Trap Cropping and Removal Trapping to Enhance Control of the Western Spotted Cucumber Beetle in Vegetable Crops

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Background and Justification

The western spotted cucumber beetle (WSCB) (*Diabrotica undecimpunctata undecimpunctata*) is the major insect pest of the Willamette Valley vegetable industry, attacking snap beans, sweet corn, and cucurbit crops. The Oregon processed vegetable industry is a significant contributor to the state agricultural economy, worth more than $67 million paid to farmers in 2000, with the total value of processed crops being considerably higher.

WSCB is a pest both as an *adult* (feeding on bean leaves, flowers and pods and cucurbit leaves and flowers), and as a *larvae* (feeding on corn and cucurbit roots). In snap beans the direct feeding damage to the pod reduces market value to the grower and excessive pod damage can cause load rejection by the processing cannery.

The fate of insecticides in groundwater, rivers, and food and their effects on non-target organisms has caused concerns to consumers and environmentalists. There is also strong interest among many vegetable growers and food processing companies in "environmental stewardship" marketing claims (i.e. Food Alliance certification).

Clearly integrated pest management strategies that can improve pest control while reducing pesticide inputs would offer advantages to farmers and society. In this proposal, we will continue development of novel approaches to management of the WSCB to reduce insecticide use as part of a biologically-integrated pest management program for snap bean production.

Literature Review

Two new, very promising potential control strategies for WSCB are *trap cropping* and *removal trapping*. These approaches are similar in that they are based on trapping and killing pest insects, but they are separate practices. *Trap cropping* involves the deliberate planting of strips or blocks of selected plants to attract pest insects away from target crops. Protection may be achieved either by preventing the pests from reaching the crop or by concentrating them in a certain part of the field where they can be economically destroyed (Javaid and Joshi 1995). The principle of trap cropping rests on the fact that virtually all pests show distinct preferences for certain plant species, cultivars, or certain crop stages. Manipulations of the trap crops in time and space so that attractive host plants are offered at the critical time in the pests' and/or the crop's phenology can lead to the concentration of the pests in the trap crop.

Removal trapping uses physical traps that combine visual and olfactory cues to attract the pest insects to the traps where they are captured and killed. Traps can be certain colors or shapes with specific chemical compounds, such as pheromones and kairomones, used to increase the attractiveness of the traps.

Trap cropping has been used successfully to control eleven pest species in four crop ecosystems, including cotton, soybeans, potato and cauliflower (Hokkanen. 1991). The bean leaf beetle (*Cerotoma trifurcata)* on soybean was managed by trap cropping in the Delta region of Mississippi (Pedigo, 1989). The beetles were suppressed by planting 5 to 10% of the field with an early maturing soybean variety. This early planting attracted bean leaf beetles that were then destroyed with an insecticide. By spraying only a small portion of the crop, dramatic savings in insecticide costs occurred. Suppression of the harlequin bug (*Murgantia histrionica)* in broccoli was obtained in Virginia by planting mustard and rape trap crops adjacent to the broccoli fields (Ludwig and Kok, 1998).

The trapping approach to cucumber beetle management is particularly promising because of the response of adult beetles to visual and olfactory cues. There's an extensive research base on the chemical ecology of *Diabrotica* beetles (WSCB is in the genus *Diabrotica)* (Anderson and Metcalf 1987; Metcalf and Lampman 1989) with work on specific kairomonal attractants to the beetles (Lewis et al. 1990; Metcalf et al. 1995).

Metcalf et al. (1995) identified *indole* as an olfactory synergist for volatile kairomones for Diabroticite beetles. An indole-based mixture known as TIC simulated the volatile kairomones from cucurbit flowers and attracted three species of Diabroticite beetles (WSCB was not included in the study). Hoffman et al (1996) tested TIC-baited sticky traps for attractiveness to several species of cucumber beetle and showed increased trapping of all beetle species <u>except</u> WSCB.

<u>Oregon Research</u>. Hongtrakul (1997) investigated various chemical attractants to the WSCB in western Oregon. A mixture of three compounds (1:1:1 indole, benzyl alcohol, and beta-ionone) known as "IBb " was shown to be more attractive to the spotted cucumber beetle than the TIC mixture of Metcalf et al (1995).

<u>Recent work at USDA.</u> In recent work reported by Weber et al. (2003), curcurbitacin baits made from a bitter mutant of Hawkesbury watermelon and insecticide-treated "fatal fabrics" have shown potential to attract and kill striped cucucmber beetles (*Acalymma trivittatum)* and the southern corn rootworm adults (*Diabrotica undecimpunctata howardi*) .

Weber et al. have evaluated selectivity of these baits for the target insects by varying the cucurbitacin and toxin types and concentrations. Their goal is to maximize efficacy while minimizing non-target toxicity and bait cost.

There has been extensive development of cucurbicin-insecticide baits for controlling the western corn rootworm (*Diabrotica virgifera*) in US cornfields (Weissling and Meinke 1991). Baits have typically been mixed with carbaryl or methyl parathion as toxicants. In USDA-ARS areawide programs during 1997 through 2001 in midwestern USA, these active ingredients were applied at 10% of the labeled rate for foliar applications, resulting in significant reduction of pesticide inputs for *Diabrotica* adult suppression (Weber et al. 2003).

Project Objectives

1. Evaluate WSCB life history, seasonal aggregation and movement patterns within diversified vegetable cropping systems
2. Evaluate the potential for trap cropping and removal trapping strategies as cultural control components of an IPM program for the WSCB in western Oregon vegetable cropping systems

Approach and Procedures

Objective 1. Evaluate WSCB reproductive life history, seasonal aggregation and movement patterns within diversified vegetable cropping systems.

Reproductive Life History and Seasonal Aggregation: Knowing where the WSCB beetles aggregate in the agricultural landscape at various times of the year is critical to the development of trapping strategies for pest management. This year we continued our exploration of landscape habitats for WSCB, with survey work beginning in January, 2004 and continuing throughout the year. During the winter of 2004, we identified two overwintering aggregations of beetles on adjacent farms near Corvallis. At the Riverside Farm, beetles overwintered in an unharvested spinach field; at the nearby Winn Farm, beetles were found aggregating in a sugar beet seed field. Approximately every two weeks 50-100 adults were collected from these fields and taken to the laboratory and frozen. Adult beetles were dissected in the lab for gender determination, egg presence and development, and parasitism by tachinid flies.

Adult beetles became very difficult to find in late May and June during the period of spring generation larval development. When the summer generation of adult beetles emerged in late June, subsequent collections for beetles were taken from a variety of crops, since the beetles move among different crops during the season.

Degree-day calculations were made using the OSU-IPPC Degree-Day calculator. A lower base temperature of 50° F and a maximum temperature of 85° F was used.

Bean Scouting. During 2004, we initiated an intensive sampling program to examine adult beetle colonization and aggregation patterns within snap beans. Working with growers south of Salem (primarily in the Stayton, Dever-Conner, Albany and Corvallis areas, we identified 78 snap bean fields for sampling. Beetle densities were estimated using a standard 15" sweep net. Two rows of beans were swept in a horizontal sweep, with a single sweep net sample consisting of 20 sweeps. Insects were counted in the field as they emerged from the net. Sweep samples were randomly distributed across the bean fields, with 10 samples taken in each field. We consider this method (200 sweeps per field) to give a reasonal estimate of beetle abundance in the field. Fields were scouted from June-August, 2004, with sampling starting prior to flower initiation, and continuing on a weekly basis. For fields where insecticides were applied, sampling was continued in only a portion of the fields.

Aggregations in Bean Field Edges next to Corn. During July, we observed intensive aggregations of beetles along the margins of many of the bean fields that adjoined sweet corn fields. We established an intensive grid sampling in three bean fields, one near Stayton, the other two fields near Dever Conner. We established 8 transect lines running the length of the bean field perpendicular to the corn/bean interface. Within the first 60 feet of each transect line (starting on the field edge next to the corn), we took four sweep net samples of 10 sweeps/sample. Throughout the rest of the field, and additional 4 sweepnet samples were taken along each transect line. A total 64 samples were taken in each field (except the "Shop Field," where ten samples were taken on nine transect lines for a total of 90 samples). A hand-held Trimble GPS unit was used to get GPS coordinates for each sample.

Movement in the Landscape: A 4 x 4 grid pattern of cylinder sticky traps were installed in a sweet corn field adjacent to the Kingston Jordon bean field (Fig. 3). Sleeves were printed and laminated to cover the 10" diameter by 10" tall sheet metal cylinders. These sleeves contained a yellow band as well as compass points. This sheet was clipped to the cylinder, then a clear plastic strip clipped over the top. Tanglefoot stickum was painted onto the clear sheet. Traps were installed on metal posts with the cylinder at the top of the corn. After three days, the plastic sheets were removed from the cylinders and returned to the laboratory for counting. Beetles were recorded by compass point as well as total trap catch.

Objective 2. Evaluate the potential for trap cropping and removal trapping strategies as cultural control components of an IPM program for the WSCB in western Oregon vegetable cropping systems.

Trap Cropping. Following our documentation of the aggregation of beetles in bean/corn interfaces, we evaluated the concept of only spraying a 60' boom width across the end of the bean field containing the aggregations. The bean field was sampled before and after the spray to determine effectiveness of this approach.

Trap and Kill Technology. Work continued to develop "trap and kill" technologies for the WSCB. Yellow fabric panels (7 x 10 inch) were treated with a freeze-dried "Hawkesbury" bitter melon extract containing high levels of curcurbicin-e, a known feeding attractact for the adult beetle. The fabric was also sprayed with a very low dose of Entrust® insecticide . A kairomone dispenser containing one gram of "IBb" kairomone (a mixture of indole, benzyl alcohol, and beta-ionone) was installed on a pole near the fabric panels. Observations were made of the panels to obtain data of (1) how long individual beetles remained on the fabrics and (2) how many beetles visited the panels during five minute intervals. Laboratory studies were conducted in petri dishes to determine approximate time needed for beetles to feed on the fabric to ingest fatal dosages of the insecticide. From these data, initial models were developed to estimate mortality of beetles feeding on the traps.

Results

Objective 1. Evaluate WSCB reproductive life history, seasonal aggregation and movement patterns within diversified vegetable cropping systems.

Reproductive Life History and Seasonal Aggregation: Adults overwintered as mostly gravid (fertilized) females. In early March (approx 5 degree days accumulated since Jan. 1) beetles began to disperse out of overwintering sites. Beetles were observed doing light feeding of leaves in early-planted bean fields, but did not cause enough defoliation to warrant insecticide applications. Beetles soon left these fields and dispersed to egg-laying sites (unknown to us at this time). From late May until June 21, adult beetles were very hard to find, regardless of where we looked. During this time beetle larvae (rootworms) were developing. we think most of the overwintering population of adult beetles died after oviposition. The peak period of egg laying appears to occur in late March to early April, with the peak of females carrying developed eggs (90%) occuring at this time (Fig. 1).

On June 21 (approx 570 degree days), the new summer generation beetles emerged and began to rapidly move into snap bean fields. Males appeared at this time and mating and egg development within the females occurs rapidly. By mid July, males have disappeared with the population being again some 80-90% female. Of the females, approx. 50% are carrying mature eggs during this period. Since corn is a preferred host of the WSCB for larval development, we are assuming many eggs are layed in corn fields, although other hosts have been noted as well (Rockwood and Chamberlin, 1943).

In early August, the male to female ratio changed rapidly, with the percentage of females dropping to less than 50%. Of these females, the percentage carrying mature eggs drops off dramatically. By mid-September, virtually no eggs are found in females. But then in late September, the new overwintering generation emerges and begins mating. A small percentage of the female beetles (less than 20%) were found to contain mature eggs during this fall period, Whether the beetles lay eggs in the fall (and the eggs hatch to larvae) is unknown at this time. But by December, no mature eggs were found in our collections.

Aggregations in Bean Field Edges next to Corn. Although we had observed aggregation behavior in several bean fields, we were able to document this behavior in only three fields. Beetles were clearly aggregated in a narrow strip along the edge of the field next to the adjacent corn fields (Fig. 2). Beetle densities in the aggregations reached very high numbers (up to 80 beetles per 10 sweeps) while beetles in the remaining portion of the fields were quite low (less than 1 beetle per 10 sweeps). Since the beetles lay eggs in corn fields, we are proposing that the beetles gather along the margins to "commute" to the corn fields to lay eggs. But because the corn in a poor food supply for the adult females compared to the higher protein bean leaves, we think the females are returning to the bean edges to feed.

<u>Movement in the Landscape</u>: The cylinder trapping conducted in the corn field adjacent to one of the bean fields with border aggregations revealed adult beetle dispersal throughout the corn field (Fig. 3). Trap catches were higher 150' away from the bean field than trap catches closer to the bean field.

Bean Scouting.

Of the 78 bean fields we scouted in 2004, twenty-four fields were not treated with insecticides. Beetle densities occuring at the early flowering stage of beans were plotted for both sprayed and unsprayed fields (Fig. 4). Although population levels in the unsprayed fields commonly exceeded the current OSU "action threshold" of two beetles per 20 sweeps, there was little "bean bite" grade loss associated with fields (no more than in fields that had been sprayed). Sweep net sampling of unsprayed fields continued until close to harvest. Seasonal abundance of beetles in unsprayed fields is shown in Fig. 5.

Objective 2. Evaluate the potential for trap cropping and removal trapping strategies as cultural control components of an IPM program for the WSCB in western Oregon vegetable cropping systems.

Trap Cropping. One approach to trap cropping may be to plant an overwintering crop, such as spinach, that would serve as as a favored habitat. This field could be sprayed in late winter, prior to dispersal of the beetles, thus shutting off the spring generation before oviposition could occur.

Trap and Kill technology (see below) could be placed around the overwintering sites to trap and kill the beetles as they left the field.

Another approach is use the beans themselves as trap crops during the growing season, assuming we understood the movement patterns of the beetles among crops. Clearly if aggregations of beetles along field borders adjacent to corn could be identified, only a small portion of the crop would need to sprayed for beetles. In one field in 2004, the grower sprayed a 60' boom width along the field edge with an aggregation. Beetle densities in the remaining section of field were sampled before and after the spray, and beetles never exceeded 1 beetle /10 sweeps in the field.

Trap and Kill Technology.

By recording time spent on the treated fabrics by individual beetles, we determined that at least 50% of the beetles spent at least one minute on the fabric feeding. Based on preliminary laboratory studies, one minute feeding will kill the beetles. By observing the "transient rate" of beetles arriving and leaving the fabric panels, we estimated approx. 7.5 beetles passing through the traps every five minutes. Applying the following formula:

Mortality = Transient Rate x proportion killed x time
= 7.5 x (0.5) x 96 (12 five-minute intervals/hour x 8 hours)
= 360 beetles per trap / day

We need to conduct additional experiments to estimate the model parameters at various times of the season when the fabric traps might be employed. We also need to experiment with optimum application rates of Hawkesbury juice and Entrust insecticide to maximize the feeding stimulant response and to deliver the quickest lethal dosage of insecticide while feeding.

We are invisioning arrays of treated fabric traps around a centralized kairomone dispenser. Traps could surround overwintering sites in the spring, or could be placed along field edges during the growing season to reduce beetle numbers. Clearly placement of traps in a aggregation of beetles could maximize their effectiveness.

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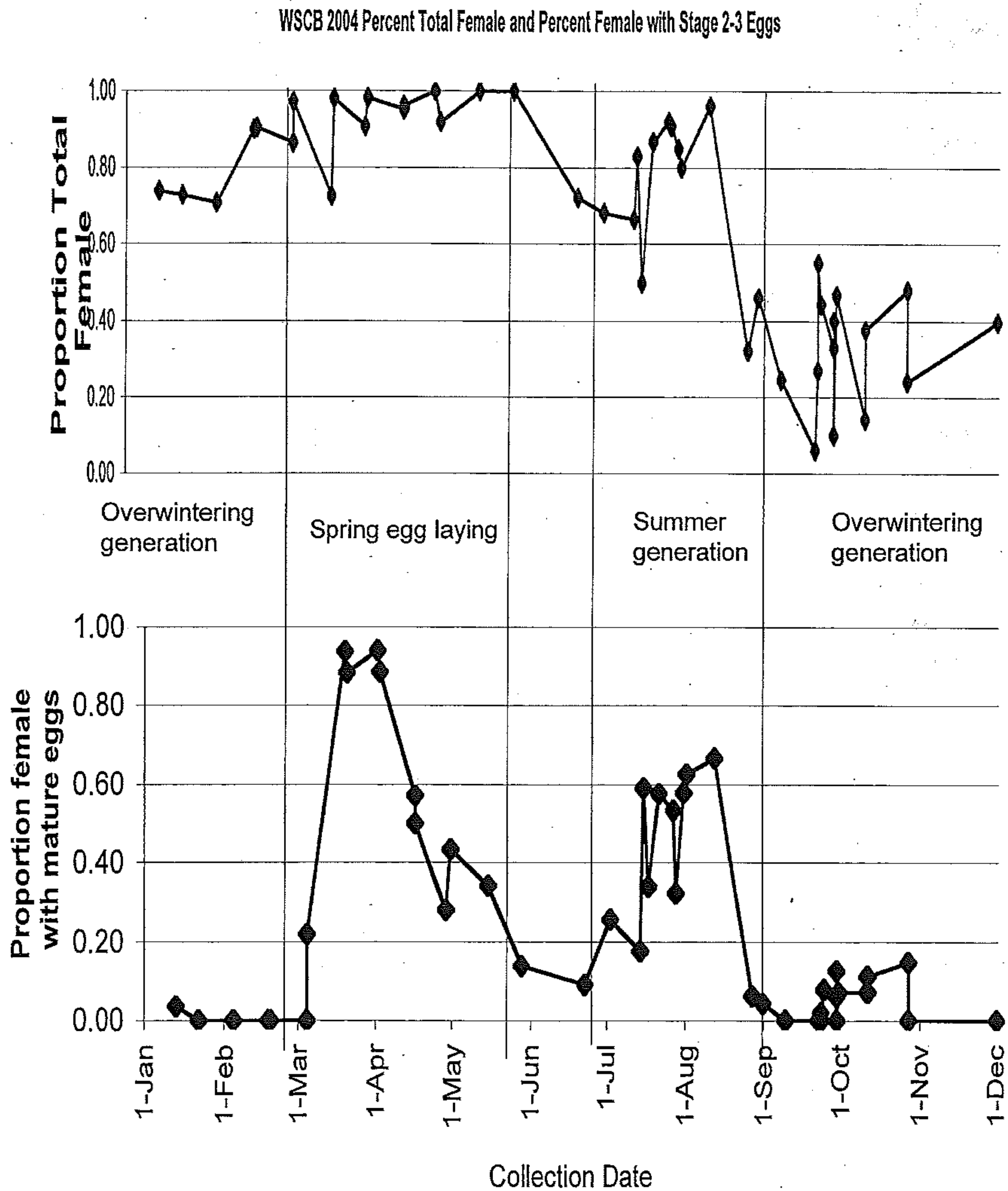
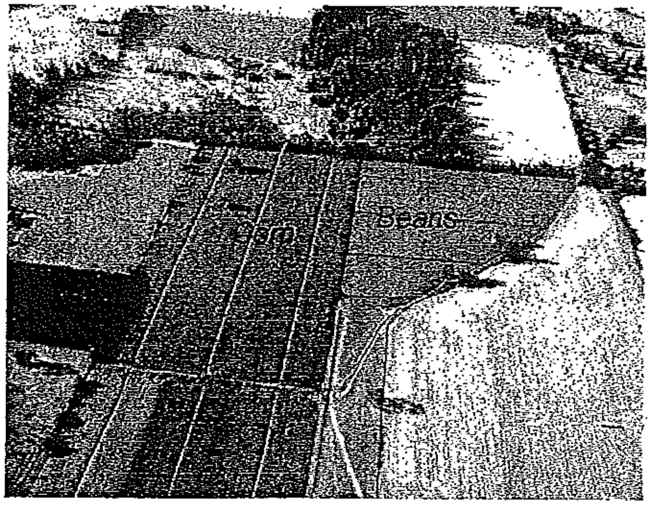
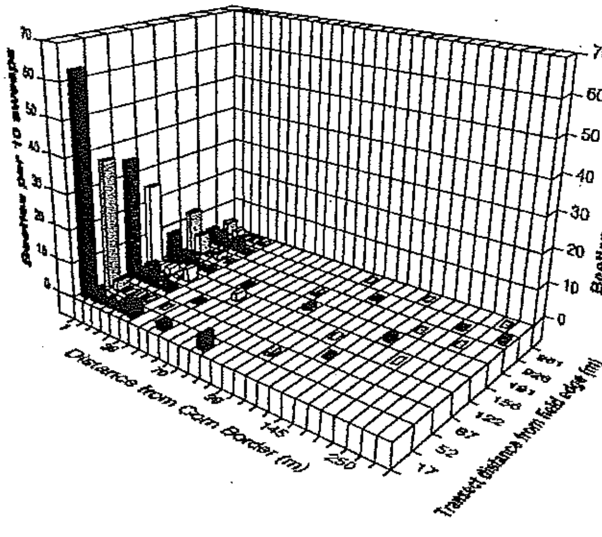
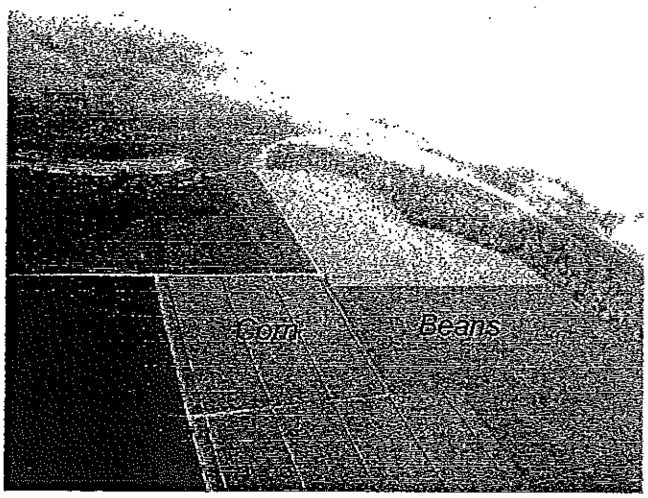


Fig. 1. Seasonal reproductive phenology of western spotted cucumber beetle in the Willamette Valley.

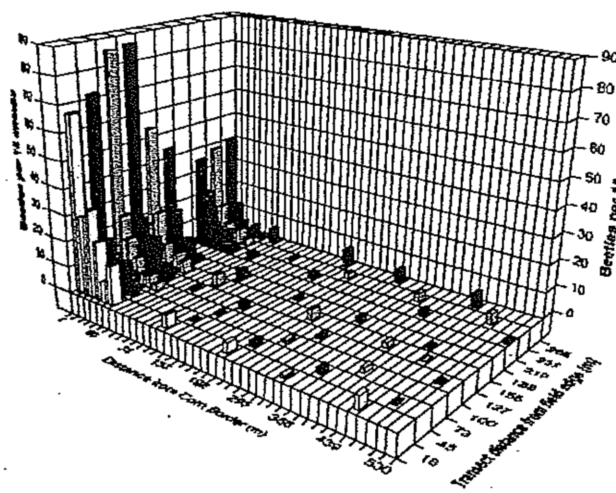


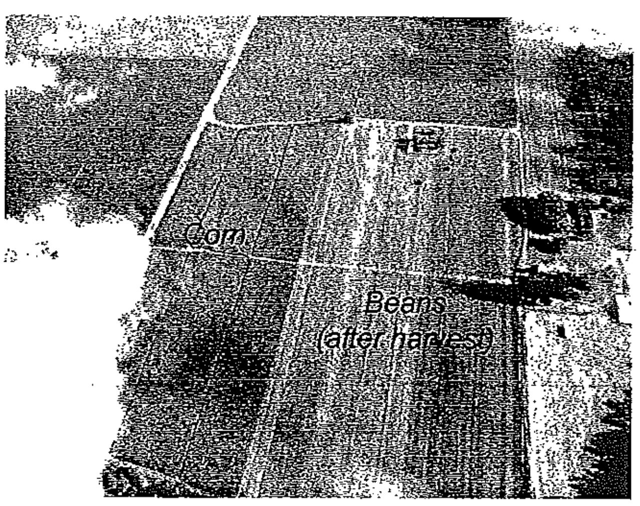
Kingston-Jordon Field





Shop field





Emmonds Road Field

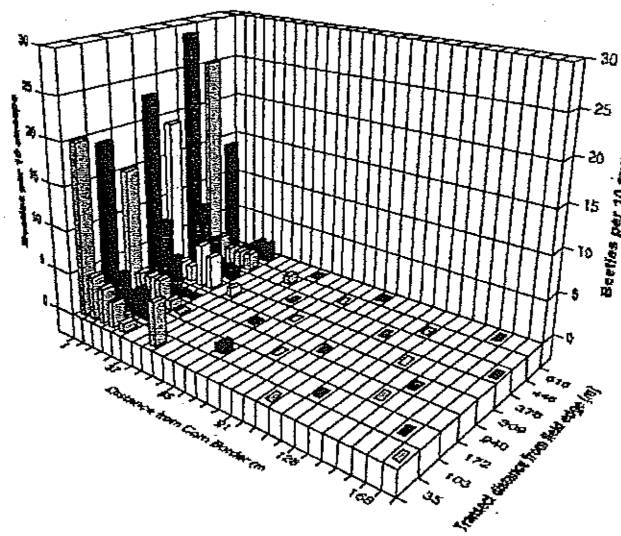
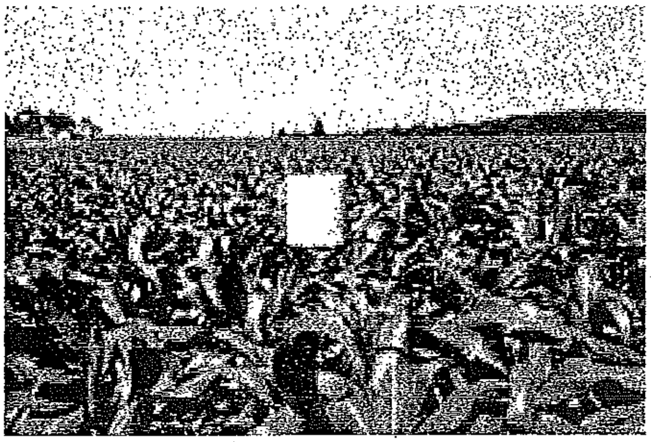
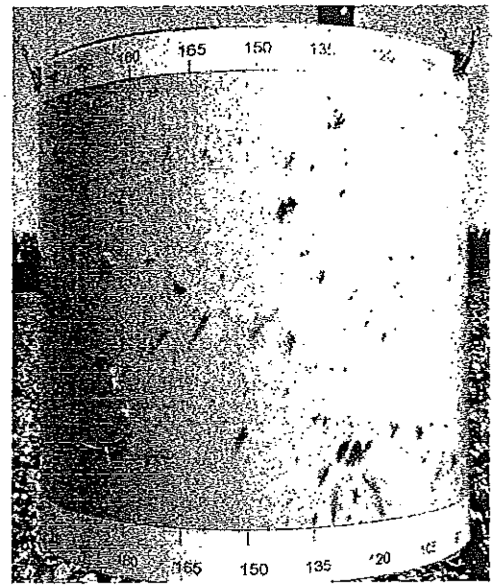


Fig. 2. *Aggregation of spotted cucumber beetles along edges of bean fields next to sweet corn. Note the left side of the graph is the side of the bean field next to corn. Vertical axis is number of beetles per 10 sweeps.*



Sixteen cyclinder sticky traps were installed in a grid pattern in sweet corn adjacent to the Kingston Jordon been field to monitor beetle flight activity.



Cylinder traps cwere intalled on true north compass directions. Tanglefoot stickum was painted on the yellow band.

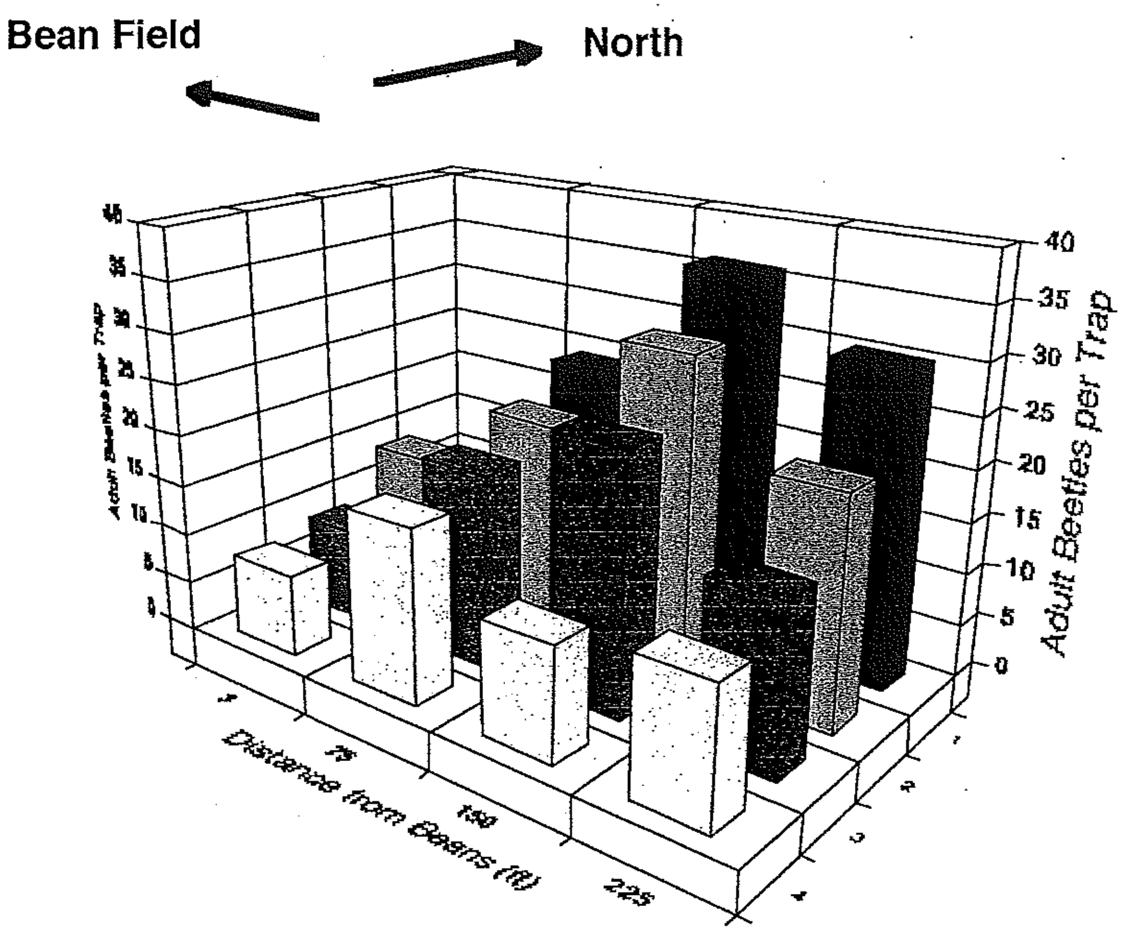
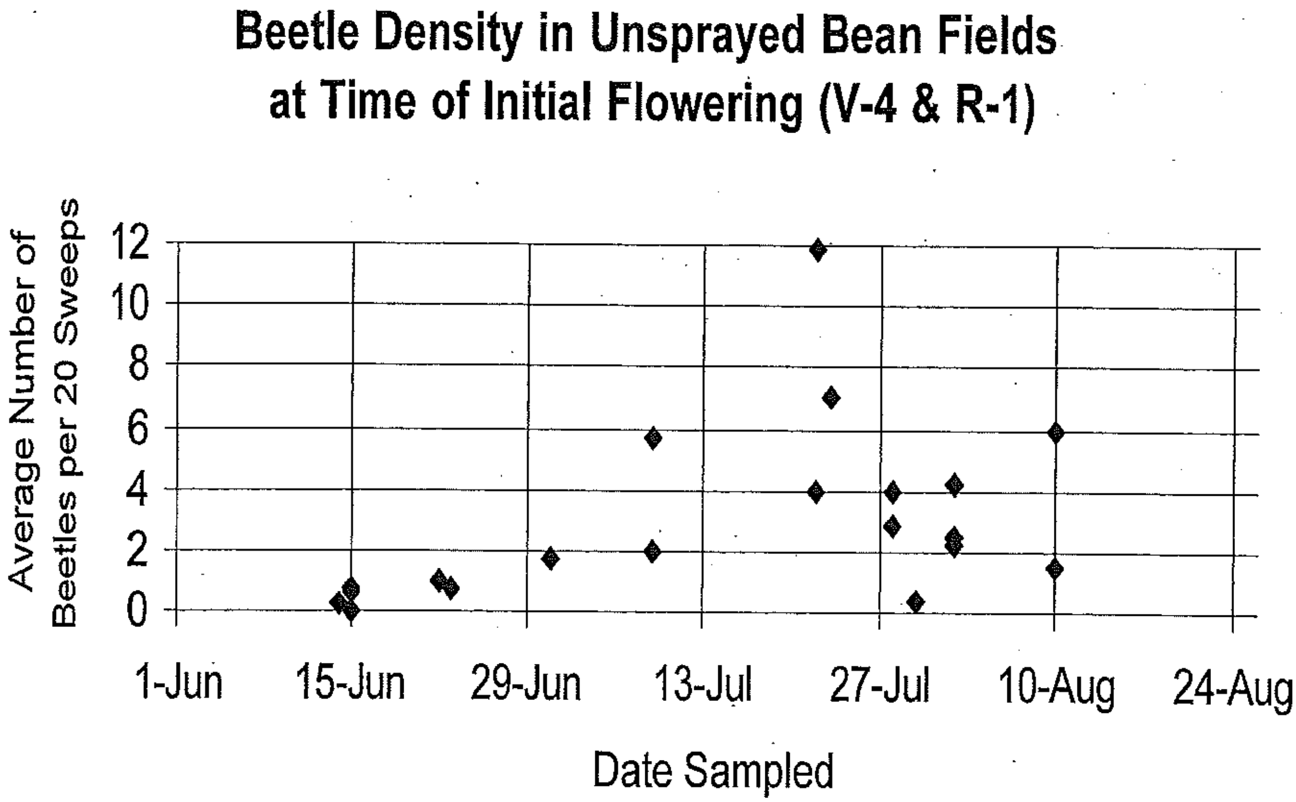


Fig. 3. *Cylinder sticky trapping of adult cucumber beetles in sweet corn adjacent to a bean field with highly aggregated populations next to the corn. Cylinder trap data represent a 3-day trapping interval.*



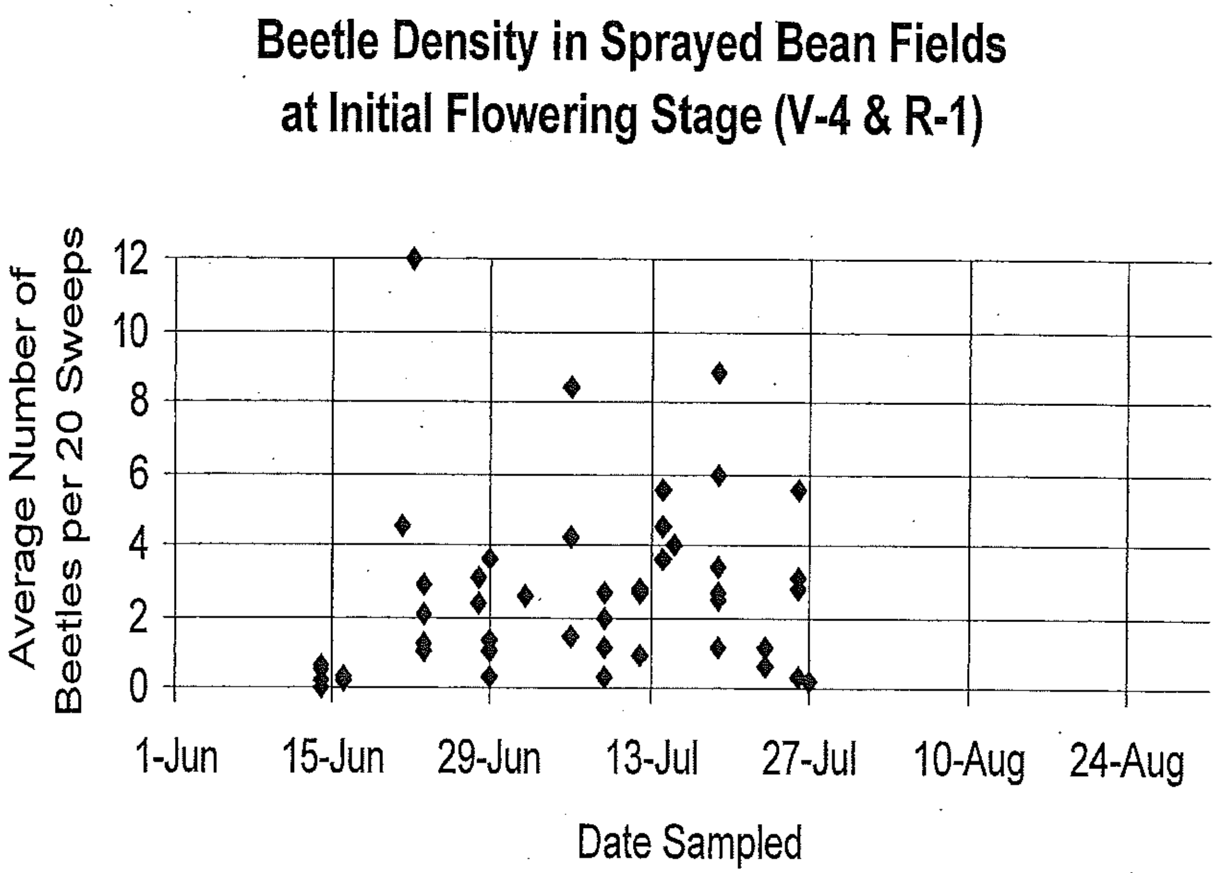


Fig.4. Density of spotted cucumber beetle in southern Willamette Valley bean fields during early bloom stage. Each data point represents a single field.

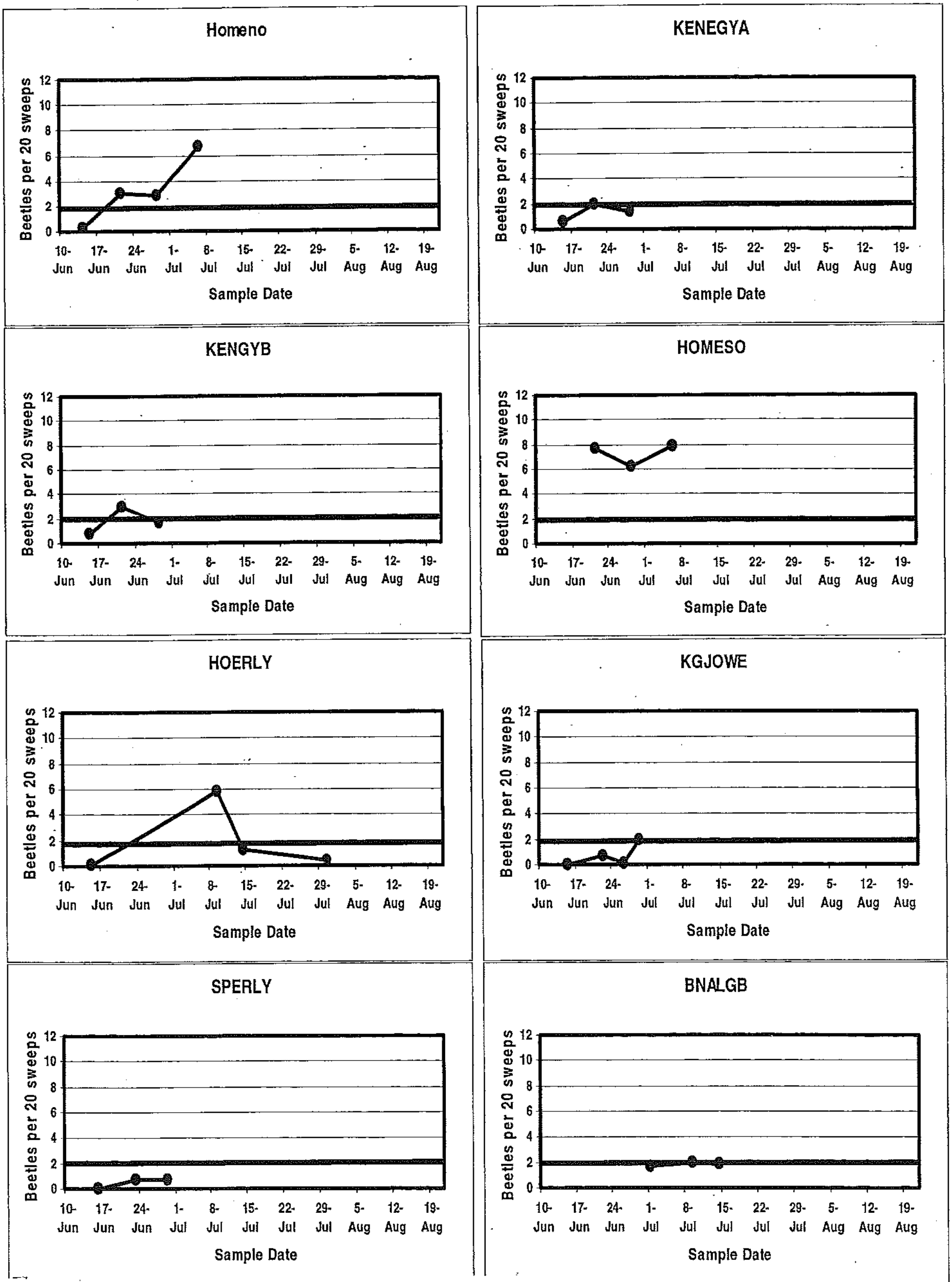
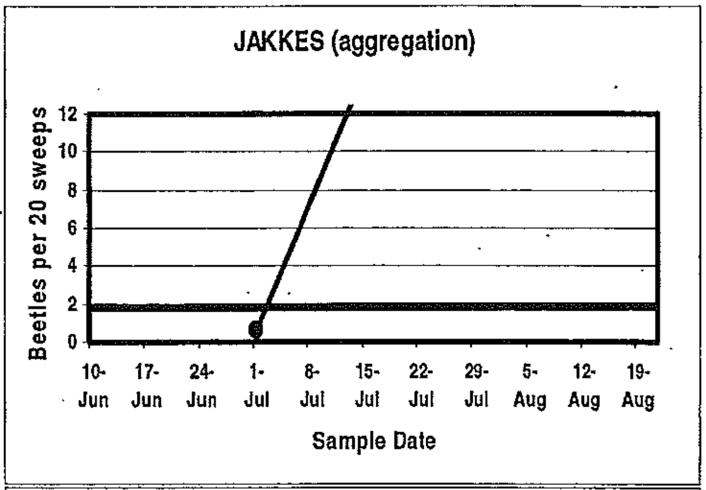
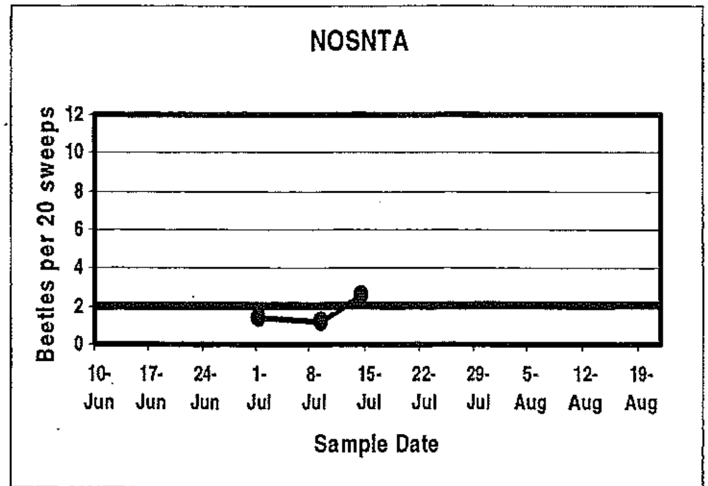
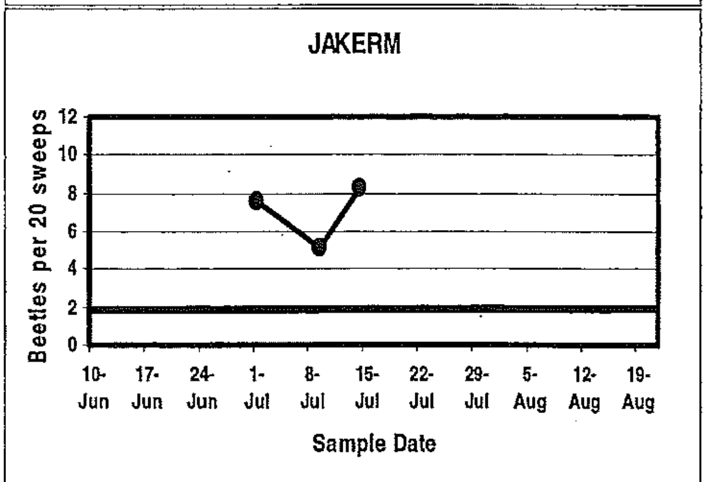
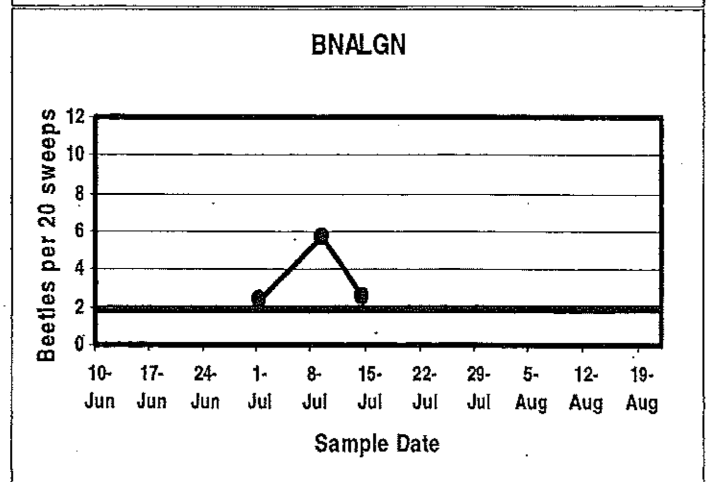


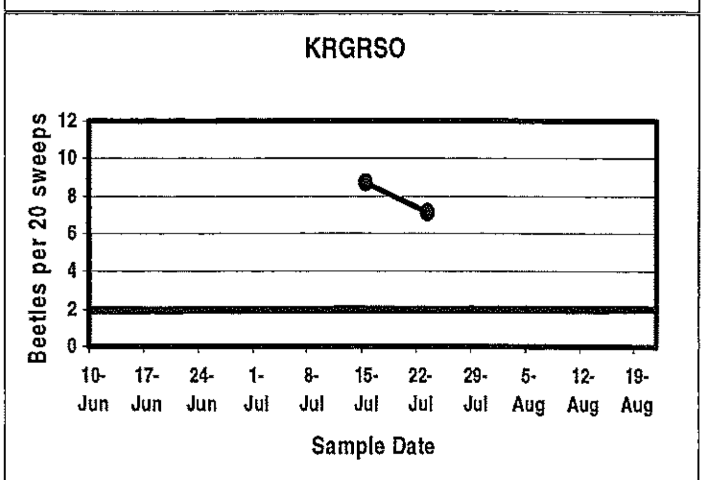
Fig. 5. Seasonal abundance of western spotted cucumber beetle in unsprayed bean fields in the southern Willamette Valley, 2004.

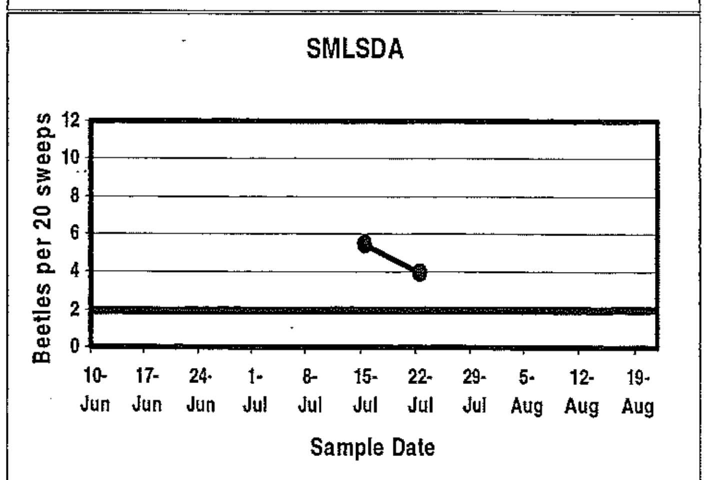

JAKKES (aggregation)
Beetles per 20 sweeps
0 2 4 6 8 10 12
10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug
Sample Date

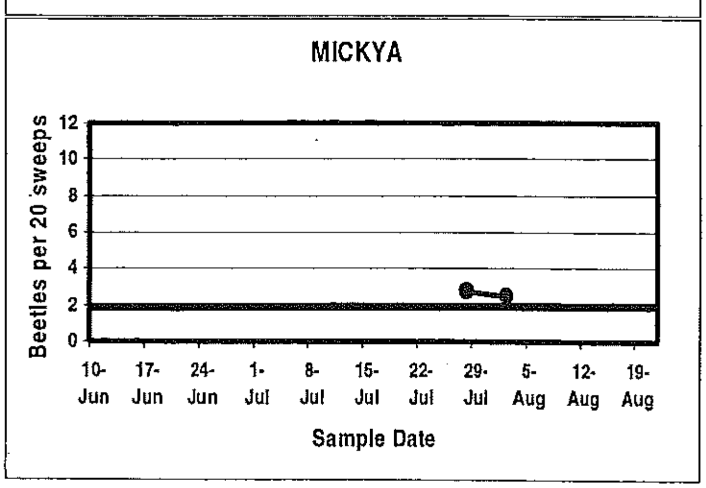

NOSNTA
Beetles per 20 sweeps
0 2 4 6 8 10 12
10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug
Sample Date

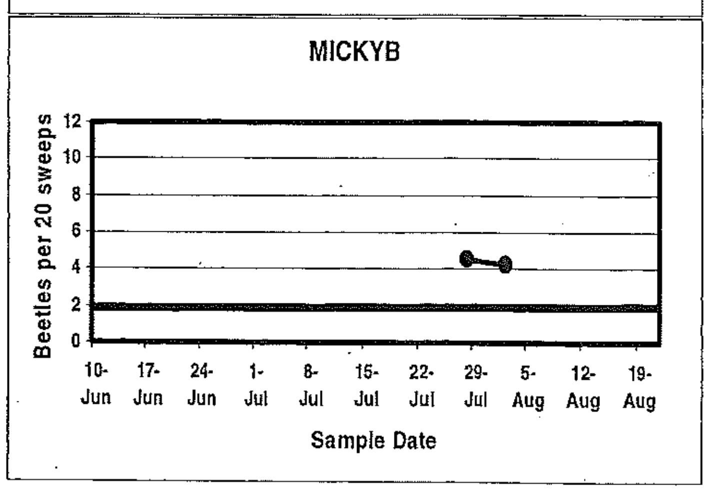

JAKERM
Beetles per 20 sweeps
0 2 4 6 8 10 12
10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug
Sample Date

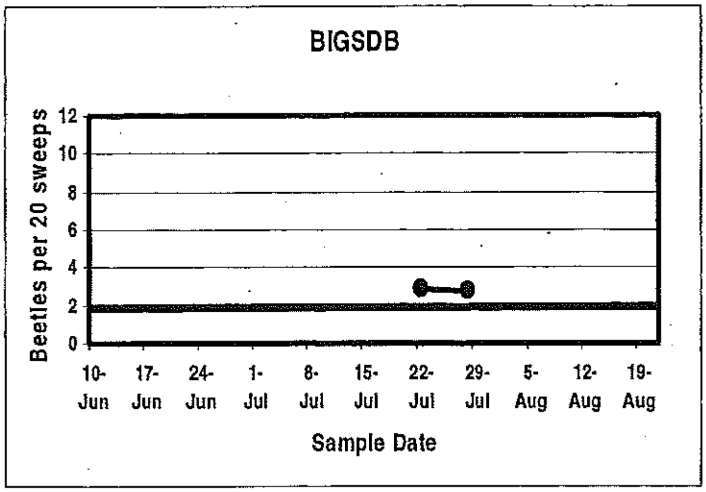

BNALGN
Beetles per 20 sweeps
0 2 4 6 8 10 12
10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug
Sample Date

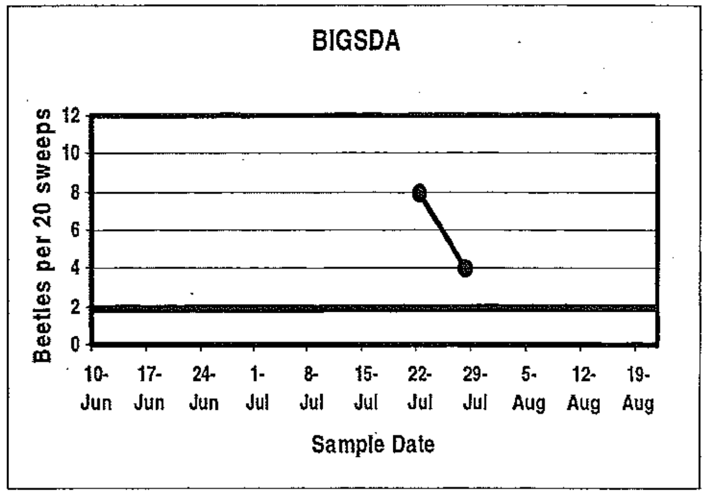

KRGRSO
Beetles per 20 sweeps
0 2 4 6 8 10 12
10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug
Sample Date

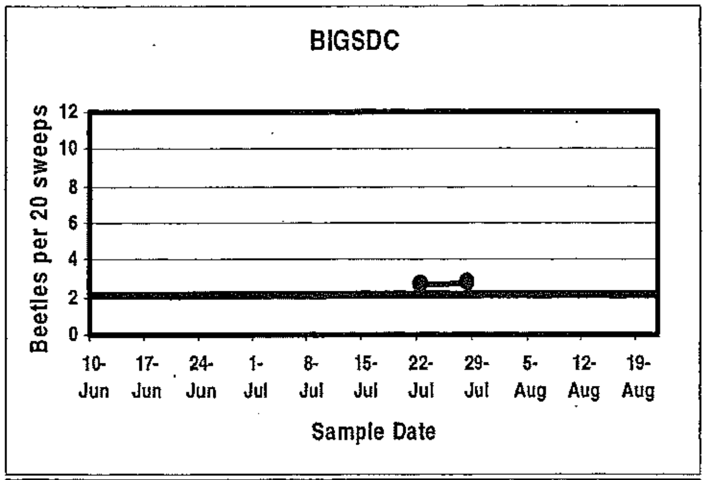

SMLSDA
Beetles per 20 sweeps
0 2 4 6 8 10 12
10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug
Sample Date

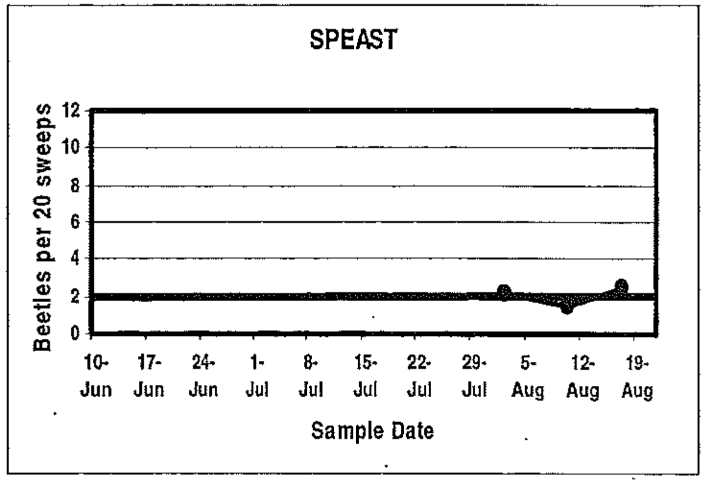

MICKYA
Beetles per 20 sweeps
0 2 4 6 8 10 12
10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug
Sample Date

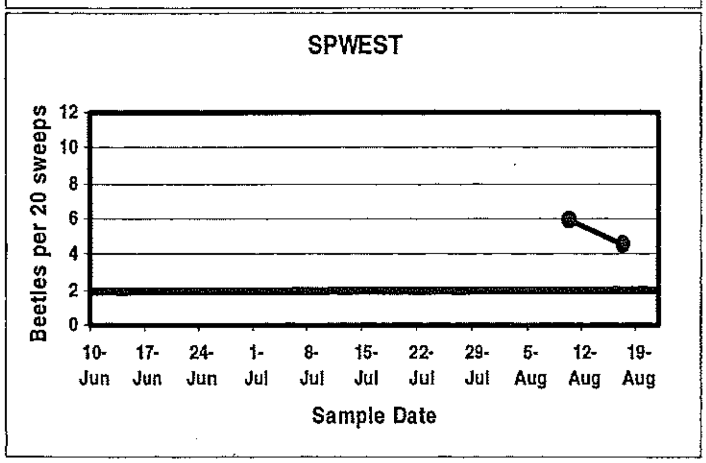

MICKYB
Beetles per 20 sweeps
0 2 4 6 8 10 12
10-Jun 17-Jun 24-Jun 1-Jul 8-Jul 15-Jul 22-Jul 29-Jul 5-Aug 12-Aug 19-Aug
Sample Date


BIGSDB
Beetles per 20 sweeps
0
2
4
6
8
10
12
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
22-Jul
29-Jul
5-Aug
12-Aug
19-Aug
Sample Date


BIGSDA
Beetles per 20 sweeps
0
2
4
6
8
10
12
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
22-Jul
29-Jul
5-Aug
12-Aug
19-Aug
Sample Date


BIGSDC
Beetles per 20 sweeps
0
2
4
6
8
10
12
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
22-Jul
29-Jul
5-Aug
12-Aug
19-Aug
Sample Date


SPEAST
Beetles per 20 sweeps
0
2
4
6
8
10
12
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
22-Jul
29-Jul
5-Aug
12-Aug
19-Aug
Sample Date


SPWEST
Beetles per 20 sweeps
0
2
4
6
8
10
12
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul
22-Jul
29-Jul
5-Aug
12-Aug
19-Aug
Sample Date