Trap Crops' Influence on Biodiversity in Agroecosystems

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Abstract In agricultural systems natural self-regulating processes, like pest control and nutrient cycling, are aided by biodiversity. Modern commercialized farming practices, using expansive monocultures, have reduced biodiversity in agroecosystems. This study assesses the influence trap crops along the edge of a field have on the arthropod diversity and richness levels through out the field. A radish/mustard blend and an alfalfa/alyssum blend of trap crops along field edges are tested for their abilities to attract and enhance arthropod diversity and richness levels through out the strawberry crops. Pitfall trapping along the trap crops and in field interiors were used to assess the diversity and richness levels of foraging arthropods through out the three treatment and control sites. Using two-way ANOVAs, no statistically significant differences were found between diversity (0.481 P-value) and richness (0.704 P-value) levels in the fields with and with out trap crops. However, differences in diversity and richness levels between edges and interiors of the strawberry crops were close to statistical significance for large field experiments with P-values of 0.103 and 0.109 respectively.

Introduction

Biodiversity is the variety of all flora and fauna living and interacting in an ecosystem. Biodiversity has an intricate role in the functioning of natural and agricultural ecosystems. In natural ecosystems plant diversity, in the form of vegetative cover, helps to protect topsoil from wind and water erosion, while reducing flood hazards to the ecosystem by enhancing infiltration and reducing runoff (Johnson, 2000; Granger, 2000). In agricultural systems natural renewal processes such as: nutrient recycling, control of microclimate, regulation of local hydrological processes, regulation of the abundance of undesirable organisms, and detoxification of noxious chemicals are largely biological processes, and therefore aided by biodiversity (Altieri, 1994).

Many traditional farming systems have utilized biodiversity. For example, intercropping, where multiple crops are grown in the same field, have been used extensively in Latin American countries where 70-90% of their bean crops are grown with maize, potatoes, and other crops (Francis, 1986). However, since the development of industrialized farming systems, during the "Green Revolution," ecologically sustainable polycultures have been replaced with large input dependent monocultures. Modern agriculture is highly dependent on huge inputs of fertilizers, pesticides, and fossil fuels to maintain the same levels of output (Johnson, 2000). Monocultures can interrupt the self-regulating characteristics of natural communities, like pest control and nutrient cycling, and consequently can become dependent on inputs**.** In effect, biodiversity's role in agroecosystem processes has been replaced with human inputs in modern agricultural systems.

The decline of biodiversity in modern agricultural systems has become a growing concern for agroecologists. Previous studies have shown that agroecosystem instability is linked to the expansion of crop monocultures and the decline in local habitat diversity (Altieri and Letourneau, 1982). When plant communities are manipulated for human use they become more susceptible to insect pests. The self-regulating characteristics of natural communities, like pest control and nutrient cycling, are lost when ecosystem interactions are disrupted by human modification (Altieri, 1999). However, the self-regulating characteristics of natural communities can be restored or repaired, agroecologists maintain, by the addition of biodiversity (Altieri, 1994). Biodiversity can improve the natural regulation of pests in agroecosystems.

If biodiversity promotes the natural regulation of insect pests and other beneficial processes, then how can it be improved in modern agricultural systems? Previous studies have found improved biodiversity in organic or ecological agricultural. Organic agricultural systems have been linked to increases in biodiversity of arable fields and grasslands and have been shown to support higher number of endangered species (van Elsen, 2000). Organic systems utilize many methods to promote biodiversity and pest regulation. For example, integrated pest management (IPM) was shown to maintain harvest quality and high productivity with less inputs than conventional practices (Brown, 1999).

Organic agriculture is a crucial component of biodiversity in agroecosystems; however, field margins/edges and proximity to natural habitats has also been linked to increases in biodiversity in agroecosystems. A study in Hungary found that near the edge of an orchard the species richness and density of epigeic spiders were higher (Bogya and Marko, 1999). Field edges potentially provide shelter and alternative food sources for natural enemies of pests. A study on birds in Southern Ontario also found that most bird species used field edges consistently more often than expected with regards to the edge/interior ratio (Boutin, Freemark, and Kirk, 1999). Natural field edges are shown to have positive effects on all trophic levels.

Given that the type of agricultural system (organic or conventional), the types of field edge, and proximity to natural habitat all affect biodiversity levels in agroecosystems; the aim of this study is to determine if biodiversity in agroecosystems can be enhanced by trap crops. Trap crops are used to attract and accumulate pest insects along the edge of a field and prevent them from infesting the major crop (Naito, 2000). Could increased insect pest levels in the trap crops bordering a field attract more beneficial insect predators into the field? I hypothesize that trap crops result in the accumulation of more arthropod species at the edge of a field and that the increased arthropod diversity and richness will spread through out an associated field crop. This hypothesis was tested in three organic strawberry fields in Watsonville, California.

Methods

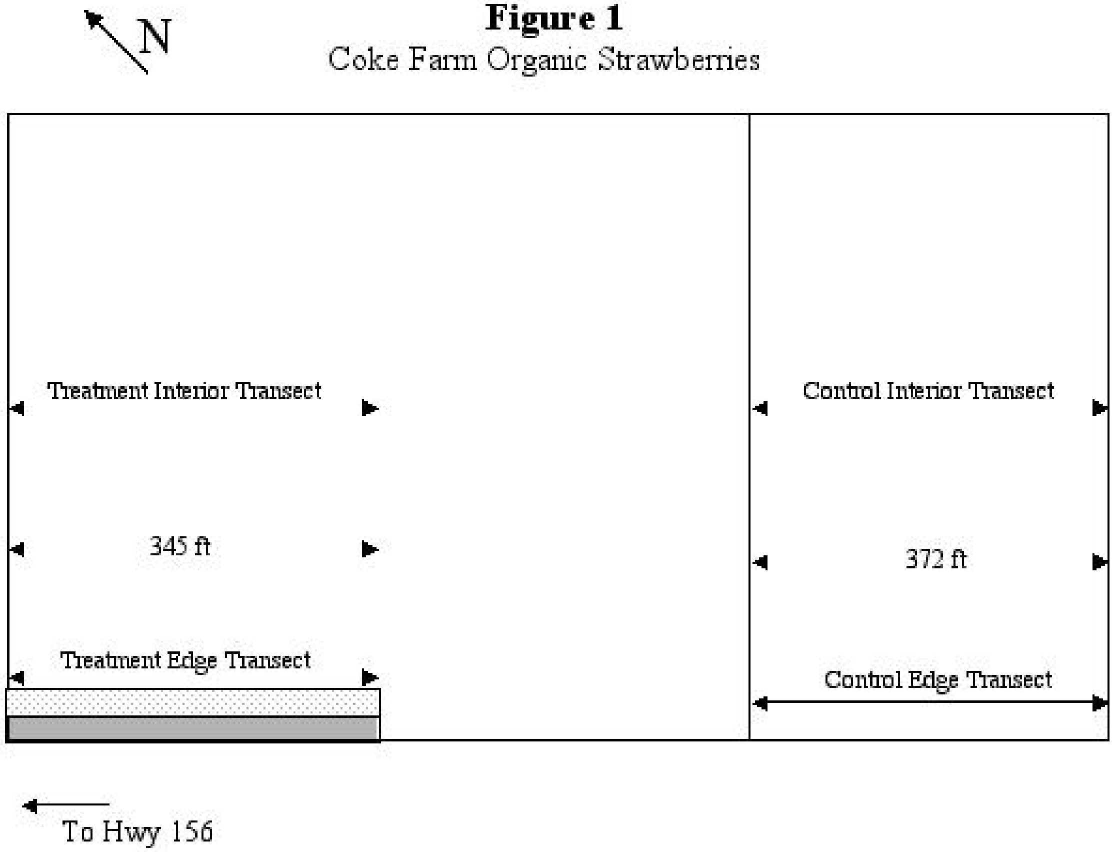
Study Site The study will be conducted in three fields, Murphy, Eagle, and Coke Farms, in the vicinity of Watsonville, California. Watsonville is located on the Central Coast of California in the Pajaro river valley. Watsonvilles' coastal fog, year round mild temperatures, and a growing season of 245 days is ideal for commercial agriculture. The top five products grown commercially are strawberries, apples, fresh flowers, lettuce and bushberries (City of Watsonville, 2000).

Experimental Design Arthropod diversity and richness levels were estimated with the use of pitfall trapping. Pitfall trapping is the most widely used technique to trap ground dwelling insect species and allowed simultaneous sampling of all sample sites in the study (Kromp, 1999). The pitfall traps will consist of plastic twelve fluid ounce cups submerged into the soil. The cups were filled partially with water and a few drops of detergent. As insects fall into the pitfall traps they drown and remain in the cups until collection. Since the strawberry fields in the study were watered with a drip system protective roofs over the pitfall traps were not be used.

To accurately estimate arthropod diversity and species richness two transect lines were established across the fields. The edge transects were two rows in from the edge of the crops in the control fields and along the inside of the two rows of trap crops in the treatment fields. Interior transects ran through the center of the field, parallel to the edge transects (see Figures 1,2, and 3). Each transect in Eagle Farm sites had ten evenly spaced pitfall traps randomly positioned along each transect, whereas the Coke Farms and Murphy Farms sites had 5 pitfall traps. Five to ten pitfall traps were considered sufficient to trap enough individuals to roughly estimate insect diversity and richness along each transect (Mills, 2000). Once transects and traps were established on March 15, 2001, a four day trapping interval began with individuals collected from the traps at the end of the fourth day.

Figure 1

Coke Farm Organic Strawberries



Legend

(solid grey)	Trap Crop Mix	Daikon & Cherry belle Radish/Mustard Blend
(dotted)	Trap Crop Mix	Semi- and non- dormant Alfalfa and White Allysum

Figure 2

Eagle Tree Organic Strawberries

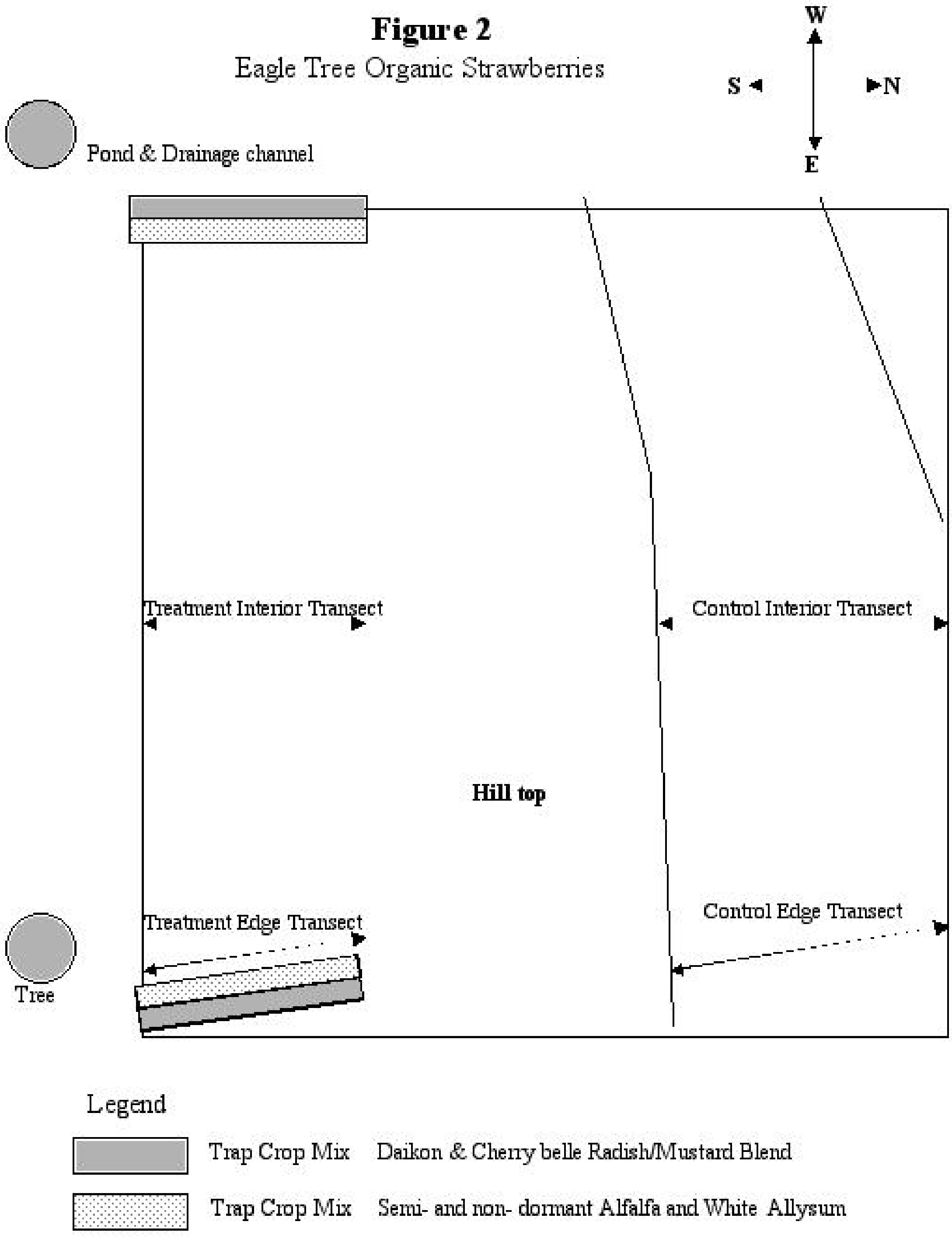
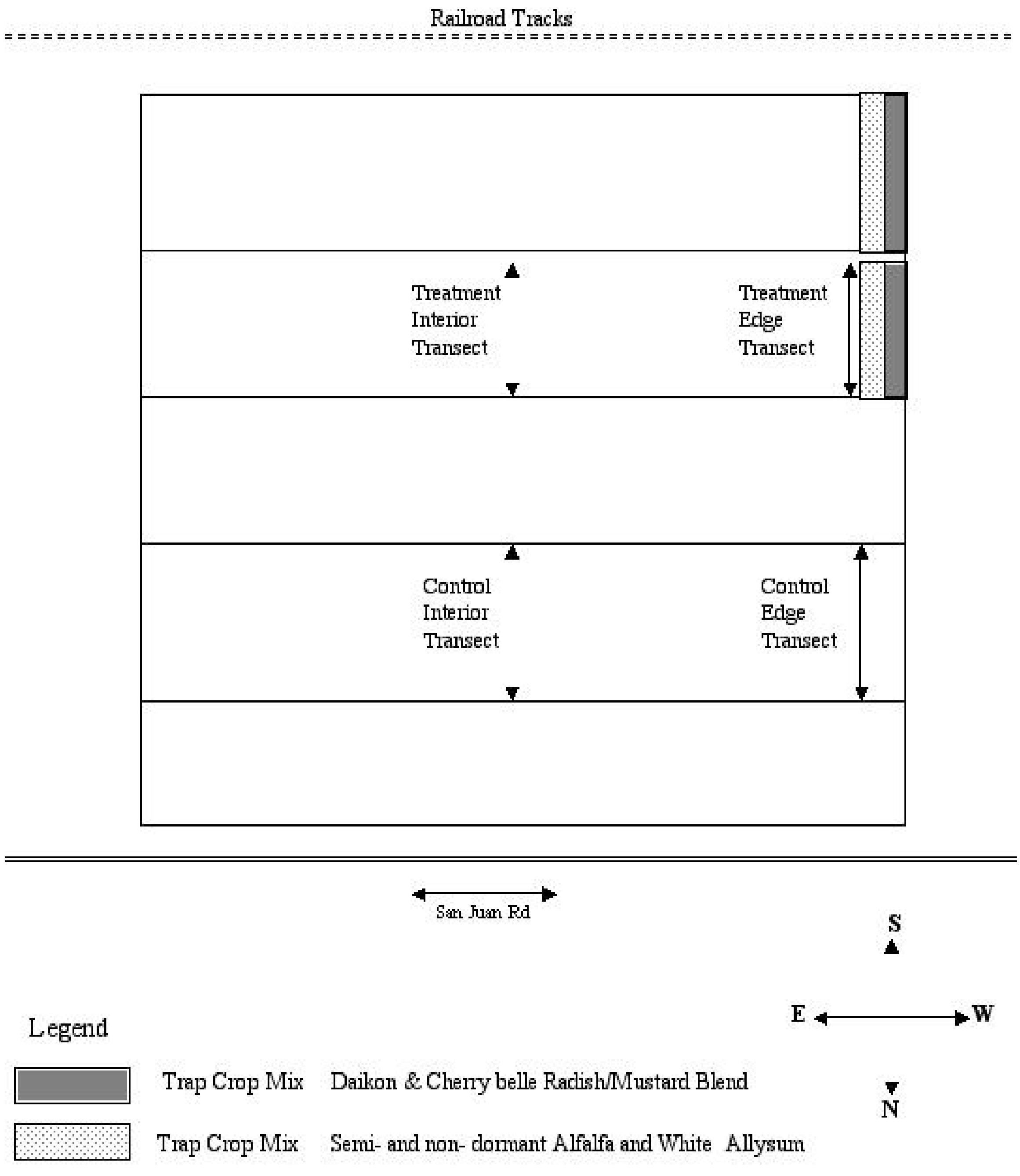


Figure 3

Miller Organic Strawberries



Objectives By arranging the one transect along the edge of the trap crops in the treatment sites, or the field edge in the control sites, and one transect in the interior of the sites, differences in insect diversity and richness levels should be observed between the treatment and control fields. The insect diversity and richness levels estimated will either support or reject my hypothesis that the trap crops in the treatment sites will enhance insect diversity and richness levels through out the strawberry fields. If trap crops enhance the insect diversity and richness levels through out the crops and improve the overall biodiversity in the fields, then trap crops could be incorporated in agriculture systems to improve biodiversity through out regions. The improved biodiversity could enhance natural renewal processes such as nutrient cycling and regulation of the abundance of undesirable organisms (Altieri, 1994).

Statistical Analysis Arthropod specimens were identified and categorized into morphospecies. Once all specimens were identified and categorized arthropod diversity and richness were calculated using the Brillouin Diversity Index and the Jackknife Estimate of species richness. The Brillouin Diversity indices were calculated with:

$$H= (1/N)\{\log (N!/(\#species\ 1)(\#\ species\ 2)(\#\ species\ 3)\ldots(\#\ species\ n)\};$$

N is the total number of individuals trapped The Jackknife Estimates of species richness were calculated as follows:

$$S = s + \{(n-1)/n)\}^{k} ;$$

s is the observed total number of species present in n samples, n is the total number of pitfall traps sampled, and k is the number of unique species.

The diversity and richness values were analyzed using Sigma Stat. A two-way ANOVA was used to test the effect of both trap crops and transect position (interior or edge) on the diversity and richness of arthropod species.

Results

After one four-day trapping interval in Coke, Eagle and Murphy farm sites a total of 324 arthropod individuals were collected. A total of 21 different morphospecies were identified and counted (see Table 1). The Brillouin Diversity indices of insect species ranged from 0.074 to

0.629 bits per individual and species richness varied from 2.64 to 11.59 species from site to site (see Table 2).

Brillouin Diversity index values for trap crop fields and control fields had a mean difference of 0.056 ± 0.0265 with a corresponding P-value of 0.481, while species richness estimates between trap crop fields and control fields had a mean difference of 0.52 ± 0.472 with a corresponding P-value of 0.704 (see table 3 and figures 4 and 5).

The Brillouin Diversity index values for transect position had a mean difference of 0.138 ± 0.265 between edge and interior transects and a corresponding P-value of 0.1025. Species richness estimates had a mean difference of 2.4 ± 0.472 between edge and interior transects with a corresponding P-value of 0.1093 (see table 3 and figures 5 and 6).

Table 1

Class/Order	**Family**	**Specie Number**	**Number Collected**
Arachnida	*Corinnidae*	*Trachelas*, SP 20	1
Arachnida	*Lycosidae*	SP 3	26
Arachnida	*Lycosidae*	SP 14	4
Arachnida	*Opilionidae*	SP 1	2
Chilopoda (sub class)	(centipede)	SP 18	16
Coleptera	*Carabidae*	SP 4	2
Coleptera	*Carabidae*	SP 8	4
Coleptera	*Carabidae*	*Amara*, SP 11	1
Coleptera	*Carabidae*	SP 21	3
Coleptera	*Coccinellidae*	SP 17	3
Dermaptera	*Forficulidae*	SP 13	1
Diptera	*Scatophagidae*	SP 2	180
Diptera	Unknown	SP 5	106
Diptera	*Scatophagidae*	SP 12	1
Heteroptera	*Scutellaridae*	SP 16	1
Homoptera	*Cicadellidae*	SP 7	5
Hymenoptera	*Apidae*	SP 15	1
Lepidoptera	Unknown (larva)	SP 10	2
Lepidoptera	*Satyridae*	SP 19	1
Orthoptera	*Gryllidae*	SP 9	2

Table 2				
Site	**Control diversity**	**Treatment diversity**	**Control Richness**	**Treatment richness**
Coke Edge	0.629	0.242	7.8	4.64
Coke Interior	0.387	0.13	5.33	2.64
Eagle Edge	0.329	0.439	4.73	11.59
Eagle Interior	0.074	0.143	3	5.66
Murphy Edge	0.47	0.477	6.41	5.64
Murphy Interior	0.188	0.333	3.75	4
Standard Errors	0.027	0.027	0.47	0.47

Table 3				
Species Diversity				
Source of Variance	DF	SS	F-value	P-value
Trap Crop	1	0.00919	0.546	0.481
Position	1	0.05713	3.398	0.103
Trap Crop X Position	1	0.00361	0.214	0.656
Residual	8	0.1345		
Total	11	0.20442		
Species Richness				
Source of Variance	DF	SS	F-value	P-value
Trap Crop	1	0.827	0.155	0.704
Position	1	17.352	3.246	0.109
Trap Crop X Position	1	0.612	0.114	0.744
Residual	8	42.766		
Total	11	61.557		

Figure 4
Species Diversity for Crop Treatment

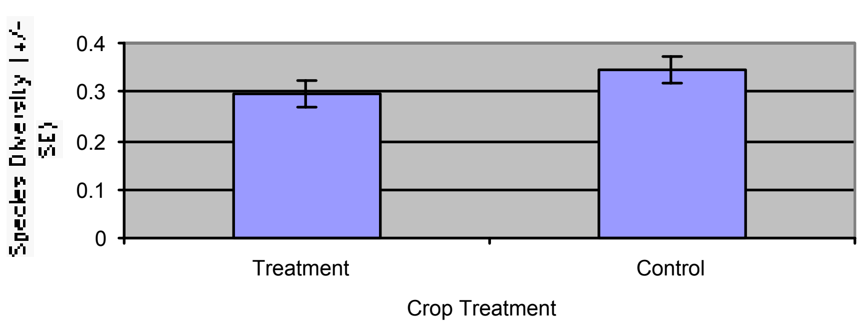


Figure 5
Species Richness for Crop Treatment

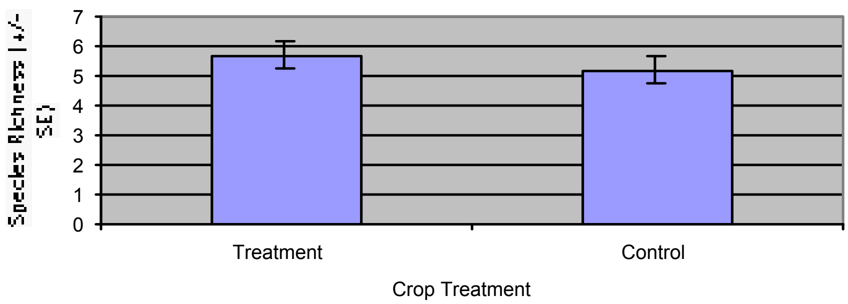


Figure 6
Species Diversity for Position

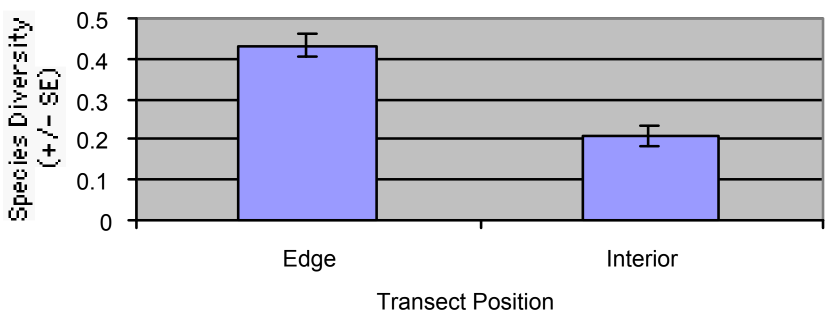
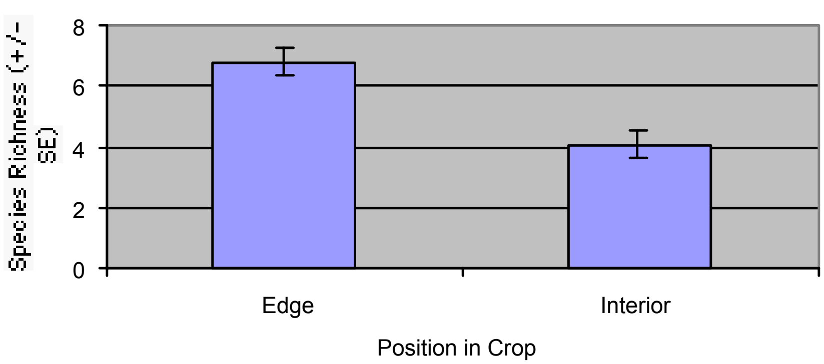


Figure 7
Species Richness for Position



Discussion

After a four day trapping interval no significant differences between the control and treatment sites were seen in either the Brillouin Diversity indices or the Jackknife estimates of species richness. The control and treatment Brillouin Diversity indices had a P-value of 0.481, in other words, insect diversity was unaffected by the presence of trap crops in the treatment sites. The control and treatment Jackknife estimates of species richness were also essentially the same with a P-value of 0.704. Trap crops seemed to have no influence at all on arthropod species diversity and richness values through out the field. In fact, in the Coke site the control had much greater species diversity and richness values than the treatment site (see Table 2).

Transect position seemed to have an effect on arthropod species diversity and richness. The edge transects, with and with out the presence of trap crops, had greater arthropod species diversity and richness. The P-values were nearly significant for large field experiments (P-value 0.10). This suggests that edge effects may have been influencing the arthropod activity in the strawberry fields. It is important to note that interaction between the transect position and the presence of trap crop were not statistically significant (see Table 3).

Even though the control and treatment arthropod diversity and richness values were essentially the same many confounding factors may have overshadowed any influences the trap crops may have had. For example, the Coke site's control site was in the corner of the property with an orchard like residential property on one edge, while the treatment site had another strawberry field instead. The presence of the orchard like property may have been a source population for arthropods trapped in the control. Field edge has been linked to increases in spider richness and diversities, a study in Hungary found that near the edge of the orchard the species richness and density of epigeic spiders were higher (Bogya and Marko, 1999). Moreover, the Eagle farm control site had much more barren surroundings relative to the Eagle farm treatment site and was in the middle of the strawberry crops while the treatment site was along the edge of the strawberry crops and had more grassy edge along the Eastern edge. Again, differences in field edges may have confounded any influences trap crops may have on arthropod diversity and richness levels through out fields.

Weather may have been another alternative explanation for having essentially no differences in species richness and diversity levels. Since beetle activity is minimal at cold temperatures, the cold nights and rainstorms of late winter/early spring may have reduced beetle activity (Mills, 2000). Decreased beetle activity may have decreased any effect the trap crops may have had. With increased beetle activity more beetle species may have foraged into the treatment crops and increased arthropod species diversity and richness values.

Five traps per transect made the uncertainty very high and may have been another potential explanation for finding no differences. Five pitfall traps per transect on the Coke and Murphy sites may have not been sufficient to accurately depict arthropod population characteristics. In ideal conditions five traps would likely be sufficient, but in late winter/early spring with rainstorms in the previous weeks and only a four day trapping interval, conditions were far from ideal. The data collected may not be representative of the true arthropod diversity and richness levels in the Coke and Murphy sites.

Another alternative explanation for having no statistically significant differences between the trap crop fields and the control fields maybe that trap crops have no influence on the arthropod species diversity and richness values of the strawberry fields. Perhaps only two rows of trap crop is insufficient to influence the whole field. Or perhaps the trap crop plant species being significantly different than the strawberry plants contributed to finding no real differences in arthropod diversity and richness values.

Even though no differences in arthropod species diversity and richness levels were found in the trap crop fields and control fields, trap crops still may enhance the overall insect diversity and richness levels in an agricultural setting. The confounding factors associated with weather, sites' orientations, and the number of traps all may be overshadowing any effect the trap crops may have had on arthropod species diversity and richness. With out eliminating the confounding factors no real conclusions could be drawn about how effective trap crops are at enhancing arthropod species diversity and richness. Further studies and a more intensive trapping effort under ideal conditions would help draw more conclusive results.

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