Using biopesticides and reduced-risk pesticides for insect control in high tunnel vegetable production

Gerald E. Brust, IPM Vegetable Specialist
Feb. 2011

Summary: Previous work by the PI has shown that if combined with the fungus *Beauveria bassiana (Bb),* diatomaceous earth may increase the efficacy of the fungal pathogen by causing slight fractures in the insect's integument and thereby increasing fungal infections. It is also important to determine if one strain of *Bb* works better in warmer or cooler temperatures and if they work better with diatomaceous earth. Tomatoes, strawberries and cucumbers were used in the study and are the most commonly grown crops in HTs in the mid-Atlantic. There were three sites used in the study across the state that represent the coastal, Piedmont and foothill areas. The major pests were aphids, thrips and mites in the early and mid part of the season with tomato fruit worm tomato hornworm and yellow striped armyworm more of a problem in August through October. The use of *Beauveria bassiana* (*Bb*) did reduce aphid, mite and thrips populations in strawberry, cucumbers and tomatoes, but only nominally reduced worm populations in tomatoes. The *Bb* strain *ATCC* reduced mites in strawberries significantly better in April, May and early June and in cucumbers in late-October and November compared with the *GHA* strain. However, the *GHA* strain reduced mite populations better in the warmer months of July, August and September in cucumbers compared with the *ATCC* strain. *Bb* increased strawberry and cucumber yields by an overall average of 35% in 2009 and by 25% in 2010. In tomatoes both *Bb* strains did a good job of reducing aphid populations through the growing season, although the *GHA* strain consistently preformed better in controlling aphids than did the *ATCC* strain. The new threshold for HT pests developed by the PI in previous biopesticide grant work again demonstrated that earlier applications of the biopesticides allowed the fungus to build up on plant foliage so that by the time pest numbers were increasing the fungus was present in sufficient concentrations to reduce their numbers before their populations were out of control. Control of the various species of Lepidoptera, i.e., hornworm, yellow striped armyworm and tomato fruit worm, was not as successful using either strain of *B. bassiana.* When reduced risk pesticides were used along with DE and *Bb*, DE alone did not improve aphid or worm control compared with the control. However, the use of *Bb* alone did somewhat reduce aphid and worm numbers compared with DE or the control, but by combining both *Bb* and DE in applications there was a significant drop in aphid and worm numbers. Worm counts showed that there was a 22% increase in the number of worms with a fungus infection in the *Bb*+DE treatment compared with the *Bb*-alone treatment. The greatest reduction in worm or aphid numbers was accomplished with the use of the reduced-risk pesticides Fulfill (aphids) and SpinTor (worms). Adding DE to either of these reduced-risk pesticides did not improve control. Where reduced risk pesticides were used there was a definite dichotomy in tomato yields when comparing the reduced risk pesticides and the combination of *Bb*+DE which produced an average yield of 19.1 lbs/plant vs. using *Bb*-alone, DE-alone or the control, which averaged significantly less at 11.4 lbs. per plant. Predator numbers were disappointedly low in all high tunnels over the two years of trials.

Introduction: Vegetable growers need new and alternative methods to bring more money into their operations without investing much capital. The use of a high tunnel (HT) has worked well for many growers, but especially small farms to increase on-farm profits. Because HTs extend the vegetable growing season growers are able to supply customers with high quality fresh produce earlier and later into the spring and fall then is normally possible. This results in increased profits for the farm. Although HTs are relatively inexpensive to construct and use there is an increase in the amount of management that goes into their operation. There are few guidelines available for growers to use regarding how to manage their insect problems because so little is known about how best to manage pests in HTs. Over the last few years aphids, mites, thrips and some worm species (tomato fruit worm *Helicoverpa zea* (Boddie) and tomato hornworm *Manduca quinquemaculata* (Haworth)) have become consistent problems in HTs. It is believed they are more of a problem in HTs because of the micro climate created for the plants, which makes the plants grow well and therefore is a good place for the pests to flourish.

Even with natural enemies present in densities that should allow for control of the pests in the HTs the pests usually prevail and increase to damaging levels. This reduces the quality and yield of produce that a grower can harvest, which reduces their profits. Because the area inside a HT is rather confined growers tend to not treat with conventional high-risk pesticides. Use of conventional insecticides also is limited because of reentry intervals (REI) and preharvest intervals (PHI) that are too long between harvests. So there are worker safety and residue concerns with conventional pesticides. The organic pesticides used (oils, soaps, plant extracts, etc.) have not worked well for most growers. Work done by the PI demonstrates that economic or action thresholds in HTs need to be adjusted for some of the major pests such as aphids, thrips, mites and worms. Waiting until pests reach thresholds established for field or even greenhouse operations resulted in consistently poor control of the pests. Even if natural enemies are present pests still increase rapidly to damaging levels. The new management program works by applying spray treatments just as pests are observed to establish themselves. A common organic insecticide is diatomaceous earth (DE). DE is the skeletal remains of ancient diatoms, tiny calcareous ocean dwellers that have built large reserves that are now mined to use in various industrial applications. Their pointed structures make for effective miniature cutting and piercing tools that can cut through the waxy layer of an insect's cuticle causing it to die of dehydration. Unfortunately when applied to insects in the field it has not worked as well as hoped. Work by the PI has shown that if combined with Bb, DE may increase the efficacy of the fungal pathogen by causing slight cracks in the insect's integument and thereby increasing fungal infection. In addition to the DE work, the PI found that *B. bassiana* strain *ATCC* (Naturalis L) seemed to work well in the early part of the season (when it was cooler), but not as well when it became warmer while the GHA strain seemed to do just the opposite. Therefore, it is important to discern if one strain of *Bb* works better in warmer or cooler temperatures and if they work better with diatomaceous earth.

Project Objectives:

Obj. 1 – Test the two strains of the biopesticide *Beauveria bassiana* Naturalis L strain *ATCC* and BotaniGard ES strain *GHA* in high tunnels for their effectiveness in controlling aphids, mites, worms and thrips.

Obj. 2 – Test the use of diatomaceous earth alone and with Naturalis L and BotaniGard ES as well as with other pesticides (in non organic systems).

Obj. 3 – Test the above chemical products in organic and non-organic tomato, strawberry and cucurbit high tunnel production sites across the state of Maryland.

Material and Methods:
Treatments:
1. Naturalis L, and Botanigard ES equivalent of 0.5 to 2 quarts /100 gallons of spray; applied at weekly intervals starting when pests reach newly developed thresholds and continue for the next four weeks. This is then repeated when pest populations reestablish. In HT-3 and -4 where Bb was applied, *ATCC* was applied in the cooler (High temps in HT < 84 ^{o}F) parts of the season while *GHA* was applied in the warmer (High temps in HT $\geq$ 85 ^{o}F) periods of crop production.

2. Diatomaceous Earth 25g/L; will be applied every week starting with the first application of *Beauveria bassiana* or reduced risk pesticide and continue for four weeks.

3. Treatments 1 and 2 combined

4. Reduced risk pesticides: Fulfill (pymetrozine) for aphids, Acramite (bifenazate) for mites and SpinTor (spinosad (same a.i. as in Entrust) for thrips and worms. Applications began when targeted pest was first observed to establish itself..

5. Treatments 2 and 4 combined

6. Control-Grower selection: either no control or Horticultural oils or insecticidal soaps applied.

Crops used: Tomatoes, strawberries and cucumbers were used in the study and are the most commonly grown crops in HTs in the mid-Atlantic and often are grown together. This exacerbates problems with insect pests such as mites and aphids as they build on one crop and move easily from one to the next (see Fig. 1).

Experimental design: Treatments were replicated three times per HT per crop. Plot size consisted of 5-20 plants of each vegetable or fruit type (tomato-5 plants, strawberry-20 plants and cucumber-5 plants). In HT-1 strawberry and cucumbers were grown, in HT-2 and HT-3 tomatoes were grown, but in HT-3 reduced risk insecticides were used as compared with only using *Bb* in HT-3. The strawberry cultivars *Chandler* and *Sweet Charlie* and the cucumber cultivars *Diva*, *Tasty Green* and *Dasher II* were used in HT-1 in 2009 and 2010. The tomato cultivars of *Mt Fresh, Florida 91, Mt Spring* and *Sunstart* were used in HTs-2 and 3 in 2010.

Locations: There were three sites used in the study across the state: Queenstown, Upper Marlboro and Frederick, MD, which represent the coastal, Piedmont and foothill areas respectively of the state.

Data collection: Strawberry, tomato and cucurbit plants were examined every 7-10 days for aphids, mites, thrips and worms. Five leaves per plant, three plants per plot were searched for pests and natural enemies in each treatment. The number of pests per plant was recorded. When flowers were present, ten flowers per plant were examined for thrips and predators (*Orius* spp.). Yields were taken from each treatment and recorded for number, weight and quality.

Pests controlled: The major pests were aphids (Green peach, *Myzus persicae* and Melon aphid, *Aphis gossypii*), thrips (mostly Eastern with some Western flower thrips, *Frankliniella tritici*, *F. occidentalis* respectively) and mites (mostly two spotted spider mite, *Tetranychus urticae*) in the early and mid part of the season with tomato fruit worm *Helicoverpa zea*, tomato hornworm *Manduca quinquemaculata* and yellow striped armyworm *Spodoptera ornithogalli* more of a problem in August through October.

Results and Discussion: In the second year of the study, 2010, the weather conditions were record setting as conditions were much warmer and drier than normal. Planting dates were 2-3 weeks earlier as were pests. The very warm dry conditions increased mites, worms and thrips populations and to a lesser extent aphid numbers compared with an 'average' season (Brust 2010).

The use of *Beauveria bassiana* (*Bb*) did reduce aphid, mite and thrips populations in strawberry, cucumbers and tomatoes, but only nominally reduced worm populations in tomatoes (Figs. 1 and 4 (bars in all figs represent $\pm$1 SE of the mean)). The *Bb* strain *ATCC* reduced mites in strawberries significantly better in April, May and early June and in cucumbers in late-October and November compared with the *GHA* strain (Fig. 1). However, the *GHA* strain reduced mite populations better in the warmer months of July, August and September in cucumbers compared with the *ATCC* strain (Fig. 1). The reduction of the mite populations, which had plagued this grower for the last few seasons, by using the strains of *Bb* increased strawberry and cucumber yields by an overall average of 35% in 2009 and by 25% in 2010 (Figs. 2 and 3). Another important finding is that cultural controls are still very important in any vegetable production system even HTs. This can be seen by the mite populations between the strawberry and cucumber crops in 2009 vs. 2010. In 2009 the grower waited only about 10 days between finishing his strawberries and starting his next crop-cucumbers and the mite population started to increase rapidly in all treatments with the *GHA* strain finally being able to reduce their populations. In 2010 however, the grower waited almost 25 days before planting his next crop of cucumbers and mite populations were much lower at the beginning of the season and throughout the cucumber growing period reducing mite levels by 30-40% compared with the season before. This is in spite of the fact that mite numbers were as great at the beginning of 2010 as they were in 2009 in strawberry. This is something we have seen over and over again in both field and HT-cultural practices are important and it is difficult to overcome high initial pest populations with organic or even reduced-risk or high-risk pesticides.

In tomatoes both *Bb* strains did a good job of reducing aphid populations through the growing season, although the *GHA* strain consistently preformed better in controlling aphids than did the *ATCC* strain (Figs. 4 and 5). The Grower control plots had more than 3-times the number of aphids in tomato plants as compared to either strain of Bb (Fig. 4). Aphid numbers started to increase quickly after the 2nd week in May. *Beauveria bassiana* applications would have normally been started at the second or third week in May when populations were building. But instead they were started at the beginning of May, when winged adults were first observed giving birth to immature aphids. This is an example of the new threshold for HTs. These earlier applications allowed the fungus to build up on tomato foliage by the time aphid numbers were rapidly increasing, which enabled the fungus to keep aphid numbers in check before their populations were too large and out of hand, as we saw with the mites in HT-1.

Control of the various species of Lepidoptera, i.e., hornworm, yellow striped armyworm and tomato fruit worm, was not as successful using either strain of *B. bassiana* (Figs 4 and 5). While *Bb* did reduce numbers of worms in tomato compared with the control the reduction was not that great and damage levels were not significantly different among treatments (Control damage-18.3% tomato fruit with some feeding; *ATCC* strain damage to fruit-15.6%; *GHA* damage to fruit-12.2%) (Fig.4). In HT-3 control of worms was excellent using the reduced-risk pesticide SpinTor applied just 3 times (Fig. 5).

In HT-3 reduced risk pesticides were used along with DE and *Bb*. Using DE alone did not improve aphid or worm control compared with the control, while the use of *Bb* alone did reduce aphid and worm numbers consistently compared with DE or the control, there was still a sizable population of both aphids and worms in these treatments (Fig. 5). However by combining both *Bb* and DE in applications there was a significant drop in aphid and worm numbers (Fig. 5). Worm counts showed that there was a 22% increase in the number of worms with a fungus infection in the *Bb*+DE treatment compared with the *Bb*-alone treatment. The greatest reduction in worm or aphid numbers was accomplished with the use of the reduced-risk pesticides Fulfill (aphids) and SpinTor (worms) (Fig. 5). Adding DE to either of these reduced-risk pesticides did not improve control (Fig.5).

Thrips numbers were only above threshold (>5 thrips/flower) once in late September and that was in the control (Fig. 6). The reduced–risk pesticide SpinTor kept thrips numbers extremely low throughout the study. *Beauveria bassiana* also reduced thrips numbers compared with the control but not as low as SpinTor. As we saw before with worms and aphids, DE alone did no better than the control in reducing thrips, but when combined with the *Bb* strains significantly increased thrips control compared to either one alone.

Tomato yields were very good in both high tunnels averaging 16 lbs per plant (Fig. 8). There were few differences in yields between the strains of Bb with both yielding about 65.6 lbs on average over the season per plot vs. the control which averaged 57.3 lbs per plot. Yields in all three treatments increased as the season progressed into September.

In HT-3 where reduced risk pesticides were used there was a definite dichotomy in yields when comparing the reduced risk pesticides and the combination of *Bb*+DE which produced an average yield of 19.1 lbs/plant vs. using *Bb*-alone, DE-alone or the control, which averaged significantly less at 11.4 lbs. per plant (Fig. 8). There were three main pests in HT-3 in the tomatoes and while *Bb* alone did reduce each of the populations of pests compared with DE-alone or the control the reduction was not enough to increase yields compared with what the reduced risk pesticides and the combination of *Bb*+DE could do (Fig. 8). This is one reason why it is important to look at several pests and not concentrate on just a single pest in pesticide trials. Not being able to reduce all pests to sufficiently low numbers can result in the “death by a thousand cuts” scenario where none of the pests are at devastating numbers, but when combined they sap the plants of their yield potential. This is the type of situation growers frequently face—

many pests all at the same time. So even though *Bb* does reduce pest numbers it is not always by enough compared with other more efficacious controls.

Predator numbers were disappointedly low in all high tunnels over the two years of trials. Lacewings, *Chrysoperla spp*, were some of the most common predators, but their numbers were not significantly different between any of the treatments (Fig. 7). Although there was a general trend that numbers were greater in the control and *Beauveria bassiana* treatments compared with the other treatments especially in the earlier part of the season Fig. 7). This general trend was found for other predators such as *Orius insidiosus*, insidious flower bug, syrphid fly larva, and parasitoids, i.e., *Anopheles* spp. There were few differences between any of the treatments and numbers were so low that it was difficult to get any consistent separation between treatments.

Fig. 1 Mite populations in strawberry and cucumbers in HT-1 in 2009 and 2010.

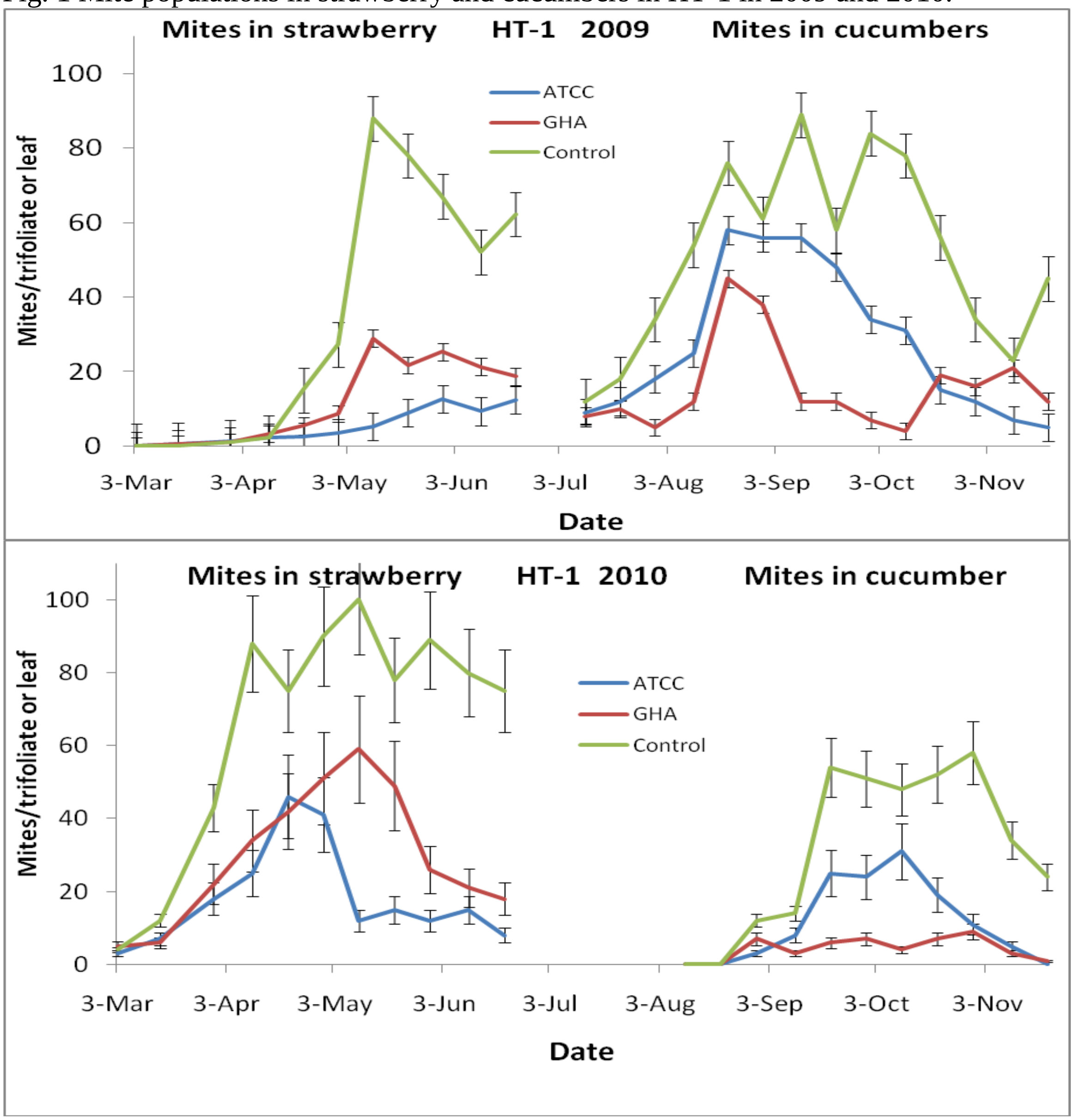
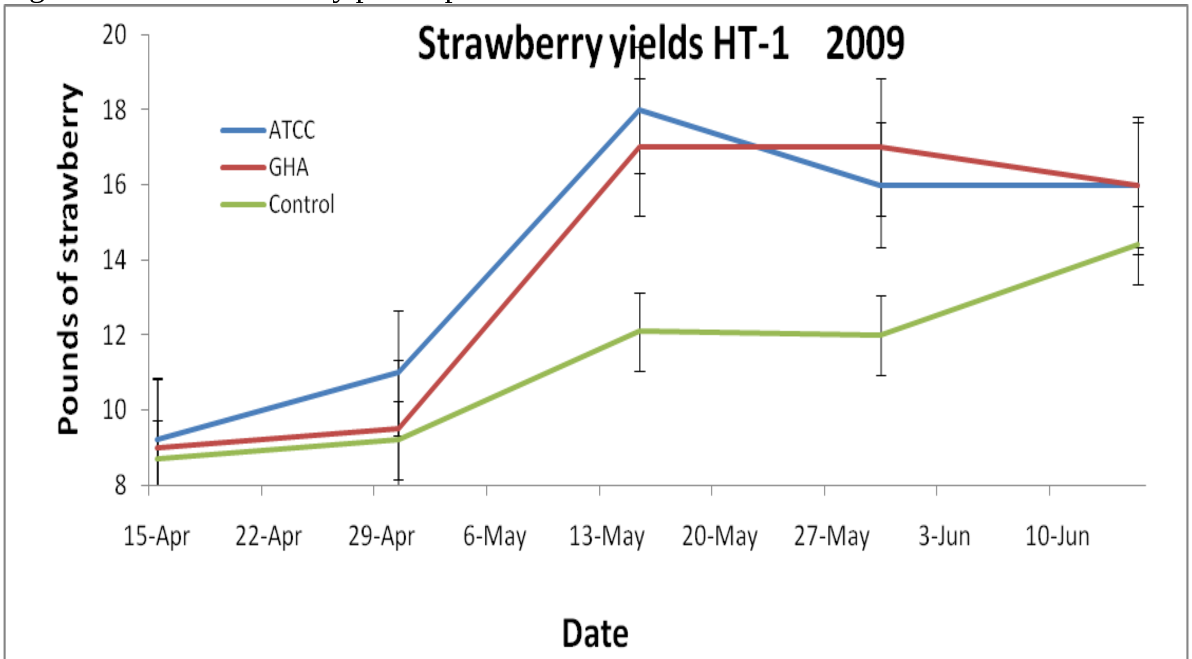


Fig. 2 Yields of strawberry per 20 plants in HT-1 in 2009 and 2010.



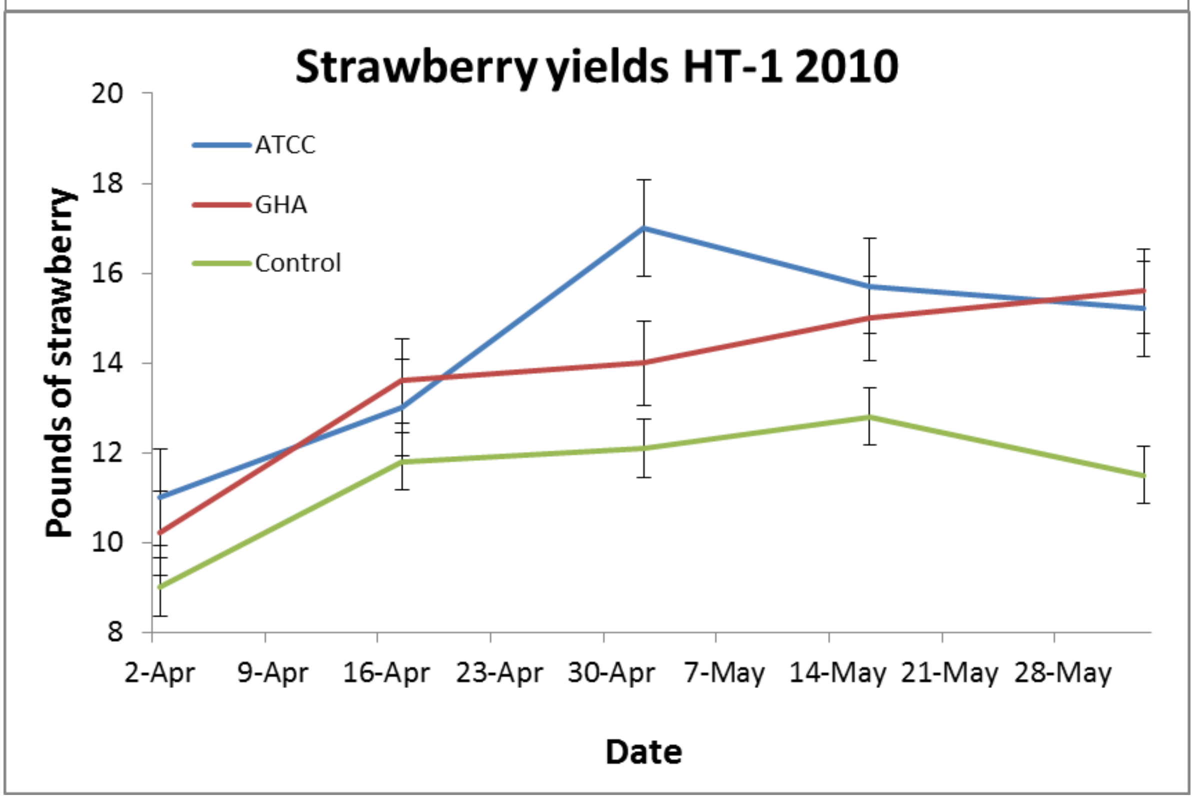
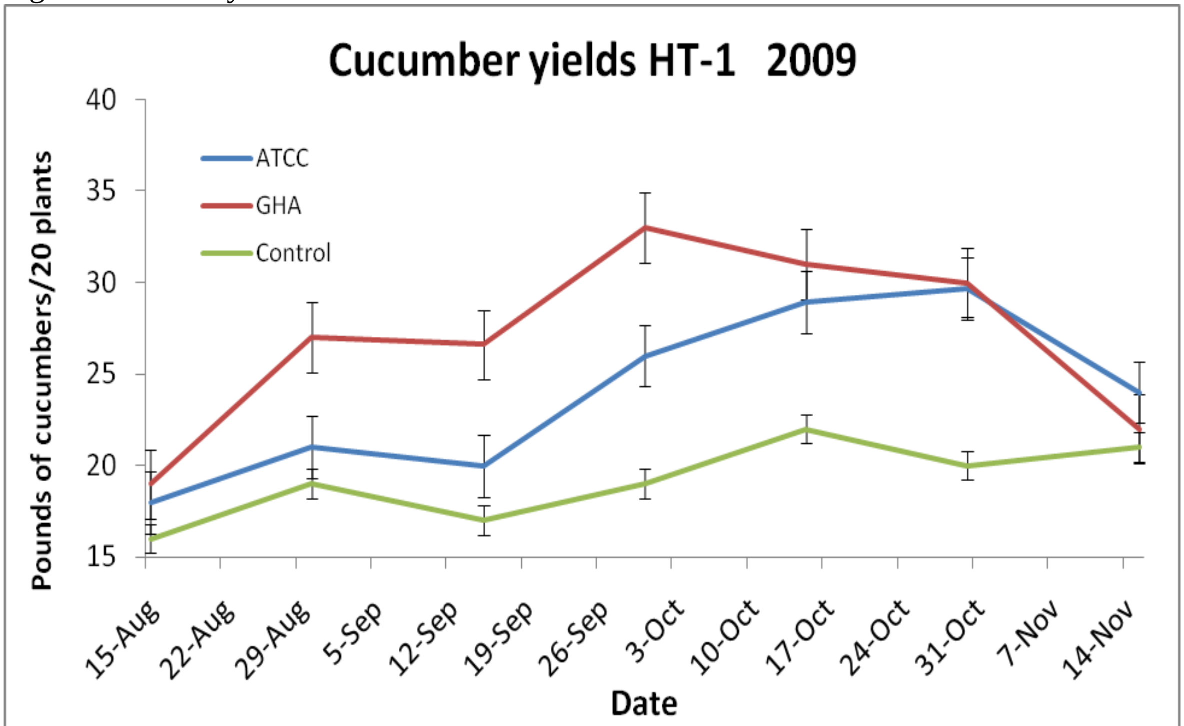


Fig. 3 Cucumber yields in HT-1 in 2009 and 2010.



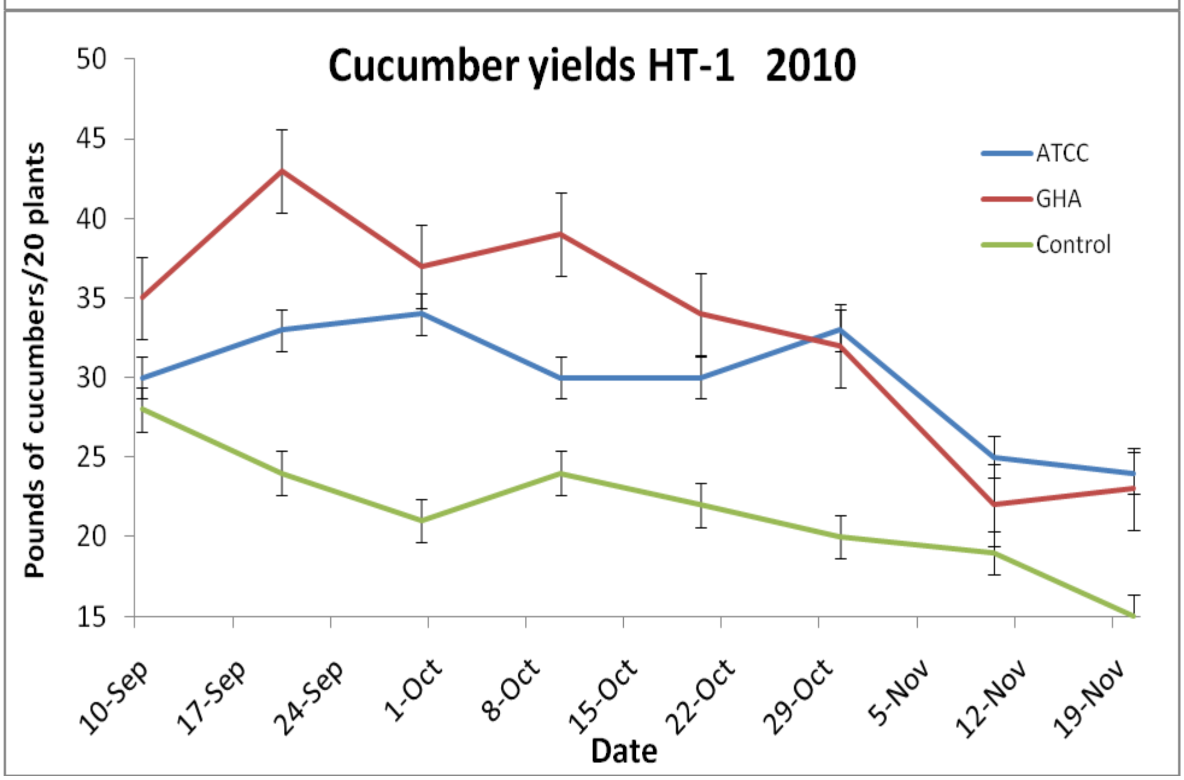
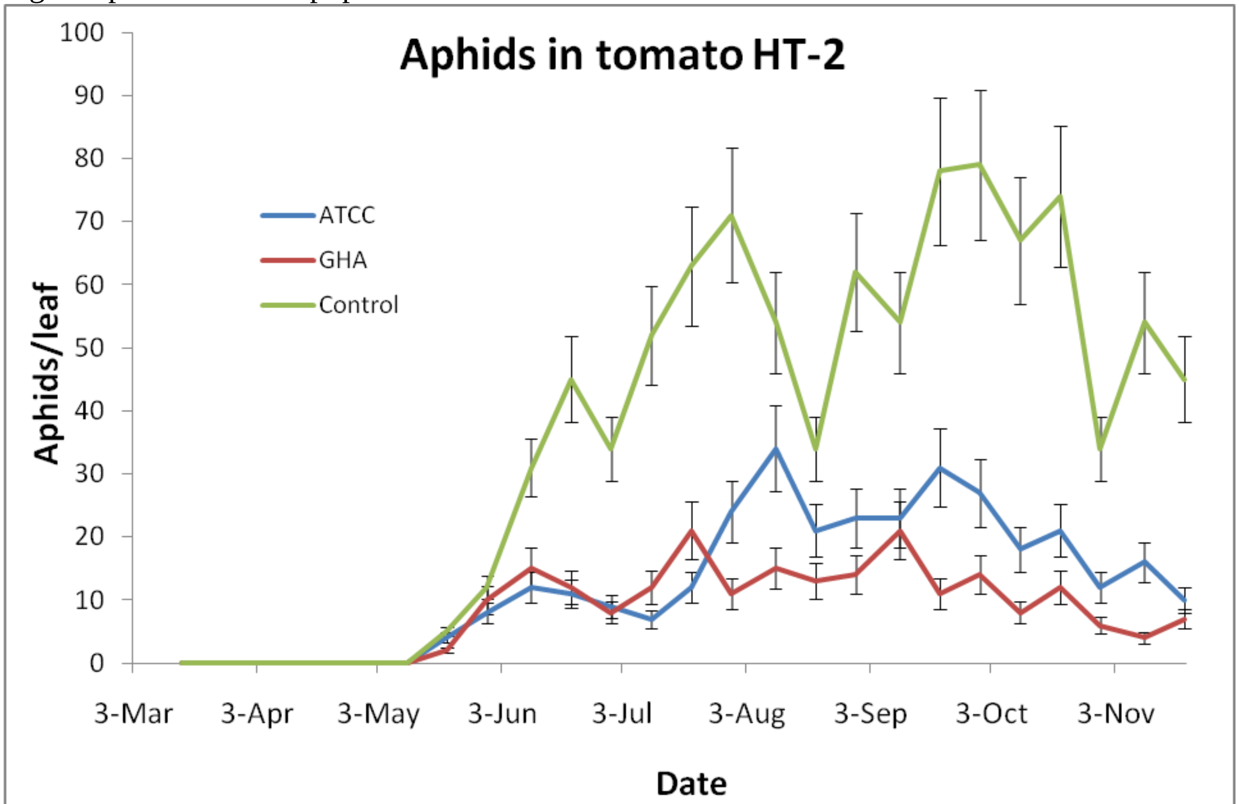


Fig. 4 Aphid and worm populations in tomato in HT-2 in 2010.



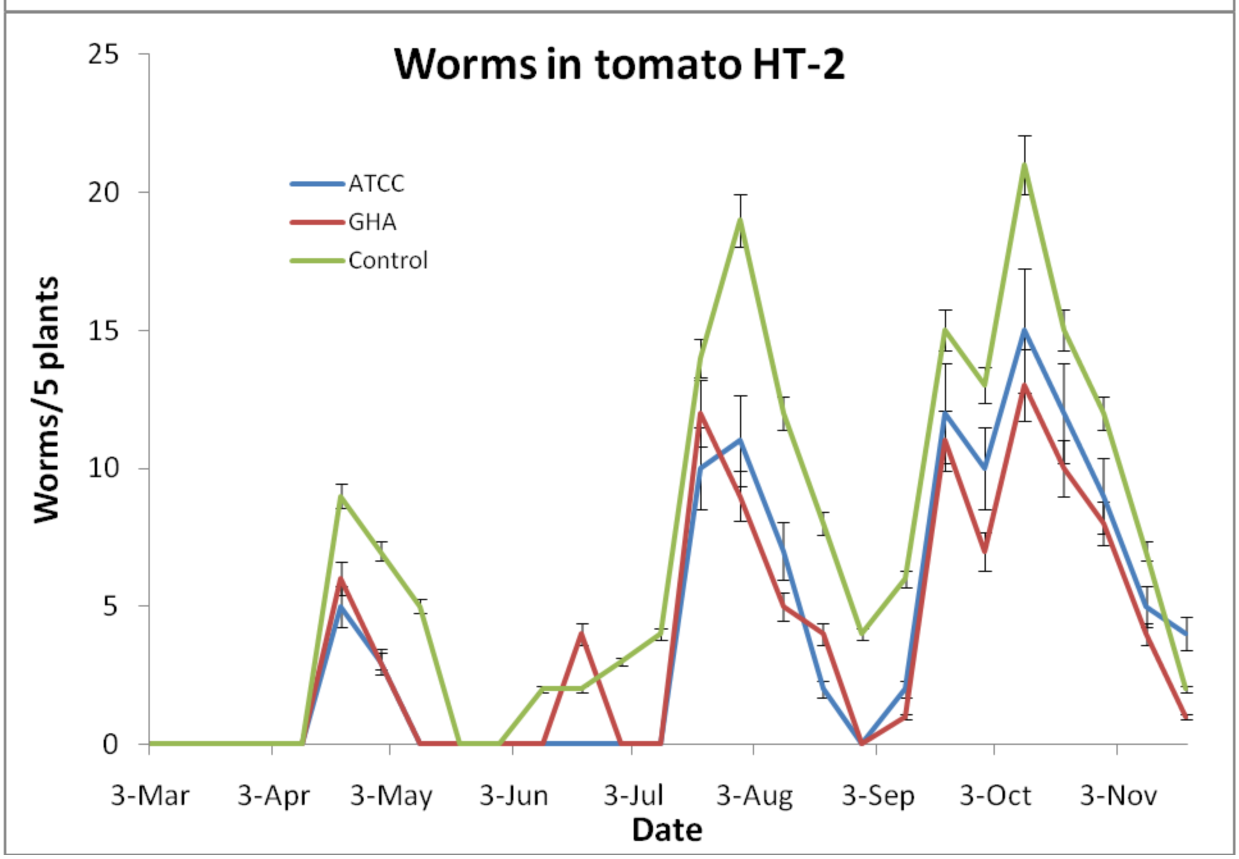
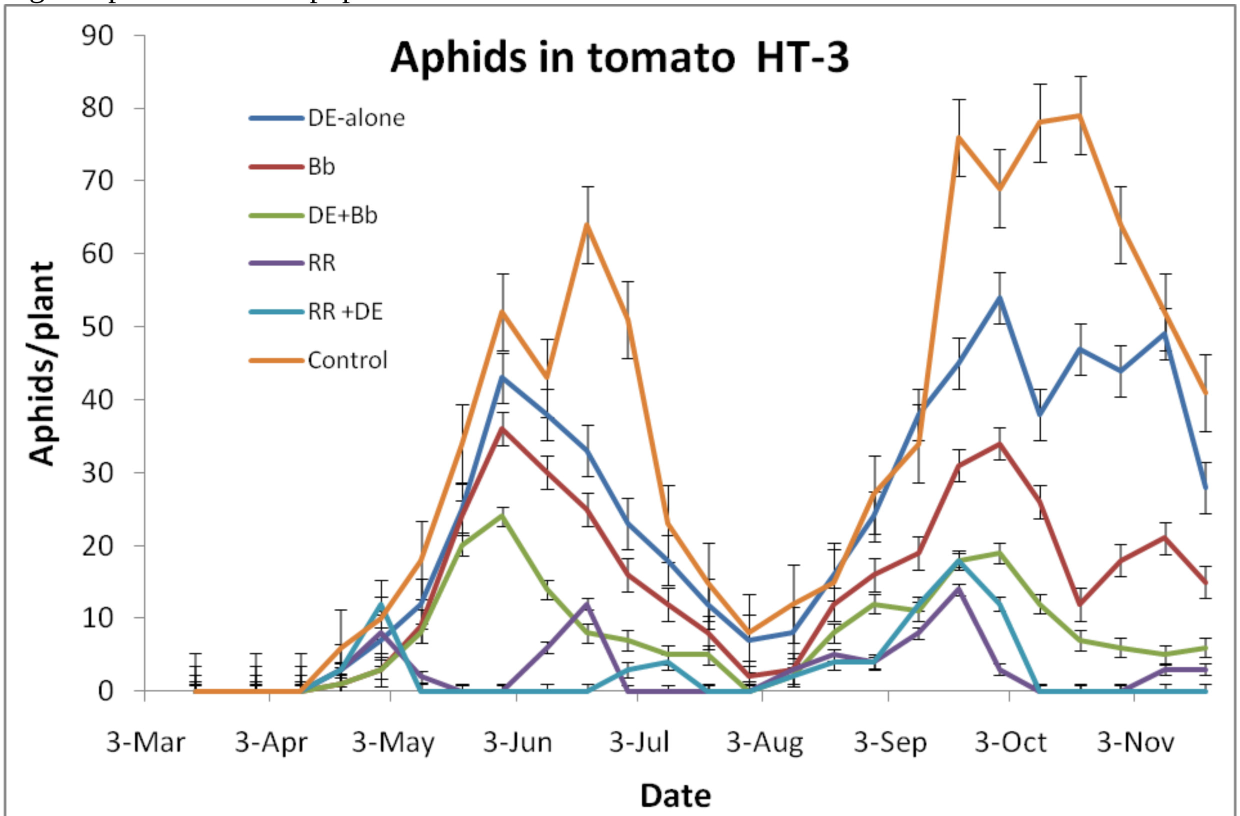


Fig. 5 Aphid and worm populations in HT-3 in 2010.



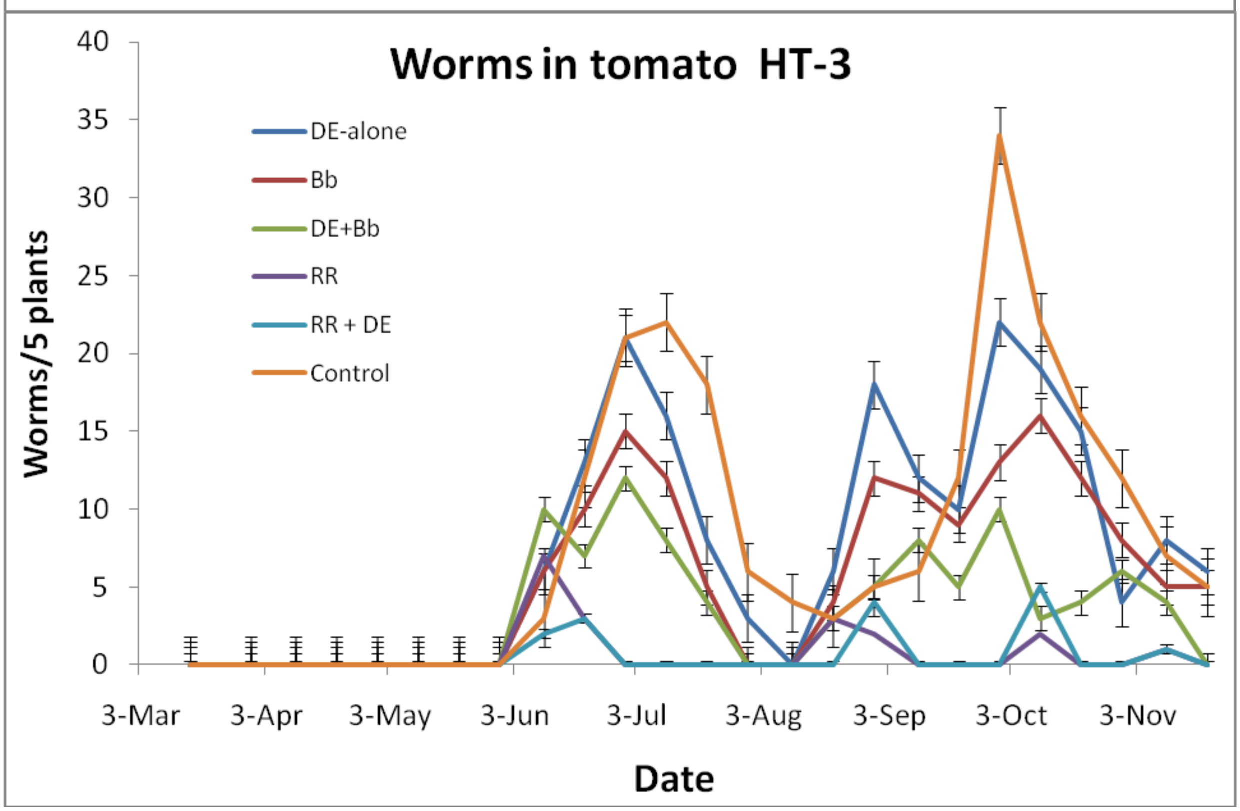


Fig. 6 Thrips populations in tomato in HT-3 in 2010.

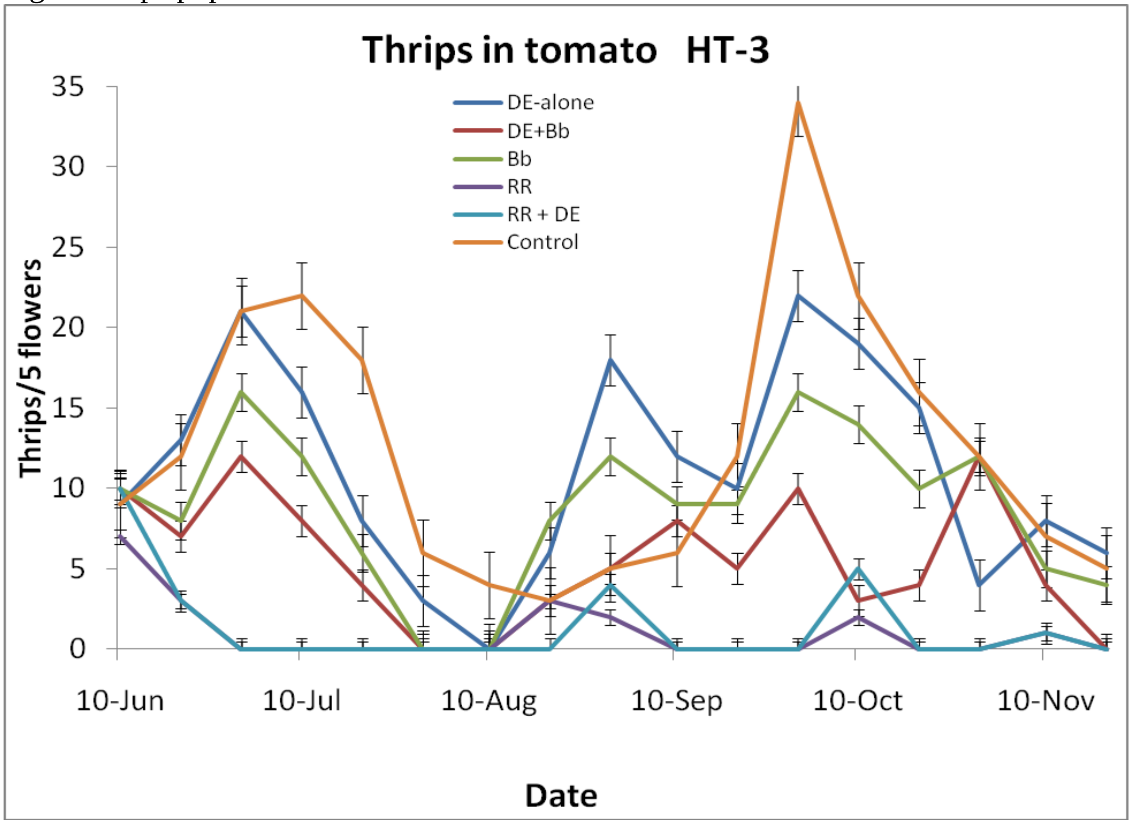


Fig. 7 Lacewing (*Chrysoperla spp*) numbers in HT-3 tomatoes in 2010.

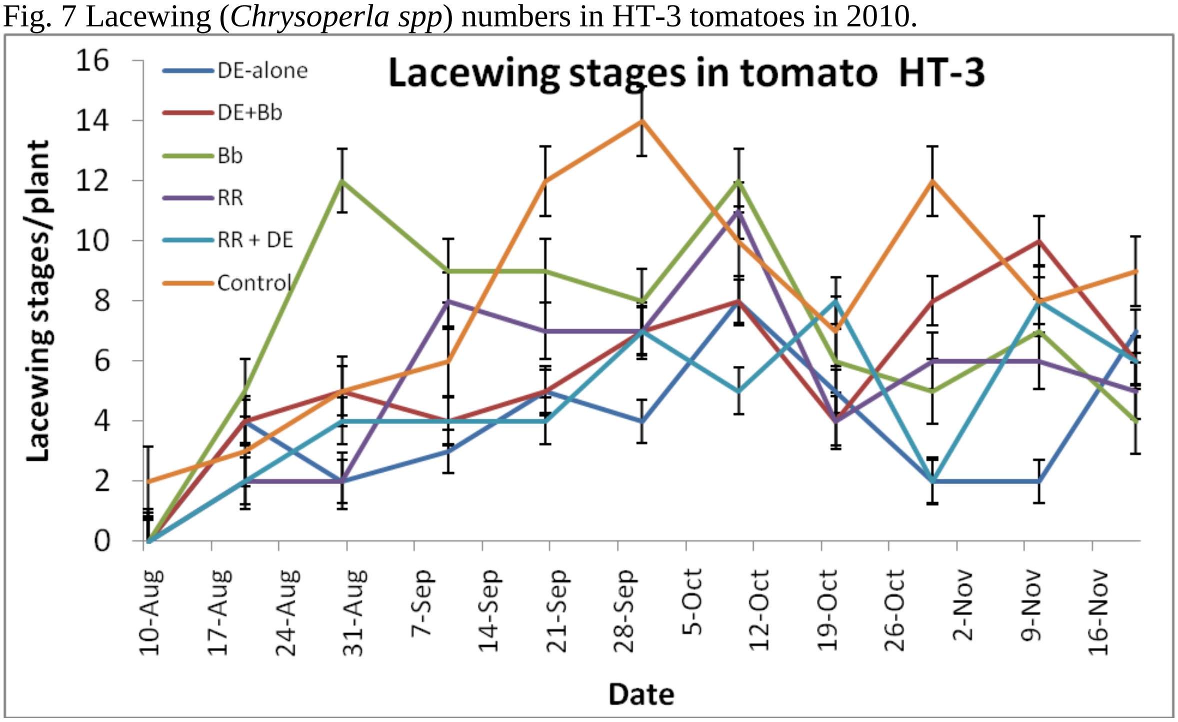
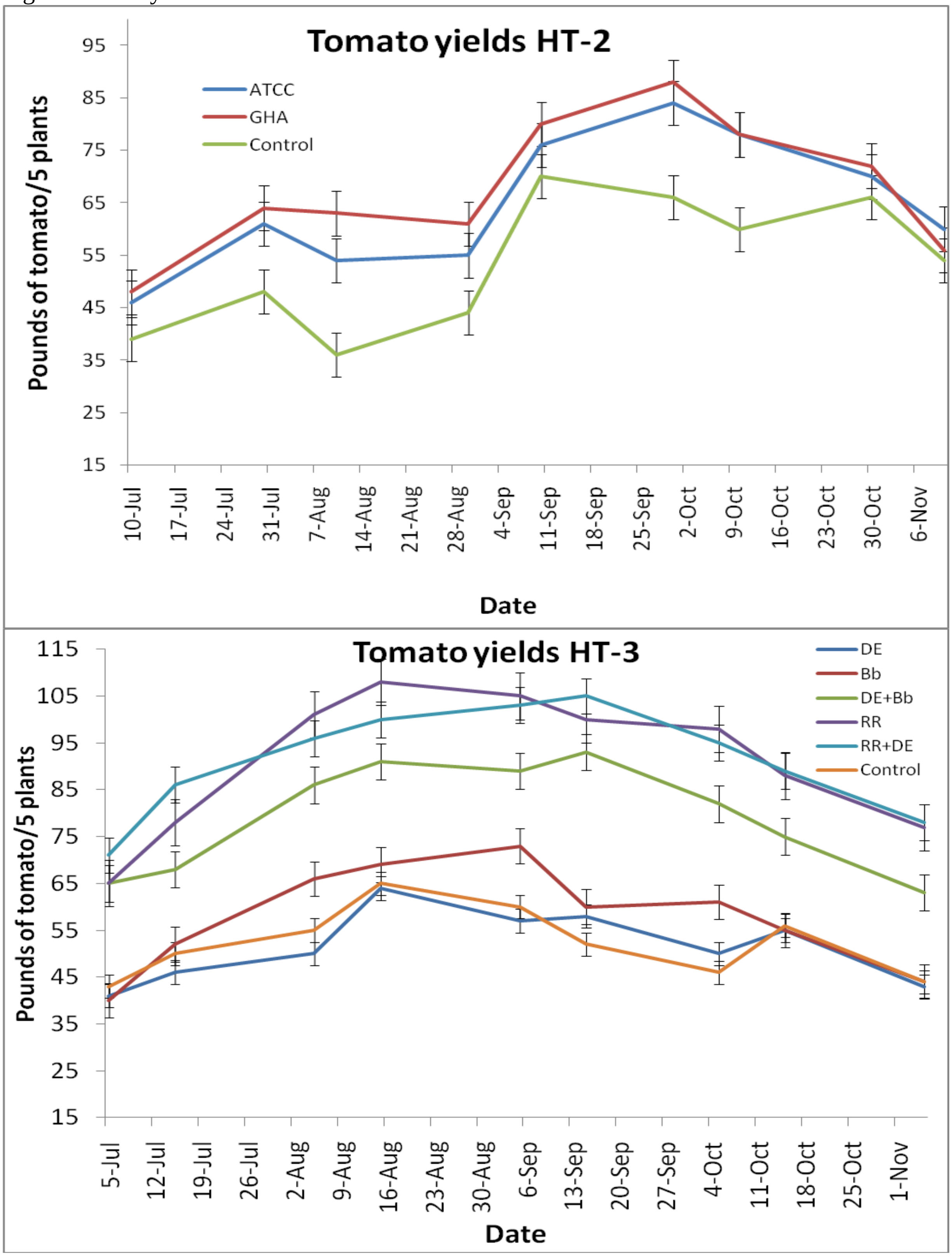


Fig. 8 Tomato yields in HT-2 and HT-3 in 2010



Risk reductions: The use of the two strains of *Beauveria bassiana* and DE and at times Entrust for thrips, worm, and aphid and mite control in organic HTs with the addition of the reduced risk products Acramite (bifenazate) for mites and Fulfill (pymetrozine) for aphids and SpinTor (spinosad) for thrips and worms does an excellent job of controlling the major pests in high tunnel vegetables. This program eliminates all high-risk pesticides, i.e., carbamates, pyrethroids and organophosphates used in the high tunnel. This allows for better worker safety and ease of harvest without the long REIs and PHIs associated with many of the conventional insecticides.

Outreach: Outreach activities included field days at two of the HTs. In 2009 we had 45 growers at a late May HT meeting and 34 at an early August meeting. In 2010 there were 26 growers at the mid-May HT meeting and 23 at the early August HT meeting. The extension publication "Managing insect pests using biopesticides and reduced risk pesticides in high tunnel vegetables", which explains the management program, is on my vegetable web site (http://mdvegetables.umd.edu/) as well as The Maryland Vegetable Growers Association's. The reduced risk program was presented at 1 winter meeting in 2009 entitled "Using reduced–risk pesticides in various vegetable production systems" and in 2010 at two winter vegetable meetings both entitled "Reduced risk chemical program in various vegetable production systems".

References cited

Brust, G. 2010. High temperatures for the 2010 season increase pest problems in vegetable high tunnels and fields. Found at: http://mdvegetables.umd.edu/.

This research was supported in large part by the USDA-CSREES and Rutgers University Biopesticide field demonstration project. Sub award no. 2008-MD002BDP-Brust

UNIVERSITY OF MARYLAND EXTENSION

Solutions in your community