Strawberry IPM: Botanical and Microbial Options
Surendra Dara, Strawberry and Vegetable Crops Advisor and Affiliated IPM Advisor, UC Cooperative Extension, Santa Barbara and San Luis Obispo Counties

Strawberry is the 6th most important agriculture commodity in California, contributing to 88% of the fresh market and 94% of the processed strawberries produced in the US (USDA-NASS, 2012). According to the Pesticide Action Network database, 9.3 million pounds of pesticides were used in 2009 in California for controlling pests, diseases, and weeds (www.pestinfo.org). Arthropod pests such as lygus bug, thrips, twospotted spider mite, and whitefly are among the important targets that require a significant amount of pesticide applications. Finding effective non-chemical alternatives is essential for ensuring environmental safety and sustainable pest management. Since some of the non-chemical solutions can be less effective or slow in their activity compared to some of the chemical pesticides, a strategy to maximize the potential of all options is essential.

![Mode of Infection](image)

Fig. 1 Mode of infection of entomopathogenic fungi. Conidial spore (a) in the formulation or discharged from an infected cadaver germinates and produces a germ tube (b). It produces an appresorium (c) on insect cuticle when it finds an ideal penetration site. Upon successful entry into the host body, it divides and produces hyphal bodies and invades the host tissues (d). Fungus emerges from the dead host and produces more conidial spores (e).
A large scale field study was conducted in Santa Maria in an attempt to incorporate a neem-based botanical insect growth regulator, azadirachtin and an insect-killing fungus, Beauveria bassiana into strawberry IPM. Combining or alternating these materials with chemical pesticides can be a practical and more acceptable solution in providing effective pest management as well as reducing chemical pesticide usage. Before going into the details of this study, here is a brief introduction to azadirachtin and microbial control.

Azadirachtin
Azadirachtin is a secondary metabolite in neem (Azadirachta indica) seeds produced from the seed cake that remains after extracting neem oil. Azadirachtin is a tetranoctiterpenoid which is similar to the molting hormone, ecdysone and its homologs in insects. Azadirachtin blocks these hormones and interferes with the molting. Azadirachtin may also act as feeding deterrent.

Microbial control
Microbial control is a part of pest management that involves using microorganisms that are pathogenic to arthropod pests. These microorganisms include bacteria (e.g. Bacillus thuringiensis and Serratia marcescens), fungi (e.g. B. bassiana, Isaria fumosorosea, and Metarhizium brunneum), viruses (e.g. nucleopolyhedroviruses and granuloviruses), nematodes (e.g. Heterorhabditis bacteriophora and Steinernema carpocapsae) and other such organisms that control pest populations.

In general, each group of pathogens is specific to or effective against a particular type of pest. Entomopathogenic fungi like B. bassiana are especially ideal for sucking pests such as the lygus bug, a major pest of strawberries. Unlike entomopathogenic bacteria and viruses which need to be ingested by the target pest, fungal pathogens cause infection when they come in contact with their host. Entomopathogenic fungal spores can germinate on various surfaces when there is sufficient moisture (Fig. 1). When they come in contact with insect cuticle (skin), they produce an appressorium or a penetration peg and enter the insect body through mechanical pressure and enzymatic degradation of the cuticle. Upon successful entry into the host, fungus multiplies as hyphal bodies, invades the host tissue, and causes mortality. One conidial spore is all it takes to cause infection for most fungi, but arthropods have their own immune system and try to ward off the invaders. In reality, infection is usually caused by multiple spores which increase the chances of invasion. Dead arthropods either stick to the plant surface or fall off the plant and fungus emerges from the cadavers producing more spores for further infection.

Potential of azadirachtin and microbial control in strawberries
Both azadirachtin and B. bassiana are commercially available for both organic and conventional agriculture and are effective against several strawberry pests or similar species (Ludwig and Oetting, 2002, McGuire et al, 2006, Pearsall and Hogue, 2000, Quesada-Moraga et al, 2006, Shi et al, 2008, Von Elling et al, 2002). Additionally, Central Coast weather is ideal with its mild temperatures, foggy conditions, and condensation on plants is favorable for insect pathogenic fungi. Botanical and microbial control options can be an excellent addition to the IPM program especially when controlling lygus bug with chemical insecticides alone has been a major challenge.

Since microbial control agents have a different mode of action than chemical pesticides, they can take longer to cause pest mortality. Fungi like B. bassiana take 2-3 days to infect and kill their hosts and this is comparable to the time that chemical insect growth regulators such as novaluron take to reduce pest populations.

In light of promising results from preliminary studies (Dara, 2011), large scale field studies were conducted on fall planted strawberries in 2012 with a particular emphasis on lygus control.

Field studies with azadirachtin and B. bassiana
A field study was conducted with chemical insecticides (neonicotinoid, pyrethroids, and insect growth regulator), and B. bassiana alone, in combination with azadirachtin and reduced rates of two chemical pesticides. The combination of azadirachtin and B. bassiana targets both nymphal and adult stages. Chemical pesticides at reduced rates help weaken the insects and improve infection by B. bassiana.

This study was conducted on a conventional strawberry field at Manzanita Berry Farms. Cultivar PS-4634 was transplanted in November, 2011. Treatments included, i) untreated control, ii) acetamiprid at 3 oz/ac, iii) novaluron at 12 fl oz/ac + bifenthrin at 16 oz/ac, iv) B. bassiana at 2 lb/ac, v) B. bassiana at 2 lb/ac + azadirachtin at 8 fl oz/ac, vi) B. bassiana at 2 lb/ac + fenpropathrin at 5.3 fl oz/ac (half the label rate), vii) B. bassiana at 2 lb/ac + acetamiprid at 1.5 oz/ac (half the label rate), viii) azadirachtin at 8 fl oz/ac, and ix) aza-
diracitin at 16 fl oz/ac, all in 50 gallons of spray volume. Each plot was 75' long and 7 beds wide and replicated four times in a randomized block design. Treatments were applied using tractor-mounted spray equipment on July 31, August 8, and August 15. Observations were made 5 or 6 days after each spray application to monitor lygus bug, twospotted spider mite, whitefly, thrips, aphids, and various natural enemy populations using standard sampling protocols. Big-eyed bug, damsel bug, lacewing, lady bug, minute pirate bug, parasitic wasp, and spiders were the natural enemies that were recorded during the observation period.

It should be noted that not all chemical treatments in this study were meant to be effective against all target pests, but pest counts from all treatments are presented (Figures 2 and 3) for comparison. Although observations were made after each spray application, data are presented as pre- and post-treatment averages to summarize results.

**Aphids** – There was more than a fivefold increase in untreated control during the treatment period. During this time, acetamiprid caused nearly 78% reduction and the combination of *B. bassiana* and half the label rate of acetamiprid caused about 44% reduction in aphid numbers. Among the remaining treatments where aphid populations increased, the combination *B. bassiana* and azadirachtin limited the increase to 19%.

**Lygus bugs** – Total number of nymphs and adults was similar in untreated control during the experimental period. Acetamiprid caused an overall reduction of 86% in lygus populations from three spray applications. *Beauveria bassiana* caused 58% reduction in lygus numbers with the first application and only 11% with the second one. It could not limit increasing numbers afterwards. However, the combinations of *B. bassiana* with azadirachtin and acetamiprid caused nearly 70% reduction in lygus bugs. While the lower rate of azadirachtin was similar to untreated, the higher rate caused a 60% reduction in lygus numbers.

**Twospotted spider mites** – In general, mite populations were very low during the observation period with some increase after the treatments were initiated. Not having a chemical miticide in the study limits meaningful treatment comparisons. While no treatment caused a reduction in mite populations, the combination of *B. bassiana* and azadirachtin seemed to limit the increase in egg numbers and the combination of *B. bassiana* and half the label rate of fenpropatrin limited the increase in mobile stages.

**Thrips** – There was more than a threefold increase in thrips numbers in untreated control during the observation period. Their numbers also increased in treatments, but it was relatively less in acetamiprid followed by the combinations of *B. bassiana* with the reduced rate of fenpropatrin and azadirachtin.

**Whiteflies** – There was a general reduction in whitefly adult numbers during the observation period. Compared to other treatments, acetamiprid alone and along with *B. bassiana* seemed to cause more reduction although it was not statistically significant.

**Natural enemies** – All species of natural enemies were combined for the comparison. There was a general decline in their numbers during the observation period. Although not statistically significant, the reduction appeared to be limited in plots treated with *B. bassiana* and azadirachtin compared to other treatments.

Although statistically significant differences among treatments could not be found with all pests, a large scale field study such as this demonstrates the potential of *B. bassiana* and azadirachtin in strawberry IPM. These materials help reduce the chemical pesticide use and the risk of pesticide resistance when substituted for one or more chemical treatments. Additionally, *B. bassiana* can improve the overall pest management when used in combination with chemical pesticides and ease the challenge of controlling lygus bug with chemical pesticides alone.

This study clearly demonstrates the potential of microbial control for strawberry IPM and warrants additional field studies.

**References**


Pearsall, L. A. and E. J. Hogue. 2000. Use of aza-
Figure 2. Number of aphids, lygus bugs, and spider mite eggs before and after treatment. For lygus bugs, average numbers post-treatment and after each application were presented.
Figure 3. Number of spider mite mobile stages, thrips, whitefly adults, and natural enemies (all species together) before and after treatment.
Tolerance of Several Strawberry Varieties to Oxyfluorfen and Flumioxazin Herbicides
Steven A. Fennimore and Jayesh Samtani, Department of Plant Sciences, University of California-Davis

Herbicides can be used to improve weed control where soil fumigant treatments such as chloropicrin alone misses many weeds. Previous studies have shown that oxyfluorfen (GoalTender) and flumioxazin (Chateau) control many weeds common to California strawberry fields. However, it is not known if herbicide tolerance is uniform among California strawberry varieties. The objective of this study was to determine if tolerance to oxyfluorfen and flumioxazin herbicides varied among strawberry varieties.

Both flumioxazin and oxyfluorfen herbicides are registered for strawberry production in California, and each product was used on over 5,000 acres of strawberry in 2010 (California Department of Pesticide Regulation). Flumioxazin at 3 and 6 oz per acre can be applied to fallow beds 30 days prior to strawberry transplanting, and film installation must occur before time of transplanting (Valent U.S.A. Corporation). Previous work has found that flumioxazin applied to the bed top at 2 and 3 oz per acre 30 days before transplanting controlled little mallow (Malva parviflora) and clover (Melilotus sp.), without causing any phytotoxicity on strawberry.

Oxyfluorfen (GoalTender) must be applied 30 days before strawberry transplanting at rates of up to 1 pint per acre. Previous work has shown that oxyfluorfen (GoalTender) 0.5 to 1 pint per acre reduced hand weeding times by 37 to 63% compared to no herbicide, and controlled California burclover, hairy nightshade (Solanum physalifolium), little mallow, shepherd’s purse (Capsella bursa-pastoris), and clovers.

Oxyfluorfen has the potential to injure plants via co-distillation or “lift off”, a process where the herbicide moves with water vapor from soil surface to strawberry foliage. Splashing of the herbicide from the soil to strawberry crown and foliage, during an irrigation event can also potentially injure the crop. These injuries via splashing and co-distillation can be reduced by film installation on the bed prior to strawberry transplanting. See the GoalTender 2ee label for details regarding fallow bed strawberry use in California.

Trials were conducted in the 2007-08 and 2009-10 growing seasons at Salinas, CA. Varieties tested in 2007-08 were ‘Albion’, ‘Camarosa’, ‘Festival’, ‘211G51’, ‘Palomar’, ‘Plant Sciences 5298’, ‘49C129’, and ‘Ventana’. Varieties tested in 2009-10 were ‘Albion’, ‘Camarosa’, ‘273M171’, ‘Palomar’, ‘Plant Sciences 4634’, ‘Plant Sciences 5298’, ‘San Andreas’, ‘49C129’, and ‘Ventana’. Treatments included a no herbicide control, pre-plant applications of flumioxazin at 2, 3 and 6 oz product per acre and oxyfluorfen was tested at 0.25 and 0.5 pints of product per acre. Note: the 6 oz rate of Chateau cannot be used in commercial strawberry, but was included to test the limits of crop safety for this product. The entire trial was fumigated with an emulsified formulation of 60% 1,3-dichloropropene + 32% chloropicrin applied at 30 GPA by drip injection to all plots. Eight strawberry varieties were included in the trial in the 2007-08 growing season, and nine varieties were included in the 2009-10 growing season. In both growing seasons, slight to no crop phytotoxicity was observed (data not shown). In 2007-08 growing season, several strawberry varieties including ‘Albion’, ‘Festival’, ‘211G51’, ‘Palomar’, ‘Plant Sciences 5298’ and ‘Ventana’ had smaller crop plant canopy diameter as compared to control when treated with 6 oz/acre of flumioxazin. Compared to the control, flumioxazin at 6 oz/acre reduced crop diameter for ‘Plant Sciences 4634’, ‘Plant Sciences 5298’, ‘San Andreas’, and ‘Ventana’ in the 2009-10 growing season.
In the 2007-08 strawberry growing season, none of the herbicide treatments reduced fruit yield in any variety except 49C129 compared to the control (Table 1). Yields of variety 49C129 were lower than the control in the flumioxazin 2 oz and oxyfluorfen 0.25 pint treatments. For the 2009-10 growing season there were no significant differences in yield compared to the control in seven of the nine varieties (Table 2). For Camarosa and Palomar strawberry, yields in plots treated with flumioxazin at 3 and 6 oz/acre were significantly lower than the untreated control. With the exception of flumioxazin at 6 oz/acre these herbicides are safe to use and can be incorporated in strawberry production practices for the varieties tested, to achieve satisfactory weed control over the growing season.

We conclude, that labeled rates of oxyfluorfen and flumioxazin herbicides are safe to use on strawberry, and can be incorporated in strawberry production practices, to achieve satisfactory weed control over the growing season. However, to avoid injury to strawberry, care must be taken when flumioxazin is applied at 3 oz product per acre to avoid overlap and doubling of the rate.

### Table 1. Marketable strawberry fruit yields for the 2007-08 growing season at Salinas, CA.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Product rate per acre</th>
<th>Albion</th>
<th>Camarosa</th>
<th>Festival</th>
<th>211GS1</th>
<th>Palomar</th>
<th>Plant Sciences 5298</th>
<th>49C129</th>
<th>Ventura</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>427.9</td>
<td>246.6</td>
<td>281.9</td>
<td>445.4</td>
<td>609.1</td>
<td>475.5</td>
<td>507.8</td>
<td>430.6</td>
</tr>
<tr>
<td>Flumioxazin 2 oz</td>
<td></td>
<td>472.8</td>
<td>272.7</td>
<td>285.2</td>
<td>384.5</td>
<td>515.9</td>
<td>532.6</td>
<td>360.3*</td>
<td>451.8</td>
</tr>
<tr>
<td>Flumioxazin 3 oz</td>
<td></td>
<td>482.1</td>
<td>272.2</td>
<td>286.2</td>
<td>383.1</td>
<td>633.7</td>
<td>504.5</td>
<td>464.4</td>
<td>451.0</td>
</tr>
<tr>
<td>Flumioxazin 6 oz</td>
<td></td>
<td>409.1</td>
<td>241.5</td>
<td>278.3</td>
<td>364.0</td>
<td>552.7</td>
<td>468.3</td>
<td>493.5</td>
<td>457.3</td>
</tr>
<tr>
<td>Oxyfluorfen 0.25 pints</td>
<td></td>
<td>479.0</td>
<td>256.0</td>
<td>257.0</td>
<td>402.4</td>
<td>496.3</td>
<td>604.0</td>
<td>365.6*</td>
<td>453.8</td>
</tr>
<tr>
<td>Oxyfluorfen 0.5 pints</td>
<td></td>
<td>548.7</td>
<td>261.8</td>
<td>271.8</td>
<td>376.4</td>
<td>564.8</td>
<td>557.3</td>
<td>439.1</td>
<td>521.0</td>
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<tr>
<td>LSD 0.05</td>
<td></td>
<td>121.3</td>
<td>73.8</td>
<td>99.3</td>
<td>106.6</td>
<td>120.1</td>
<td>164.9</td>
<td>124.2</td>
<td>141.5</td>
</tr>
</tbody>
</table>

* indicates that the treatment is significantly less than the control.

### Table 2. Marketable strawberry fruit yields for the 2009-10 growing season at Salinas, CA.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Product rate per acre</th>
<th>Albion</th>
<th>Camarosa</th>
<th>273 M171</th>
<th>Palomar</th>
<th>Plant Sciences 4634</th>
<th>Plant Sciences 5298</th>
<th>San Andreas</th>
<th>49C129</th>
<th>Ventura</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>802.3</td>
<td>724.0</td>
<td>584.4</td>
<td>466.3</td>
<td>918.5</td>
<td>830.5</td>
<td>1045.6</td>
<td>735.5</td>
<td>528.0</td>
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<tr>
<td>Flumioxazin 2 oz</td>
<td></td>
<td>720.8</td>
<td>640.3</td>
<td>516.6</td>
<td>323.0</td>
<td>853.8</td>
<td>893.1</td>
<td>995.7</td>
<td>662.3</td>
<td>466.5</td>
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<tr>
<td>Flumioxazin 3 oz</td>
<td></td>
<td>816.4</td>
<td>616.6*</td>
<td>609.1</td>
<td>267.9*</td>
<td>906.8</td>
<td>884.8</td>
<td>1180.8</td>
<td>745.2</td>
<td>523.0</td>
</tr>
<tr>
<td>Flumioxazin 6 oz</td>
<td></td>
<td>645.9</td>
<td>569.1*</td>
<td>544.8</td>
<td>267.0*</td>
<td>748.7*</td>
<td>823.3</td>
<td>958.0</td>
<td>706.9</td>
<td>467.4</td>
</tr>
<tr>
<td>Oxyfluorfen 0.25 pints</td>
<td></td>
<td>834.0</td>
<td>653.4</td>
<td>598.6</td>
<td>436.5</td>
<td>922.9</td>
<td>864.1</td>
<td>1145.7</td>
<td>773.2</td>
<td>638.8</td>
</tr>
<tr>
<td>Oxyfluorfen 0.5 pints</td>
<td></td>
<td>714.9</td>
<td>628.6</td>
<td>554.6</td>
<td>474.4</td>
<td>844.5</td>
<td>859.9</td>
<td>1013.9</td>
<td>665.1</td>
<td>583.4</td>
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<tr>
<td>LSD 0.05</td>
<td></td>
<td>132.3</td>
<td>103.6</td>
<td>137.7</td>
<td>145.0</td>
<td>140.8</td>
<td>114.6</td>
<td>142.0</td>
<td>169.1</td>
<td>166.1</td>
</tr>
</tbody>
</table>

* indicates that the treatment is significantly less than the control.
Feeding behavior and host preference of the Bagrada bug
Suchitra Dara, Buena Vista Elementary School and Surendra Dara, Strawberry and Vegetable Crops Advisor and Affiliated IPM Advisor, UC Cooperative Extension, Santa Barbara and San Luis Obispo Counties

Introduction
Bagrada bug (*Bagrada hilaris*) is a new invasive pest in California which attacks various crop plants. Brassica plants such as broccoli, cabbage, cauliflower, and kale are particularly vulnerable. Many farmers and home gardeners are concerned about Bagrada bug damage. Since it is a new pest, information on its biology, host preference, and control is limited. This study aims at evaluating the feeding behavior and host preference of the Bagrada bug for various crop and non-crop plants. This information will help understand its food choices and may be useful in developing cultural pest control strategies.

Origin and distribution
Bagrada bug is native to Africa and is reported to infest or cause crop damage in parts of Asia and Europe. It is an exotic pest in the US.

Biology
Adults are 5-7 mm long, 3-4 mm wide and are black with orange and white markings. Females are larger than males and lay an average of 95 barrel shaped whitish eggs in clusters on foliage or in the soil. Eggs turn orange with maturity and hatch in 3-6 days. Nymphs resemble ladybugs due to their dark head and thorax and reddish or orange abdomen with white or black markings. They go through five instars before adults emerge in 5-8 weeks depending on the temperature. They have multiple generations in a year.

Damage
Bagrada bugs have piercing and sucking mouthparts and feed on the plant juices. Depending on the crop and plant part they infest, damage can vary from stippling with necrotic spots, stunted growth, loss of apical dominance and formation of multiple heads, to death.

Methodology
Five species of plants that represent cultivated and weed host were included in the study (Table 1).

Table 1. Ornamental, crop, and weed hosts of Bagrada bugs used in the study.

<table>
<thead>
<tr>
<th>Host</th>
<th>Scientific name</th>
<th>Family</th>
<th>Host type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alyssum</td>
<td>Lobularia maritima</td>
<td>Brassicaceae</td>
<td>Ornamental plant</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Brassica oleracea var. botrytis</td>
<td>Brassicaceae</td>
<td>Crop plant</td>
</tr>
<tr>
<td>Green bean</td>
<td>Phaseolus vulgaris</td>
<td>Fabaceae</td>
<td>Crop plant</td>
</tr>
<tr>
<td>Tomato</td>
<td>Solanum lycopersicum</td>
<td>Solanaceae</td>
<td>Crop plant</td>
</tr>
<tr>
<td>Wild mustard</td>
<td>Synapis arvensis</td>
<td>Brassicaceae</td>
<td>Weed plant</td>
</tr>
</tbody>
</table>

Field-collected Bagrada bugs were maintained in the lab on broccoli and wild mustard. They were starved for 24 or 48 hours before starting the experiment. Feeding arena was constructed using plastic containers and clear vinyl tubing where a central container was connected with five similar ones (Figure 1). Sprigs of alyssum, florets of broccoli, freshly cut green beans, cubes of tomato, and sprigs of wild mustard each were placed in five different containers with filter papers and covered with ventilated lids secured bugs in containers.

Figure 1 Feeding arena for the Bagrada bugs. Insects released in the container in the middle were allowed to choose different food sources. Ventilated lids secured bugs in containers.
perforated lids. Heated forceps were used to make perforations to the lids. Fifteen adult or 2nd to 3rd instar nymphs of Bagrada bugs, which have been starved for 24 or 48 hours, were placed in the central container. Insects were allowed to choose different food sources based on olfactory stimuli. Number of bugs in different cups was periodically monitored. The experiment with adults was repeated three times.

Results and Conclusions

- Bagrada bug adults showed similar preference, on average, for alyssum, broccoli, and wild mustard followed by green beans (Table 2).

- Nymphs preferred green beans followed by alyssum (Table 3).

- Starving the adults for 24 or 48 hours did not seem to have any effect on their food choices. Even after 24-48 hours of starvation, several insects did not seek food, indicating their ability to survive longer periods without food.

- Although Bagrada bugs were known to feed on solanaceous hosts like green peppers and eggplant to some extent, they did not prefer another solanaceous host, tomato when other choices were offered. So, tomato plants do not seem to be at risk of this pest and could be used in crop rotation.

- A strong preference for green beans is a significant finding. This is probably the first report of Bagrada bug feeding on and preferring green beans. Bean growers should be cautious of this pest.

- Alyssum and wild mustard can probably be used as trap crops.

References


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<td>Brassica oleracea</td>
<td>Brassicaceae</td>
<td>Crop plant</td>
</tr>
<tr>
<td>Green bean</td>
<td>Phaseolus vulgaris</td>
<td>Fabaceae</td>
<td>Crop plant</td>
</tr>
<tr>
<td>Tomato</td>
<td>Solanum lycopersicum</td>
<td>Solanaceae</td>
<td>Crop plant</td>
</tr>
<tr>
<td>Wild mustard</td>
<td>Synapsis arvensis</td>
<td>Brassicaceae</td>
<td>Weed plant</td>
</tr>
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</table>

Table 2. Preference of Bagrada bug adults as expressed by percent insects found on different plants

<table>
<thead>
<tr>
<th>Host</th>
<th>Assay 1</th>
<th>Assay 2</th>
<th>Assay 3</th>
<th>Mean</th>
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</thead>
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<td>Broccoli</td>
<td>8.3</td>
<td>16.7</td>
<td>50.0</td>
<td>25.0</td>
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<tr>
<td>Green bean</td>
<td>8.3</td>
<td>33.3</td>
<td>16.7</td>
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<tr>
<td>Tomato</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Wild mustard</td>
<td>33.3</td>
<td>50.0</td>
<td>0.0</td>
<td>27.8</td>
</tr>
</tbody>
</table>

Table 3. Preference of Bagrada bug nymphs as expressed by the proportion insects found on different food sources

<table>
<thead>
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<th>Host</th>
<th>Proportion of insects</th>
</tr>
</thead>
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</tr>
<tr>
<td>Broccoli</td>
<td>0.0</td>
</tr>
<tr>
<td>Green bean</td>
<td>60.0</td>
</tr>
<tr>
<td>Tomato</td>
<td>0.0</td>
</tr>
<tr>
<td>Wild mustard</td>
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</tbody>
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NEW ANR PUBLICATION!

Caneberry consumption is increasing in the US and elsewhere around the world with California producing over 90 percent of the US fresh market raspberries. Although California has led total caneberry production in recent years, this is the first caneberry production manual designed for Western fresh market growers. This manual can be purchased through University of California ANR catalog.

To order click on: [http://anrcatalog.ucdavis.edu/](http://anrcatalog.ucdavis.edu/)

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Year-round Strawberry IPM Program
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Integrated Pest Management is pivotal in providing effective and sustainable management of pests and diseases in various crops. University of California has an extensive IPM program with sound science-based solutions for numerous pests, diseases, and weeds. One of our approaches is to provide guidelines for year-round IPM to help mitigate environmental health issues while providing practical management options.

Year-round IPM program enables the growers to make appropriate decisions before and throughout the growing season to avoid or mitigate pest problems. From choosing the right field or ideal cultivar to timely harvesting or postharvest field sanitation are important in avoiding several problems. Here is a brief overview of year-round strawberry IPM.

Before planting

**Crop rotation:** Rotating strawberries with nonsusceptible hosts is recommended for some diseases like charcoal rot.

**Field selection:** A clean, well-drained field free of diseases or away from sources of pest infestations will reduce the risk of some diseases like Fusarium wilt and pests like lygus bug and spider mites.

**Fumigation or solarization:** Several soilborne diseases and weeds can be effectively controlled through fumigation or solarization (where practical). Studies with non-chemical fumigation techniques such as anaerobic soil disinfection are under way and can provide alternative solutions to chemical fumigants.

**Cultivar selection:** Choose a cultivar that is resistant to major pests and diseases.

**Weed management:** Several flowering weeds serve as a source of lygus bugs. Managing such weeds in winter reduces the risk of lygus bug.

**Plastic mulch:** Using a mulch that promotes healthy plant growth helps plants withstand some disease and pest issues.

**At planting**

**Clean and strong transplants:** Diseases such as angular leaf spot, anthracnose, common leaf spot, phytophthora crown rot, powdery mildew, and pallidosis-related decline of strawberry are among the diseases that can be introduced to the production fields through infected transplants. Pests like spider mites and cyclamen mites can also be brought in through transplants. Inadequate or excessive chilling of transplants can result in reduced yields and predispose plants to pest or disease problems. Obtaining transplants from a reputable nursery is always a good investment.

**Planting:** Adequate spacing and other care while planting are important for optimal plant growth and yield as well as reducing the risk of certain diseases.

**Careful handling ensures a healthy start for the production fields.**

**After planting**

**Irrigation:** Since strawberries are sensitive to salinity, good water source is important for plant health. Excessive drip or overhead irrigation causes several disease problems such as angular leaf spot, common leaf spot, and red stele. Water stress can weaken plants and worsen the spider mite problem.

**Nutrition:** Optimal fertilizer supply is important for a
healthy crop and good yields. Excessive nitrogen application can worsen some pest problems or diseases like powdery mildew and Verticillium wilt.

**Sanitation:** Removal of infected or old fruit or plant material is important for minimizing botrytis fruit rot, leather rot, mucor rot, and Rhizopus fruit rot. This practice also important in managing spotted-wing drosophila or other such pests.

Regular monitoring: Regularly monitoring fields for pest, disease or other problems and taking preventive or proactive measures is critical. Proper sampling techniques are important for making treatment decisions.

Watering the drive ways prevents dust which can worsen spider mite problem.

Testing spider mite resistance to miticides. Prepare a small quantity of miticide solution at the field application rate. Dip a leaf with suspected mite populations. Keep the leaf in a cool, dry place and observe mite mortality for 1-3 days after miticide treatment. Mortality will be low if they are resistant.

**Pesticides:** Timely application of right pesticides is critical in preventing and minimizing the problems. Rotating chemicals with different modes of action increases the control efficacy and reduces the risk of resistance. If insecticide resistance is suspected, test over a small area or on suspected populations before large scale application.

**Biological control:** Conserve natural enemies by providing alternate hosts as refuges and by using softer chemicals. Good natural enemy populations play a major role in managing pest populations. Predatory mites are effective in controlling spider mites, but choosing the right species at the right time is important.

Releasing predatory mites to control spider mites.

**Microbial control:** In recent field studies, the entomopathogenic fungus, *Beauveria bassiana* showed a potential for managing lygus bug and spider mites.

**Botanical pesticides:** Recent field trials produced promising results with azadirachtin, a neem-based insect growth regulator in managing some pests including lygus bug.

Other measures and all-time care with good agricultural practices are important for a successful IPM. IPM is an ecosystem-based strategy for a long-term prevention of pests or their damage through a combination of various techniques. Pesticides are used only as necessary with appropriate materials that have minimal risk to humans, non-target organisms, and the environment.

Additional details on various pests, diseases, and weeds, sampling procedures, survey forms, management options, and year-round strawberry IPM program can be found at the following UC resources:

http://www.ipm.ucdavis.edu/PMG/C734/m734yi01.html

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