds can improve capture of specialist insect species on cultivated crops (Feeny et al. 1970, Pivnick et al. 1992). The volatile products following hydrolysis of the glucosinalates found in Brassicaceae appear to be attractants for several insect species (Renwick 2002). Vincent and Stewart (1984) found allyl isothiocyanate baited water traps caught more of the flea beetles *P. cruciferae*, *P. striolata*, *P. bipustulata* and *Psylliodes punctulata* than did unbaited water traps. In addition, sticky traps with allyl isothiocyanate also have captured significantly more flea beetles than those without allyl isothiocyanate. Other reports of attractiveness of allyl isothiocyanate to *P. cruciferae* and *P. striolata* include Feeny et al. (1970), Hicks (1972), Metcalf (1987), and Pivnick et al. (1992). In WBFB studies, Al-Doghairi (2000) showed traps baited with allyl isothiocyanate consistently captured significantly more WBFB than control traps.

HOST PLANT RESISTANCE

All currently registered varieties of canola (*Brassica napus* L.) and oilseed rape (*B. rapa* L.) are susceptible to attack by *Phyllotreta cruciferae*, although to varying degrees (Gavloski et al. 2000). *B. napus* cv. Cresor sustained the lowest damage rating by *P. cruciferae* among tested cultivars. *B. napus* cv. Zephyr was resistant to feeding by flea beetle in the second year, and yet the previous year had been rated as susceptible to flea beetle. *B. rapa* cv. Horizon was the most susceptible among tested *B. rapa* cultivars.

Palaniswamy et al. (1992) reported that no resistance *P. cruciferae* of the antixenosis mechanism was present among 19 cultivars of *B. napus* and *B. campestris*. One accession of *B. carinata* A. Braun., and two accessions of *Sinapis alba* L. exhibited antixenosis. Overall, *S. alba* exhibited the greatest antixenosis while *B. juncea* resulted in the least. Of the other species tested, *B. carinata* and *S. arvensis* L. suffered significantly less damage than *B. nigra* (L.) Koch, *B. campestris* L., *B. oleracea*, and *B. napus*, which did not differ significantly from each other. Radish (*Raphanus sativus* L.) was more susceptible than *B. campestris* and *S. arvensis* to *P. cruciferae* feeding. Palaniswamy and Lamb (1992) reported that *B. oleraceae* and *Brassica napus* were more susceptible than were *Sinapis alba*, *B. nigra*, *B. campestris*, and *S. arvensis* in choice test of *P. cruciferae* feeding on cotyledons evaluated 7-10 days after seeding.

Palaniswamy and Lamb (1992) also reported on choice test involving *P. striolata*. *B. campestris* was more susceptible to feeding than all other tested crucifers except for *Raphanus sativus* and *Sinapis arvensis*. *B. oleracea* was least damaged, and it differed significantly from *B. campestris*, *R. sativus*, and *S. arvensis*. The cotyledons of *Sinapis* species, particularly *Sinapis arvensis*, received the least damage; *B. oleracea* and *B. napus* received the most damage.

Bodnaryk and Lamb (1991) concluded seedlings of *Sinapis alba* have both antixenosis and tolerance resistance mechanisms and are well able to resist flea beetle attack in the field. *B. napus* showed no evidence of either resistance mechanism. *B. napus* and *B. campestris* were most susceptible to *P. cruciferae* injury, while *Sinapis alba* and *Crambe abyssinica* Hoshst was the least damaged (Anderson et al. 1992). Palaniswamy et al. (1997) reported *B. juncea*, *B. napus* and *B. rapa* showed low antixenosis to *P. cruciferae*, *B. carinata* and *S. alba* showed moderate antixenosis, and *Thlaspi arvense* L. exhibited high antixenosis with flea beetles feeding very little on intact seedling foliage of this plant.

Al-Doghairi (2000) reported that higher WBFB densities occurred on Chinese cabbage (*B. juncea*) than on *B. oleracea* cultivars. Chittenden and Marsh (1920) reported radish to be seriously attacked by WBFB. Turnip and mustard were about equally attractive to the beetles and unprotected beds are frequently destroyed. However, Chittenden and Marsh (1920) reported that horseradish was very resistant to WBFB.

CULTURAL CONTROL

Several cultural controls can be significant parts of an integrated pest management of *Phyllotreta* species on cruciferous cultivars. These can include removal of volunteer cruciferous weeds on plots and near fields, arranging planting times to avoid period of peak activity of key *Phyllotreta* species, use of trap crops that *Phyllotreta* species prefer to the main crop, proper irrigation, and use of polyculture planting to decrease per plant flea beetle populations.

Turnock (1982), and Burgess (1977a) suggest that removing volunteer rape, mustard, and cruciferous weeds can decrease population density of flea beetles on nearby cultivated crops (Turnock 1982, Burgess 1977a). In Colorado the winter annual flixweed (*Descurainia sophia*) can be important in early season populations of WBFB (Chittenden and Marsh 1920, Al-Doghairi 2000).

Chittenden and Marsh (1920), and Newton (1928) noted the importance of planting date on WBFB injury. Damage by the overwintered beetles active in late April and May is often most critical as it occurs during seedling stages and stand establishment. Delaying planting avoids this period, or very early planting to establish stand prior to peak periods of feeding injury, was suggested by Chittenden and Marsh (1920) for managing WBFB.

The use of preferred hosts provides opportunities to develop flea beetle trap crops to protect the main crops. For example, white turnip (Newton 1928), radish and Chinese cabbage are particularly favored by WBFB (Chittenden and Marsh 1920). Al-Doghairi (2000) successfully used interplanted radish and daikon to reduce WBFB populations on adjacent cabbage.

Polycultures planting also can decrease density of some flea beetles on plants compared to monocultures. Altieri and Schmidt (1986) reported that population densities of *P. cruciferae* were lower per unit collard plant in polycultures composed either of non-host plants (field bean, vetch and barley) or of additional host plants (wild mustard) than in collard monocultures. Flea beetle exhibited decreased movement patterns in the non-host polycultures, but similar movement activity in the monoculture and collard-wild mustard polyculture. Differences in flea beetle abundance between collard monoculture and collard–wild mustard polyculture disappeared when flowers were artificially removed from wild mustard.

Regular irrigation can assist control of flea beetle species on cruciferous crops, allowing plants to better recover from flea beetle attacks (Chittenden and Marsh 1920). Similarly, the occurrence of cool, moist weather also encourage growth of rape plants and enabling them to pass quickly through the early susceptible to injury by *Phyllotreta* (Burgess 1977a, Turnock 1982).

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CHAPTER XI

EFFECTS OF PREVIOUS LEAF INJURY TO CANOLA ON WESTERN BLACK FLEA BEETLE FEEDING

INTRODUCTION

Flea beetles of the genus *Phyllotreta* (Coleoptera: Chrysomelidae) are important pests of cruciferous crops in North America (Chittenden and Marsh 1920, Newton 1928, Lamb 1989). At least four species are important to oilseed cultivars: *P. cruciferae* (Geoze), *P. striolata* (F.), *P. undulata* Kutsch. (Lamb 1989), and *Phyllotreta pusilla* Horn (Chittenden and Marsh 1920). The latter, known as the western black flea beetle (WBFB), is particularly injurious in the Rocky Mountain States, including Colorado (Chittenden and Marsh 1920, Al-Doghairi 2000). Primary feeding injury is done by adults, which chew small pits ("shotholes") into leaves. Seedlings are frequently killed or severely stunted by these injuries. Very high populations can also defoliate established plants (personal observation).

Plants produce range of semiochemicals that affect various receiving species of insect attractants, arrestants, excitants, and feeding stimulants (Wiseman 1985). Plants of the Brassicaceae are characteristically recognized by the distinctive tastes and odors imparted by the presence of the glucosinolates (Feeny 1977, Finch 1980). One of these, allyl isothiocyanate, has been shown to be a powerful attractant for adults of *P. cruciferae*, *P. striolata* (Feeny et al. 1970, Pivnick et al. 1992) and *P. pusilla* in trapping trials (Al-Doghairi 2000).

During the early stages of colonization, many *Phyllotreta* spp. associated with cruciferous plants feed on cotyledons of emerging seedlings in which the concentrations of glucosinolates are relatively high (Finch 1980). All currently registered varieties of canola and oilseed rape, *Brassica napus* and *Brassica rapa*, are susceptible to attack by flea beetles, although to varying degrees (Gavloski et al. 2000). Release of allyl isothiocyanate is particularly rapid after damage of plant tissues. This is a break down product of sinigrin (allyl glucosinolate) (Feeny 1977, Aliabadi and Whitman 2001).

Mechanical wounding or feeding by *P.* cruciferae caused concentration of indole glucosinolate (3-indolymethyl and 4-hydroxy-3-indolylmethyl) to increase as much as three-fold in the cotyledons of one-week old seedling of the oilseed rapes *B. napus* and *B. rapa* and the mustard *Brassica juncea* (Bodnaryk 1992). These previous studies establish a relationship between plant injury and production of plant compounds known to be attractive to *Phyllotreta* spp. The purposes of this study were to evaluate the effects of previous wounding of different spring canola cultivars on subsequent feeding injury by WBFB.

MATERIALS AND METHODS

Trials were conducted during 2002 with 14 day-old spring canola (*Brassica napus*) seedlings in greenhouse located on the campus of Colorado State University, Fort Collins, CO. Two separate runs of the trial were made: the first seeded 9 May and initiated 23 May; the second seeded 12 May and initiated 26 May. In each, six different cultivars were included: Apollo, Excel, IMC205, 46A65, Hyola, and IMC204.

The plants were tested at the two true leaf stage. Treatment involved removal by cutting of one-half of a leaf within one hour of initiating the trial. An untreated control consisted of undamaged plants. Trials were conducted within cages (61 cm high x 61 cm long x 37 cm wide) into which 12 plants were introduced-six treated by cutting, six left uncut. Five replications (cages) were used in each trial run. One hundred field-collected WBFB beetle adults were introduced into each of cages.

Evaluations of were done at 24 hours intervals following introduction of the beetles. Counting the number of leaf pits and leaf holes per leaf assessed feeding damage. Leaf pits were defined as chewing injuries that did not penetrate the leaf; leaf holes completely penetrated the leaf. In the second run a damage rating was also scored using a 0-3 scale: 0 = no injury; 1 = slight injury; 2 = moderate injury; 3 = severe injury. Numbers of flea beetles per plant were also determined. Two people did all evaluations with the data averaged. Evaluations for the first trial were made over a three-day period from 24 to 26 May; evaluations were made over a two-day period (27 to 28 May) during the second trial. All data were analyzed by using Student–Newman-Keuls (SNK) (SAS Institute 1990).

RESULTS AND DISCUSSION

There were few significant differences by any of the measures between plants damaged by cutting and uncut plants (Table 11.1). Differences that were detected during the first run almost entirely involved the cultivar IMC205. With this cultivar there were significantly greater numbers of pits and holes in cut leaves at the 24-hour evaluation ($F=7.85$, $P=0.0487$; $F=9.85$, $P=0.0349$, respectively) and significantly greater number of flea beetles at the 48 hours ($F=14.71$, $P=0.0185$). The same cultivar had also significant greater number of flea beetle and a higher leaf damage rating in cutting leaves at 72 hours

(*F=8.26*, *P=0.0453*; *F=10.76*, *P=0.0305*, respectively). The only other significant difference occurred at 72 hours with the IMC204 cultivar, which showed a reverse trend, i.e., greater pits to undamaged plants compared to previously cut plants (*F=15.89*, *P=0.0163*).

Furthermore, the effects of leaf cutting indicated some other reverse effects during the second trial run. At this time IMC205 had higher numbers of pits and holes chewed on non-damaged plants compared to those cut prior to WBFB exposure (*F=1.37*, *P=0.3074*; *F=8.46*, *P=0.0437*, respectively) (Table 11. 2). There were a greater number of holes in cutting leaves comparing to undamaged leaves of Apollo on 27-May (*F=12.64*, *P=0.0237*). The cultivars of Hyola had also significant greater number of flea beetle on non-damaged plants on 28-May (*F=57.04*, *P=0.0016*).

There have been variable reports on interaction of plant wounding to flea beetle infestation of brassicas. Vaughn and Hoy (1993) reported the greatest differences in number of feeding holes were observed between injured and uninjured leaves, but canola also had fewer feeding holes than did collard or kale regardless of injury. However, Peng et al. (1992) found that mechanical wounding of the cotyledons of two crucifer species did not influence flea beetle response or feeding. Palaniswamy and Lamb (1993) mechanically wounded (i.e., 6, 24 or 96 punctures per cotyledon) *B. napus* cv. Westar and showed no significant reduction in damage by *P. cruciferae*, although there was a trend for the wounded seedlings to be less damaged than the unwounded ones.

This study indicates only minor effects from prior leaf cutting on subsequent infestation and injury by WBFB to spring canola. Furthermore, such effects may be cultivar specific. Only IMC205 showed significant differences at more than one measure during these studies, and results were contradictory. Three cultivars showed significant results at only a single measure and two (Excel, and 46A65) showed no responses in injury or infestation between previously cut and uncut plants.

This absence of effects may be related to the nature of the injury inflicted in these studies, a single cut across one of two existing true leaves. Under natural conditions feeding by WBFB is almost continuous, producing fresh wounding. Kendall and Bjostad (1990) showed that ethylene production from onion plants was significantly lower following mechanical damage when compared to plants infested by onion thrips, *Thrips tabaci* (Lindemann), which produced sustained injury. Similarly, the increased production of glucosinolates following injury crucifers reported to follow mechanical injury or WBFB feeding (Bodnaryk 1992) may differ due to the nature of the leaf injury. However, overall the results of this study do not suggest a strong relationship between previous injury and *Phyllotreta* infestation, consistent with the reports of Peng et al. (1992) and Palaniswamy and Lamb (1993).

Table 11. 1. Effect of leaf cutting on subsequent damage (leaf pitting, holes) and number of western black flea beetles, *Phyllotreta pusilla*, on different canola cultivars. First greenhouse trial, May 2002.

	24 May		25 May		26 May	
Cultivars	Cut	Uncut	Cut	Uncut	Cut	Uncut
			Number of Pits/Plant[a]			
Apollo	7.4 a	4.2 a	15.2 a	9.0 a	15.8 a	18.6 a
Excel	5.0 a	4.2 a	10.4 a	18.2 a	17.4 a	17.4 a
IMC205	4.2 a	2.2 b	16.6 a	10.6 a	14.2 a	15.0 a
46A65	2.6 a	2.6 a	10.6 a	12.8 a	20.6 a	30.4 a
Hyola	2.0 a	1.6 a	15.4 a	11.6 a	28.8 a	26.6 a
IMC204	1.4 a	4.0 a	10.2 a	17.8 a	14.2 b	29.4 a
			Number of Holes/Plant[a]			
Apollo	3.8 a	3.2 a	12.4 a	18.2 a	35.8 a	48.0 a
Excel	3.6 a	3.4 a	8.2 a	10.6 a	39.2 a	44.2 a
IMC205	3.6 a	2.0 b	12.2 a	7.8 a	56.4 a	31.6 a
46A65	4.6 a	1.8 a	16.2 a	8.6 a	43.0 a	40.2 a
Hyola	2.8 a	2.0 a	7.4 a	9.4 a	31.2 a	47.2 a
IMC204	1.8 a	2.4 a	10.4 a	7.0 a	34.0 a	34.4 a
			Number of Flea Beetles/Plant[a]			
Apollo	3.0 a	2.4 a	4.2 a	5.8 a	4.8 a	7.6 a
Excel	2.6 a	2.8 a	2.6 a	5.4 a	7.4 a	7.8 a
IMC205	2.2 a	1.6 a	6.8 a	1.8 b	18.8 a	6.4 b
46A65	1.2 a	2.2 a	5.0 a	3.8 a	9.6 a	12.6 a
Hyola	1.0 a	2.6 a	3.6 a	3.4 a	11.2 a	10.8 a
IMC204	1.0 a	1.6 a	4.2 a	3.4 a	6.4 a	4.4 a
			Mean Leaf Damage Rating[b]			
Apollo					2.2 a	2.3 a
Excel					2.8 a	2.1 a
IMC205					2.7 a	1.7 b
46A65					1.9 a	2.0 a
Hyola					1.6 a	2.3 a
IMC204					1.4 a	1.8 a

[a] Data were analyzed separately for each cultivar on each date. Means within a row for a sample date that are followed by the same letter are not significantly different ($P > 0.05$) by SNK.
[b] 0-3 Leaf Damage Rating Scale with 0 = no damage; 1 = slight feeding damage; 2 = moderate feeding damage; 3 = severe feeding damage.

Table 11. 2. Effect of leaf cutting on subsequent damage (leaf pitting, holes, damage rating) and number of western black flea beetles, *Phyllotreta pusilla*, on different canola cultivars. Second greenhouse trial, May 2002.

	27 May		28 May	
Cultivars	Cut	Uncut	Cut	Uncut
		Number of Pits/Plant[a]		
Apollo	5.6 a	2.4 a	10.2 a	7.4 a
Excel	8.4 a	7.4 a	8.6 a	8.8 a
IMC205	5.6 a	2.8 b	10.4 a	9.2 a
46A65	3.0 a	3.6 a	7.6 a	11.6 a
Hyola	5.0 a	9.4 a	7.6 a	13.2 a
IMC204	5.4 a	5.4 a	9.2 a	7.8 a
		Number of Holes/Plant[a]		
Apollo	9.4 a	4.2 b	33.0 a	23.0 a
Excel	40.2 a	38.8 a	46.0 a	53.4 a
IMC205	10.0 b	29.6 a	31.8 b	49.6 a
46A65	17.6 a	20.4 a	22.2 a	40.6 a
Hyola	46.4 a	33.2 a	60.0 a	65.0 a
IMC204	18.4 a	25.6 a	59.0 a	54.6 a
		Number of Flea Beetles/Plant[a]		
Apollo	4.8 a	3.6 a	7.8 a	4.4 a
Excel	12.8 a	14.8 a	6.4 a	12.3 a
IMC205	9.2 a	6.6 a	11.8 a	7.4 a
46A65	6.0 a	7.8 a	3.2 a	8.4 a
Hyola	17.4 a	19.2 a	11.6 b	19.0 a
IMC204	9.4 a	14.4 a	7.8 a	9.2 a
		Mean Leaf Damage Rating[b]		
Apollo			2.5 a	1.6 a
Excel			2.9 a	2.3 a
IMC205			2.2 a	2.6 a
46A65			1.1 a	1.7 a
Hyola			2.6 a	2.4 a
IMC204			2.0 a	2.3 a

[a] Data were analyzed separately for each cultivar on each date. Means within a row for a sample date that are followed by the same letter are not significantly different ($P > 0.05$) by SNK.
[b] 0-3 Leaf Damage Rating Scale with 0 = no damage; 1 = slight feeding damage; 2 = moderate feeding damage; 3 = severe feeding damage.

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CHAPTER XII

RELATIVE HOST PLANT PREFERENCE OF WESTERN BLACK FLEA BEETLE FOR SPRING CANOLA AND MUSTARD IN GREENHOUSE AND FIELD EVALUATIONS

INTRODUCTION

The western black flea beetle (WBFB), *Phyllotreta pusilla* Horn, is a key pest of cruciferous plants grown in the Rocky Mountain region of Colorado (Chittenden and Marsh 1920, Al-Doghairi 2000). It has a wide host range among cultivated *Brassica* crops including turnip, cabbage, cauliflower, broccoli, collards, kale, mustards, and canola. Radish (*Raphanus* spp.) is commonly damaged and various weed hosts are also important in biology of WBFB including tansy mustard, *Descurainia pinnata* (Walt.) Britt., and flixweed, *D. sophia* (L.) Webb ex Prantl. (Chittenden and Marsh 1920, Al-Doghairi 2000).

There has been interested in and some production of oilseed brassica crops in Colorado, particularly canola. However, an important limitation to production is insects, notably WBFB, false chinch bug, *Nysius raphanus* Howard, several *Lygus* spp., and cabbage aphid, *Brevicoryne brassicae* (L.).

WBFB is one of a complex of at least four *Phyllotreta* species affecting oilseed crucifers that also includes *P. cruciferae* (Goetze), *P. striolata* (F.) and *P. undulata* Kutsch. (Lamb 1989). Adult stages of *Phyllotreta* spp. are primarily damaging, causing feeding wounds in foliage, stems, and pods. The most important damage to the canola crop occurs within three weeks of germination (Turnock 1982, Lamb 1984, Bracken and Bucher 1986, Gavloski et al. 2000). Surviving seedlings grow slowly and more susceptible to effects of further attack. Seedling damage is ultimately important in contributing to yield reduction (Lamb 1984, Bracken and Bucher 1986).

Gavloski et al. (2000) reported that all currently registered varieties of canola (*Brassica napus*) and oilseed rape (*B. rapa*) are susceptible to attack by *Phyllotreta cruciferae*, although to varying degrees. Differences in cultivar susceptibility can be critical to stand and seedling establishment under WBFB feeding pressure common to Colorado. The purposes of this study were to evaluate several oilseed brassicas for relative WBFB susceptibility so that this information could be incorporated into cultivar selection and possible breeding.

MATERIALS AND METHODS

Greenhouse Host Plant Preference Trial 2000. Two trials were conducted under greenhouse conditions at Colorado State University, Ft. Collins, CO. For evaluation, plants were confined within screened cages, 61 cm high x 61 cm long x 37 cm wide, into which field collected approximately 100 WBFB adults were introduced. After introduction host plant preference was repeatedly evaluated by various means, described below.

In the course of these trials 11 different canola and mustard varieties were evaluated for relative WBFB preference. Seven spring canola (*Brassica napus*) cultivars were included: CO1, Helios, IMCO1, Westar, Sterling, Springfield, and Alto. Also one cultivar of winter canola (*Brassica napus* cv. Casino), one winter mustard (*Brassica juncea* cv. Debut), and two spring mustard cultivars (*Brassica juncea* cvs. ZEM 1, W1-23) were included.

The first trial was set up on 7 August using potted plants seeded 23 June and consisted of four replications (individual plants). This was repeated 9 August, using potted plants seeded 25 June, during which five replications were included. Into each cage a single potted plant of each variety was placed, arranged in random order. Subsequently 100 WBFB adults, collected by sweeping winter canola, were introduced.

Evaluations were made beginning at 24 hours. Two evaluations were made. The first was a visual count of all flea beetles on plants. At the end of the evaluation period damage rating evaluation was made using a 0-3 scale. In the scale: 0 indicated no damage observed on the plants; 1 indicated slight damage observed on the plants; 2 indicated moderate damage to plants; and 3 indicated the highest amount of damage. During these evaluations two persons made the assessments and data from both were averaged for analysis.

Field Host Plant Preference Trials 2001. Plots were established at the Horticulture Research Center by direct seeding on 26 April to 6.1 m double-row beds at 76.2 cm row spacing. In the first trial seven different spring canola (*Brassica napus*) varieties were included: Hyola, Excel, Apollo, Helios, Alto, Defender, and 46A65. The second trial repeated planting of five of these (Hyola, Excel, Apollo, Defender, and 46A65) in a separate area of the field. Plots consisted of two beds and both trials were arranged in randomized complete block design with 4 replications.

Two different evaluations were done in both plots. Flea beetle numbers on plants were measured by counting all beetles on five plants in the center of each plot. The second measurement was assessment of feeding damage using a 0-3 scale describing the percentage of leaf area damaged by flea beetles. In this scale 0 was applied to plots showing 10 percent or less leaf area damage; 1 for slight injury in the range of 11 to 30 percent leaf area injury; 2 for moderate injury of 31-60 percent leaf area injury; and 3 for severe leaf injury exceeding 60 percent. Evaluations were made simultaneously by two observers walking through the plot and estimating the leaf damage.

Field Host Plant Preference Trials 2002: Three different trials were established by direct seeding 3 April at the Horticulture Research Center. Individual plots were 6.09 m long double-row beds at 76.2 cm row spacing. Seven spring canola cultivars were used in the first trial (Apollo, Excel, Defender, Hyola, Helios, IMC205, and 46A65) and five of these were repeated in a second trial (Apollo, Excel, Defender, Hyola, and 46A65). The third trial compared to two spring canola cultivars, IMC204, and IMC205.

All of three trials were arranged as a randomized complete block design with four replications. Estimates of the number of flea beetles/plant and feeding damage assessments were made in a manner similar to that used the previous season. Data for all trials were analyzed using Student–Newman-Keuls (SNK) (SAS Institute 1990) setting significance at $P > 0.05$.

RESULTS AND DISCUSSION

Greenhouse Host Plant Preference Trials 2000. In the first three evaluations (1, 3, 4 DAT) no significant differences were observed in numbers of flea beetles on plants ($F=2.08$, $P=0.0591$; $F=1.20$, $P=0.3291$; $F=1.35$, $P=0.2513$, respectively) (Table 12. 1). On August 14 (7 DAT) greatest numbers of flea beetles were present on the spring mustard ZEM 1 ($F=2.88$, $P=0.0121$). WBFB feeding occurred on all cultivars, but there was a 2.7X range in the total number of beetles on plants when all counts were combined.

Interestingly the two spring mustards included the cultivars that supported the greatest number of WBFB (ZEM 1), and the lowest (W1-23) (*F=4.64*, *P=0.0001*). The winter mustard Debut had also the greater number of flea beetle comparing to spring canolas Helios, Springfield, Westar, and Alto (*F=4.64*, *P=0.0001*). Plant damage was generally correlated with number of adult beetles present on plants. Greatest injury occurred to ZEM 1, the winter mustard Debut, and the spring canola CO1 (*F=3.69*, *P=0.0026*). Least plant injury was observed on the spring canolas Helios, Sterling, and Alto and with the spring mustard W1-23 (*F=3.69*, *P=0.0026*).

Results were similar to the repeat trial (Table 12. 2). Lowest numbers of WBFB adults were present on Alto (*F=4.82*, *P=0.0001*). ZEM 1 (10.3X) and Debut (7.0X) again supported the greatest number of WBFB on plants and had the greatest associated plant injury compared with Alto (*F=4.82*, *P=0.0001*; *F=1.49*, *P=0.1928*, respectively). Palaniswamy et al. (1992) similarly found greater feeding injury by *Phyllotreta cruciferae* on *Brassica juncea* (L.) Czern. (mustards) compared to *Brassica campestris* L., *Brassica oleracea* L. (cabbage) and *Brassica napus* L. (canola). Chittenden and Marsh (1920) mentioned that the turnip (*Brassica rapa* L.) and mustard were about equally attractive to the beetles and unprotected beds are frequently destroyed. However, the relatively low preference and injury to the spring mustard W1-23 found in this study suggests that mustards are not uniformly susceptible to WBFB.

Field Host Plant Preference Trials 2001. Few differences were observed in the number of flea beetles/plant (Table 12. 3) among the seven spring canola cultivars. The cultivars 46A65 had significantly lower numbers of flea beetles, while Apollo had high numbers of beetles on the first plot but these differences were not repeated on the second plot

($F=3.72$, $P=0.0140$). No differences in amount of leaf injury were observed in the two trials ($F=2.30$, $P=0.0799$; $F=2.22$, $P=0.1283$, respectively).

Field Host Plant Preference Trials 2002. Again, few significant differences were observed in the number of WBFB found on the various spring canola cultivars (Table 12. 4). On the 28 May evaluation significantly higher WBFB numbers were observed on Hyola, and Excel ($F=4.35$, $P=0.0070$); this trend was consistent with Hyola on the second plot ($F=0.74$, $P=0.5807$). Lower numbers of flea beetles on Helios and Defender were also observed on one observation (28 May) in the first plot, but these were not repeated ($F=4.35$, $P=0.0070$). The highest number of flea beetle occurred the varieties of Hyola, while the lowest number of flea beetle occurred on varieties of Helios (7 June) in first plots ($F=0.60$, $P=0.7259$). The variety of Excel had the highest preference by flea beetle in (7 June) in second plots ($F=2.00$, $P=0.1591$). There was no significant WBFB preference between IMC204 and IMC205 in the third plot ($F=0.29$, $P=0.6286$).

Observed differences in leaf damage on 23 May indicated that the greatest damage occurred on Helios at seven cultivars ($F=8.23$, $P=0.0002$). Lowest leaf injury occurred on 46A65, Excel, and IMC205 ($F=8.23$, $P=0.0002$). Cultivars of Apollo, Defender, and Hyola also had greatest damage at second plot ($F=3.91$, $P=0.0294$). There was no significant different leaf damage injury of third plot ($F=2.00$, $P=0.2522$). All three of these cultivars were heavily infested by WBFB and the relatively lower leaf injury is suggestive of some host plant resistance, perhaps in the form of tolerance. Conversely, Helios sustained relatively high plant injury with WBFB plant populations that were low, suggesting in tolerance to WBFB injury.

Although all tested cultivars in these trials were susceptible to WBFB feeding injury there was a range. Gavloski et al. (2000) similarly noted some range among brassica cultivar to feeding by the flea beetle *P. cruciferae*. *Brassica napus* cv. Cresor had the lowest damage rating canola cultivars, although it was not significantly different from the control cultivars. *Brassica napus* cv. Zephyr showed variable resistance between seasons, being more resistant to feeding by flea beetle in the second year than in the first year of testing. *Brassica rapa* cv. Horizon was particularly susceptible to *P. cruciferae* among *B. rapa* cultivars. Furthermore, within tested *Brassica juncea* the cultivar Cutlass was more susceptible to *P. cruciferae* than was Demo.

Observations in this trial generally support those of Gavloski et al. (2000) that currently registered varieties of canola are susceptible to WBFB as well as to *P. cruciferae*. However, indications of lower susceptibility in W1-23 suggest a possible source of reduced susceptibility in oilseed mustards.

Table 12. 1. Western black flea beetle adult numbers and damage rating to young brassica plants exposed to western cabbage flea beetle, *Phyllotreta pusilla*, in cage trials, Trial One, 2000.

	Number of WBFB adults/plant [a]					
Cultivars	8-Aug	10-Aug	11-Aug	14-Aug	Avg. WBFB/ Plant[b]	Injury Scale[c]
ZEM 1	8.5 a	7.0 a	10.0 a	9.8 a	8.8 a	2.9 ab
Debut	10.3 a	8.8 a	10.5 a	5.3 ab	8.7 a	3.0 a
CO1	8.8 a	7.3 a	4.0 a	6.0 ab	6.5 ab	2.8 ab
Casino	4.5 a	8.0 a	6.8 a	5.5 ab	6.2 ab	2.0 ab
IMCO1	7.0 a	6.3 a	5.3 a	3.0 b	5.4 ab	2.1 ab
Sterling	5.3 a	5.5 a	6.3 a	4.3 ab	5.3 ab	1.9 b
Helios	7.0 a	4.5 a	6.0 a	3.0 b	5.1 b	1.9 b
Springfield	3.3 a	6.3 a	5.8 a	3.0 b	4.6 b	2.4 ab
Westar	5.3 a	3.8 a	4.3 a	2.3 b	3.9 b	2.4 ab
Alto	2.5 a	3.8 a	5.0 a	2.8 b	3.5 b	1.8 b
W1-23	5.5 a	3.8 a	2.3 a	1.5 b	3.3 b	1.8 b

[a] Means within a column that are followed by the same letter are not significantly different ($P > 0.05$) by SNK.

[b] Average over four dates- 8, 10, 11, 14 Aug.

[c] (0-3) scale of injury: 0 indicated no damage observed on the plants, 1 indicated slight damage observed on the plants, 2 indicated moderate damage to plants; 3 indicated the highest amount of observed damage.

Table 12. 2. Western black flea beetle adult numbers and damage rating to young brassica plants exposed to western cabbage flea beetle, *Phyllotreta pusilla*, in cage trials, Trial Two, 2000.

	Number of WBFB adults/plant [a]				
Cultivars	10-Aug	11-Aug	14-Aug	Avg. WBFB/ Plant[b]	Injury Scale[c]
ZEM 1	18.0 a	21.5 a	11.8 a	17.1 a	3.0 a
Debut	13.5 ab	16.0 a	5.3 a	11.6 b	3.0 a
CO1	8.5 ab	11.0 ab	6.0 a	8.5 bc	2.0 a
Helios	13.0 ab	5.8 ab	2.3 a	7.0 bc	2.0 a
Casino	7.3 ab	6.5 ab	7.0 a	6.9 bc	2.3 a
Sterling	7.0 ab	7.5 ab	5.5 a	6.7 bc	2.0 a
Springfield	6.0 ab	6.0 ab	2.8 a	4.9 bc	2.3 a
W1-23	7.0 ab	5.0 ab	2.5 a	4.8 bc	2.0 a
Westar	4.8 ab	3.8 ab	5.3 a	4.6 bc	2.0 a
IMCO1	2.5 b	3.8 ab	2.8 a	3.0 bc	2.1 a
Alto	2.0 b	1.5 b	1.5 a	1.7 c	1.3 a

[a] Means within a column that are followed by the same letter are not significantly different ($P>0.05$) by SNK.

[b] Average over three sampling dates - 10, 11, and 14 August.

[c] (0-3) Injury scale: 0 indicated no damage observed on the plants, 1 indicated slight damage observed on the plants, 2 indicated moderate damage to plants; 3 indicated the highest amount of observed damage. Evaluation made 14 August.

Table 12. 3. Numbers of western black flea beetles/plant and leaf damage to canola cultivars. Horticulture Research Center, Ft. Collins, CO. June 6, 2001 evaluation.

Cultivars	WBFB/5 plants	Leaf Damage Rating[b]
	Plot One[a]	
46A65	1.0 b	1.1 a
Apollo	6.5 a	1.9 a
Alto	2.0 ab	1.8 a
Defender	1.7 ab	1.9 a
Excel	4.8 ab	2.0 a
Helios	5.3 ab	1.5 a
Hyola	3.5 ab	1.8 a
	Plot Two[a]	
46A65	3.8 a	1.6 a
Apollo	2.3 a	2.0 a
Defender	4.8 a	2.0 a
Excel	3.8 a	1.9 a
Hyola	6.0 a	2.0 a

[a] Within each plot, means within a column that are followed by the same letter are not significantly different ($P > 0.05$) by SNK.

[b] (0-3) scale of feeding injury was used: 0 less than 10% leaf area showing injury; 1 - between 11 and 30% leaf injury; 2 - between 31 and 60% leaf injury; and 3 - greater than 60% of the leaf area damaged by flea beetle feeding.

Table 12. 4. Numbers of western black flea beetles/plant and leaf damage to canola cultivars. Horticulture Research Center, Ft. Collins, CO, 2002.

Cultivars	WBFB/5 Plants[a]				LeafDamage Rating[b]
	15 May	23 May	28 May	7 June	
			Plot One		
46A65	0.5 a	3.5 a	20.8 ab	46.3 a	1.3 c
Apollo	0.3 a	1.5 a	24.3 ab	40.3 a	1.4 bc
Defender	0.8 a	3.0 a	13.3 b	41.0 a	2.1 ab
Excel	0.5 a	3.0 a	35.3 a	51.3 a	1.0 c
Helios	0.5 a	1.0 a	10.0 b	38.8 a	2.7 a
Hyola	0.8 a	7.3 a	38.0 a	66.3 a	1.7 bc
IMC205	0.8 a	3.8 a	20.8 ab	54.0 a	0.9 c
			Plot Two		
46A65	1.8 a	9.5 a	44.0 a	90.5 a	1.0 b
Apollo	0.3 a	7.3 a	38.0 a	58.3 a	1.8 a
Defender	1.8 a	9.0 a	33.0 a	56.5 a	1.8 a
Excel	3.2 a	7.3 a	44.5 a	92.8 a	1.4 ab
Hyola	4.8 a	13.5 a	54.0 a	81.0 a	1.7 a
			Plot Three		
IMC204	2.3 a	6.0 a	49.3 a	64.8 a	1.4 a
IMC205	1.5 a	7.0 a	37.8 a	62.0 a	1.6 a

[a] Within each plot, means within a column that are followed by the same letter are not significantly different (P > 0.05) by SNK.

[b] Leaf damage assessed 23 May using a (0-3) scale of feeding injury. A rating of 0 indicated less than 10% leaf area showing injury; 1 - between 11 and 30% leaf injury; 2 - between 31 and 60% leaf injury; 3 - greater than 60% of the leaf area damaged by flea beetle feeding.

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CHAPTER XIII

COLONIZATION OF CABBAGE BY WESTERN BLACK FLEA BEETLE AS AFFECTED BY MULCHES AND TIME OF DAY

INTRODUCTION

The western black flea beetle (WBFB), *Phyllotreta pusilla* Horn (Chrysomelidae: Coleoptera), is one of the most important pests on cruciferous plants in Colorado (Al-Doghairi 2000) including radish (*Raphanus* spp.), turnip (*Brassica rapa* L.) and cabbage (*B. oleracea* L.) (Chittenden 1909, Chittenden and Marsh 1920). WBFB overwinters as adults under clods of earth, or under heaps of weeds, dead leaves, or other rubbish. There are apparently three generations annually in Colorado. Egg lying begins as early as mid-April and continues into early September (Chittenden and Marsh 1920). Important injury of cabbage is confined to young plants in seedbeds or to plants soon after they have been transplanted in the field (Chittenden and Marsh 1920, Al-Doghairi 2000).

The use of mulch is an important cultural method to conserve soil moisture, modify soil temperature (increasing or decreasing), control weeds, and has effects on different crop pests (Stoner 1997, Tarara 2000). The color of the mulch can have different effects. For example, black mulches increase soil temperature (Tarner 1974, Tarara 2000), whereas white and aluminized mulches increase reflectance of light (Tarara 2000). Increasing reflection of light sometimes repels pest species. For example, aluminum foil when used as mulch reflected up to 20.3 percent of the light, effectively repelling adult leafhoppers. Decreasing light reflection with black plastic, with only 5.3 percent light reflection, did not cause any repellent effects on the pest (Cardona et al. 1981).

The purposes of this study were to evaluate responses of WBFB to different colored mulches. Also, this study sought to determine if there were diurnal differences in the effect of mulches on WBFB colonization of plants.

MATERIALS AND METHODS

Trials were conducted over three years (1999, 2000, and 2002) at the Colorado State University Horticulture Research Center in Ft. Collins, CO. Plots were established using transplanted cabbage ('Green Boy') planted at 38 cm in row spacing. Transplant dates for the three years were 20 June 1999, 30 May 2000, and 27 June 2002. Individual plots consisted of 4 plants within a single row and plots were separated by 2 untreated plants. During 1999 and 2000 plants were located between cosmos. In 2002 trial was bordered on both sides by canola.

Mulch treatments consisted of placing a 30 cm (in-row) x 40 cm (across row) rectangle of different colored plastic or fabric around the base of the plant. Different color mulches were black landscape plastic mulch, white plastic mulch (spray painted with Rust-Oleum Gloss White 1992 (Rust-Oleum, Vernon Hills, IL), a woven aluminum mulch (Aluminet^{R}), orange plastic mulch (spray painted with Rust Oleum Fluorescent Orange, yellow plastic mulch (spray painted with Rust-Oleum Yellow 7443), and used bare soil as a control. Experimental design was randomized complete block with 4 replications and included 6 treatments.

Sampling was done by counting all flea beetles on the plants. Sampling was conducted daily at 3 different times, early (8 AM to 8: 30 AM), mid (12 AM to 1 PM) and late day (4 PM to 4:30), over 4 consecutive dates in 1999 and 2002 and three different times over 3 consecutive dates in 2000. Data were analyzed using Student-Newman-Keuls (SNK) (SAS Institute 1990).

RESULTS AND DISCUSSION

Effects of Mulch Color. In 1999, across all dates the greatest number of flea beetles was present on plants surrounded by aluminum mulch ($F=24.84$, $P=0.0001$) (Table 13. 1). In order, WBFB numbers on plants were: aluminum > orange > yellow, white > bare soil > black. There were some variations over time. For example, on the first sampling date (28 June) highest numbers were present on plants surrounded by orange-colored mulch at three different time evaluations ($F=1.79$, $P=0.1667$; $F=6.46$, $P=0.0013$; $F=21.50$, $P=0.0001$, respectively). All treatments, except for black mulches, showed significantly higher WBFB in late day counts (4 PM) compared to early morning counts in 1999 ($F=34.86$, $P=0.0001$) (Table 13. 1).

In 2000, the plots were surrounded by aluminum mulch again supported the highest WBFB numbers with black the lowest ($F=28.15$, $P=0.0001$) (Table 13. 2). There were no significant differences among rest of the treatments during this evaluation period. In order, WBFB numbers were: aluminum > orange, yellow, white, bare soil > black mulch.

Although aluminum mulches are most commonly documented to repel insects (Adlerz and Everett 1968, Cardona et al. 1981) they have been found attractive to some. For example, squash grown in aluminum mulch was slightly more attractive to squash bug, *Anasa tristis* (DeGeer), (Heteroptera: Coreidae) compared with squash plants grown with other mulches (Cartwright et al. 1990). However, two other chrysomelids, the banded cucumber beetle, *Diabrotica balteata* LeConte, and the spotted cucumber beetle, *D. undecimpunctata howardi* Barber, were the lowest on the aluminum and aluminized plastic mulches. The highest population of *Diabrotica* spp. was observed on black mulches in cucumber and squash plants (Schalk et al. 1979). In addition, adults of the chrysomelid, *Leptinotarsa decemlineata* (Say), the Colorado potato beetle, had the highest populations on plants grown over black plastic mulches (Stoner 1997).

Several significant differences occurred during 2002 trial (Table 13.3) and some also were different from previous seasons. In order flea beetle numbers on plants over different colored mulches were: orange, white > yellow, bare soil > aluminum and black ($F=15.21$, $P=0.0001$). Unlike previous years, aluminum mulch treatment in this season resulted in much lower numbers relative to other treatments.

This may have been due to weather. Most notably temperatures were much higher during 2002 (Table 13. 5). Highest average temperature (79.3 °F) and lowest average wind speeds (4.1 mph) were observed in 2002. The lowest average temperature (69.5 °F) and highest wind speeds (6.3 mph) were recorded in 1999. The higher temperatures and higher light intensity may have modified effects of the reflective aluminum mulch on WBFB behavior.

Conversely numbers of flea beetles on plants surround by white mulch were much higher than previous years. Plants surrounded by orange and yellow continued to support high numbers, about twice that of the bare soil control. No treatments resulted in significant differences in the early, mid and late day counting in 2002 ($F=0.27$, $P=0.7648$) (Table 13. 3).

Different insect species can have different response to colored mulches. In this study plants grown among aluminum mulches had the highest WBFB populations 1999 and in 2000 but not in 2002. Black mulches had the lowest number of flea beetles in all sampling years in these trials (*F=24.84*, *P=0.0001*; *F=28.15*, *P=0.0001*; *F=15.21*, *P=0.0001*, respectively) (Tables 13. 1, 13. 2, 13. 3). No treatments resulted in significant difference between early, mid and late day counts in 2000 (*F=1.82*, *P=0.1641*) (Table 13. 2).

Effects of Time of Day. Time of day significantly affected WBFB populations over different mulches in 1999 (*F=34.86*, *P=0.0001*) (Table 13. 1). The highest populations of WBFB were observed in late day counting, except over black mulch. However, there were no significant differences among treatments in 2000 and 2002 (*F=1.82*, *P=0.1641*; *F=0.27*, *P=0.7648*, respectively) (Tables 13. 2, 13. 3).

The number of WBFB on all mulches increased gradually during the course of the day in 1999 (*F=24.84*, *P=0.0001*) (Table 13. 4). The highest numbers of WBFB on plants were present in late day counts, whereas the lowest number of WBFB observed during early day (*F=34.86*, *P=0.0001*). However, the numbers of WBFB were not changed in the days in 2000 and 2002 (*F=1.82*, *P=0.1641*; *F=0.27*, *P=0.7648*, respectively) (Table 13. 4). Higher (about 2X-3X higher) numbers of WBFB were observed on all treatments in 2002 compared with the previous years (Table 13. 4).

Chittenden and Marsh (1920) reported WBFB as active in greatest number during the middle of day compared to the earlier or later in the day, when they usually stayed lower level of plant leaves or around the crown or on the ground (Chittenden and Marsh

1920). Such a relationship was only observed on one (1999) of the three years of this study.

Table 13. 1. Western black flea beetles, *Phyllotreta pusilla*, on cabbage plants grown over mulches of various color. Colorado State University Horticulture Field Research Center, Ft. Collins, CO 1999.

	Number of flea beetle/ 4 plants [a]								
	June 28			June 29			June 30		
Mulch	8 AM	1 PM	4 PM	8 AM	1 PM	4 PM	8 AM	1 PM	4 PM
Aluminum	8.8 ab	10.5 bc	16.0 a	11.0 a	24.8 a	26.0 a	16.8 a	22.0 a	27.8 a
Orange	12.5 a	23.5 a	18.3 a	12.3 a	14.5 b	18.0 ab	12.3 ab	20.8 a	23.3 a
Yellow	10.0 ab	17.3 ab	12.0 b	9.5 ab	14.0 b	16.0 ab	13.0 ab	14.5 ab	25.3 a
White	5.5 b	7.5 c	10.3 bc	6.5 bc	12.0 b	15.5 b	13.3 ab	17.8 ab	22.5 a
Black	6.0 b	7.3 c	6.0 d	6.0 c	7.0 b	4.8 c	4.8 c	8.3 b	7.8 b
Bare soil	7.0 ab	8.0 c	8.0 cd	4.5 c	10.8 b	11.8 bc	9.3 bc	16.0 ab	17.8 ab

	July 1			June 28-July 1	June 28-July 1 [b]		
	8 AM	1 PM	4 PM	All times	8 AM	1 PM	4 PM
Aluminum	15.5 a	22.3 a	37.8 a	19.9 a	12.4 c	19.9 b	26.9 a
Orange	12.3 a	12.3 bc	25.8 ab	17.1 b	12.3 b	17.8 a	21.3 a
Yellow	13.0 a	8.8 c	18.3 bc	14.3 c	11.4 b	13.6 b	17.9 a
White	13.3 a	14.8 b	22.5 bc	13.4 cd	9.6 b	15.5 a	18.1 a
Black	4.8 b	3.0 d	10.8 c	6.4 e	5.6 a	8.6 a	7.6 a
Bare soil	9.0 ab	8.8 c	24.0 b	11.2 d	6.9 c	12.1 b	16.4 a

[a] Numbers within a column that are not followed by the same letter are significantly different (P > 0.05) by SNK.
[b] Numbers within a row that are not followed by the same letter are significantly different (P> 0.05) by SNK.

Table 13. 2. Western black flea beetles, *Phyllotreta pusilla*, on cabbage plants grown over mulches of various color. Colorado State University Horticulture Field Research Center, Ft. Collins, CO 2000.

Number of flea beetle/ 4 plants [a]

Mulch	June 6 8 AM	June 6 1 PM	June 6 4 PM	June 7 8 AM	June 7 1 PM	June 7 4 PM
Aluminum	5.5 a	10.3 a	11.3 a	11.0 a	12.3 a	13.5 a
Orange	4.5 ab	5.0 b	4.3 b	5.3 b	6.8 b	7.5 bc
Yellow	4.5 ab	3.3 b	3.3 b	5.8 b	7.0 b	8.3 b
White	5.8 a	5.8 b	5.0 b	4.5 bc	4.0 c	5.0 d
Black	1.5 b	1.8 b	1.8 b	2.5 c	3.0 c	4.3 d
Bare soil	3.8 ab	5.3 b	5.8 b	5.0 bc	5.3 bc	5.8 cd

Mulch	July 8 8 AM	July 8 1 PM	July 8 4 PM	June 6-8 All times	June 6-8 [b] 8 AM	June 6-8 [b] 1 PM	June 6-8 [b] 4 PM
Aluminum	7.8 a	8.5 a	10.0 a	10.0 a	5.3 a	8.0 a	8.9 a
Orange	6.0 ab	6.3 ab	5.8 ab	5.7 b	5.3 a	5.6 a	5.0 a
Yellow	4.5 ab	4.8 ab	4.0 b	5.0 b	4.5 a	4.0 a	3.6 a
White	6.8 ab	3.8 b	6.0 ab	5.2 b	6.3 a	4.8 a	5.9 a
Black	2.5 b	3.5 b	3.0 b	2.6 c	2.5 a	2.6 a	2.4 a
Bare soil	7.5 a	5.8 ab	5.8 ab	5.5 b	5.6 a	5.5 a	5.8 a

[a] Numbers within a column that are not followed by the same letter are significantly different ($P > 0.05$) by SNK.
[b] Numbers within a row that are not followed by the same letter are significantly different ($P>0.05$) by SNK.

Table 13. 3. Western black flea beetles, *Phyllotreta pusilla*, on cabbage plants grown over mulches of various color. Colorado State University Horticulture Field Research Center, Ft. Collins, CO 2002.

Number of flea beetle/ 4 plants [a]

	June 28			July 1			July 3		
Mulch	8 AM	1 PM	4 PM	8 AM	1 PM	4 PM	8 AM	1 PM	4 PM
Aluminum	19.0 a	22.0 a	23.0 a	10.5 c	12.5 b	13.0 c	12.3 b	18.8 bc	13.0 bc
Orange	30.3 a	13.8 a	30.8 a	35.8 a	27.8 a	30.5 a	26.0 a	37.0 a	20.3 ab
Yellow	33.5 a	20.0 a	38.3 a	27.5 ab	18.3 ab	26.3 ab	22.8 ab	32.5 ab	17.5 abc
White	32.5 a	18.8 a	33.0 a	35.5 a	18.8 ab	23.5 abc	28.0 a	27.3 ab	26.5 a
Black	17.0 a	14.3 a	20.0 a	12.0 c	8.3 b	13.5 bc	12.0 b	9.5 c	10.3 c
Bare soil	19.5 a	16.0 a	27.3 a	15.0 bc	18.8 ab	19.5 abc	14.5 b	28.8 ab	13.5 abc

	July 9			June 28-July 9	June 6-8 [b]		
	8 AM	1 PM	4 PM	All times	8 AM	1 PM	4 PM
Aluminum	13.5 a	18.0 c	15.3 a	15.9 c	13.8 a	17.8 a	16.1 a
Orange	13.0 a	29.5 ab	18.0 a	26.0 a	26.3 a	27.0 a	24.9 a
Yellow	17.3 a	22.3 abc	26.5 a	25.2 ab	25.3 a	23.3 a	27.1 a
White	15.5 a	32.3 a	25.3 a	26.4 a	27.9 a	24.3 a	27.1 a
Black	13.0 a	15.3 c	5.0 a	13.3 c	13.5 a	11.8 a	14.7 a
Bare soil	18.3 a	20.8 abc	20.8 a	19.4 b	16.8 a	21.1 a	20.3 a

[a] Numbers within a column that are not followed by the same letter are significantly different (P>0.05) by SNK.
[b] Numbers within a row that are not followed by the same letter are significantly different (P>0.05) by SNK.

Table 13. 4. Effect of time of day [a] on western black flea beetle, *Phyllotreta pusilla*, populations on cabbage. Colorado State University Horticulture Field Research Center, Ft. Collins, CO, 1999-2002.

	28 June-1 July, 1999	6-8 June, 2000	28 June-9 July, 2002
Early day (8 AM)	9.9 c	5.3 a	20.6 a
Mid day (1 PM)	13.6 b	5.7 a	20.9 a
Late day (4 PM)	17.7 a	6.1 a	21.7 a

[a] Numbers within a column that are not followed by the same letter are significantly different ($P > 0.05$) by SNK.

Table 13. 5. Daily mean of temperature and wind speed of sampling days in 1999, 2000, and 2002. Data from COAGMET from Fort Collins Weather Station.

Date	Mean Temp. (^{0}F)	Wind (mph)	Date	Mean Temp. (^{0}F)	Wind (mph)	Date	Mean Temp. (^{0}F)	Wind (mph)
June 28	67.2	7.4	June 6	73.6	4.3	June 28	78.6	4.6
June 29	71.3	7.3	June 7	79.0	3.7	July 1	83.3	2.9
June 30	70.4	5.5	June 8	76.6	4.6	July 3	75.2	4.7
July 1	69.0	5.1	----	----	-----	July 9	79.9	4.2
	69.5	6.3		76.4	4.2		79.3	4.1

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CHAPTER XIV

INSECTICIDE AND REPELLENT TRIALS INVOLVING WESTERN BLACK FLEA BEETLE

INTRODUCTION

Flea beetles of the genus *Phyllotreta* spp. (Coleoptera: Chrysomelidae) are important pests of brassica crops in North America (Chittenden and Marsh 1920, Newton 1928). One of these, the western black flea beetle (WBFB), *Phyllotreta pusilla* Horn, is particularly damaging in Colorado (Al-Doghairi 2000) and insecticides are routinely applied for its management. Synthetic insecticides are typically used but there is considerable interest in alternative products that are acceptable for Certified Organic production and/or available for using in home gardens. Microbial and plant derived biopesticides are often of particular interest as such alternatives.

Microbial pesticides can involve viruses, bacteria, protozoa or fungi (Copping and Menn 2000) and may include the whole organism or derivatives. One of the latter is spinosad, produced by an actinomycete bacterium, *Saccharopolyspora spinosa* Mertz & Yao., (Bret et al. 1997, Thompson and Hutchins 1999, Copping and Menn 2000, Thompson et al. 2000). Spinosad consists of a mixture of the two most biologically active compounds (spinosyns) secreted by *S. spinosa*, spinosyn A and spinosyn D (Bret et al. 1997, Thompson and Hutchins 1999, Sparks et al. 2001).

Spinosad provides effective control of pests in the insect orders Lepidoptera, Diptera (Thompson et al. 1997, Thompson et al. 2000, Sparks et al. 2001) and Thysanoptera (Copping and Menn 2000, Thompson et al. 2000). It is also effective against some Coleoptera (elm leaf beetle, willow leaf beetle, and Colorado potato beetle) (Bret et al. 1997) and Orthoptera (migratory grasshopper) (Demirel 1998) that consume large amounts of foliage (Thompson et al. 2000). In addition, spinosad has relatively low activity against predaceous beetles, lacewings, most sucking insects and mites (Thompson et al. 2000).

Among the most common plant derived or botanical insecticides are azadirachtin, pyrethrins, rotenone and ryania extracts (Copping and Menn 2000). Of these, the most recent attention has been given to azadirachtin as a promising botanical pesticide for use in integrated pest management with activity against members of at least nine insect orders and some mites (Schmutterer 1995). Azadirachtin is obtained from seed extracts of the neem tree, *Azadirachta indica* A. Juss, a plant widely grown throughout tropical and subtropical Asia, Africa, Australia, and Central and South America (Ermel 1995, Schmutterer 1995). Azadirachtin is a very complex tetranortriterpenoid (Ascher 1993, Schmutterer 1995). It acts as a repellent, antifeedant (Saxena 1995, Copping and Menn 2000), oviposition deterrent, growth-retardant, molt-inhibitor, and sterilant (Schmutterer 1988, Schmutterer 1995, Schmutterer and Wilps 1995, Immaraju 1998).

Schmutterer and Singh (1995) reported activity of azadirachtin against three *Phyllotreta* spp. (*P. cruciferae* Goeze, *P. downsei* (F.), *P. striolata* (F.)). Al-Doghairi (2000) conducted some evaluations of neem-derived pesticides against WBFB and additionally looked a horticultural oils and hot pepper wax. The purposes of the following studies were to extend these evaluations of microbial biopesticides, plant-derived repellents, and synthetic insecticides on WBFB.

MATERIALS AND METHODS

Greenhouse Trial on Canola, 1999. Trials were conducted in greenhouse at the Colorado State University in Ft.Collins, CO. Two different spring canola (*Brassica napus*) varieties (Helios, CO1) were used. These were planted 11 June into individual pots (6.35 cm square). Five treatments of various potential repellents and insecticides were included in the trial: Conserve SC (spinosad), BioNeem (neem-derived insecticide/repellent), SunSpray (horticultural oil), Hot Pepper Wax Spray, and an untreated check.

Insecticides were applied 1 July as a point of run-of spray and plants were moved to cages 2 hours after spraying, allowing time to dry. The cages sizes were 61 cm high x 61 cm long x 37 cm wide. The treated plants were placed in the cage in randomized complete block design with six replications. Trials were simultaneously conducted on both varieties, in separate cages. One hundred WBFB adults were released into each of the cages. Evaluations were done every 24-hour (2-4 July), counting number of WBFB feeding holes on leaves. Data were analyzed using Least Significant Difference (LSD) (SAS Institute 1990).

Field Trial on Cabbage, 1999. Trials were conducted at the Colorado State University Horticulture Research Center in Ft. Collins, CO. Plots were established on 20 June using cabbage transplants (cv. Green Boy). The plots consisted of single rows and each plot contained six cabbage plants. The trials were conducted as randomized completed design with four replications. The five treatments were identical to the above trial. Applications were made to point of run-off on 2 July and 7 July. Evaluations were done by counting the number of flea beetle adults on the middle four plants. Data were analyzed using Least Significant Difference (LSD) (SAS Institute 1990).

Permethrin Application Timing/Frequency Field Trial, 1999. Trials were conducted at the Colorado State University Horticulture Research Center on 'Green Boy' cabbage transplanted 20 June. Each plot consisted of a single row of seven cabbage plants, arranged in randomized complete block design with four replications. Treatments consisted of applications of a commonly available garden formulation of permethrin (Bug Stop Concentrate) at 1 fl oz/gal concentration applied to point of run-off at various intervals.

The six different timing treatments included in the trial were: weekly treatment beginning June 23, weekly treatment beginning June 30, weekly treatment beginning July 7, treatment on June 23 and June 30 with no subsequent treatment, treatment on June 30 and July 7 with no subsequent treatment, and no treatment. Evaluations were made by counting all the flea beetles on five plants from the center of each plot and data were analyzed similarly to the above trials. Data were analyzed using Least Significant Difference (LSD) (SAS Institute 1990).

RESULTS AND DISCUSSION

Greenhouse Trial on Canola, 1999. Spinosad (Conserve SC) caused significant reduction in WBFB injury to both canola cultivars (Table 14. 1). At all evaluation date, Spinosad, and Hot Pepper Wax Spray caused significant reduction of WBFB feeding ($F=2.00$, $P=0.1333$; $F=3.88$, $P=0.0172$; $F=10.81$, $P=0.0001$, respectively). In addition, at the 2-day evaluation there was feeding reduction on cv. Helios following two other treatments: SunSpray, and BioNeem (*F=3.88*, *P=0.0172*; *F=10.81*, *P=0.0001*, respectively). However, none of the latter treatments produced significant reduction in WBFB damage on the cultivar CO1 (*F=1.31*, *P=0.2990*; *F=2.65*, *P=0.0638*; *F=4.16*, *P=0.0130*, respectively). Leaf structures are different on the two varieties that may have affected distribution of the applied repellent solutions. CO1 has a hairy leaf, while Helios has a much smoother leaf surface.

Field Trial on Cabbage, 1999. In field trials, spinosad (Conserve SC) reduced WBFB numbers on plants at both evaluation dates (*F=6.18*, *P=0.0062*; *F=12.46*, *P=0.0003*, respectively) (Table 14. 2). The repellent treatment BioNeem produced significant WBFB reductions only when compared to the Hot Pepper Wax treatment on 7-July (*F=6.18*, *P=0.0062*). None of the other repellent treatments evaluated (horticultural oil, hot pepper wax) ever produced significant reduction in flea beetle numbers and BioNeem also did not show any reduction at the second evaluation date (*F=12.46*, *P=0.0003*). These data do indicate the potential use of spinosad for WBFB and recently (2003) a spinosad formulation (Entrust) has been allowed for use on Certified Organic production. McLeod et al (2002) reported spinosad activity against another flea beetle, *Epitrix fuscula* Crotch, providing greater than 90 percent mortality at six days and indicated that it offers a viable alternative to carbamate and pyrethroid insecticides. This conclusion is supported by these WBFB data.

However, efficacy of horticultural oil, neem, and hot pepper wax was marginal in these studies. Activity of neem against three *Phyllotreta* species was reported by Schmutterer and Singh (1995), and against WBFB specifically by Al-Doghairi (2000), using the formulations Margosan-O and Azatin. Palaniswamy and Wise (1994) conducted trials to determine their repellent and feeding deterrent effects of three-neem formulation on *P. cruciferae* on canola in laboratory and field studies. At concentrations ranging from 0.05 to 12 percent concentrate, Safer's Neem Insecticide (SNI) was more effective than RD-9 Repelin or Margosan-O in decreasing plants damage through higher beetle mortality and repellency.

At the highest two concentrations of SNI, no damage to seedlings was observed after 2 day because of high beetle mortality (Palaniswamy and Wise 1994). In addition, RD-9 Repelin showed repellency for one or two days at 12 percent concentration and for 6 hours at 1.2 and 6 percent levels. However, the repellency of Margosan-O was limited to 6 hours at the 6 percent concentration. Overall, given the poor performance in this study, neem insecticides do not appear to have acceptable efficacy against *Phyllotreta* flea beetles of crucifers where infestations are heavy and migration into the crop is continual.

SunSpray (horticultural oil) also showed only minimal effectiveness in this trial, only reducing feeding injury on one of the cultivars in the greenhouse trial. Some activity had been demonstrated earlier by Al-Doghairi (2000). Similarly, WBFB response to hot pepper wax treatment was minimal, although this was the most effective repellent insecticide for reducing leaf area consumption by migratory grasshopper in field trials (Demirel 1998).

Permethrin Application Timing/Frequency Field Trial, 1999. In evaluations of permethrin, cabbage plants that had received two applications (23, 30 June) showed significant per plant WBFB reductions, but those receiving a single treatment (30 June) did not ($F=47.32$, $P=0.0001$; $F=3.32$, $P=0.0241$, respectively) (Table 14. 3). None of the plots treated with permethrin 7 July showed significant reduction on the 13 July. Previous studies indicated that endosulfan (Thiodan) and esfenvalerate (Asana) were considerably more effective at controlling WBFB than imidacloprid (Provado), carbaryl (Sevin), fipronil (Agenda), lambdacyhalothrin (Warrior), cypermethrin (Mustang and Ammo), permethrin (Ambush), and methomyl (Lannate) (Al-Doghairi 2000).

On the other hand, Weiss et al. (1991) mentioned that the carbaryl was the most effective insecticide, for control of *Phyllotreta cruciferae* on canola, followed by permethrin, endosulfan, esfenvalerate, and malathion. In addition, carbaryl was also the most persistent of the insecticides with 95 percent mortality obtained 1.82 d after application. Permethrin, esfenvalerate, and endosulfan produced 95 percent mortalities at 1.67, 1.25 and 1.13 d after application. Permethrin is now the most commonly available garden insecticide in Colorado (Whitney Cranshaw, personal communications). Although it does show some WBFB activity the need for repeated applications at fairly short intervals to control WBFB is indicated by these studies.

Table 14. 1. Western black flea beetle, *Phyllotreta pusilla*, injury to seedlings of two spring canola varieties treated with different insecticides and repellents, greenhouse trial, 1999.

	No. Holes/Plant, cv. Helios[a]			No. Holes/plant, cv. CO1[a]		
Treatment and Rate	2-Jul	3-Jul	4-Jul	2-Jul	3-Jul	4-Jul
Conserve SC 10 fl oz/100 gal	1.8 b	3.2 b	6.7 b	1.8 b	6.5 b	15.3 b
SunSpray 2% conc.	5.8 ab	7.8 b	16.3 b	24.0 ab	41.2 ab	64.8 a
BioNeem 1:150 v.v	5.3 ab	7.3 b	11.8 b	38.3 a	60.0 a	95.3 a
Hot Pepper Wax Spray 10% conc.	1.8 b	5.2 b	11.7 b	21.3 ab	35.2 ab	55.2 ab
Untreated Check	10.7 a	20.2 a	36.8 a	25.3 ab	54.2 a	81.7 a

[a] Means within a column that are followed by the same letter are not significantly different (P>0.05) by LSD.

Table 14. 2. Western black flea beetle, *Phyllotreta pusilla,* numbers on cabbage transplants treated [a] with different insecticides and repellents, field trial, 1999.

	Number of WBFB/plant [b]	
Treatment and Rate	7 July	12 July
Conserve SC 10 fl oz/100 gal	4.5 c	1.5 b
SunSpray 2% conc.	21.0 ab	9.3 a
BioNeem 1:150 v.v	12.3 bc	10.8 a
Hot Pepper Wax Spray 10% conc.	24.8 a	11.8 a
Untreated Check	17.3 ab	12.0 a

[a] Treatment dates were 2 July and 7 July.

[b] Means within a column that are followed by the same letter are not significantly different (P>0.05) by LSD.

Table 14. 3. Western black flea beetle, *Phyllotreta pusilla,* numbers on cabbage transplants treated with permethrin at different intervals, field trial, 1999.

	Number of WBFB/plant [a]	
Date of Permethrin Application	July 6	July 13
June 23, June 30, July 7	1.4 b	6.4 c
June 23, June 30	0.4 b	9.2 bc
June 30, July 7	21.8 a	9.8 abc
June 30, July 7	18.6 a	14.0 a
July 7	15.6 a	9.0 bc
Untreated Check	24.0 a	11.8 ab

[a] Means within a column that are followed by the same letter are not significantly different (P>0.05) by LSD.

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SEASONAL SURVEY OF CANOLA INSECT POPULATIONS IN NON-CROP AREAS

CHAPTER XV

SURVEY OF THREE CANOLA PESTS ON CULTIVATED AND NON-CULTIVATED PLANTS THROUGHOUT THE GROWING SEASON

INTRODUCTION

The three most damaging insect pests of oilseed brassica crops in Colorado are false chinch bug (FCB), *Nysius raphanus* (Howard) (Hemiptera: Lygaeidae), western black flea beetle (WBFB), *Phyllotreta pusilla* Horn (Coleoptera: Chrysomelidae) and plant bugs of the genus *Lygus* (LB) (Hemiptera: Miridae).

The false chinch bug (FCB) is the most serious pest among North America species of *Nysius* (Ashlock 1977, Sweet 2000). FCB has a broad host range (Knowlton 1934, Knowlton and Wood 1943, Barnes 1970, Tappan 1970, Sweet 2000, Capinera 2002). Plant damage usually results when masses congregate upon plants causing wilting (Milliken 1918, Knowlton 1934, Smith 1942, Knowlton and Wood 1943, Leigh 1961, Byers 1973, Young and Teetes 1977).

The western black flea (WBFB) genus *Phyllotreta* contains several important agricultural pest species that mainly attack cruciferous host plants (Chittenden 1909, Chittenden and Marsh 1920, Newton 1928). The WBFB is also a key pest of cruciferous plants grown in Colorado (Chittenden and Marsh 1920, Al-Doghairi 2000). WBFB damage to plants is almost entirely due to adult feeding, larval feeding on roots is considered negligible (Chittenden and Marsh 1920, Al-Doghairi 2000). WBFB has a wide host range (Chapter 10, Table 10. 1) (Chittenden 1909, Chittenden and Marsh 1920, Al-Doghairi 2000).

The genus *Lygus* Hahn (Hemiptera: Miridae) contains plant bugs generally referred to as lygus bugs and includes several economically important species in the United States (Schuh and Slater 1995, Wheeler 2000, Wheeler 2001). All species of *Lygus* are generalist plant feeders; they will also attack smaller and less active insects for food (Kelton 1975). Most common in Colorado are the pale legume bug, *Lygus elisus* Van Duzee, tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), and western tarnished plant bug, *Lygus hesperus* Knight (Kelton 1975).

All of these common pests of oilseed brassicas are highly mobile and annually migrate to crop areas. However, there is little information on the biology of these species in Colorado outside croplands. Such non-crop areas can be critical to population development of all three insect groups, prior to migration into canola. Furthermore, practices affecting non-cropland areas, such as cutting, can greatly influence timing and intensity of migrations. For example, alfalfa is well documented as an important breeding source of *Lygus* (Sevacherian and Stern 1974, 1975). Furthermore, manipulations of alfalfa through strip harvest have also been shown to prevent migration of *Lygus* to adjacent crops (Stern et al. 1964, Stewart and Layton 2000). Therefore, a study of populations of key canola pests outside of canola was thought useful in understanding factors contributing to damaging outbreaks.

For these surveys, sampling was done by sweep net. The sweep net is very widely used for collecting different insect species on different types of vegetation. Deficiencies and biases of sweep net sampling have been reviewed by Southwood (1978) and others. However, sweep net sampling has strong advantages of ease of use, ability to sample different vegetaton, and relatively low cost. It can be particularly useful when comparing relative numbers of insects over time. A three-year survey was conducted for this study.

MATERIALS AND METHODS

Annual surveys were conducted in 2000, 2001, and 2002. Sampling began in spring with active growth of winter annuals and herbaceous perennials (e.g., alfalfa) - 18-April to 2-August in 2000, 18-April to 14-August in 2001 and 18 April to 13 August in 2002. All sampling took place in Larimer County and western Weld County (Tables 15. 1, 15. 2, 15. 3). In 2000, the samples were collected from 12 sites with a combination of vegetation including alfalfa fields, weedy sites dominated by flixweed (*Descurainia* spp.), and mixed grasses and weeds along a roadside. At flixweed sites, all were predominantly the introduced European species, *D. sophia* (L.) except at a roadside waste area site adjacent to a feedlot, which was predominantly the native *D. pinnata* (Walt.) (tansy mustard). Relative amounts of flixweed in alfalfa were categorized as "some" and "little". Alfalfa fields where flixweed was common throughout the field were described as having "some flixweed". Fields where flixweed was present but uncommon were described as having "little flixweed". Ten sites were sampled in 2001, the majority from areas included in the previous year survey. In the final survey year of 2002, thirteen sites, all samplings took place in alfalfa fields, most of which supported substantial weed populations including flixweed.

All samples were done using a 15-in diameter sweep-net, taking 20 (back-forth) sweep samples per site. Sampling took place between 10 AM to 4 PM to allow warming so that insects may move onto the surface of plants Southwood (1978). All samples were done the same person, usually a straight line transect across the sample site. Samples were immediately placed into plastic bags and returned to the lab for evaluation. Counts of FCB and *Lygus* spp. included nymphs and adults. Adults only of WBFB were counted, as larval stages occur in soil.

RESULTS AND DISCUSSION

False chinch bug. High numbers of FCB were collected on the first, 18-April sampling date in 2000 (Table 15. 4), but were not caught until the 25-April and 8-May sampling (Tables 15. 5, 15. 6) in the subsequent two years. This suggests that movement from overwintering sites and active feeding on hosts may begin over a nearly month-long period in midspring, depending on season.

Large numbers of nymphs, as well as adults, were captured during these surveys. This indicates that the sampled sites (e.g, alfalfa, flixweed) reflect areas of early season FCB population development.

Substantial differences in numbers of false chinch bugs were collected during the three years. Much higher populations were present in 2000 than in the following two seasons (Table 15. 4, 15. 5, 15. 6). Total numbers of FCB caught during 2000 in sweep net samples were 162X and 42X higher in than in 2001 and 2002, respectively. In part, higher FCB captures during 2000 may be related to the excellent growing conditions for winter annual mustards, notably flixweed. Also, more sites where this weed was present were sampled during 2000.

Peak FCB numbers occurred over a two-week range - 23-May, 6-Jun, 27-May in 2000-2002, respectively (Fig. 15. 1, 15. 2, 15. 3). Dramatic declines in FCB captures occurred shortly following peak capture in 2001 and 2002, but was more gradual in 2000. This decrease can largely be attributable to first cutting of alfalfa. The first cutting of alfalfa occurred 23 May 2000 at Ardec C; the remaining alfalfa fields were first cut in June (H257 A, June 7; HortFarm, June 14; Severence B, June 14; I25, June 14; W. Cargill, June 14; CR15 C, June 21). The first cutting of alfalfa occurred between the first week and third week of June in 2001. The first alfalfa cutting occurred the second week of June 2002.

Alfalfa cutting apparently induces migration from fields earlier than would occur in its absence. For example, in 2000 high FCB populations were sustained through late June in the predominantly flixweed sites of ARDEC A, ARDEC B, CR15 B and Severance A (Table 15. 4). Subsequent reductions in FCB numbers in early July reflect drying of these weeds.

Although alfalfa fields do appear to serve as a major source of FCB early in the season, this does appear due largely to winter annual mustards associated with the crop. During the high FCB population year of 2000, alfalfa fields with little flixweed (ARDEC C, HortFarm) produced far fewer FCB in weekly captures than did alfalfa fields where this weed was more abundant. Also FCB numbers captured in alfalfa fields declined sharply after late June, when flixweed had largely matured and was no longer a suitable host.

Leigh (1961) similarly reported that FCB populations built up on several spring mustards (*Sisymbrium irio* L., *Capsella bursa-pastoris* (L.) Medik., *Lepidium nitidium* Nutt.) prior to migration into cotton fields. The importance of *S. irio* was also noted by Barnes (1970) as the major source of FCB prior to migration into vineyards. In northern Colorado *Descurainia sophia* and, to lesser extent, *D. pinnata* appear to be very important in early season populations of *N. raphanus*.

However, there are some weekly changes in FCB capture that are more difficult to explain. For example, between May-18 and May-27 captures at ARDEC and HortFarm went from 0 to very high number in one week, whereas Ardec B went from very high number to 0 the same week. This may be due in part to sampling biases inherent in use of the sweep net (Southwood 1978). It also could be related to the highly aggregated distribution of FCB within sample sites, which was repeatedly observed in with individual plants or small patches hosting thousands of individuals. Capinera (2002) commented that the highly aggregated distribution of FCB requires systematic inspection when doing field survey. Extreme aggregation was observed in the course of these samplings, particularly in fields that were predominantly flixweed (e.g., ARDEC A, B in 2000).

Weather conditions can also be a factor in FCB population changes, at least as assessed by sweep net sampling. For example, FCB can be hard to find following heavy rainfall (Howard 1872), which was observed in these studies. However, heavy rainfall did not have persistent effect on FCB capture. During sampling, heavy rainfall events at the ARDEC site occurred on 17- May (0.91 in) in 2000, on 5-May, and 17-May (0.94, and 0.33 in) in 2001, and on 23-May (1.01 in) in 2002. There was no consistent trend of lower FCB capture in sample sites around the ARDEC area following these rainfall events.

Western Black Flea Beetle. Western black flea beetle was recovered from the first, mid-April samples in all three seasons (Tables 15. 7, 15. 8, 15. 9). This is consistent with the early season movement of adults reported by Chittenden and Marsh (1920).

WBFB was found at the sample sites throughout the season in all years. Greatest numbers were recovered in 2000 with total capture 10X and 1.6X greater than in 2001 and 2002, respectively. Unlike FCB, there were multiple population peaks observed in 2000 and 2001 (Figures 15. 4, 15. 5, 15. 6). Peak numbers were recovered in mid-May in 2002. WBFB is reported to have up to three generations per year in Colorado (Chittenden 1909, Chittenden and Marsh 1920). The documentation of sustained adult activity over the four-month period of these studies would be consistent with such a life cycle, although larval stages were not sampled.

Sites dominated by flixweed, both *D. sophia,* and *D. pinnata,* supported large early season WBFB populations, suggesting that this winter annual mustard can be an important host plant for this canola pest species, as well as for false chinch bug. Where flixweed occurred in alfalfa, cutting of the crop appear to trigger migration, as with FCB. Chittenden and Marsh (1920) reported on winter annual weeds as early season hosts for WBFB.

***Lygus* species**. *Lygus* spp. was found in every year during the first, mid-April surveys (Tables 15. 10, 15. 11, 15. 12). This reflects movement of this species from winter shelter by early spring (Kelton 1975). Not as great differences in numbers between seasons were observed as occurred with the previously discussed species. The greatest numbers were recovered in 2000 with total capture 2X and 2.9X greater than in 2001 and 2002, respectively.

Lygus were also found more consistently throughout the season and did not show the sharp decline in populations of the above after early July. Two peaks were noted in 2001 and 2002, about one month apart, but only a single peak in 2000 (Figures 15. 7, 15. 8,

15. 9). This may largely due to most survey sites including alfalfa, a favored food source of many *Lygus* spp. (Sevacherian and Stern 1974, 1975).

However, flixweed sites, even in the absence of alfalfa were also important in early season populations. For example, in 2000 (Ardec A, Ardec B, CR15 C, H257 B, Severance A) and 2001 (H257 A, Severance A) sites with flixweed alone had high *Lygus* populations (Tables 15. 10,15. 11).

Lygus collections were summed captures of at least three species. In Chapter 9 more detailed observations of *Lygus* documented seasonal shifts in the species complex, as well as sustained activity into October.

Sharp declines in *Lygus* captures occurred after alfalfa cutting. This suggests that alfalfa harvest contributes to *Lygus* migration. Stern et al. (1964) and Stewart and Layton (2000) reported that manipulations of alfalfa through strip harvest can prevent migration of *Lygus* to adjacent crops.

Table 15. 1. Sites used in surveys of false chinch bugs, western black flea beetle, and *Lygus* spp. in 2000.

Site	Location	Predominant Vegetation[1]
ARDEC A	Colorado State Agricultural Research Development and Education Center (ARDEC), Larimer County	Flixweed
ARDEC B	ARDEC	Flixweed
ARDEC C	Immediately southwest of ARDEC along CR 56	Alfalfa with little flixweed
HortFarm	Colorado State Horticulture Research Farm	Alfalfa with little flixweed
CR15 A	Weld County Rd 15, 1. 5 miles to East 14	Mixed roadside weeds, predominantly grasses
CR15 B	Weld County Rd 15, 2 miles to East 14	Mixed roadside weeds, predominantly flixweed
CR15 C	Weld County Rd 15, intersection of Hwy 86	Alfalfa field with some flixweed
H257 A	Southeast corner, Hwy 257 and 14-intersection	Alfalfa field with some flixweed
H257 B	Weld County Hwy 257, 2 miles south of Hwy 14	Flixweed
Severance A	Two blocks NW of downtown Severance center	Abandoned garden overrun with flixweed
Severance B	Adjacent to above Severance site	Alfalfa field with some flixweed
EI25	One half mile east of I25, on right of Strauss Cabin Rd	Alfalfa field with some flixweed
W.Cargill	Cargill Oilseed Research Center, Ft. Collins	Alfalfa field with some flixweed

[1] Flixweed at H257 B was predominantly the native species, *Descurainia pinnata* (Walt.) Britt. Flixweed at all other sites was predominantly the introduced European species, *Descurainia sophia* (L.) Webb. ex Prantl.

Table 15. 2. Sites used in surveys of false chinch bugs, western black flea beetle, and *Lygus* spp. in 2001.

Site	Location	Predominant Vegetation[1]
ARDEC A	Colorado State Agricultural Research Development and Education Center (ARDEC), Larimer County	Alfalfa, with little flixweed
ARDEC B	ARDEC	Alfalfa, with some flixweed
HortFarm	Colorado State Horticulture Research Farm	Alfalfa with little flixweed
CR15	Weld County Rd 15, intersection of Hwy 86	Alfalfa field with some flixweed
H257 A	Weld County Hwy 257, 2 miles south of Hwy 14	Flixweed
H257 B	Weld County Hwy 257 intersection at CR 80	Alfalfa field with little flixweed
Severance A	Two blocks NW of downtown Severance center	Abandoned garden overrun with flixweed
Severance B	Adjacent to above Severance site	Alfalfa field with some flixweed
EI25	One half mile east of I25, on right of Strauss Cabin Rd	Alfalfa field with some flixweed
W.Cargill	Cargill Oilseed Research Center, Ft. Collins	Alfalfa field with some flixweed

[1] Flixweed at H257 A was predominantly the native species, *Descurainia pinnata* (Walt.) Britt. Flixweed at all other sites was predominantly the introduced European species, *Descurainia sophia* (L.) Webb. ex Prantl.

Table 15. 3. Sites used in surveys of false chinch bugs, western black flea beetle, and *Lygus* spp. in 2002.

Site	Location	Predominant Vegetation[1]
ARDEC A	Southwest of ARDEC at intersection of Larimer County Rd 56 and Frontage Rd	Alfalfa field with little flixweed
ARDEC B	Immediately west of ARDEC A	Alfalfa field with some flixweed
HortFarm	Colorado State Horticulture Research Farm	Alfalfa field with little flixweed
North Budweiser	Larimer County Rd 54, north of Budweiser Plant	Alfalfa field with little flixweed
Mountain Vista	Corner of Mountain Vista Rd and Timberline Rd	Alfalfa field with little flixweed
CR15	Weld County Rd 15, intersection of Hwy 86	Alfalfa field with some flixweed
H257	Weld County Hwy 257 intersection at CR 80	Alfalfa field with little flixweed
Severance	Two blocks NW of downtown Severance center	Alfalfa field with some flixweed
EI25	One half mile east of I25, on right of Strauss Cabin Rd	Alfalfa field with some flixweed
W.Cargill	Cargill Oilseed Research Center, Ft. Collins	Alfalfa field with some flixweed
BayFarm A	Colorado State University Bay Farm	Alfalfa field
BayFarm B	Colorado State University Bay Farm	Alfalfa field
CSFS Nursery	Colorado State Forest Service Nursery	Alfalfa field

[1] Flixweed at all other sites was predominantly the introduced European species, *Descurainia sophia* (L.) Webb. ex Prantl.

Table 15. 4: Weekly samples of false chinch bugs, *Nysius raphanus*, on different crops at Larimer County in Colorado in 2000.

Site	18-Apr	25-Apr	2-May	9-May	16-May	23-May	30-May	7-June	14-June	21-June	29-June	5-Jul	11-Jul	18-Jul	28-Jul	2-Aug
Ardec A	7	7	46	51	108	275	791	1253	97	185	1502	881	0	0	0	0
Ardec B	10	14	21	15	34	803	326	12071	19	163	1598	388	0	0	0	0
Ardec C	6	8	8	10	10	0	4	1	0	18	1	8	0	0	0	0
Hortfarm	3	89	41	30	58	152	462	180	27	0	0	0	0	0	0	0
CR15 A	0	54	3	2	4	0	1	0	0	0	0	0	0	0	0	0
CR15 B	1	25	32	36	62	380	708	1416	22	9469	666	549	0	0	0	0
CR15 C	0	169	44	285	84	5990	4002	7613	1722	22	23	18	55	14	44	0
H257 A	38	80	115	641	888	3441	1368	5	1	15	14	4	1	0	0	0
H257 B	15	45	25	515	321	1189	770	248	11	0	2	0	0	0	0	0
Severance A	0	850	580	750	390	980	103	425	13845	11562	3416	82	6	6	9	0
Severance B	4	0	0	190	180	835	96	188	25	150	235	87	0	0	0	0
EI25	0	201	240	466	475	2609	895	323	0	3	9	8 0	0	1	0	4
W.Cargill	635	255	440	454	474	2437	460	178	47	1125	176	10785	19	1	2	2
	719	1797	1595	3445	3088	29077	9986	23901	15816	22712	7642	12810	81	21	65	6

Figure 15. 1: Weekly samples of false chinch bugs, *Nysius raphanus*, on different crops at Larimer County in Colorado in 2000.

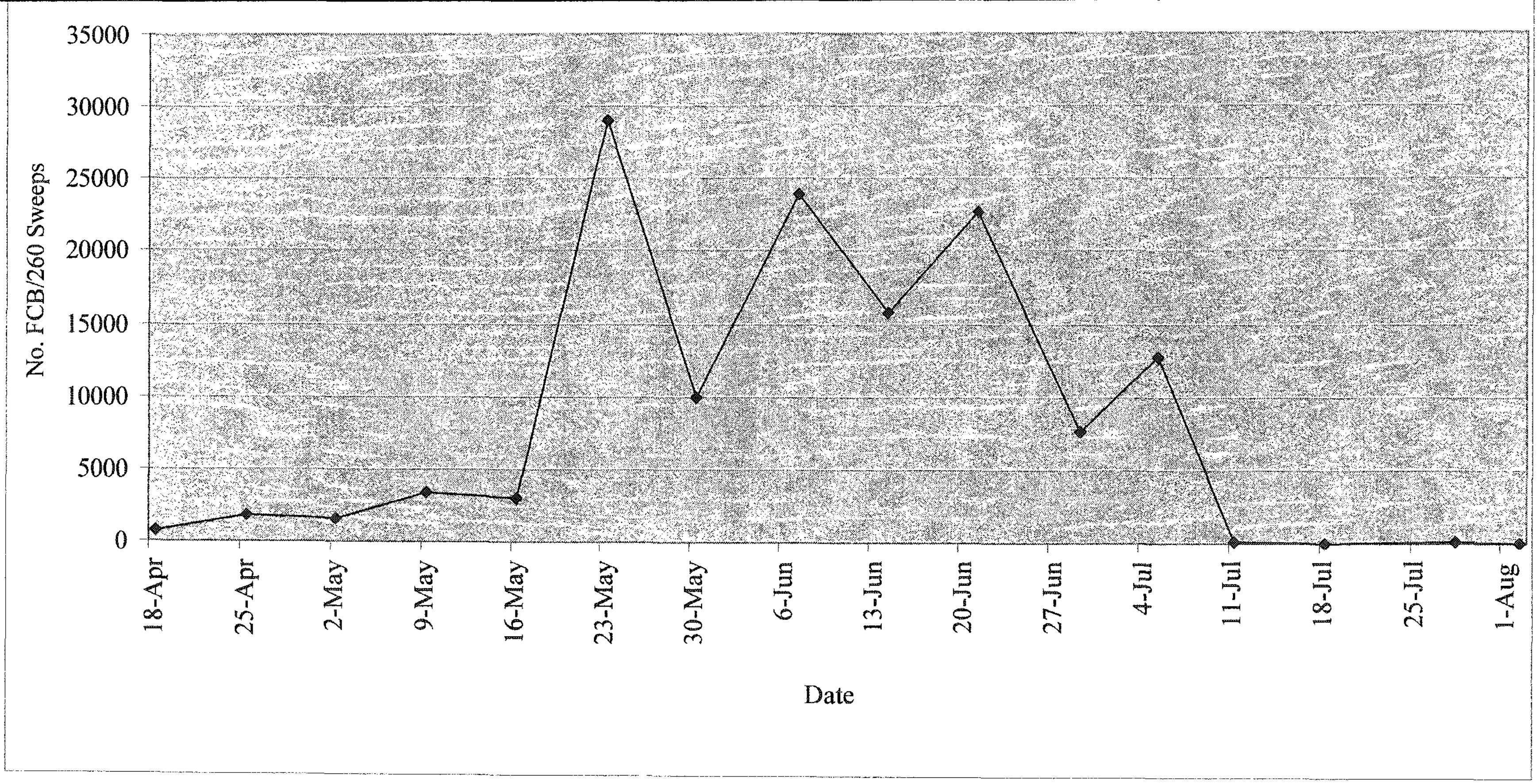


Table 15. 5: Weekly samples of false chinch bugs, *Nysius raphanus*, on different crops at Larimer County in Colorado in 2001.

Site	18-Apr	25-Apr	3-May	8-May	23-May	29-May	7-June	12-June	19-June	27-June	3-Jul	12-Jul	21-Jul	25-Jul	7-Aug	14-Aug
Ardec A	0	0	2	7	0	3	0	4	5	7	24	5	0	16	4	3
Ardec B	0	0	2	0	0	0	0	0	1	0	0	2	1	5	6	5
Hortfarm	0	0	0	0	0	0	5	0	0	0	0	3	2	0	0	0
CR15	0	0	0	0	0	1	2	0	0	1	4	16	58	4	0	0
H257 A	0	8	4	0	2	71	2	6	0	0	2	2	0	0	0	0
H257 B	0	3	0	0	0	2	169	30	28	36	25	16	46	13	1	0
Severance A	0	3	4	3	2	1	3	0	1	5	3	0	0	0	0	0
Severance B	0	8	13	4	5	3	4	10	0	2	25	10	2	0	0	0
EI25	0	2	1	0	0	0	0	5	0	1	0	16	1	0	0	0
W.Cargill	0	1	0	1	0	2	0	3	0	1	3	4	2	0	0	0
	0	25	26	15	9	83	185	58	35	53	86	74	112	38	11	8

Figure 15. 2: Weekly samples of false chinch bugs, *Nysius raphanus*, on different crops at Larimer County in Colorado in 2001.

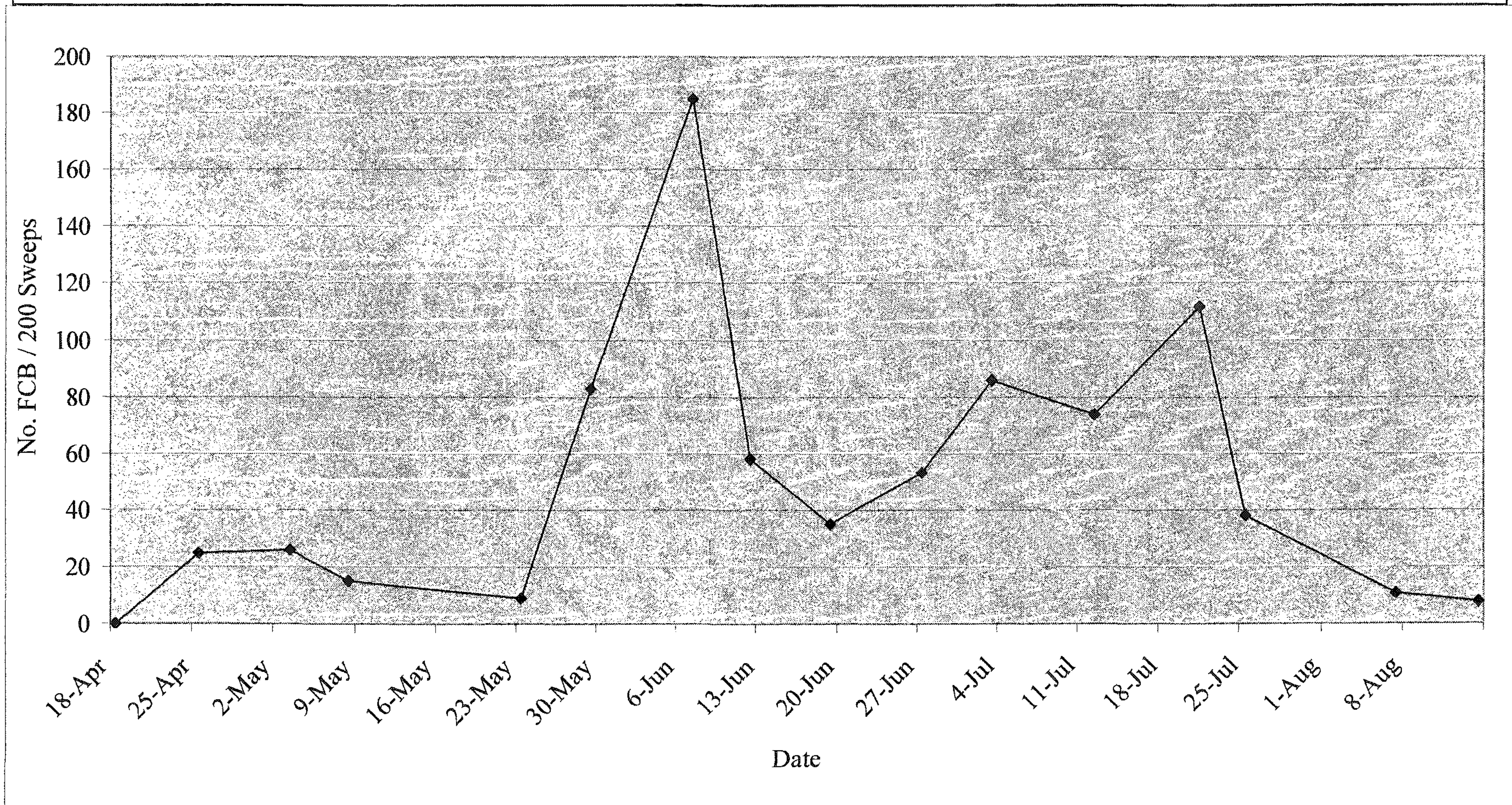


Table 15. 6: Weekly samples of false chinch bugs, *Nysius raphanus*, on different crops at Larimer County in Colorado in 2002.

Site	18-Apr	25-Apr	2-May	8-May	18-May	27-May	4-June	12-June	18-June	28-June	5-Jul	12-Jul	22-Jul	5-Aug	13-Aug
Ardec A	0	0	0	0	0	3951	3210	0	0	0	6	0	0	0	0
Ardec B	0	0	0	249	7819	3	10	0	0	0	0	0	0	0	0
Hortfarm	0	0	0	0	0	7169	7101	2	48	0	0	0	0	0	0
N.Bud	0	0	0	0	3	4	3	0	0	0	4	0	0	0	0
Mon.Vista	0	0	0	0	0	0	0	0	0	4	4	0	0	0	3
CR15	0	0	0	21	435	2111	2010	2	0	0	0	0	0	0	1
H257	0	0	0	0	2	0	6	1	4	2	6	0	0	0	0
Severance	0	0	0	2	0	5	2	0	0	0	0	0	0	0	0
I25	0	0	0	0	0	0	0	0	4	0	0	0	0	0	6
W.Cargill	1	0	1	4	0	2	0	10	7	0	0	0	0	0	0
Bayfarm A	0	0	0	1	2	210	2	0	0	0	0	0	0	0	0
Bayfarm B	0	0	0	0	2	2	1	0	3	0	3	0	0	2	0
CSFS Nursery	0	0	0	0	1	2	24	0	2	2	7	0	0	0	3
	1	0	1	277	8264	13459	12369	15	68	8	30	0	0	2	13

Figure 15. 3: Weekly samples of false chinch bugs, *Nysius raphanus*, on different crops at Larimer County in Colorado in 2002.

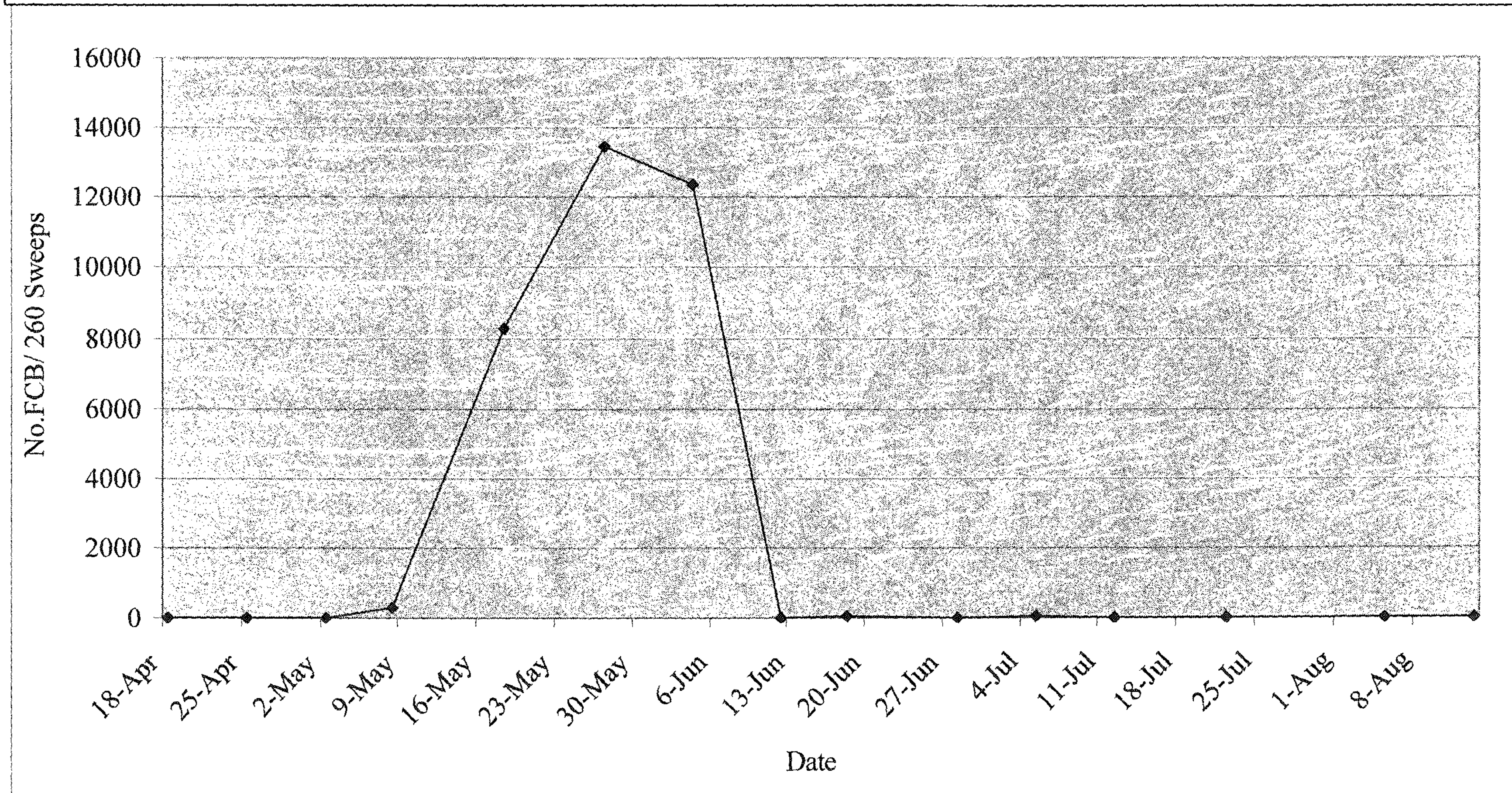


Table 15. 7: Weekly samples of Western Black Flea Beetle, *Phyllotreta pusilla*, on different crops at Larimer County in Colorado in 2000.

Site	18-Apr	25-Apr	2-May	9-May	16-May	23-May	30-May	7-June	14-June	21-June	29-June	5-Jul	11-Jul	18-Jul	28-Jul	2-Aug
Ardec A	25	35	14	75	75	35	511	9	444	26	506	395	0	0	0	0
Ardec B	14	16	65	33	61	87	270	18	300	775	166	206	0	0	0	0
Ardec C	44	88	30	18	99	0	1	3	52	0	3	14	0	0	0	0
Hortfarm	19	10	73	27	96	86	227	34	16	0	1	1	17	4	4	0
CR15 A	21	12	12	21	30	0	6	0	0	0	0	0	0	0	0	0
CR15 B	65	10	115	44	148	115	137	36	28	72	51	1	0	0	0	0
CR15 C	24	25	13	19	4	25	0	17	145	0	9	9	11	0	9	2
H257 A	10	10	4	75	8	37	180	0	1	1	16	2	0	0	0	0
H257 B	11	10	11	14	32	313	315	33	24	1	1	0	0	0	0	0
Severance A	10	4	25	0	4	50	77	35	144	933	653	153	70	16	4	14
Severance B	9	0	0	18	4	16	73	18	48	8	131	6	0	0	0	0
EI25	0	10	14	18	24	4	645	16	0	1	6	32	16	3	2	16
W.Cargill	5	12	4	13	24	3	832	35	47	229	38	42	16	0	4	9
	247	242	380	375	609	771	3274	254	1249	2046	1581	861	130	23	23	41

Figure 15. 4: Weekly samples of Western Black Flea Beetle, *Phyllotreta pusilla*, on different crops at Larimer County in Colorado in 2000.

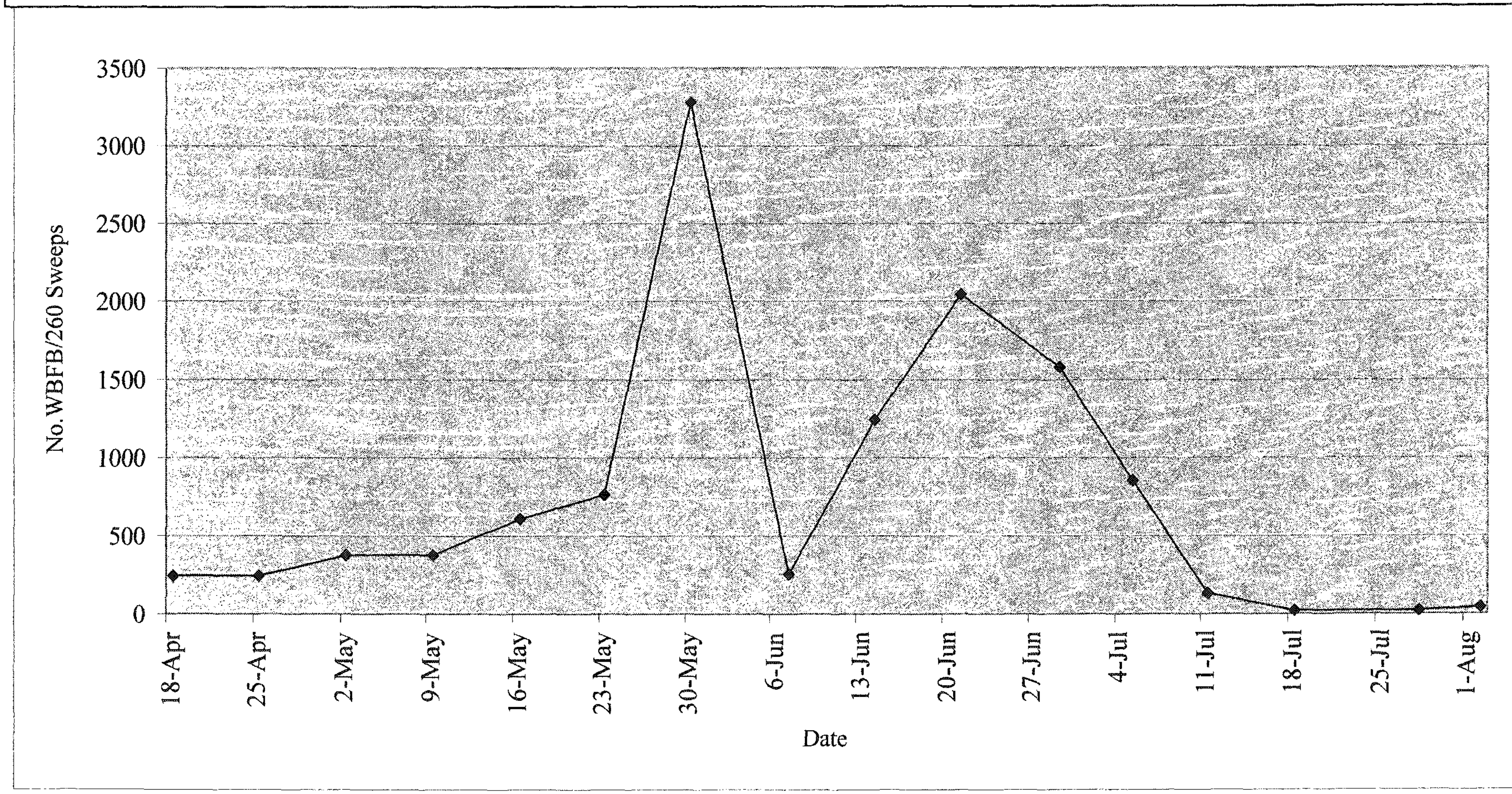


Table 15. 8: Weekly samples of Western Black Flea Beetle, *Phyllotreta pusilla,* on different crops at Larimer County in Colorado in 2001.

Site	18-Apr	25-Apr	3-May	8-May	23-May	29-May	7-June	12-June	19-June	27-June	3-Jul	12-Jul	21-Jul	25-Jul	7-Aug	14-Aug
Ardec A	0	2	48	34	0	1	1	6	0	19	0	2	2	0	1	1
Ardecl B	0	0	25	4	0	33	3	7	0	0	3	2	0	0	1	0
Hortfarm	0	0	5	1	9	9	0	2	0	1	11	14	0	0	0	0
CR15	0	5	3	14	4	20	2	5	1	6	14	2	0	0	2	0
W.Cargill	0	3	17	4	2	35	1	0	1	0	4	0	0	0	1	1
H257 A	2	4	6	10	7	2	10	3	4	5	0	4	0	0	0	0
H257 B	4	2	6	10	7	2	10	3	4	5	0	4	0	0	0	0
Severance A	92	4	4	29	3	36	24	10	19	6	3	0	0	0	11	3
Severance B	69	17	29	13	2	16	9	8	2	4	5	2	2	0	0	0
EI25	31	4	4	2	0	39	0	2	0	2	2	4	0	0	0	1
	198	41	148	115	29	203	51	60	27	120	117	30	4	0	16	6

Figure 15. 5: Weekly samples of Western Black Flea Beetle, *Phyllotreta pusilla,* on different crops at Larimer County in Colorado in 2001.

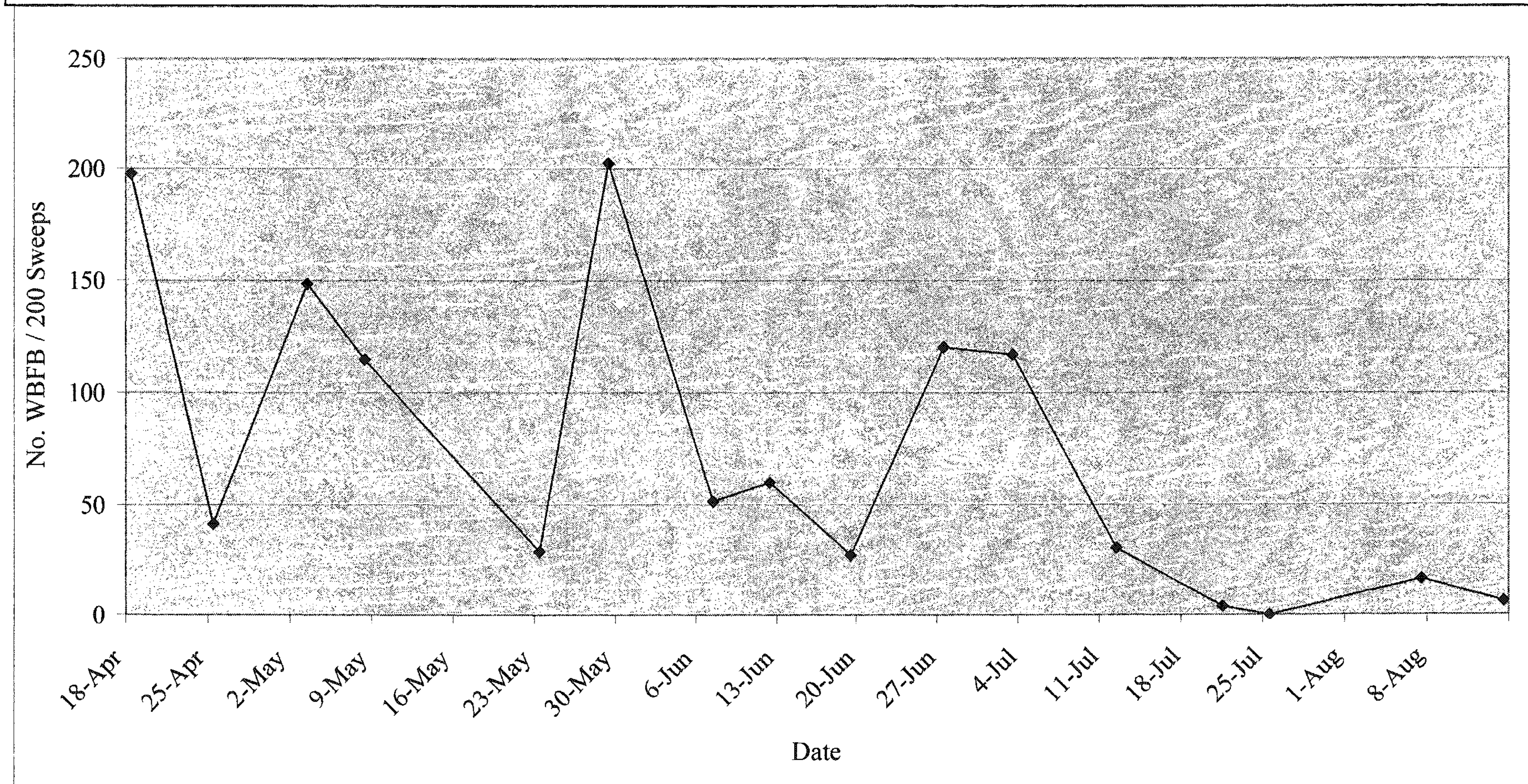


Table 15. 9: Weekly samples of Western Black Flea Beetle, *Phyllotreta pusilla,* on different crops at Larimer County in Colorado in 2002.

Site	18-Apr	25-Apr	2-May	8-May	18-May	27-May	4-June	12-June	18-June	28-June	5-Jul	12-Jul	22-Jul	5-Aug	13-Aug
Ardec A	0	0	0	0	0	119	97	6	9	0	2	0	0	4	25
Ardec B	1	0	2	38	1566	9	16	0	0	0	2	0	0	5	19
Hortfarm	0	0	0	193	4	1322	1310	4	10	2	4	0	2	2	13
N.Bud	0	0	0	14	2	0	0	4	10	0	0	0	0	3	16
Mon.Vista	0	0	0	1	31	3	20	2	0	0	2	0	0	0	0
CR15	1	0	0	78	1770	267	216	0	5	2	2	0	0	0	13
H257	0	0	0	10	6	42	0	6	2	0	5	0	0	0	4
Severance	0	0	0	38	2	77	0	18	0	0	0	0	0	0	2
I25	1	0	3	17	13	2	0	0	0	0	0	0	0	0	10
W.Cargill	0	0	0	6	2	34	0	12	2	0	3	0	0	0	8
Bayfarm A	0	0	0	23	0	19	6	0	2	0	3	0	0	0	1
BayfarmI B	1	0	0	13	2	42	0	0	0	0	4	0	0	0	2
CSFS Nursery	0	0	1	5	4	4	0	0	0	0	12	0	0	3	6
	4	0	6	436	3402	1940	1665	52	40	4	39	0	2	17	119

Figure 15. 6: Weekly samples of Western Black Flea Beetle, *Phyllotreta pusilla,* on different crops at Larimer County in Colorado in 2002.

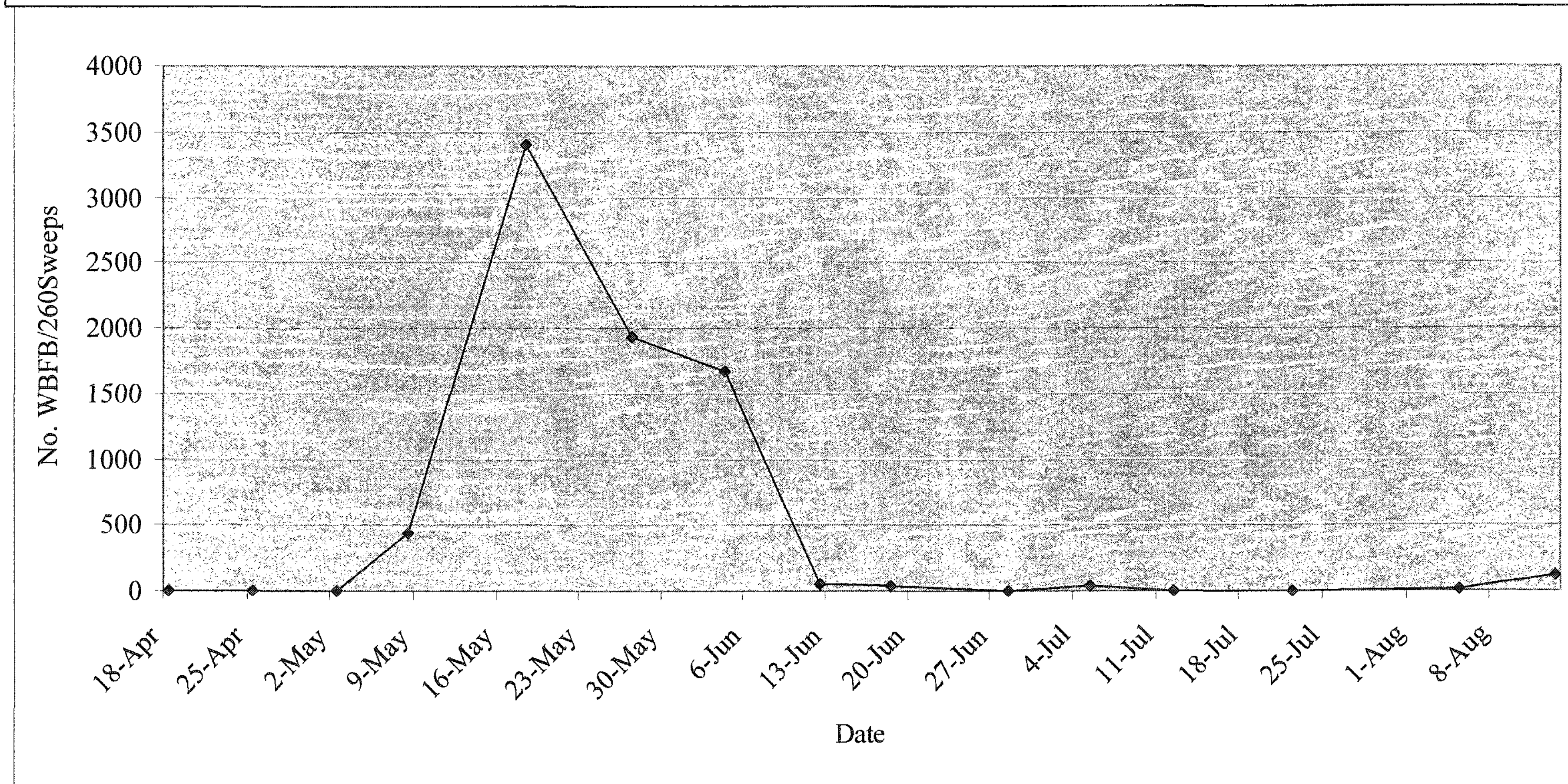


Table 15. 10: Weekly samples of *Lygus* spp. (*Lygus elisus*, *Lygus hesperus* and *Lygus lineolaris*) on different crops at Larimer County in Colorado in 2000.

Site	18-Apr	25-Apr	2-May	9-May	16-May	23-May	30-May	7-June	14-June	21-June	29-June	5-Jul	11-Jul	18-Jul	28-Jul	2-Aug
Ardec A	20	28	77	62	51	110	25	380	83	32	19	9	0	0	0	0
Ardec B	25	32	34	55	69	143	36	388	87	61	11	5	0	0	0	0
Ardec C	17	17	51	16	42	0	1	2	3	25	16	17	0	0	0	0
Hortfarm	29	18	58	26	47	72	52	133	24	0	0	3	88	31	15	15
CR15 A	9	20	2	0	6	0	4	0	0	0	0	0	0	0	0	0
CR15 B	25	33	49	61	110	65	120	295	268	23	5	3	0	0	0	0
CR15 C	66	55	81	61	1	0	0	33	12	1	1	1	4	0	64	16
H257 A	45	20	25	25	17	0	0	0	1	8	5	13	76	0	0	0
H257 A	71	15	16	42	27	182	51	499	10	3	0	0	0	0	0	0
Severance A	0	10	11	7	60	45	13	493	285	197	11	1	1	31	31	19
Severance B	49	0	0	12	17	54	20	175	42	20	31	1	0	0	0	0
EI25	0	7	7	19	60	267	6	629	0	11	0	37	38	11	54	24
W.Cargill	96	35	9	8	11	150	4	805	271	457	14	66	10	0	10	16
	452	290	420	394	518	1088	332	3832	1078	838	113	156	217	73	174	90

Figure 15. 7: Weekly samples of *Lygus* spp. (*Lygus elisus*, *Lygus hesperus* and *Lygus lineolaris*) on different crops at Larimer County in Colorado in 2000.

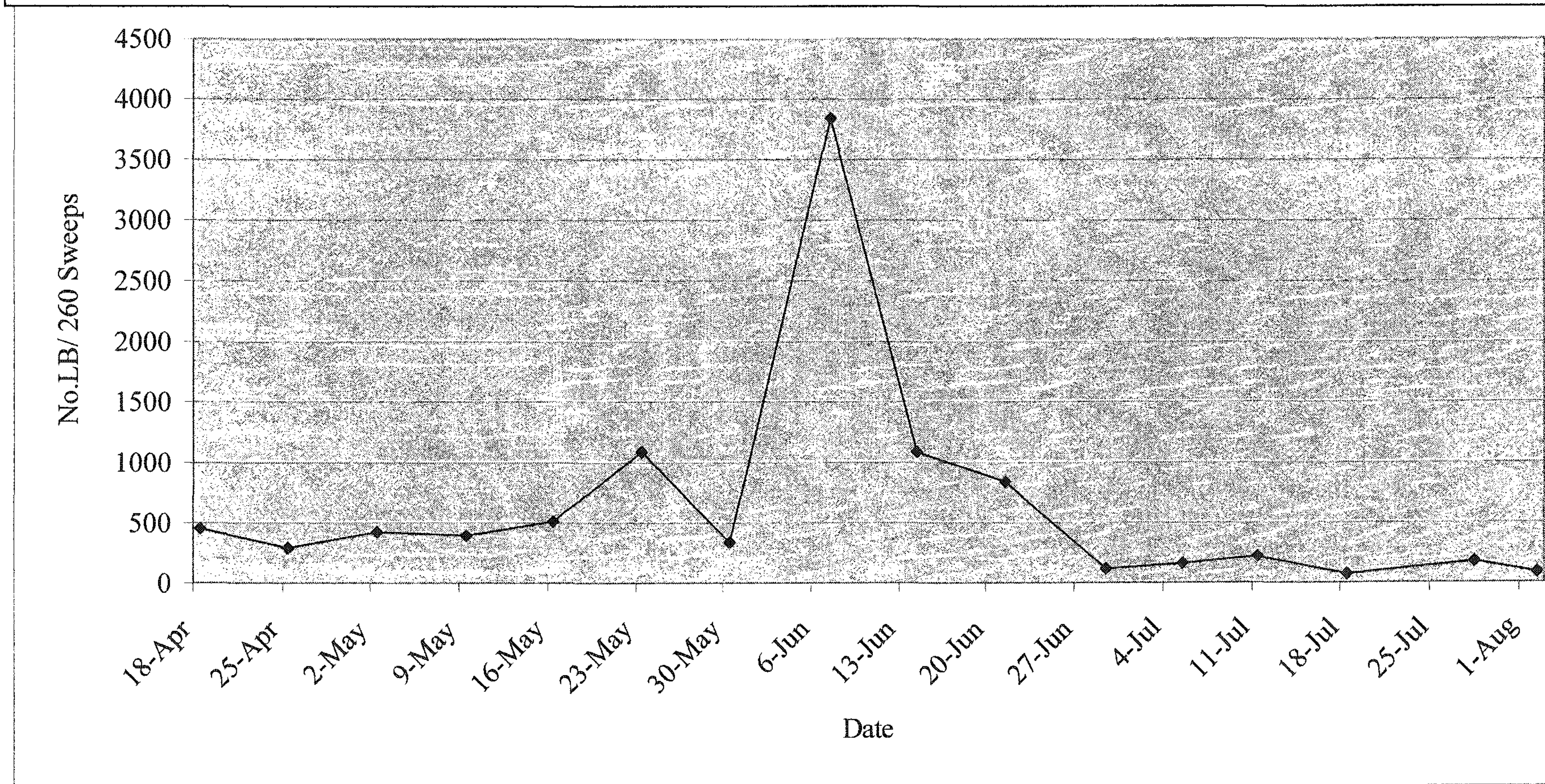


Table 15. 11: Weekly samples of *Lygus* spp. (*Lygus elisus*, *Lygus hesperus*, and *Lygus lineolaris*) on different crops at Larimer County in Colorado in 2001.

Site	18-Apr	25-Apr	3-May	8-May	23-May	29-May	7-June	12-June	19-June	27-June	3-Jul	12-Jul	21-Jul	25-Jul	7-Aug	14-Aug
Ardec A	0	4	15	14	16	21	5	24	7	15	37	36	55	79	6	9
Ardec B	0	6	15	4	7	26	9	35	0	14	26	18	73	53	18	27
Hortfarm	2	8	3	19	20	6	71	2	0	6	14	23	64	24	0	0
CR15	0	10	5	13	2	65	5	15	21	1	6	65	45	64	20	4
W.Cargill	5	13	63	8	3	25	12	3	154	26	74	18	61	7	6	27
H257	91	71	14	31	58	228	18	33	0	8	16	15	0	0	0	0
H257	10	5	11	14	6	8	404	160	42	3	0	10	36	37	17	19
Severance A	51	14	17	12	24	91	65	64	36	24	28	66	108	64	3	19
Severance B	133	64	58	32	44	32	15	36	10	13	89	45	10	14	0	12
EI25	30	39	2	4	10	64	4	43	25	26	35	66	68	7	18	21
	322	234	203	151	190	566	608	415	295	136	325	362	520	349	88	138

Figure 15. 8: Weekly samples of *Lygus* spp. (*Lygus elisus*, *Lygus hesperus*, and *Lygus lineolaris*) on different crops at Larimer County in Colorado in 2001.

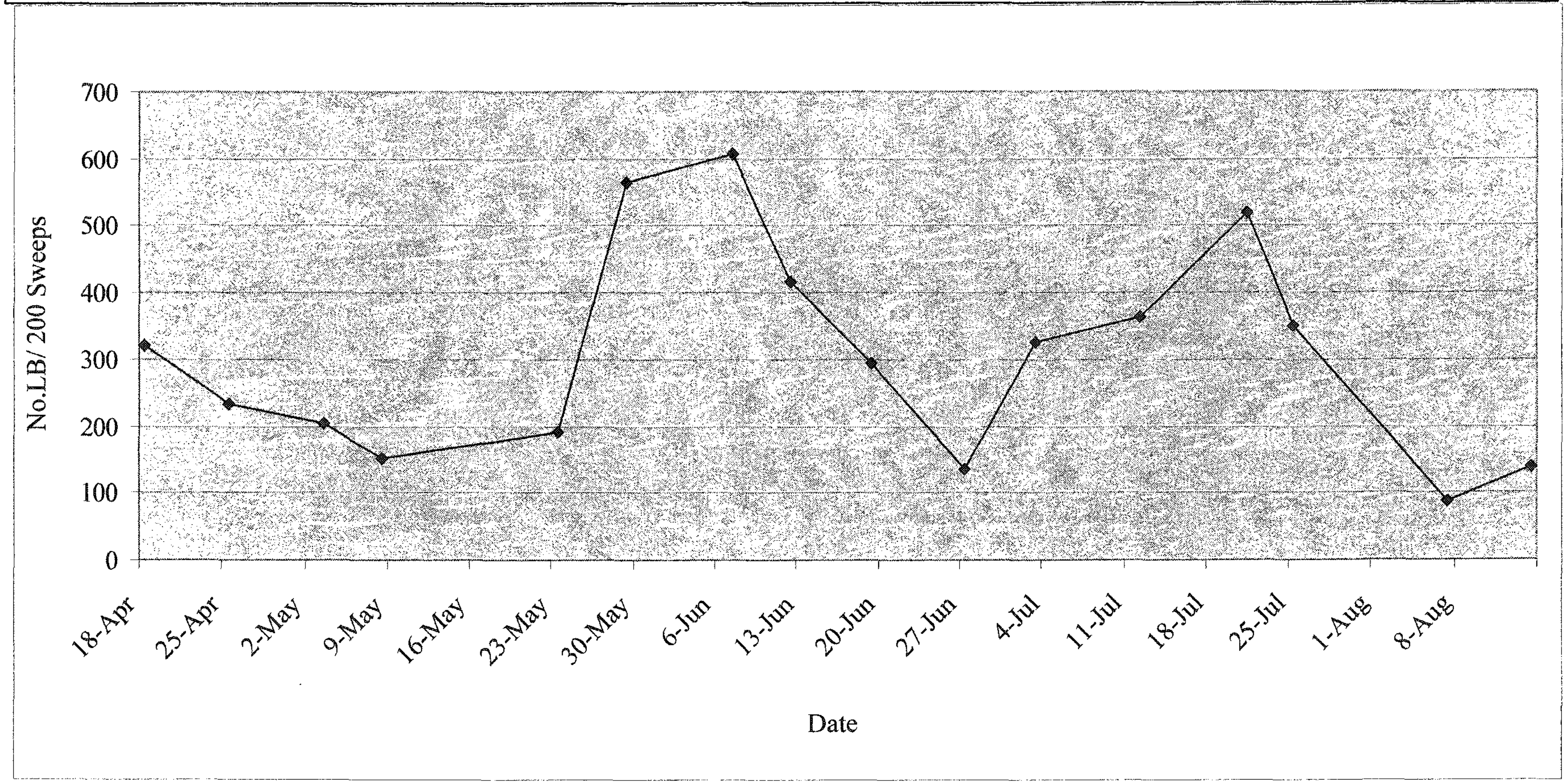
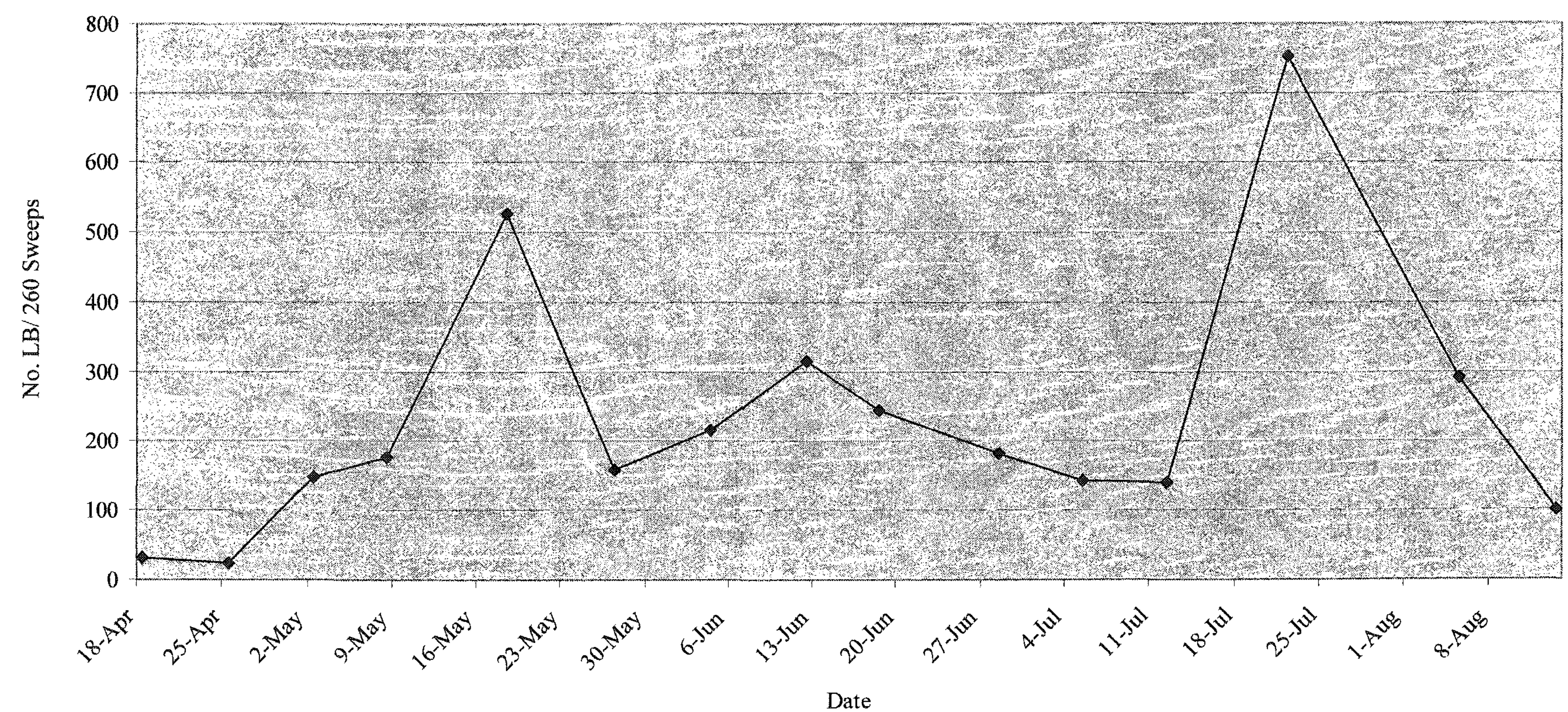


Table 15. 12: Weekly samples of *Lygus* spp. (*Lygus elisus*, *Lygus hesperus*, and *Lygus lineolaris*) on different crops at Larimer County in Colorado in 2002.

Site	18-Apr	25-Apr	2-May	8-May	18-May	27-May	4-June	12-June	18-June	28-June	5-Jul	12-Jul	22-Jul	5-Aug	13-Aug
Ardec A	4	3	14	11	2	5	10	12	8	18	4	3	69	36	19
Ardec B	1	2	39	19	101	0	11	3	4	12	4	4	209	19	12
Hortfarm	2	0	5	7	10	65	16	25	108	6	22	12	39	14	9
N.Bud	4	4	4	17	13	14	8	21	18	29	25	28	51	76	4
Mon.Vista	1	1	5	0	2	0	5	18	4	16	8	8	0	0	0
CR15	1	3	2	8	305	23	61	10	24	4	11	0	57	25	9
H257	2	3	12	26	13	12	0	4	18	29	16	25	167	17	2
Severance	0	0	0	7	8	0	16	16	10	2	15	15	16	32	9
I25	3	1	15	28	18	4	7	125	28	10	2	2	10	43	22
W.Cargill	3	0	29	23	25	8	8	25	8	22	9	9	59	5	8
Bayfarm A	6	4	3	5	11	14	38	35	3	10	7	7	21	16	2
Bayfarm B	4	4	8	15	9	2	22	12	8	6	13	21	54	0	1
CSFS Nursery	0	0	12	11	10	12	15	10	4	18	6	6	0	10	3
	31	25	148	177	527	159	217	316	245	182	142	140	752	293	100

Figure 15. 9: Weekly samples of *Lygus* spp. (*Lygus elisus*, *Lygus hesperus*, and *Lygus lineolaris*) on different crops at Larimer County in Colorado in 2002.



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CABBAGE APHID STUDIES

CHAPTER XVI

EVALUATION OF CANOLA AND MUSTARD CULTIVARS FOR SUSCEPTIBILITY TO CABBAGE APHID, *BREVICORYNE BRASSICAE* (L.)

INTRODUCTION

The cabbage aphid, *Brevicoryne brassicae* (L.), is an economically important insect pest that is a specialist of Brassicaceae (Hughes 1963, Feeny 1977) including broccoli, brussels sprouts, cabbage, cauliflower, collard, kale, kohlrabi, mustard, swede, and turnips (Ellis et al. 1996). Among oilseed brassica cultivars, winter and spring canola, rape and mustards are commonly infested (Scarisbrick and Daniels 1986), the aphid feeding on leaves, stems, buds, flowers, and pods (Lamb 1989).

Cabbage aphids usually aggregate on young seedlings and the apex of plants, where glucosinolate levels are highest (Fenwick 1983, Scarisbrick and Daniels 1986, McGregor 1988, Bodnaryk and Palaniswamy 1990, Costello and Altieri 1994, Hopkins et al. 1998). Glucosinolates, present in sixteen families of dicotyledonous angiosperms (Fahey et al. 2000), are secondary compounds of the Brassicaceae (Feeny 1977, Finch 1980, Sang et al. 1984, Hopkins et al. 1998, Fahey et al. 2000, Renwick 2002).

Cabbage aphid may cause both direct and indirect injuries to plants (Ellis et al. 1996). Direct feeding action occurs with high aphid density producing distortion, stunting and occasional death of young plants. Indirect damage results from the presence of cast skins, honeydew and the insects themselves that produce contamination that makes certain vegetable crops unmarketable.

In oilseed brassicas cabbage aphid can reduce oil content and increase glucosinolate content of seed (Lamb 1989). Brown et al. (1999) reported that uncontrolled insect infestation reduced seed yield by 37 percent and 32 percent in *Brassica napus* L. and *B. rapa* L., respectively. Another crucifer, *Sinapis alba* L., sustained only 10 percent yield reduction without insecticide application. The purposes of this study were to evaluate feeding preferences of cabbage aphids on different cultivars of both spring and winter canola and oilseed mustard.

MATERIALS AND METHODS

Greenhouse trials were conducted at Colorado State University in Ft. Collins, CO, to examine relative susceptibility of canola and mustard cultivars to cabbage aphid and injury. Twelve different brassica cultivars were included in trials: *Brassica napus* cv. Kaystar winter canola, *B. napus* cv. Casino winter canola, *B. juncea* cv. Debut winter mustard, *B. napus* cv. CO1 spring canola, *B. napus* cv. Alto spring canola, *B. napus* cv. Springfield spring canola, *B. napus* cv. Westar spring canola, *B. juncea* cv. ZEM 1 spring mustard, *B. napus* cv. Helios spring canola, *B. napus* cv. Sterling spring canola, *B. napus* cv. IMCO1 spring canola and *B. juncea* cv. W1-23 spring mustard. These were seeded 5 November 1999 then transplanted to pots of (11.43 square) on 5 December.

The trial was conducted within a cage and two cages were used. In one cage five plants of each cultivar were introduced and subsequently infested with cabbage aphids; the second cage included five identical plants that were not exposed to aphids and served as an untreated check. Within each cage plants were arranged in a randomized complete block design. Infestation consisted of placing on 11 December 20 cabbage aphids on each plant. Evaluations were made 24 December and 5 January 2000 using two different measurements. Plant height was measured to determine the relative effect of cabbage aphid on each of cultivars by comparing infested versus non-infested plants. The numbers of aphids were counted on infested plants to determine the relative host suitability among the different cultivars. Data were analyzed with using Student-Newman-Keuls (SNK) (SAS Institute 1990).

RESULTS AND DISCUSSION

Infestation with cabbage aphids did not result in any significant suppression of plant height of the cultivars CO1, Kaystar, Sterling, W1-23, and ZEM 1 on the first evaluation date, 13 days after infestation (*F=5.49*, *P=0.0792*; *F=4.26*, *P=0.1078*; *F=0.55*, *P=0.500*; *F=1.00*, *P=0.3739*; *F=5.20*, *P=0.0848*, respectively) (Table 16. 1). All cultivars, except Sterling, showed suppressed growth on the second evaluation, 26 days after infestation (*F=4.81*, *P=0.0933*). The greatest reduction of plant height from cabbage aphid infestation occurred on IMCO1 (*F=26.91*, *P=0.0066*).

There were significant differences in number of cabbage aphids on the second evaluation date, but not the first (Table 16. 2). Lowest numbers of aphids were observed on the spring mustard ZEM 1 (*F=2.18*, *P=0.0337*), a cultivar that showed the second greatest reduction in plant height from infestation (Table 16. 1). Conversely the highest number of aphids per plant occurred on Sterling (*F=2.18*, *P=0.0337*), a spring canola cultivar that did not show any significant effects in plant height from infestation (*F=0.55*, *P=0.500*; *F=4.81*, *P=0.0933*, respectively). These results suggest that there may be a range of tolerance (Painter 1951, Smith 1998) among *Brassica* spp. to cabbage aphid infestation.

In previous evaluations of brassicas for resistance to cabbage aphid (Hashmi et al. 1985) reported *B. napus* as moderately resistant and *B. campestris* L. most preferred. Singh et al. (1994) observed high resistance levels of both antixenosis and antibiosis mechanisms in accessions of *B. fluticulosa* Cirillo, *B. spinescens*, *B. juncea* (L.) Czern., breeding line., and *Eruca sativa* Mill to feeding of the cabbage aphid. Antixenosis resistance associated with red cultivars was noted by Ellis et al (1996). The data from this study suggest resistant mechanisms to cabbage aphid also exist (e.g., Sterling spring canola) that should be considered in cultivar development.

Table 16. 1. Comparison of plant height (cm) [a] of 12 cultivars of seedling canola and mustard infested with cabbage aphid, *Brevicoryne brassicae*, versus non-infested plants.

	24 Dec[b]		5 Jan[b]	
Cultivars[a]	Infested	Non-infested	Infested	Non-infested
Alto	19.4 b	25.4 a	19.8 b	30.6 a
Casino	17.8 b	25.0 a	18.4 b	28.8 a
CO1	17.8 a	26.2 a	18.0 b	52.6 a
Debut	14.2 b	22.4 a	14.4 b	26.2 a
Helios	17.6 b	25.2 a	18.0 b	28.4 a
Springfield	16.0 b	24.4 a	17.0 b	30.4 a
IMCO1	13.0 b	23.2 a	14.0 b	28.8 a
Kaystar	19.0 a	24.2 a	17.2 b	28.8 a
Sterling	19.0 a	21.0 a	19.8 a	25.2 a
Westar	14.0 b	23.2 a	14.8 b	28.2 a
W1-23	18.0 a	21.4 a	18.8 b	30.2 a
ZEM 1	14.8 a	23.0 a	15.0 b	31.8 a

[a] Plants seeded 5 November and infested with 15-20 cabbage aphids 11 December. Average plant height of five paired plants.

[b] Means within a row for each treatment date that are followed by the same letter are not significantly different ($P > 0.05$) by SNK.

Table 16. 2. Number of aphids on various canola and mustard cultivars following infestation with cabbage aphid, *Brevicoryne brassicae*.

	Cabbage aphids/Plant[a]	
Cultivars	24 Dec	5 Jan
Alto	80.6 a	102.0 abc
Casino	87.2 a	63.8 abcd
CO1	58.2 a	59.8 abcd
Debut	57.6 a	26.2 bcd
Helios	97.0 a	104.8 abcd
Springfield	56.4 a	34.8 abcd
IMCO1	73.6 a	30.0 cd
Kaystar	118.0 a	108.0 ab
Sterling	108.6 a	142.0 a
Westar	49.4 a	31.4 abcd
W1-23	88.4 a	118.4 abc
ZEM 1	39.8 a	10.6 d

[a] Plants infested with 15-20 cabbage aphids on 11 December. Average from five plants; means within a column that are followed by the same letter are not significantly different ($P > 0.05$) by SNK.

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SUMMARY

Trials were conducted in 2001 and 2002 to establish the relationship of *Nysius raphanus*, the false chinch bug (FCB) to injury of canola heads. This was done by artificially infesting bagged heads with different numbers of FCB (0, 10, 20, 40/head) at two different growth stages (early flowering, early pod).

In the first 2001 trial, yields of seven canola cultivars were reduced an average 43, 68 and 69 percent with infestations of 10, 20, and 40 FCB/head, compared to the 0 FCB/head control during the early flower stage in 2001. At the early pod stage yields were not reduced at 10 FCB/head but were reduced 26 and 23 percent with 20 FCB/head, and 40 FCB/head, compared with the 0 FCB/head control.

In the second 2001 trial, combining five cultivars, yields were decreased an average 26, 58, and 55 percent with infestations at the early flower stage of 10, 20, and 40 FCB/head, compared to the 0 FCB/head control. Yields were not decreased with FCB infestation during early pod stages.

Averaged yield reduction of the combined cultivars in the first 2002 trial was 31, 51 and 68 percent with infestations of 10, 20, and 40 FCB/head. With early pod stage infestation, yields were reduced 32 percent with 20 FCB/head.

There were no significant yield losses from FCB infestation during early flowering and pod stages in the second trial. In the third trial, averaged yield reduction from FCB infestation at the early flower stage were 63, and 81 percent with 20, and 40 FCB/head. There was no significant yield reduction from infestations at early pod stages.

The cultivar Excel had greatest yield reductions, sustaining significant yield loss from all treatments (10, 20, 40 FCB/head) when infested at early flower stages in first trial

in 2001. The cultivars Helios, and Defender had yield reductions from infestation levels of 20 and 40 FCB/head. However, the cultivars of Alto, and 46A65 had no significant yield reduction from any FCB infestation treatment that was applied at early flower stages.

In the second 2001 trial, infestation levels of 10, and 20 FCB/head caused significantly yield reductions on the cultivar Apollo at early flower stage. Significant yield reductions were also recorded on Defender, 46A65, and Hyola with the highest FCB infestations. However, Excel showed no yield reduction from any FCB infestation.

No significant yield reductions occurred from infestations of 10 FCB/head in the first trial at early pod stages in 2001. Yield reductions did occur on Apollo, Helios, and Excel with 20 FCB/head at the early pod stage. No significant yield reductions occurred from any FCB infestation to the cultivars 46A65, Alto, and Defender.

In the second trial yield reduction at early pod stages of canola occurred on the cultivars of Apollo, and 46A65 with 10 FCB/head in 2001. Yield losses occurred at 20 FCB/head on Excel and at 40 FCB/head with all cultivars, except 46A65. Yield losses from infestations of 40 FCB/head also occurred on IMC204 in the third trial.

Yield reductions from FCB infestation were lower in all 2002 trials, compared to 2001. Infestations during early flowering produced some significant yield reductions in the first trial. Greatest effects occurred on IMC205, which sustained yield loss at 10 FCB/head. In the third trial yield losses occurred only with 40 FCB on the cultivar IMC204 in 2002.

The cultivar Helios had significant yield reduction with 20 FCB/head compared with the 0 FCB/head control at early pod growth stages in the first trial in 2002. However, the second and third trials no cultivars showed yield reduction following FCB infestation at the early pod stage.

The effects of bagging were evaluated by comparing yield on heads that were bagged but had no FCB introduced compared to non-bagged heads. There were minimal yield effects resulting from bagging. In the first trial, yield of Helios was lower on the non-bagged control, compared to the 0 FCB/head bagged treatment. In the second trial, Hyola had significantly lower yields on bagged plant.

Overall, canola cultivars showed greater yield reduction by false chinch bug (FCB) when plants were infested with insects at the early flower stages compared to early pod stages. The growth stage of canola can affect FCB damage potential, with plants at pod fill less susceptible than those during early flowering. Number of FCB required causing 10 percent yield loss at early flowering stage infestation in the five trials ranged from 4.8-39.4 FCB/head (avg. 12.8). At early pod stage 10 percent yield loss resulted from average FCB infestations of 15.4-109.8 (avg. 39.7). Economic threshold may depend on cultivars and plant grown stages. Proposal economic threshold estimates value 25 FCB/plant at early flower stages and 80 FCB/plant at early pod stages.

Eleven different Brassica cultivars were tested at two different seedling stages for relative feeding preferences by false chinch bug in the greenhouse condition. Overall, FCB showed strong feeding preference for older plants, particularly among the cultivars ZEM1, Debut, and CO1. Cultivars that showed least differences due to age were Helios, Alto, and W1-23. The spring mustard W1-23 was consistently least infested by false chinch bug.

Yellow cups baited with mustard and canola oil caught significantly higher number of false chinch bug comparing to rest of treatment. The use of canola oil baits with yellow cups also increased capture of the tachinid, *Phasia occidentis*, a FCB parasitoid. The use of canola oil bait with blue cups caught *P. occidentis* than canola and mustard oil baits used with yellow cups.

The greatest numbers of false chinch bugs were caught on yellow sticky traps. Blue was significantly most attractive to *Phasia occidentis* among all tested colors.

Permethrin treatment of bags covering canola heads can suppress FCB aggregating on bags. In addition, substantial yield improvements to canola yield resulted from these protective treatments.

Trials were conducted in 2001 and 2002 to establish the relationship of *Lygus elisus*, the pale legume bug (PLB), to injury of canola heads. This was done by artificially infesting bagged heads with different numbers of PLB (0, 2, 8, 16/head) at two different growth stages (early flowering, early pod).

Averaged across all three 2001 trials the average yield reduction was 51.1, 63.8, and 65.8 percent for heads infested at 2 PLB, 8 PLB, and 16 PLB at early flower stages. Averaged across all three 2001 trials the average yield reduction was 14. 9, 24.1, and 47.3 percent for heads infested at 2 PLB, 8 PLB, and 16 PLB at early pod stages.

Overall yield reduction among all combined cultivars in first trial were 33, and 49 percent for heads infested at 8 PLB, and 16 PLB at early flower stages in 2001. However, there were no significant yield reduction occurred at early pod stages during the first 2001 trial.

In the second 2001 trial, overall yield reduction among all combined cultivars was 21, and 27 percent for heads infested at 8 PLB, and 16 PLB at early flower stages. Averaged yield reduction of all cultivars combined was 16 percent with 16 PLB/head at early pod stages. There were no significant yield reductions from any PLB infestation during the third trial.

The cultivars of Defender, Hyola, Alto, and Apollo sustained significant yield loss at the lowest level of infestation (2 PLB/head) during early flower in the 2001 trials. Helios, and 46A65 showed significant yield reductions at 8 PLB/head. Excel did not have significant yield reductions until introduction of 16 PLB/head.

However, Excel, Defender, and Apollo showed significant yield reductions at 2 PLB/head in the second trial. IMC204 showed significant yield reductions at 8 PLB/head in the third trial.

The extent of effects on yield following *L. elisus* infestation at early flowering were not repeated in 2002. The cultivar Excel, in one trial, showed significant yield suppression, at infestation of 8 PLB/head.

Overall yield effects were less following PLB infestation at the later early pod stage, compared to early flower stage infestation. In a 2001 trial, the cultivar Alto incurred significant yield losses with infestations of 2 PLB/head. With few exceptions, however, yield reductions observed during 2001 only resulted from infestations at the highest level, 16 PLB/head. In 2002 trials significant yield reductions only occurred on one cultivar (46A65) when infested at the highest level.

Comparison of the non-bagged heads with bagged heads where no PLB suggested that there was little effect on yield from bagging.

Overall, canola cultivars showed greater yield reduction by pale legume bug (PLB) when plants were infested with insects at the early flower stages compared to early pod stages. The growth stage of canola can affect PLB damage potential, with plants at pod fill less susceptible than those during early flowering. In these studies comparisons of 10 percent yield loss occurred with infestations of 3.1-5.6 PLB/head (avg. 3.3) with early flowering stage infestations and 3.4-19.0 PLB/head (avg. 8.72) at early pod stage infestations. Economic threshold may depend on cultivars and plant grown stages. Proposal economic threshold will be 3.3 PLB/head and over this number for early flower stages. Proposal economic threshold will be 8.72 PLB/head and over this number for early pod stages.

A total of 776 nymphs from 50 different samples were collected during 2001 sampling. *Leiophron uniformis* emerged from a total of 43 nymphs for an overall parasitism of 5.5 percent. In 2002, 3046 nymphs were collected from 257 samples and 144 parasitoids were observed to emerge for overall parasitism of 7.6 percent.

Parasites were recovered in June and July in 2001. However, parasitism was observed in all months from May through October, peaking at over 34 percent in August in 2002.

In 2001 and 2002 sampling period, *L.uniformis* was recovered Larimer, Weld, Morgan, Logan, and Pueblo counties. However, recoveries of *L. uniformis* did not happen Mesa, Delta, Montrose, and Alamosa counties. The highest percent of *L. uniformis* was recovered Larimer County in 2001. The highest percent of *L. uniformis* was recovered from Pueblo county, followed Morgan, Larimer, and Weld countries in 2002.

Sampling of different *Lygus* hosts indicated that parasitism by *L. uniformis* occurred in alfalfa, flixweed, alfalfa/flixweed mixtures, kochia, lambsquarters, canola, and redroot pigweed. The highest percentage parasitism occurred in canola during both

2001 and 2002 sampling - 20 percent and 11.8 percent, respectively. Parasitism in alfalfa, the most intensively sampled crop, was 4.1 and 10.9 percent in the two years.

Lygus collected in 2002 indicated three species were present; *L. elisus*, *L. hesperus*, and *L. lineolaris*. *L. elisus* was recovered in highest numbers at 58.4 percent of the total. *L. hesperus* was the second most abundant species in sampling (29.3 percent) followed by *L. lineolaris* (12.3 percent).

The highest population of *L. elisus* occurred during the early season and were mainly associated with flixweed and alfalfa/flixweed mixtures.

Lygus hesperus tended to occur in higher percentage later in the season, where it was the species most commonly recovered from lambsquarters (87.8 percent), kochia (80.3 percent), canola (57.3 percent), redroot pigweed (47.4 percent), and alfalfa (21 percent).

Lygus lineolaris was the species recovered in lowest numbers during 2002 sampling. In this study the highest percentage of *L. lineolaris* was found in collections of the two cultivated crops alfalfa (22.3 percent), and canola (18.0 percent).

Previous injury has been suggested as predisposing plants to attack by *Phyllotreta* spp. due to release of allyl isothiocyanate and other secondary compounds attractive to these beetles. However, prior wounding by leaf cutting did not significantly increase attraction of plants to *Phyllotreta pusilla*, the western black flea beetle (WBFB), in greenhouse trials. Only IMC205 showed significant differences at more than one measure during these studies. The cultivars Excel, and 46A65 showed no responses in injury or infestation between previously cut and uncut plants.

Evaluations were made of relative feeding injury by western black flea beetle to seedling stages of 11 canola and oilseed mustard cultivars. The two spring mustards included the cultivars that supported the greatest number of WBFB (ZEM 1) and the lowest (W1-23). Debut supported the greatest number of WBFB on plants and had the greatest associated plant injury. Plant damage was generally correlated with number of adult beetles present on plants. Greatest injury occurred to ZEM 1, the winter mustard Debut, and the spring canola CO1. Least plant injury was observed on the spring canolas Helios, Sterling, and Alto and with the spring mustard W1-23.

Colonization of cabbage plants by western black flea beetle was affected by colored mulches surrounding plants. In two years (1999, 2000) highest numbers of beetles were found on plants surrounded by reflective, aluminum mulch. This effect was not observed in 2002, when highest numbers occurred over white mulch. However, the lowest numbers of western black flea beetles consistently were present on plants surrounded by black mulches during three samples years. The highest number of flea beetle on plants observed on mulches at 4:00 PM in 1999, while there were no significant differences in 2000 and 2002.

Insecticide evaluations indicated that spinosad has activity against western black flea beetle. Horticultural oil, neem, and hot pepper wax spray showed modest activity in the greenhouse trial on one canola cultivar (Helios) but not on another (CO1) and were ineffective in field trials. Permethrin provided short-term reductions of western black flea beetle on seedling plants but reinvasion occurred within a few days.

In a 3-year survey of insects found outside canola field highest numbers of FCB were caught during 2000 in sweep net samples - 162X and 42X higher in than in 2001 and 2002, respectively. False chinch bug first appeared in midspring, usually on winter annual mustard weed species, and has multiple generations in Colorado. Migrations of FCB occur for first cuttings of alfalfa, particularly when fields support high populations of flixweed. FCB migrations from non-cultivated areas of flixweed occur later, with maturing of the plants.

In the surveys WBFB was found at the off-field sample sites throughout the season in all years. The highest amounts of WBFB were recovered in 2000 with total capture 10X and 1.6X greater than in 2001 and 2002, respectively. It has multiple generations in Colorado. The winter mustards flixweed and tansy mustard are important in supporting early season populations.

Lygus were also found in every year during the first, mid-April surveys, and were found more consistently throughout the season than WBFB and FCB. The greatest numbers were also recovered in 2000 with total capture 2X and 2.9X greater than in 2001 and 2002, respectively. Although winter mustard also was utilized by early season population alfalfa appears to be the primary host plant for *Lygus*.

The greatest reduction of plant height from cabbage aphid infestation occurred on IMCO1. Lowest numbers of aphids were observed on the spring mustard ZEM 1, a cultivar that showed the second greatest reduction in plant height from infestation. On the other hand, the highest number of aphids per plant occurred on Sterling, a spring canola cultivar that did not show any significant effects in plant height from infestation.