The Use of Non-Crop Vegetation to Manage Lygus in Organic Strawberries

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Abstract

The objectives of this research project were: a) to assess the major predator and pest populations in an organic strawberry field in the B.C. Fraser Valley by sampling over three seasons (2004 to 2006), and, b) to determine whether planting insectary plants and a hedgerow in part of the field would lead to a reduction in numbers of *Lygus shulli*, the major pest in this field. The results showed that lygus populations increased between 2004 and 2005, when the economic losses were the greatest, but decreased in 2006, when predator populations also decreased. The numbers of lygus were not significantly different between the treated rows and the untreated rows, except on one early date. The results are discussed in relation to the bottom-up effects of declining plant quality, time needed to establish permanent insectary plantings, and more effective methods of farmscaping for optimum biological control of pests by beneficial insects.

Executive Summary

The objectives of this research project were as follows:
1. Through regular sweep net sampling of an organic strawberry field over several seasons to obtain an estimate of the insect diversity in an organic strawberry field, including potential or actual pests and their natural enemies, and
2. To determine whether a high lygus bug (*Lygus shulli*) population could be reduced by planting a hedgerow along the side of the field and by planting insectary plants within the strawberry rows.

There are a variety of different ways of enhancing populations of beneficial insects that are currently being investigated by researchers involving the planting of non-crop vegetation, or farmscaping, in or around fields. Farmscaping is an ecological approach to pest management that is being used increasingly by organic growers and IPM practitioners in coastal U.S. states, particularly California, and is being researched for its effectiveness by researchers in the agricultural departments of state colleges and funded by federal grants through agencies such as Attra (Appropriate Technology Transfer for Rural Areas) and CASFS (The Centre for Agroecology and Sustainable Food Systems). Its purpose is to enhance the attractiveness of the environment to natural enemies by providing sources of nectar and pollen, as well as refugia.

In this project, two of these methods were used – insectary plantings and a hedgerow – to provide alternative food sources for the natural enemies of the lygus bug. It was hypothesized that interspersing flowering plants that were attractive to lygus predators in between strawberry plants in a section of the field, along with a hedgerow of native trees and flowering shrubs planted at the side of the treated area, would result in a reduction in lygus numbers compared to the section that had no insectary plants. This is because predators need a constant supply of food, either in the form of prey when they are abundant, or pollen and nectar from flowers when the prey is scarce, and providing a source of plants that flower all through the season ensures that predators will not leave the area when the prey numbers decrease to low levels.

The main lygus predators in this field were generalists, which feed on a variety of small soft-bodies insects and eggs including lygus bugs. They included big-eyed bugs, damsel bugs, lacewings, assassin bugs, the minute pirate bug, and some beetles. Lygus bugs can also be parasitized by tiny wasps, and such wasps were also present in the field, although none were identified as lygus parasites.

In this research project, insects were collected and identified over three seasons, from 2004 to 2006, and population numbers of key insects were averaged and graphed. Results are shown in tables and graphs in the full-length report. The results showed that lygus was a significant pest in this field in 2004 and 2005, and the grower's report of up to 40% loss of #1 berries confirmed this.

In the third growing season, from May 2006 to September 2006, the experiment with planting non-crop vegetation was carried out. The field was divided into two halves, and one half was planted with the insectary plants yarrow, dill, fennel, and cosmos (which were known to be attractive to both predators and parasites of lygus bugs), and a hedgerow containing cascara (*Rhamnus purshiana),* willows (*Salix* sp.), elderberry (*Sambucus racemosa),* and native roses (*Rosa woodsii* and *Rosa nutkana*).

The results did not show a significant difference in numbers of lygus bugs between the experimental and the control sections of the field except on one early date, and overall insect populations, including lygus, dropped dramatically from mid-June to the end of the season. This was most likely due to a decline in crop plant quality, as the strawberries were in their fourth year of production, and to some problems with the irrigation system which resulted in some areas of the field not receiving adequate water during the hot dry months of July and August.

One of the suggested improvements to the method used in this project would be planting the insectary plants in strips within the crop or at the edges of the field, rather than interspersed with the crop plants. This would allow for a permanent planting if perennials were used and provide a denser area of vegetation and refugia for beneficials.

Trials should be done to assess which native plants are most attractive to the lygus predators in this area, and to ensure they do not also attract lygus bugs. However, a California researcher does not think this is necessarily a problem. He has developed a blend of plant seeds called the Good Bug Blend, and found that planting this in hedgerows attracted both lygus bugs and beneficial insects to the field edges. He reasoned that this could be an advantage, because the predators would have the opportunity to control the pests outside of the crop area, and because the perennial hedgerow provided a stable overwintering environment for the predators, their numbers would build up earlier the next spring than in a field without one.

A row of trap crops could also be planted at one edge of the field a short distance away; these could include alfalfa and specific varieties of radish that have been shown to attract lygus bugs. These crops could then be vacuumed using a Bug-Vac to remove lygus, and thus reduce their numbers in the strawberry crop as has been done in California and the Fraser Valley.

Weed management is another factor that could be investigated. Total removal of weeds would decrease the amount of non-crop vegetation, and thus might decrease the numbers and diversity of natural enemies, but leaving weeds in the fields between seasons provides overwintering habitat for lygus which can result in high populations in the spring. A better solution might be to remove the weeds completely in the fall by tilling them under and/or heavily mulching, and mowing between rows regularly during the season. Alternatively, a cover crop could be planted in the fall and tilled under in the spring.

Permanent insectary plantings take several years to become established, so a project such as this should be continued over more than one year to obtain useful data. In conclusion, developing a good farmscaping program for organic farms is a matter of trial and error for each farm to determine the best methods to use for the pests that are present, but it can result in a significant reduction of pests and an economic savings to the grower that will more than make up for the time and resources invested.

Introduction

Biodiversity and pest management

Biodiversity refers to all species of plants, animals and microorganisms existing and interacting within an ecosystem. (Altieri, 1993). This biodiversity performs a variety of ecological functions in agro-ecosystems, such as providing vegetative cover to prevent soil erosion, maintaining the water balance, retaining and recycling nutrients, and aiding in the control of undesirable organisms (Altieri and Letourneau, 1982). When these natural functions are compromised, due to the adoption of monocultures or use of high-input technologies, including insecticides, fungicides, herbicides, and nematicides, biodiversity in agricultural systems, particularly in monoculture systems, is sacrificed, often leading to an increase in pest outbreaks (Wilby & Thomas, 2002). Diversified cropping systems, like many organic systems today where a variety of crops are grown together, usually contain natural elements of pest control, which can be enhanced by:
(1) providing alternative host-prey at times of pest host scarcity; (2) providing food (pollen and nectar) for adult parasitoids and predators; (3) providing refuges for overwintering, and (4) maintaining acceptable populations of the pest over extended periods to ensure continued survival of beneficial insects (Altieri 1993).

Organic agricultural practices aim to preserve and enhance biodiversity so that natural enemies can keep pest populations below the economic threshold. They include growing a variety of crops in one field, minimizing or eliminating tillage, a ban on the use of pesticides, herbicides, fungicides and inorganic fertilizers, amending the soil with organic materials to increase biomass, and providing food and habitat for natural enemies.

Biological Control and Natural Enemies

Biological control can be defined as "the process (both art and science) of balancing pest and natural enemy populations to a non-pest level" (Bellows, 2001). It can be done by introducing natural enemies of pests or by optimizing the habitat to conserve and increase existing natural enemies. Natural enemy introduction is an effective tool to restore balance in a community where an introduced pest species has appeared with no natural enemies to keep them in check and has subsequently become dominant (Bellows, 2001). Conserving and augmenting the habitat is an effective tool when natural enemies of native pests already exist but are not in high enough numbers to keep the pests in check.

Farmscaping

Farmscaping, defined as "the use of hedgerows, insectary plants, cover crops and water reservoirs to attract and support populations of beneficial insects such as insects, bats, and birds of prey"(Dufour, 2000), is an ecological approach to pest management that is being used increasingly by organic growers and IPM practitioners in coastal U.S. states, particularly California, and is being researched for its effectiveness by researchers in the agricultural departments of state colleges and funded by federal grants through agencies such as Attra (Appropriate Technology Transfer for Rural Areas) and CASFS (The Centre for Agroecology and Sustainable Food Systems). Its purpose is to enhance the attractiveness of the environment to natural enemies by providing sources of nectar and pollen, as well as refugia.

Refugia, or places of hiding, are important sources of natural enemies and alternative prey and hosts for them in organic crops. They can include natural refugia, or untended areas of native plants around the fields, or artificial refugia, which include habitats such as beetle banks, hedges, and areas planted with non-crop species, either native or introduced.

Because of the impermanence of annual cropping systems, permanent insectary strips or hedgerows in or along the side of a field are valuable for providing an undisturbed habitat for beneficial insects. In California, hedgerows in the central coast area include *Ceanothus* spp., *Rhamnus* spp. (coffeeberry), *Eriogonum* spp. (buckwheat), *Achillea millefolium* (yarrow), *Rosa californica* (wild rose), *Rubus ursinus* (blackberry), *Sambucus mexicana* (elderberry, and asters (CAFF publication, 2005). Other plants that are good in insectary strips include many members of the carrot (Apiaceae), sunflower (Asteraceae), and mint (Labiaceae) families. Swezey (2000) found that a hedgerow of insectary plants in a California strawberry field attracted beneficial insects that could control lygus bugs as well as mites.

Swezey & Goldman (2001) planted 200-600 square foot rows (perennial hedgerows) of growers' fields with native vegetation specific to the area and habitat in California. Plants included yarrow (*Achillea millefolium)*, coast buckwheat (*Eriogonum latifolium)*, several species of *Ceanothus*, coffeeberry (*Rhamnus californica)*, blue elderberry (*Sambucus mexicana,)*, an aster (*Coratherage californica)*, and a daisy (*Erigeron glaucus)*. Of these plants, the yarrow and the buckwheat were found to be most effective in establishing rapidly and attracting natural enemies.

A CAFS research program in California (Bryer et al, 2003) developed a trap crop system consisting of early-season plantings of radish and late-season plantings of alfalfa which provided continuous bloom over the season, and attracted lygus bugs away from the strawberries. A tractor-mounted Bug-Vac was used to remove the lygus from the trap crop.

Lygus as a Pest of Strawberries

Lygus bugs (*Lygus shulli*) are serious pests of many agricultural crops, resulting in annual losses to fruits and vegetables in Ontario of $12 million and to alfalfa in Saskatchewan of $50 million (Broadbent et. al. 2000). The industry in B.C. is worth $6 million annually; losses due to lygus bug could not be found in any published data. Since control of lygus has not been achieved using cultural practices such as crop rotation and weed management, conventional growers resort to chemical insecticides despite their toxicity to pollinating and beneficial insects.
Lygus bugs feed on the achenes of the strawberry, causing a deformation called “cat facing” or “monkey facing”. The greatest damage is done when lygus bugs feed on the fruit immediately after petal fall, and all stages of lygus from small nymphs to adults are capable of causing damage (Allen & Gaede, 1963). The deformity is caused by lygus puncturing individual achenes and sucking out the juices, and if a sufficient number of achenes are punctured on a berry, receptacle growth is affected and the berry develops unevenly (Allen & Gaede, 1963).

Natural Enemies of Lygus

Many insects which are generalist predators and feed on soft-bodies insects and mites also feed on lygus bugs, especially on young nymphs (Whitcomb & Bell, 1964; Clancy & Pierce, 1966). These include predators such as big-eyed bugs (*Geocoris sp.*), damsel bugs (*Nabis sp.*), brown lacewings (*Hemerobius* sp.), green lacewings (*Chrysoperla* sp.), assassin bugs (*Zelus* and *Sinea* species), ground beetles, rove beetles, and spiders; and parasites such as tachinid flies, and ichneumonid and braconid wasps. Henderson (1991) gives a thorough review of the pests and beneficial insects in strawberries and raspberries. While none of these native enemies has proved consistently effective in providing a commercial level of control in strawberries (Dufour, 2007), not much research has been done on their biology and ecology in cropping systems, and on the effects of conserving and augmenting them, particularly in organic crops. Very few of them are being commercially reared at this time.

Lygus Phenology

Lygus bugs overwinter as eggs laid in plants or adults hibernating in plant debris in the field. In the spring, eggs hatch or adults become active and lay eggs. They go through five nymphal stages, with a moult in between each one, until they reach the adult stage in about five weeks (Henderson, 1991). In the Fraser Valley, Gillespie et. al. (2003) found there were two generations of *Lygus shulli* Knight, *Lygus elisus* Van Duzee, and *Lygus hesperus*. Overwintering adults of *L. shulli* and *L. elisus* first appeared in April-May. Nymphs of the first generation of *L. shulli* appeared in early June, completed development by mid July, and nymphs of the second generation appeared in late July. There was no evidence of a third generation. Data suggested that adults collected in sweeps in late September were already in or close to their overwintering habitat and that they did not disperse from this habitat, meaning they overwinter in the strawberry plants.

Objectives of the Study

The objectives of this study were:
a) Through regular sweep net sampling of an organic strawberry field over several seasons to obtain an estimate of the insect diversity in an organic strawberry field, including potential or actual pests and their natural enemies, and
2) To determine whether a high lygus bug population could be reduced by planting a hedgerow along the side of the field and by planting insectary plants within the strawberry rows.

Materials and Method

2004-2005 Survey

An organic strawberry field, 100 m X 120 m containing 42 rows of the Seascape everbearing strawberry cultivar, was monitored during the 2004 and 2005 growing seasons by collecting and identifying samples of insects over the season. Data was collected in 2004 from July 13 to October 27, and in 2005 from April 20 to October 4. Sampling was done by sweeping with an insect net. A sample consisted of 25 sweeps in sets of five. A set consisted of sweeping back and forth five times in a straight line in one row of strawberries, then moving several paces to an adjacent area in the same row for the next set. The strawberry plants were contacted with the net during the sweeping in order to dislodge insects on the plants. The contents of the net were emptied into wide mouth black plastic jars with lids, placed into a cooler in the field, and taken to the lab for identification. Samples were kept in the freezer for at least 24 hours before identification to ensure all insects were dead. Samples were collected weekly except when it was raining.

Identification was done with a dissecting microscope and insect identification keys. Pests and beneficial insects were identified as far as possible to order and family by the author. Larger insects were pinned and placed into insect specimen boxes, and smaller ones were put into small vials containing 70% ethanol, and they were all housed in the insect collection at University College of the Fraser Valley in Abbotsford, B.C. A sample of aphids was sent to Cho-Kai Chan (SFU, retired) for identification. A sample of insects was identified by Dave Gillespie of PARC, Agassiz. A sample of parasitic wasps as well as other insects was sent to the National Identification Service in Ottawa for identification. Beetles were identified using the collection at PARC Agassiz with the help of Sheila Fitzpatrick. A weed survey was also done in August, 2005.

A hedgerow of flowering trees and shrubs was also planted in May 2005 along one side of the treated half of the field, with a path separating it from the field. The plants included cascara (*Rhamnus purshiana),* willows (*Salix* sp.), elderberry (*Sambucus racemosa),* and native roses (*Rosa woodsii* and *Rosa nutkana*).

2006 Research Experiment

In the 2006 season, the field was divided into two halves, each half containing 21 rows of strawberry plants. In the experimental half of the field, alternate rows were planted with five kinds of insectary plants – yarrow, dill, fennel, cosmos, and chrysanthemum – one plant of each kind per experimental row. In each of these rows, the five plants were spaced equally apart within the row. The order of plants was randomly determined. The plants were obtained as bedding plants from a local nursery, and were planted initially in late April. Considerable replanting was necessary due to slug damage, and most of the chrysanthemum and dill plants did not survive. The control half of the field received no treatment.

Within each half of the field, eight sampling sites were selected, consisting of two per row in four rows spaced equally apart, and marked with flagging tape on a bamboo stake set into the ground. Rows 1 to 8 were controls and rows 9 to 16 were treatment rows. Sampling was done using the sweep net method as in the previous two years at approximately weekly intervals. Insects were grouped into the categories listed in Table 1 and counted from each of the eight sites separately, and the data was averaged.

Results

Insect Diversity and Lygus Predators

The sweep net samples contained a wide variety of insects, not all of which were identified or counted. Those which were potential pests, predators or parasites were counted, and, where possible, identified. Table 1 lists the insects identified over the three year period from 2004 to 2006, and Appendices A to C contain the averaged raw data for each year.

Population numbers for the three main generalist predators, *Geocoris, Nabis and Hemerobius,* are given in Table 2. In 2004, *Geocoris* were not collected until the end of the season, when there were an average number of 2.25 *Geocoris* per 25 sweeps in September and 3.13 in October. In 2005, *Geocoris* was collected in June at 0.12 per 25 sweeps, and in October at 1.00 per 25 sweeps. In 2006, they were collected only in October at 0.10 per 25 sweeps.

Damsel bugs (*Nabis* sp.) were collected in September and October, 2004, at an average of 0.38 per 25 sweeps; in both 2005 and 2006 none were collected.

Brown lacewings (*Hemerobius* sp.) were collected at the rate of 0.25 and 1.00 per 25 sweeps in August and October 2004 respectively, and throughout the summer of 2005 at rates of 0.12 to 0.88 per 25 sweeps. They were collected in April 2006 at 0.60 per 25 sweeps, but not in any subsequent months of that year.

Other potential predators or parasites collected in the field samples included assassin bugs (Family Reduviidae), minute pirate bugs (*Orius* sp.), ladybird beetles, rove beetles, tachinid flies, and parasitic wasps from the families Pteromalidae, Encyrtidae, Ichneumonidae, Braconidae, Sceleonidae, and Proctotrupidae. Some of these were identified by Agriculture Canada's National Identification Service in Ottawa, and are listed in Table 1.

Lygus Population Trends

In 2004, data collection started July 13, and the low numbers of lygus on that date would indicate that the first generation had completed development. A peak on July 28 could be attributed to a second generation of lygus, and another peak on September 6 is evidence of a third generation. There were a relatively large number of adults still in the field on October 27, 2004.

In 2005 and 2006, the first generation of nymphs appeared in mid-May and completed development by the end of June. Due to a hiatus in data collecting for two months in 2005 the timing of the second generation cannot be verified for that year. In 2006 the numbers of adults and nymphs declined to such low levels from July to September that a second generation did not appear. Numbers of overwintering adults in the samples in 2005 were slightly lower than in 2004, and almost none in September 2006.

Effect of Insectary Plantings

Yarrow, fennel and cosmos plantings became established in the treated half of the field and started blooming in early August. Compared to the two previous years, the population of lygus in 2006 was much lower from mid-June to the end of the season in mid-September in both the rows that had insectary plantings and those that did not. There was a significant difference between the treated and untreated rows on May 18 (Student's t-test, $p = 0.04$) but not on any other dates (see Figure 4).

Discussion

Insect Diversity and Lygus Predators

Lygus predators were present in 2004 at levels that indicate they could have been important biocontrol agents of lygus. In September 2004, the ratio of *Geocoris* to lygus was 2.25 *Geocoris* to 6.63 lygus per 25 sweeps. Clancy and Pierce (1966) reported that in laboratory feeding studies *Geocoris* consumed 1.5 to 4.2 lygus eggs per predator per day. Damsel bugs, which also prey on lygus eggs and nymphs, can consume up to 3.8 nymphs per predator per day (Clancy and Pierce, 1966) and even at low numbers can help to reduce pest numbers. Lacewings are other generalist predators that feed on lygus eggs and nymphs. Brown lacewings (*Hemerobius* sp.) are very good biocontrol agents; the adults are long-lived, have a high reproductive capacity, and both adults and larvae have voracious appetites, whereas only the larvae of green lacewings (*Chrysoperla* sp.) are insect predators. The population of *Hemerobius* increased from August to September of

2004, and they were collected in April of the next year, indicating that they overwintered that year, probably in the strawberry plants and surrounding weeds. Similarly, there was an overwintering population between the fall of 2005 and the spring of 2006, but by the end of the summer there were no lacewings collected in any of the samples. The reason for this is most likely correlated with a general decline in numbers of all insects, including lygus, in the field from the third week of June on, indicating a lower quality of plant nutrition.

Lygus Population Trends

Nymphs of the first generation of *L. shulli* were collected earlier in the spring, in mid-May, in both 2005 and 2006, than has been reported in previous research done in the Fraser Valley (Gillespie et al, 2003), when they were first collected in early June. This could be due to a change in weather patterns, with warmer weather occurring earlier than in previous years. This earlier onset of warm weather as well as unseasonably warm weather (above 20C) continuing into October could also account for three generations of lygus in 2004, as evidenced by a peak of nymphs on September 6 and an increase in adults continuing until the last sample on October 27, which also still included some nymphs.

In 2005, the average number of nymphs of the first generation was very high at over 20 per 25 sweeps, and accounts for the high percentage of berries being downgraded to #2 (the grower estimated 40-50%). However, the price that could be obtained for #1 berries ($4 per pound at that time) compensated for the losses, and the deformed berries were still attractive to buyers because they were organic, and could be sold at a reasonable price (about $2 per pound). Nevertheless, lygus damage resulted in considerable economic loss to this grower that year.

In 2006, the number of nymphs in the first generation was as high as it had been in 2005, but most of these nymphs did not appear to develop into adults or perhaps left the area, because the number of adults declined after June 30 to less than 2 per 25 sweeps. The grower rented out the field that year, and the renter sold the berries at one grade and reported relatively low losses due to lygus. Two theories can account for this decline in lygus numbers: the natural enemies hypothesis (top-down), or the resource concentration hypothesis (bottom-up) (Muller & Brodeur, 2002). The natural enemies hypothesis would explain a reduction in pests mainly as a result of an increase in predators/natural enemies, and the resource concentration hypothesis would explain it as a result of a decrease in the quality or quantity of the food supply. In this experiment, the quality and quantity of the lygus bug food source declined over the three years of the study. The strawberry plants were in their fourth year of production and nutrients had not been applied to the soil since compost was added the year they were planted. Many plants had died in the last two years also, due to the watering system not reaching all areas of some rows, so that the density was reduced compared to the previous two years. Weeds had taken over the areas where plants had died, so there was additional competition for nutrients. The plants in the third year were visibly smaller, as were the berries. The purpose of this research project was to attempt to manipulate top-down effects by increasing natural enemy populations, but there was no evidence of an increase in predators during the 2006 season; in fact, their numbers declined. Thus, there is more evidence to conclude that the bottom-up effects of poor plant quality were responsible for reduced lygus populations, as well as of other insects as well.

Effect of Insectary Plantings

The results did not show a significant difference in numbers of lygus bugs between the experimental and the control sections of the field except on one early date, and overall insect populations, including lygus, dropped dramatically from mid-June to the end of the season. This was most likely due to a decline in crop plant quality, as the strawberries were in their fourth year of production, and to some problems with the irrigation system which resulted in some areas of the field not receiving adequate water during the hot dry months of July and August. Because of the overall decline in insect numbers after the end of June 2006, it is not possible to draw any conclusions about the effect of the insectary plantings and the hedgerow based on this one year of data. Treatment effects of a perennial hedgerow may not appear in the first year, due to the long establishment time of many of the plants (Swezey, 1999). In addition, the hedgerow planted in this project did not have as wide a diversity of flowering plants as has been found successful in other research (Swezey & Goldman, 2001), and could have included other shrubs such as *Ceanothus* sp., *Erigeron* sp. and *Eriogonum* sp.

Further Research

One of the suggested improvements to the method used in this project would be planting the insectary plants in strips within or near the crop, rather than interspersed with the crop plants. Swezey (1999) found that strawberry field edges planted with a mixture of annuals called the Good Bug Blend attracted more lygus and more generalist predators than did a control area. He considered it advantageous to concentrate beneficial insects in the non-crop vegetation because this might prevent pest species from ever reaching the crop area. In the second year of this two-year project, Swezey modified the Good Bug Blend to include only alfalfa, mustard and alyssum, which are all lygus attractors. In the spring, lygus went into the trap crop before they moved into the strawberries, and counts obtained then could be used to predict future populations in the strawberries using a degree-day model. These predictions were then used to time application of control measures, such as mowing, release of predators or pesticide application.

A CAFS research program in California developed a trap crop system consisting of early season plantings of radish and late season plantings of alfalfa which provided continuous bloom over the season, and attracted lygus away from the strawberry crop. A tractor-mounted Bug-Vac was used to remove the lygus from the trap crop.

The Bug-Vac was also used in B.C. and it was found to decrease lygus populations in Fraser Valley strawberries by 31%, while not affecting the numbers of two-spotted mites, aphids, predator mites and ladybugs (Krause, 1996).

Other possible methods of control include the use of fungal pathogens such as *Beauveria bassiana*, and the release of parasitoids such as *Peristenus digenutis* and *Anaphes iole*. The fungus *Beauveria bassiana* has been shown to reduce lygus damage by about 50% when applied to younger nymphs and with adequate humidity (Kovach & English-Loeb, 1997). *Peristenus digenutis* has been introduced in the U.S. and has established in the northeastern states (Tilmon & Hoffman, 2003).

Weed management is another factor that could be investigated. Total removal of weeds would decrease the amount of non-crop vegetation, and thus might decrease the numbers and diversity of natural enemies, but leaving weeds in the fields between seasons provides overwintering habitat for lygus which can result in high populations in the spring. A better solution might be to remove the weeds completely in the fall by tilling them under and/or heavily mulching, and mowing between rows regularly during the season. Alternatively, a cover crop could be planted in the fall and tilled under in the spring. *Anaphes iole* has been used in California with some success (Udayagiri et. al., 2000).

Summary and Conclusions

A three-year study of pest and predator populations in a Langley strawberry field showed a variety of generalist predators with the potential to keep lygus bugs in check. This potential could be enhanced if combined with farmscaping tools such as permanent insectary plantings, trap crops, the use of a Bug-Vac to remove pests, and good weed management.

Because lygus phenology is directly affected by temperature and host plant quality, one year of collecting data is not sufficient to assess the effectiveness of adding non-crop vegetation to this field. It illustrates the complexity and instability of agricultural ecosystems, where a major pest can be present one year and gone the next, and the difficulty of translating theory into practice over a short time period. Better information could be achieved by doing a longer term study in fields with well-established permanent plantings as well as annual plantings such as the Good Bug Blend.

As a tool, farmscaping requires more knowledge and skill on the part of the grower than conventional pest management. Consideration must be given to the cost of developing and maintaining beneficial habitats, as well as the cost of the land taken out of production. A systematic type of approach, taking into consideration the ecology of the pests and beneficials, their development cycles, their food sources, their movement in and out of the crop, as well as the role of the existing vegetation in and around the field will result in a successful plan which can be a significant part of a successful pest control strategy.

In conclusion, developing a good farmscaping program for organic farms is a matter of trial and error for each farm to determine the best methods to use for the pests that are present, but it can result in a significant reduction of pests and an economic savings to the grower that will more than make up for the time and resources invested.

References

Allen, W.W., & S.E. Gaede. 1963. The relationship of lygus bugs and thrips to fruit deformity in strawberries. Journal of Economic Entomology 56: 823-825.

Altieri, M.A. 1993. Biodiversity and pest management in agroecosystems. Haworth Press, Inc., New York, NY, US.

Altieri, M.A. and Letourneau.1982. Vegetation management and biological control in agroecosystems. Crop Protection 1: 405-430.

Bellows, T.S. 2001. Restoring population balance through natural enemy introductions. Biological Control 21: 199-205.

Broadbent, A.B., P.G. Mason, S. Lachance, J.W. Whistlecraft, J.J. Soroka and U. Kuhlmann. 2000. *Lygus* spp., Plant Bugs (Hemiptera: Miridae). In P.G. Mason and J.T. Huber (eds.) Biological Control Programmes in Canada, 1981-2000. CABI Publishing, Oxon, U.K.

Bryer, J., D. Nieto, R Holbrook, and Swezey, S. 2003. *Lygus hesperus* control in strawberries. In CASFS 2001-2003 Activity Report and Research Summary, University of California, Santa Cruz.

Clancy, D.W. and Harold D. Pierce. 1966. Natural Enemies of some lygus bugs. Journal of Economic Entomology Vol. 59, No.4: 853-858.

Dufour, Rex. 2000. Farmscaping to enhance biological control. NCAT/ATTRA Pest Management Series. National Center for Appropriate Technology, Fayetteville, Arkansas.

Gillespie, D.R., Foottit, R.G., Shipp, J.L., Schwartz, M.D., Quiring, D.M.J., and Wang, K. 2003. Diversity, distribution and phenology of *Lygus* species (Hemiptera: Miridae) in relation to vegetable greenhouses in the lower Fraser Valley, British Columbia, and southwestern Ontario. Journal of the Entomological Society of British Columbia 100: 1-12.

Guerena, Martin and Holly Born. 2007. Strawberries: Organic Production. NCAT/ATTRA publication. National Center for Appropriate Technology, Fayetteville, Arkansas.

Henderson, D.E. and D.A. Raworth. 1991. Beneficial insects and common pests on strawberry and raspberry crops. Agriculture Canada Publication 1863/E. 33 pp.

Kovach, J. and G. English-Loeb. 1997. Testing the efficacy of Mycotrol ES, *Beauvaria bassiana*, on tarnished plant bugs, Lygus lineiolaris, in New York Strawberries. http://www.nysipm.cornell.edu/publications/beauveria/beauveria.html

Krause, E. 1996. The Bug-Vac and lygus bug control. In: Soraka, Juliana. 1996. Proceedings of the Lygus Working Group Meeting. Agriculture and Agri-Food Canada. Ottawa, Ontario, Canada. April 11-12.

Muller, C. B. and J. Brodeur. 2002. Intraguild predation in biological control and conservation biology. Biological Control 25: 216-223.

Swezey, S. 1999. Impacts of non-crop farmscape vegetation on strawberry pest dynamics in the Elkhorn slough watershed. Pest Management Grants Final Report for contract #97-0234. Prepared for California Department of Pesticide Regulation. 10 pp.

Swezey, S. and P. Goldman. 2001. Expansion and optimization of farmscaping in strawberries for pesticide use reduction and erosion control –final report. U.S. Environmental Protection Agency, Pesticide Environmental Stewardship Program.

Tilmon, K.J., and M.P. Hoffmann. 2003. Biological control of *Lygus lineolaris* by *Peristenus* spp. in strawberry. Biological Control, 26 (3): 287-292.

Udayagiri, S., S. C. Welter, and A. P. Norton. 2000.Biological control of *Lygus hesperus* with inundative releases of *Anaphes iole* in a high cash value crop. Southwestern Entomologist Supplement 23.

Whitcomb, W.H. and K. Bell. 1964. Predaceous insects, spiders and mites of Arkansas cotton fields. Arkansas Ahr. Exp. Sta. Bull. 690. 84 pp.

Wilby, A. and M.B. Thomas. 2002. Are the ecological concepts of assembly and function of biodiversity useful frameworks for understanding natural pest control? Agricultural and Forest Entomology 4: 237-243.

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Table 1. Pests and Beneficial Insects in a Langley Strawberry Field
July 2004 - September 2006

Order	Common Name	Scientific Name	Notes
Hemiptera	Lygus bugs	*Lygus shulli* (Knight)	
	Bigeyed bugs	*Geocoris sp.*	
	Minute pirate bugs	*Orius tristicolor*	
	Damsel bugs	*Nabis alternatus*	
	Damsel bugs	*Neides muticus*	
	Assassin bugs	*Empicoris rubromaculatus* (Blackburn)	found in spider webs
	Lace bugs	*Acalypha parvula* (Fallen)	feeds on moss, incidental to strawberries
	Seed bugs	*Scolopostethus thomsoni* Reuter	
Homoptera	Aphids	*Macrosiphon rosae*	
		Sitobion fragariae	
		Rhopalosiphum sp.	
		Acyrthosiphon pisum	
		Ericaphis fimbriata	
	Froghoppers	*Philaenus spumarius* (L.)	meadow spittle bug
	Leafhoppers	*Empoasca sp.*	
		Macrosteles sp.	
		Dikraneura sp.	
		Euscelis (Euscelidius) variegatus (Kirschbaum)	new Canadian record
Coleoptera	Ladybird beetles	*Psyllobora 20-maculata*	
		Harmonia axyridis	
	Spider mite destroyer	*Stethorus punctatum*	
	Rove beetles	not identified to genus	
	Flea beetles	not identified to genus	
	Leaf beetles	not identified to genus	
	Ground beetles	*Trechus obtusus*	
	Ground beetles	*Awara sp.*	
	Ground beetles	*Carabus granulatus*	
	Ground beetles	*Pterostichus melanarius*	
	Carrion beetles	*Nicrphorus defoiens*	
	Click beetles	*Agriotes lineatus*	
	Clover weevil	*Sitona sp.*	
	Broad-nosed weevil	not identified to genus	
Hymenoptera	Parasitic wasps: chalcids	Encyrtidae family, not identified to genus	
		Torymus sp. (Torymidae)	parasites of gall-forming insects
		Cyrtogaster vulgaris Walker (Pteromalidae)	parasites of dipterans (flies)
		Asaphes californicus Girault (Pteromalidae)	hyperparasites of aphids
		Miscogaster sp. (Pteromalidae)	
		Trichomalopsis sp. (Pteromalidae)	parasites of beetles, moths and butterflies
	Parasitic wasps:		
	Ichneumonidae	Orthocentrinae group	parasitoids of fungus gnats
		Phygadeuontini: *Atractodes sp.*	parasitoids of muscomorph flies
		Phygadeuontini group	parasitize a wide variety of insect hosts
	Parasitic wasps:		
	Sceleonidae	not identified to genus	
	Parasitic wasps:		
	Braconidae	not identified to genus	
	Parasitic wasps:		
	Proctotrupidae	not identified to genus	
	Gall wasps		
	Sawflies		
Diptera	Syrphids	*Syrita pipiens*	
Neuroptera	Brown lacewings	*Hemerobius sp.*	
	Green lacewings	*Chrysoperla sp.*	
Arthropoda	Twospotted spider mites	*Tetranychus urticae*	
	Red mites	not identified to genus	

Table 2. Predator Populations in a Langley Strawberry Field: July 2004 - September 2006

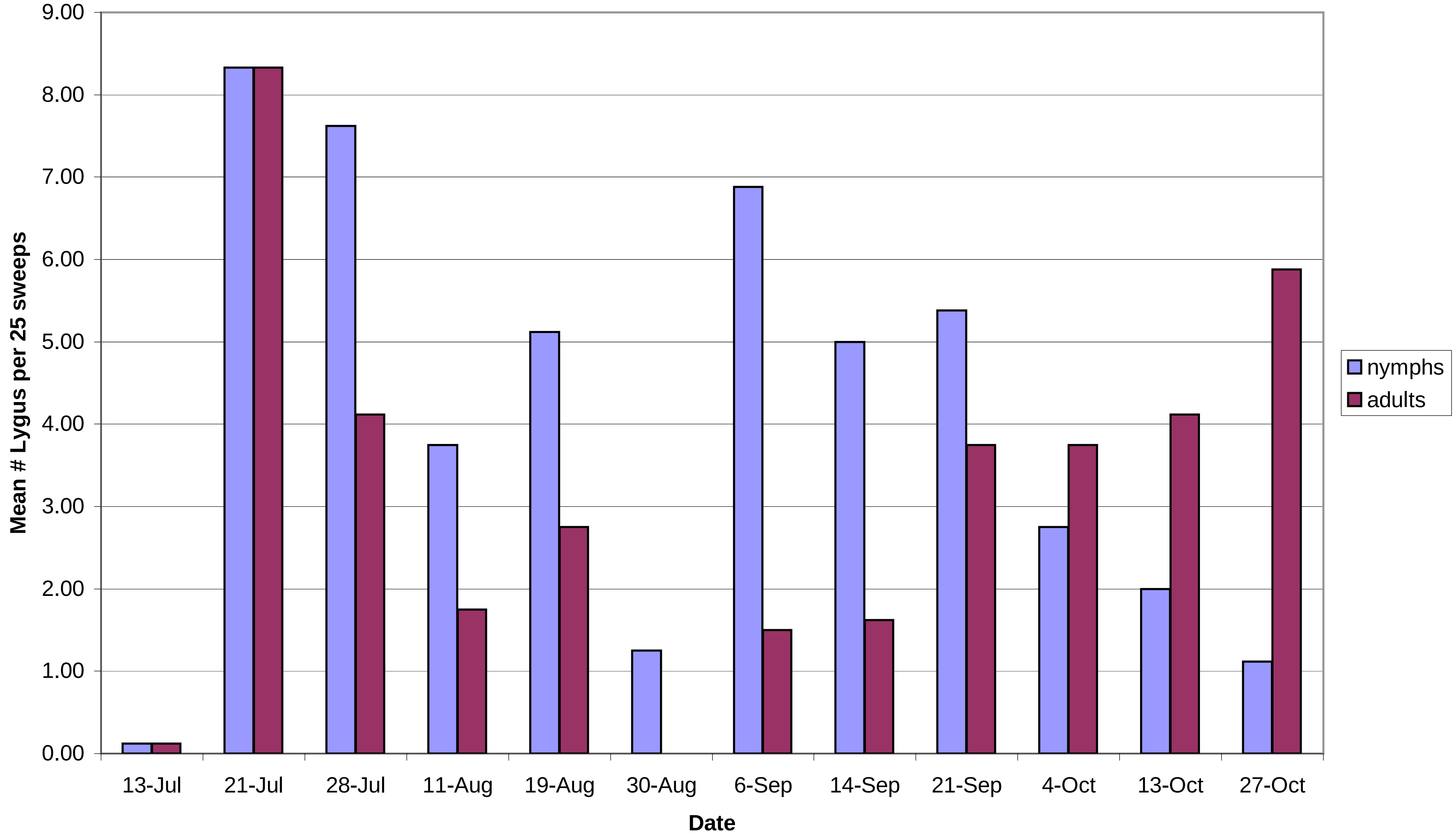
	Average # per 25 sweeps						
2004:							
	April	May	June	July	August	September	October
Geocoris				0.00	0.63	2.25	3.13
Nabis				0.00	0.00	0.38	0.37
Hemerobius				0.00	0.25	0.00	1.00
2005:							
	April	May	June	July	Aug	Sept	Oct
Geocoris	0.00	0.00	0.12		0.00		1.00
Nabis	0.00	0.00	0.00		0.00		0.00
Hemerobius	0.12	0.25	0.12		0.88		0.12
2006:							
	April	May	June	July	Aug	Sept	Oct
Geocoris	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Nabis	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemerobius	0.60	0.00	0.00	0.00	0.00	0.00	0.00

Table 3: Mean numbers of *Lygus shulli* in strawberries, 2004	
Date	Mean ± stdev
13-Jul	0.13 ± 0.00
21-Jul	8.38 ± 4.69
28-Jul	11.75 ± 6.25
11-Aug	5.50 ± 3.63
19-Aug	7.88 ± 3.80
30-Aug	1.25 ± 1.58
6-Sep	8.38 ± 4.78
14-Sep	6.63 ± 5.55
21-Sep	9.13 ± 5.03
4-Oct	6.50 + 3.12
13-Oct	6.13 + 4.58
27-Oct	7.00 + 3.78

Table 4: Mean numbers of *Lygus shulli* in strawberries, 2005	
Date	Mean ± st dev
20-Apr	0 ± 0
27-Apr	0.50 ± 0.53
11-May	19.75 ± 8.91
19-May	21.06 ± 8.29
6-Jun	12.44 ± 6.09
15-Jun	7.07 ± 4.45
23-Jun	1.50 ± 1.67
26-Aug	4.88 ± 4.88
4-Oct	3.94 ± 3.43

Table 5: Mean numbers of *Lygus shulli* in treated and untreated rows of strawberries, 2006		
Date	rows 1-8 (untreated)	rows 9-16 (treated)
12-May	3.38 ± 2.50	2.38 ± 3.80
18-May	13.88± 6.56	7.62 ± 4.41
30-May	5.62 ± 2.97	5.00 ± 3.16
9-Jun	5.88 ± 2.30	6.38 ± 2.56
22-Jun	2.25 ± 1.04	1.50 ± 1.51
30-Jun	0.25 ± 0.46	0.25 ± 0.46
14-Jul	0.50 ± 0.53	0.12 ± 0.35
1-Aug	1.25 ± 1.16	1.12 ± 1.13
13-Aug	2.00 ± 1.31	0.88 ± 1.13
24-Aug	2.25 ± 2.55	1.25 ± 1.28
13-Sep	1.00 ± 1.31	0.38 ± 0.74

Figure 1: Lygus populations at Murray Creek 2004



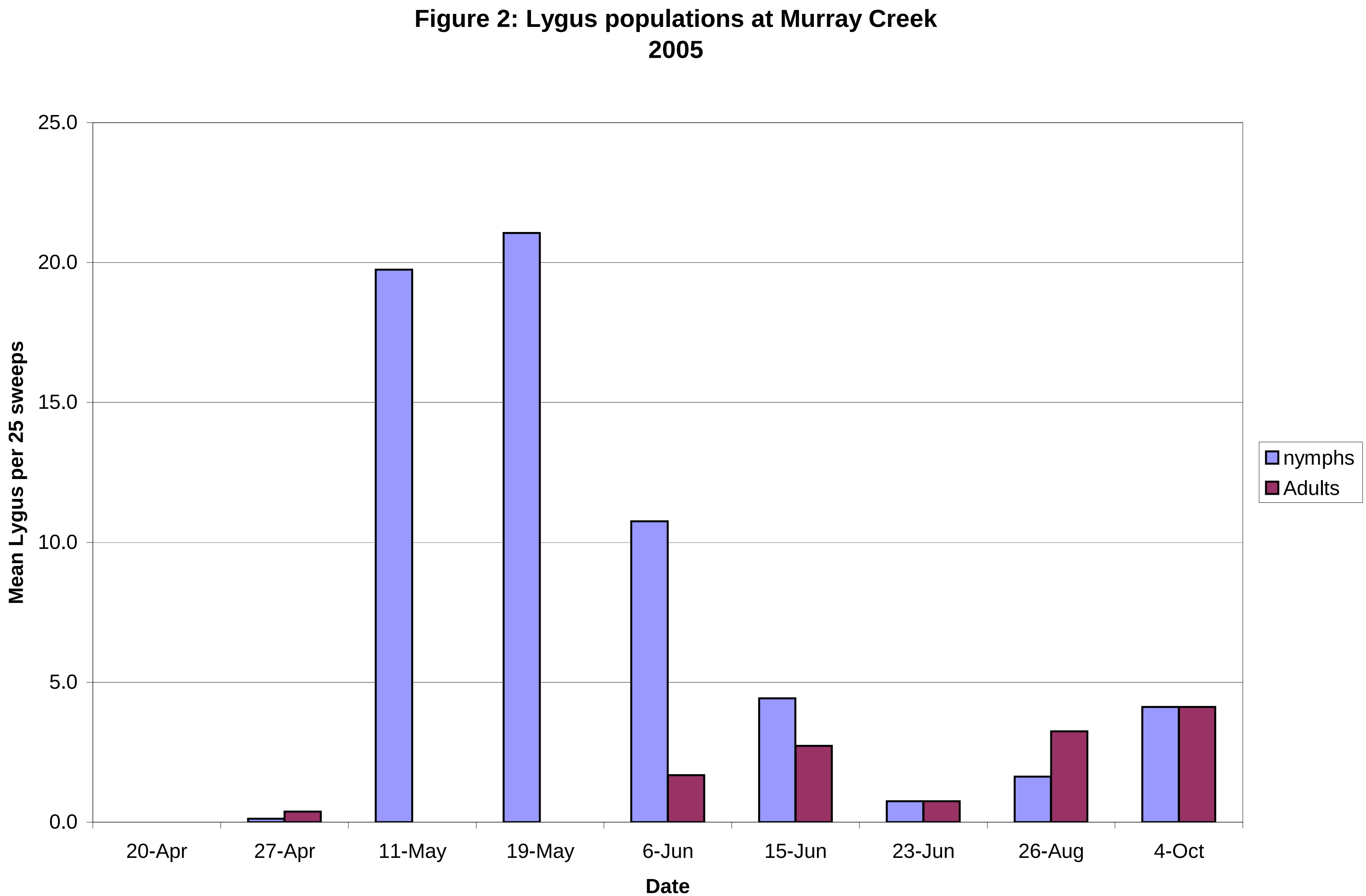


Figure 2: Lygus populations at Murray Creek
2005
Mean Lygus per 25 sweeps
25.0
20.0
15.0
10.0
5.0
0.0
20-Apr
27-Apr
11-May
19-May
6-Jun
15-Jun
23-Jun
26-Aug
4-Oct
Date
nymphs
Adults

Figure 3: Lygus populations at Murray Creek
2006

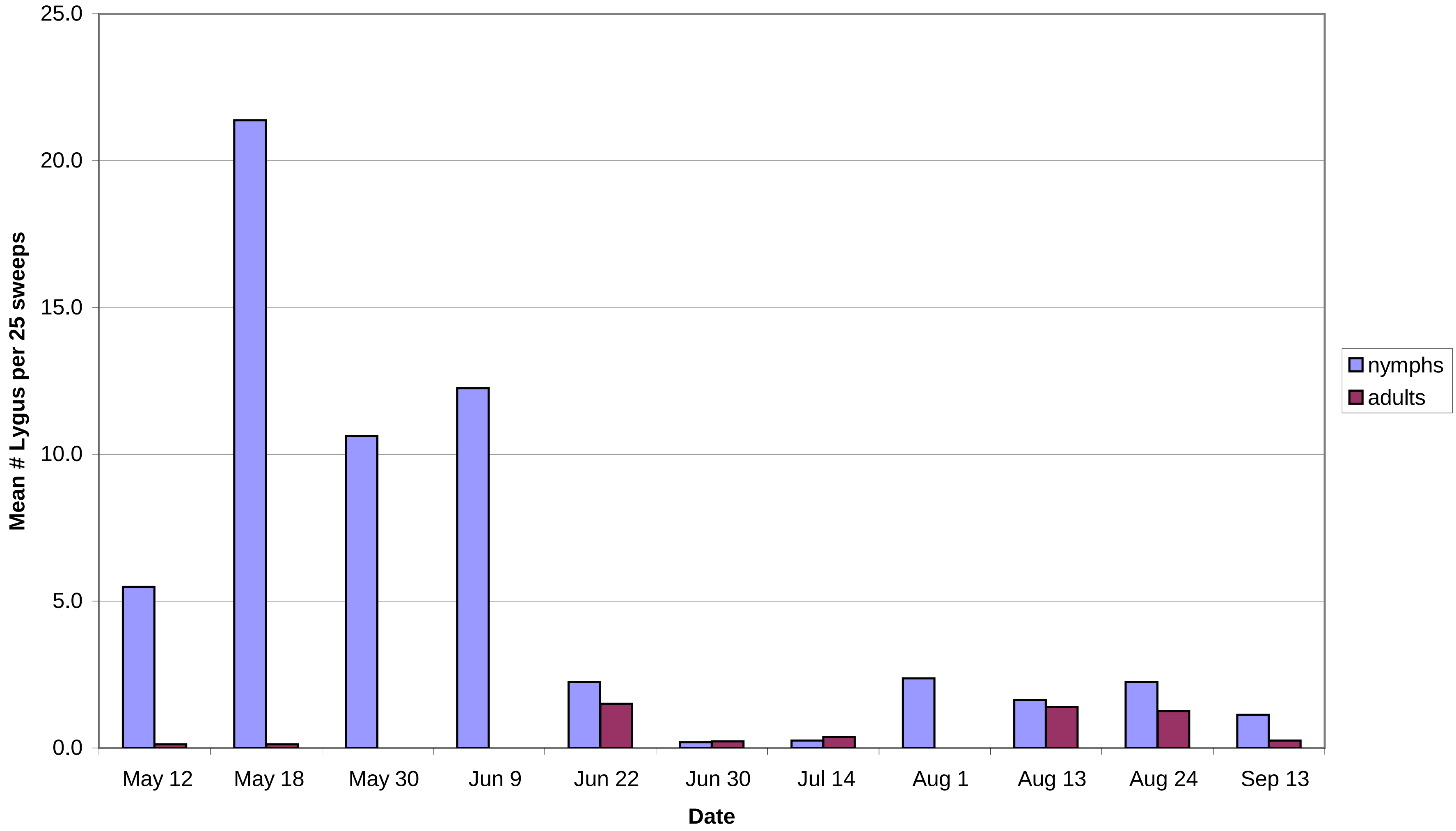
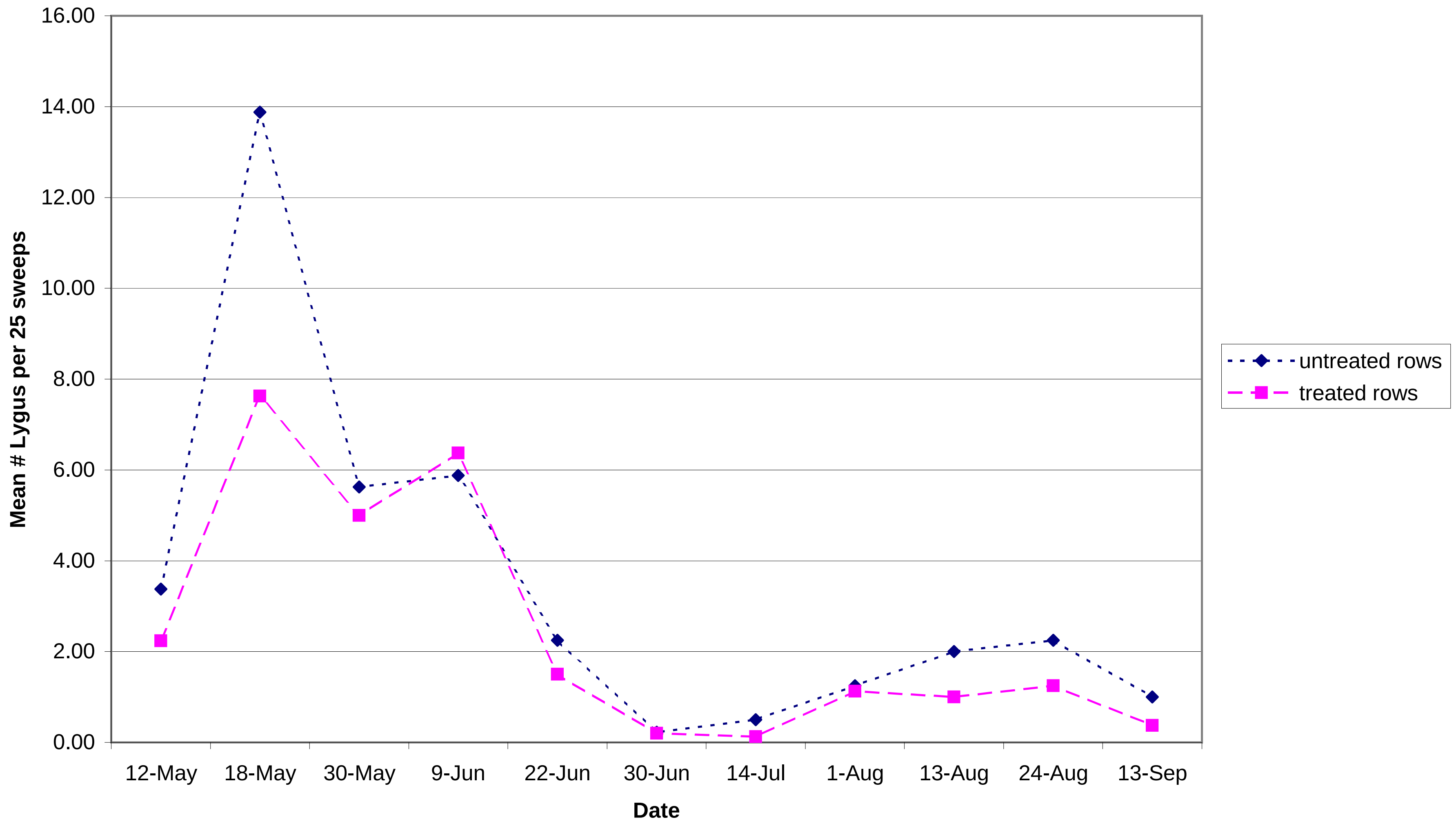


Figure 4: Lygus populations in treated and untreated rows of strawberries at Murray Creek Farm, Langley, B.C. in 2006



Appendix A
Murray Creek Data 2004

Murray Creek Data - 2004													
Average number of insects per 25 sweeps													
		13-Jul	21-Jul	28-Jul	11-Aug	19-Aug	30-Aug	6-Sep	14-Sep	21-Sep	4-Oct	13-Oct	27-Oct
Hemiptera	Mirids (excl Lygus)												
	Lygus sp. adults	0.12	8.33	4.12	1.75	2.75	0.00	1.50	1.62	3.75	3.75	4.12	5.88
	Lygus sp. nymphs	0.12	8.33	7.62	3.75	5.12	1.25	6.88	5.00	5.38	2.75	2.00	1.12
	Geocoris sp.			0.00	0.38	0.25	0.00	0.00	1.00	1.25	0.88	1.00	1.25
	other Lygaeidae												
	Pentatomidae	0.12		0.00	0.00		0.25	0.12	0.12		0.00	0.12	0.12
	Anthocoridae	3.81	2.08	6.38	5.75	2.88	0.50	3.00	0.88	2.38	0.12	0.50	0.50
	Reduviidae			0.00		0.00		0.00	0.00	0.12	0.00	0.25	0.25
	Nabidea			0.00		0.00		0.00	0.00	0.38	0.00	0.25	0.12
Homoptera	Aphids	4.19	6.25	6.25	0.88	0.00	0.00	0.50	1.25	5.25	5.62	11.62	24.62
	Froghoppers	1.44	3.33	3.00	3.38	0.12	2.25	0.00	1.25	2.12	2.50	7.25	22.50
	Leafhoppers	4.12	7.92	11.50	19.25	22.38	1.12	18.00	7.38	22.38	12.62	8.75	20.00
	Whiteflies		0.20	0.00	0.00	0.12	0.00	0.88	0.38	0.75		0.00	0.25
	Thrips							0.88	0.68	0.38	0.00	0.12	0.00
Coleoptera	Ladybugs-red	0.19	0.20	0.12	0.12	0.12	0.12	0.25	0.25	0.00	0.00	0.00	0.12
	Ladybugs-yellow	0.88	0.42	0.50	0.88	0.50	0.00	0.88	0.68	0.62	0.12	0.12	0.12
	Ladybug larvae	0.25	0.42							0.25			0.12
	Flea beetles	2.44	2.50	1.62	2.50	3.12	1.12	7.62	6.62	22.75	3.50	5.00	9.38
	Leaf beetles	0.56	1.47	0.88	0.50	1.50	0.88	3.62	2.88	12.38	6.25	7.50	10.38
	Stethorus sp.	1.56	1.87	3.12	1.00	0.88	1.75	0.25	0.12	0.62	0.12	0.00	0.00
	Weevils												
	Rove beetles						0.12	0.00	0.00	0.00	0.00	0.50	0.62
Hymenoptera	Aphelinidae		3.33	2.12	2.88	2.25	0.88	0.38	0.38	1.62	0.50	0.00	0.25
	Sceleonidae		0.00	0.38	1.50	0.88	1.12	0.68	0.25	0.88	0.50	0.50	0.38
	Pteromalidae		0.83	1.12	1.00	0.88	0.68	0.12	0.12	0.62	0.25	0.62	0.75
	Braconidae	0.06	4.58	2.62	1.00	0.88	1.62	0.38	0.25	0.88	0.88	0.62	0.88
	Ichneumonidae		0.00	0.12	0.00	0.12	0.00	0.12	0.38	0.25	0.12	0.88	0.88
	Proctotrupidae		0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12
	Gall wasps	0.56	0.42	0.50	0.12	0.38	0.12	0.12	0.00	0.50	0.12	0.38	0.50
	Sawflies												
Diptera	Syrphids		0.42	0.12	0.25	0.00	0.00	0.12	0.00	0.12	0.12	0.12	0.12
	Fungus gnats		0.63	1.00	0.38	0.12	0.68	1.00	0.25	1.38	0.62	0.25	0.25
	Midges		0.20	0.50	0.88	0.12	0.50	0.50	5.50	0.50	5.25	0.50	0.68
	Tipulidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.62	13.38	13.38	6.88
	Tachinidae												
	Fruit flies												
Neuroptera	Lacewings - adults							0.00	0.00	0.00	0.00		
	Lacewings - larvae					0.25		0.00	0.00	0.00		0.38	0.62
Arthropoda	Spider mites						18.38	0.25	0.00	0.12	0.12	0.00	0.00

Appendix B
Murray Creek Data 2005

Murray Creek Data - 2005																
Average number of insects per 25 sweeps																
		20-Apr	27-Apr	11-May	19-May	19-May	6-Jun	6-Jun	15-Jun	15-Jun	23-Jun	23-Jun	26-Aug	26-Aug	4-Oct	4-Oct
	rows	1-16	1-16	1-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16
Hemiptera	Mirids (excl Lygus)															
	Lygus adults	0	0.38	0	0	0	1.62	1.75	1.88	3.57	0.5	1	5	1.5	0	0
	Lygus nymphs	0	0.12	19.75	19.25	22.87	10.38	11.12	4	4.86	0.25	1	5	1.5	0	0
	Total Lygus	0	0.5	19.75	19.25	22.87	12	12.87	5.88	8.43	0.75	2	10	3	0	0
	Geocoris sp.							0.12							0.5	0.5
	Pentatomidae															
	Anthocoridae	0.12				0.12							2.62	0.25		
	Reduviidae															
	Nabidae															
Homoptera	Aphids, green		0.5	0.25		0.25	0.38	0.12		0.25			0.38			
	Aphids, brown	0.12	0.12	0.12	0.12	0.75	0.75	0.88	0.12	2.38			1.12	3.25	2.88	2
	Froghoppers	0.38			0.25	0.62	1.5	2.38	2.88	3.57	2.25	3.38	0.5	0.38	1.5	
	Leafhoppers	1.5	0.38		0.62	0.5	3.38	4.88	3.88	7.57	4.25	6.25	8.5	2.38	14.62	19.88
Coleoptera	Ladybugs, red				0.12											
	Ladybugs, yellow															
	Ladybug larvae															
	Flea beetles	7.88	11.75	9.12	3.25	14.62	2.38	1.25	1.62	1	2.75	4.25	2.62	1	3.88	3.5
	Leaf beetles								0.62	2.88	6.25	1.12	0.88	0.38	5.12	4.12
	Stethorus sp.	0.12		0.12		0.38		0.25	0.62	1.12	0.75	1	1	0.62	1.62	2.12
	Rove beetles	0.38						0.25	0.38	0.57					0.12	0.12
	Clover weevils	0.25			0.12	0.5	0.12	0.38	3.25	3.88					0.25	0.12
	Broadnosed weevils	0.12														
Hymenoptera	Chalcids	1.25		0.25	0.62	1.75	0.5	1.75	0.75	0.57	0.62	0.38	2.38	2.88	1.38	1.12
	Other parasitic	0.38	0.38	1.12		1.25	0.25	0.25	1.29	1	1	0.62	0.25	0.38	1.75	1
	Gall wasps															
	Sawflies															
Diptera	Syrphids															
Arthropoda	Spider mites															
	Red mites	0.25	0.12	0.12	0.75	0.5	1.38	1	1	1	0.38	0.25				
Neuroptera	Green lacewings												0.25			0.12
	Brown lacewings		0.12	0.25							0.12		0.25	0.38		

Appendix C
Murray Creek Data 2006

Murray Creek Data - 2006																							
Average number of insects per 25 sweeps																							
		12-May	12-May	18-May	18-May	30-May	30-May	9-Jun	9-Jun	22-Jun	22-Jun	30-Jun	30-Jun	14-Jul	14-Jul	1-Aug	1-Aug	13-Aug	13-Aug	24-Aug	24-Aug	13-Sep	13-Sep
	rows	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16	1-8	9-16
Hemiptera	Mirids (excl Lygus)		0.3							0.1		0.4	0.8	0.3	0.3	0.6	0.5		0.1				
	Lygus adults	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.1	0.0	0.3	0.1	0.0	0.0	1.0	0.3	0.6	0.6	0.3	0.0
	Lygus nymphs	3.4	2.1	13.8	7.6	5.6	5.0	5.9	6.4	1.3	1.0	0.1	0.3	0.3	0.0	1.3	1.1	2.0	0.9	1.6	0.6	0.8	0.4
	Total Lygus	3.4	2.2	13.9	7.6	5.6	5.0	5.9	6.4	2.3	1.5	0.2	0.3	0.5	0.1	1.3	1.1	3.0	1.1	2.3	1.3	1.0	0.4
	Geocoris sp.																						0.1
	Pentatomidae													0.3									
	Anthocoridae	0.1				0.1	0.4		0.1	0.3		0.1	0.1	0.4	0.3	3.1	1.4	1.8	1.3	0.8	1.6	0.4	0.1
	Reduviidae																						
	Nabidae																						
Homoptera	Aphids, green/peach	0.3	3.1	0.1	0.9			0.1	0.3	0.5	0.4	0.6	0.8	0.6	0.3	0.5	1.1		0.3	1.4		0.0	18.3
	Aphids, brown	0.1	0.6	0.0	0.4	0.3	0.3					0.5	0.5	5.5	8.6	1.4	2.5	0.9	1.9	0.5	0.1		
	Froghoppers			0.3	0.1	0.5	0.3	0.8	2.1	1.0	3.8	0.8	2.0	0.8	0.9	0.6	1.1	0.8	0.9	0.4	1.3	1.0	0.8
	Leafhoppers	0.5	0.4	0.0	0.3	0.0	0.5	0.3	0.5	1.3	1.9	2.4	2.3	2.0	3.5	6.6	10.1	13.4	19.8	10.9	10.4	5.5	5.0
Coleoptera	Ladybugs, red						0.3			0.1													
	Ladybugs, yellow						0.1				0.1	0.1											
	Ladybug larvae			0.4	0.1	0.9	2.0					0.4	0.1	0.1		0.3				0.1	0.1		
	Flea beetles	6.0	9.0	1.8	0.8	0.9	2.0			0.1	0.1	1.1	1.5	3.1	3.9	1.9	1.9	0.8	0.6	0.5	0.9	0.8	0.6
	Leaf beetles	0.3	0.1	0.5	0.3	0.5	0.4	0.4	1.4				0.1	0.4	0.6	1.0	1.3	2.6	2.5	1.0	1.1	2.6	2.9
	Stethorus sp.	0.0	0.3	0.4	0.8	0.3	0.6	0.5	0.1	0.4	0.4	0.6	0.6	1.3	0.8	3.6	4.1	2.3	2.4	0.0	0.9	0.0	0.4
	Rove beetles																						
	Clover weevils			0.3	0.5			0.1		1.0		0.3	0.1	0.6			0.1		0.5	0.1	0.1		
	Broadnosed weevils											0.1											
Hymenoptera	Chalcids	0.1	0.1	0.4	0.0	0.0	0.5	0.9	0.1	0.3	0.3	0.3	0.4	1.6	2.5	1.3	1.3	2.9	3.9	3.3	2.3	0.3	0.6
	Other parasitic	0.9	0.6	0.1	0.7	0.4	0.8	0.1	0.3	0.1	0.5	0.8	0.4	0.5	0.1	1.1	1.6	1.9	1.1	1.3	1.1	0.5	0.4
	Gall wasps			0.1										0.3						0.1		0.1	0.4
	Sawflies		0.1	0.0	0.3						0.1						0.1						
Diptera	Syrphids							0.1		0.1			0.1	0.1		0.1	0.3						
Arthropoda	Spider mites			0.8	0.4					0.4													
	Red mites									0.4	0.1	1.8	0.5	0.6	0.4	0.6	0.5	4.9	7.0	1.9	0.6	2.8	1.3
Neuroptera	Green lacewings																						
	Brown lacewings		0.1	0.1	0.3		0.1																