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Effects of organic management practices on diversity and pest abundance in a cucurbit production system

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Introduction

Native ecosystems are affected by a variety of biotic and abiotic factors that govern an organism's ability to persist and keep any one species from competitively excluding all others. A complex community structure is thus formed in which many species occupy the same general habitat but each with their own set of behaviors, preferences, and life histories forming their ecological niche. This complexity in community structure facilitates a system to cope with disturbance and can be thought of as biodiversity. Biodiversity increases the probability that some number of species will go unaffected or are able to quickly adapt to changes in their environment. Since environmental variability and disturbances naturally occur, biodiversity becomes necessary for an ecosystem's stability and productivity.[7,8,12]

Within the context of arthropods, most insect populations are stabilized by environmental factors such as predation, host-plant availability, and pathogens. When any of these limiting factors are removed, exponential population growth may occur and result in a pest outbreak. Although any of these factors could be limiting population growth, predation and parasitism are responsible for the greatest percentage of mortality to herbivorous arthropods.[11] In agroecosystems, insects are often equipped with an almost endless supply of their host plant therefore predation and parasitism become especially important in suppressing crop pest populations.[11] Ironically, agroecosystems harbor a low diversity of predators as compared to native vegetation. Crops managed conventionally usually exhibit even lower levels of predator diversity.[11] This is due, in part, to the fact that intensive management practices in agriculture act as disturbances to native arthropods. After initial management, these ecosystems become even more vulnerable to future anthropogenic disturbances because their diversity is so greatly affected. The result is a low diversity of natural enemies and the ideal situation for a pest outbreak to occur. Since a natural enemy complex that is more diverse is better able to suppress pest populations, research needs to be done to understand the community interactions occurring in their cropping systems.[1,7]

In this study, diversity is used to assess the viability of management strategies in promoting control of pest populations by either excluding pests or conserving natural enemies. Diversity is quantified in a variety of ways with the most common method being an analysis of species richness and abundance. One agroecosystem with limited information on its community structure and diversity is the cucurbit production system. Cucurbitaceae is a family of flowering plants that include squashes, melons, cucumbers, and other vegetables and when cultivated requires intensive management to control their associated pests. The most common of these pest species in the Southeastern United States are the striped and spotted cucumber beetles and squash bugs.

Striped and spotted cucumber beetles, *Acalymma vittatum* and *Diabrotica undecimpunctata* respectively, are members of the beetle family, Chyrsomelidae. Not only do these pests feed on the leaf tissue of cucurbit crops, but their larvae grow in the root system of the plant as well. All stages of the beetles' life cycle account for tremendous crop damage, but their greatest threat is actually the ability of both species to vector a bacterium, *E. tracheiphila*, which causes bacterial wilt disease in cucurbits. This disease accounts for up to 80% of losses in muskmelon and is a prominent disease in all cultivated cucurbits except for watermelon.[15,18] In order to minimize such losses, cucumber beetle populations must be kept low. Brust et al.'s study of the economic threshold of cucumber beetles indicated that four beetles on one plant caused significant wilting and yield loss while other studies have suggested that as low a one beetle per plant can induce bacterial wilt in some cucurbit species.[2,17]

While cucumber beetles are responsible for the spread of disease, the squash bug (*Anasa tristis*) instead causes wilting due to the feeding habits of their large populations.[7] All life stages of this insect feed on the succulent material of the plant and also cause scaring to some vegetables which makes them unmarketable. During mild winters squash bugs are able to persist in leaf litter and then produce a new generation of adults in the summer every few weeks allowing for overwhelming populations to develop quickly after planting.[16]

Multiple applications of a conventional pesticide may keep these pests from having an outbreak, but their suppression in an organic system proves to be more of a challenge. Little is known about the natural enemies of cucumber beetles and squash bugs, thus it is necessary to explore this topic in order to gain insight on the community interactions taking place in the cucurbit system. This information is absolutely necessary to manage these crops organically and produce high yields of quality produce. The need for an integrated management plan to suppress cucurbit crop pests is the impetus behind this study of diversity and trophic interactions of arthropods.

The objectives of the project are as follows: (1) Record the abundance of pests including striped and spotted cucumber beetles and squash bugs (2) Quantify species richness and evenness of the arthropod community in a cucurbit system with special attention to functional diversity (3) Compare how these values change throughout the growing season, between treatments of various organic management practices and in two types of cucurbits, butternut squash and muskmelon (4) Use this information to characterize the cucurbit community structure and trophic interactions and better understand effective methods to control pest populations.

By examining the diversity of this community throughout the season and in relation to various management activities relationships between pest abundances and potential predators may emerge. Collected arthropods will be sorted and identified to obtain abundance, richness, and evenness diversity values. It is hypothesized that those experimental plots, or subcommunities, with the most intensive management, and therefore disturbance, will have the lowest natural enemy diversity. Those plots with the greatest amount of natural enemy diversity will harbor lower pest abundances than plots with low predator diversity. Control plots will have the highest population of cucumber beetles and squash bugs and this will be especially apparent during the period of the season when other plots will have row covers.

Methods

Study Site

The cucurbit system observed in this study was located at the University of Kentucky's South Farm Experimental Station. Two 50 by 180 feet fields comprised of butternut squash and muskmelon were planted five meters apart and were divided into three rows. The fields were subdivided into twelve plots that were treated with contrasting row cover management practices. Experimental treatments consisted of: Treatment 1 (T1): open plots (no management), Treatment 2 (T2): Row covers applied at planting, removed at anthesis (flowering) and reapplied after pollination; pesticides applied while uncovered, and Treatment 3 (T3): Row covers applied at planting and removed at anthesis; pesticides applied while uncovered. Organic insecticide applications were applied to T2 and T3 when the plots were uncovered. The compound used was a plant-based pyrethrum known as Pyganic ®, mixed with a kaolin clay coating designed to inhibit insect feeding. Pesticides were applied 3 times to T2 plots and 4 times to T3 plots.

Arthropod Sampling Methods

A variety of sampling methods were used to provide a comprehensive picture of the community structure and the way in which it changed over time in the system. During each sampling period suction, hand, pitfall, and sticky trap samples were observed between each of the key management activities in organic cucurbit production. These management activities included planting, application and removal of row covers, multiple applications of organic pesticides, and harvest initiation.

Each sampling day took place at least two days after any management activity to ensure that disturbance was not the cause of observed results. Hand and suction samples were taken on the same day and followed a strict sampling protocol. Randomly selected numbers dictated the order in which plots were sampled. At each plot, a one minute suction sample was taken using a modified leaf blower with an average of 22 placements of the vacuum head on plant material. The collected arthropods were immediately stored and frozen. After this, five minute hand collections took place by two participants using an aspirator and individual alcohol-filled vials. Collectors caught as many arthropods as they could in this time period with a focus on those less likely to be caught in suction samples including spiders and other ground-dwelling predators. As the suction sampler is able to collect large quantities of insects in a short period of time, these samples will give a snap shot of the total diversity and abundances at a specific moment in time. Hand collections complement this by observing specimens that are too large or conspicuous to be caught in the suction samples.

Within the same week as the suction/hand samples but before the next management activity took place, a pitfall and sticky trap sample was also collected. These samples were taken on different days, again to ensure that disturbance from our presence was minimized. To deploy the pitfall traps, a hole just big enough for a one quart container was dug in the center of each plot. A plastic container fit with a funnel was then inserted and covered with a Styrofoam plate held in place with nails, 2 inches from the ground, to act as a rain guard. Pitfalls were left dry in order to keep arthropods clean for future molecular work. This trap was coupled with a standard 1’ by ½’ yellow sticky card designed to attract and trap any flying arthropods. Pitfall trap samples yield data on the movement of ground-dwelling arthropods into and out of the fields during the day and night, while sticky cards serve the same purpose but for flying specimens Unlike the snapshot that suction and hand samples provide, pitfall and sticky traps show movement of arthropods over a defined period of time.

Statistical Analyses

The first step after sampling for arthropods is to sort, identify and store them. The data presented here will only include vacuum samples due to the extent of identification required. A vacuum sample was spilt onto a sorting tray in which a microscope was first used to identify them to order and then group them according to prey, predator, and other. Information on the location of collection and identification to the lowest possible taxa at that time were also recorded. Upon sorting and identifying all arthropods collected in the samples, diversity assessments were applied including Shannon’s diversity index and measures of functional diversity. These measures will be compared across treatments and time using ANOVA. Pest populations and their change with presence of predators, effects of management, and effects of time will also be computed using MANOVA.

Results

Due to the intensity of sampling effort and the identification of thousands of insects collected, sampling the fields took place for most of the summer and identification and analysis will continue into the next year. Of the first two sampling periods on which sorting and identification have already occurred, there are a few initial trends that may be indicators of information revealed upon further data analysis.

Upon our basic analysis of diversity it was found that there are no significant differences between crop types, therefore the data from each crop for each treatment were pooled together. The first sampling period including suction and hand samples occurred on June 1st, exactly one week after transplanting. T2 and T3 plots had spun-bonded row covers applied at planting. The second sampling period occurred on June 21st, which was two days after the removal of row covers at anthesis.

From the analysis of the suction samples for these two periods, diversity was significantly related to date ($F_{1, 35}$=111.99, P<0.0001). Figure 1 shows the significant increase in diversity from June 1st to June 21st. Treatments with row covers exhibited a lower diversity than control plots ($F_{2, 35}$=10.31, P<0.0003) but this was not constant over time, which is indicated by a significant date by treatment interaction ($F_{2, 35}$=3.91, P=0.029).

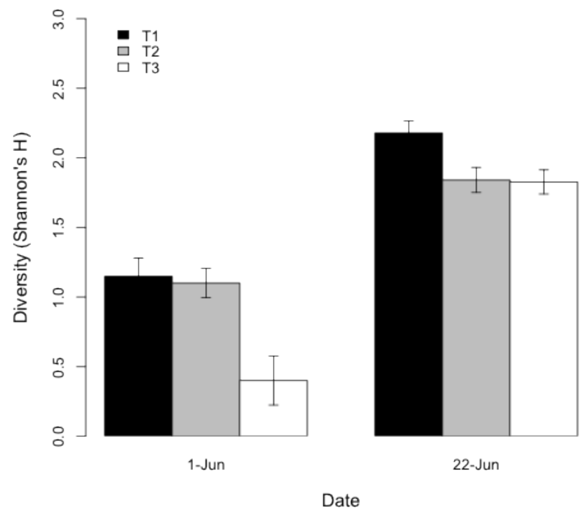

Figure 1. Change in diversity as related to date in three experimental treatments

Our analyses of pest abundance over time, across treatments, and between fields for suction samples during the first two sampling periods also yield some significant results. Overall abundance of pests changed between dates (F3, 78=42.82, p<0.0001), row cover treatments (F6,78=5.72, p<0.0001), and between fields (F3, 78=7.85, p=0.0003).

If any pests were detected, the high abundances tended to be in the control treatments, except for in spotted cucumber beetles where the populations were similar within dates and between treatments (Figure 2). Striped cucumber beetles exhibited the highest abundances with significant differences between dates and treatments (Figure 3). There were very low numbers of squash bugs detected in this first month since transplant in either crop type (Figure 4). Overall, there were greater abundance of pests in the muskmelon field (figures 2b, 3b, 4b).

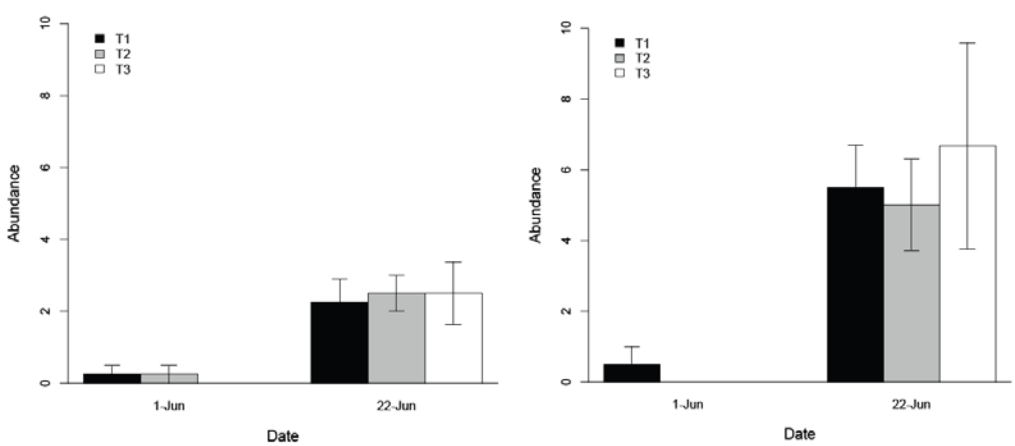

Figure 2. Abundance of spotted cucumber beetles between dates and across treatments in butternut squash fields (a) and muskmelon (b)

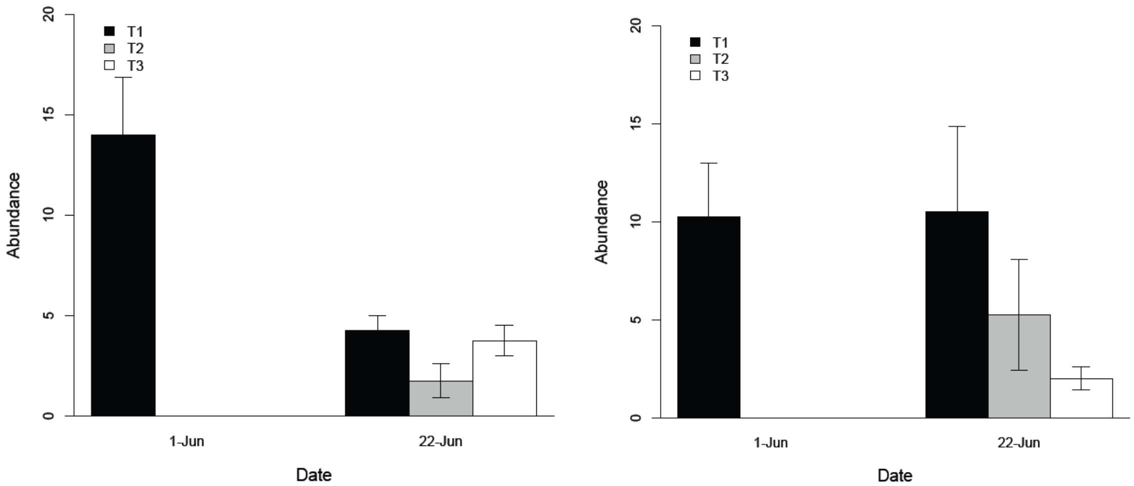

Figure 3. Abundances of striped cucumber beetles between dates and across treatments in butternut squash (a) and muskmelon (b)

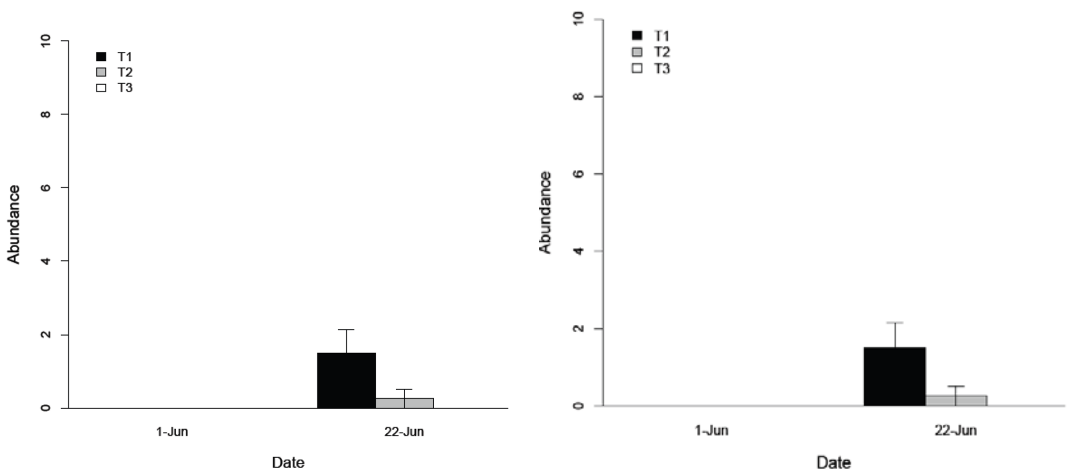

Figure 4. Abundances of squash bugs between dates and across treatments in butternut squash (a) and muskmelon (b).

The abundance of natural enemies was also quantified and compared across crop types, between dates, and between treatments. Abundance of natural enemies was significantly related to date ($F_{1,40}$ =177.04, $p<0.0001$). Significant differences were also found between abundance and crop type ($F_{1,40}=7.08$, $p=0.01$)), and a significant amount of the variation in abundance can be explained by row cover treatments ($F_{2, 40}=5.18$, $p=0.01$).

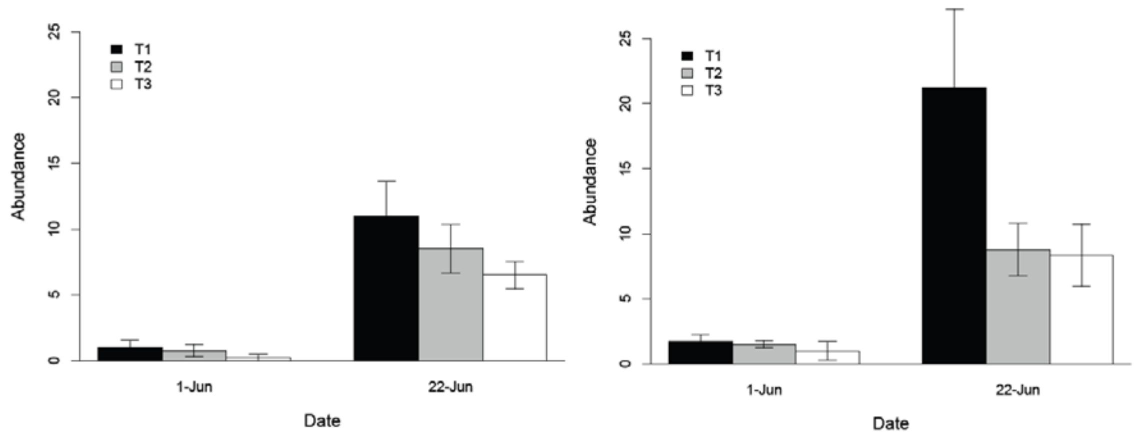

Figure 5. Abundances of predators between dates and across treatments in butternut squash (a) and muskmelon (b)

Conclusion

At this point in our data analysis, striped cucumber beetles are the most common pest and have the highest abundance in plots without row covers. Upon removal of row covers, the populations of both cucumber beetle species began to rise in all plots. There are very low densities of squash bugs in the first two sampling periods but by qualitative observation during sampling it is clear that squash bug populations grew exponentially in the following sampling periods. Diversity in both crop types and in all treatments is relatively low, but began to increase upon the removal of row covers. Those plots left uncovered (T1) most likely acted as a source of pests and other arthropods to colonize the newly unveiled plots. As predicted, those plots with row covers have much lower diversities than the control plots but this may change throughout the season as host-plant quality declines.

Very few predators were collected on the first sampling date but the diversity and abundance greatly increased in all plots by the second sample period. This could mean that natural predators of cucurbit crop pests do exist but are unable to colonize the crops immediately after transplanting. This is a common problem in agriculture as the landscape context of the crops is not favorable to predators therefore they cannot persist in a decent population size until pests colonize the plants first.

Although this data is preliminary, the exhibited trends support our hypothesis and more conclusive results should be yielded upon the analysis of all collected sample material. If trends are to continue, we should see increasing populations of pests as the season progresses since they have had at least two weeks with little disturbance or predation to allow for population growth. Predator diversity and abundance should also increase as their prey’s abundance increases. Other insects classified as neither pest nor predator will also likely appear and increase the complexity of this system’s food web resulting in an increase in system biodiversity.

Works Cited

1. Altieri, Miguel A. "The ecological role of biodiversity in agroecosystems." *Agriculture, Ecosystems ad Environment* 74(1999): 19-31.

2. Brust, G.E. and Foster, R.E. "New economic threshold for striped cucumber beetle (Coleoptera: Chrysomelidae) in cantaloupe in the Midwest." *Journal of Economic Entomology* 92.4 (1999): 936-940.
3. Crowder, D.W. et al. "Organic agriculture promotes evenness and natural pest control." *nature* 466(2010): 109-113.
4. Doledec, S. et al. "Species traits for future biomonitoring across ecoregions: patterns along a human-impacted river." *Freshwater Biology* 42(1999): 737-758.
5. Gagic, V. et al. "Food web structure and biocontrol in a four-trophic level system across a landscape complexity gradient." Proceedings of the Royal Society B 278(2011): 2946-2953.
6. Flynn, D.F.B. et al. "Loss of functional diversity under land use intensification across multiple taxa." *Ecology Letters* 12(2009): 22-33.
7. Heino, Jani. "Patterns of functional biodiversity and function-environment relationships in lake littoral macroinvertebrates." Limnology and Oceanography 53.4(2008): 1446-1455.
8. Hooper, D.U. et al. "Species diversity, functional diversity, and ecosystem functioning." *Biodiversity and Ecosystem Functioning: Synthesis and Perspectives 17(2002): 195-281.*
9. Kongming, Y. L. et al. "Widespread adoption of Bt cotton and insecticide promotes biocontrol services." *nature* (2012): 1-6.
10. Kuhlmann, U. and van der Burgt, A.C.M. "Possibilities for biological control of the western corn rootworm, *Diabrotica virgifera virgifera* LeConte, in Central Europe."*Biocontrol* 19.2 (1998) 59-68.
11. Letourneau, D.K. et al. "Effects of natural enemy biodiversity on the suppression of arthropod herbivores in terrestrial ecosystems." Annual Review of Ecology Evolution and Systematics 40 (2009): 573-592.
12. Petchey, O.L. et al. "How do different measures of functional diversity perform?" *Ecology* 85.3(2004): 847-857.
13. Petchey, O.L. and Gaston, K.J. "Functional diversity: back to basics and looking forward." *Ecology Letters* 9(2006): 741-758.
14. Philpott, S.M. et al. "Crytic biodiversity effects: importance of functional redundancy revealed through addition of food web complexity." *Ecology* 93.5 (2012): 992–100.
15. Rojas, E.S. et al. "Feasibility of Delaying Removal of Row Covers to Suppress Bacterial Wilt of Muskmelon (Cucumis melo)." *Plant Disease* 95.6(2011):729-734.
16. Rondon, S. I. et al. "*Anasa tristis* (Heteroptera: Coreidae) development, survival and egg distribution on Beit Alpha cucumber and as prey for *Coleomegilla maculata* (Coleoptera: Coccinellidae) and *Geocoris punctipes* (Heteroptera: Lygaeidae) *Florida Entomologist* 86.4 (2003): 488-490.
17. Smyth, R.R. and Hoffman, M.P. "Seasonal incidence of two co-occurring adult parasitoids of Acalymma vittatum in New York State: Centistes (Syrrhizus) diabroticae and Celatoria setosa." *BioControl* 55(2010): 219-228.
18. Yao, C. et al. "Relationship between cucumber beetle (Coleoptera: Chrysomelidae) density and incidence of bacterial wilt of cucurbits." *Journal of Economic Entomology* 89.2 (1996): 510-514.