EFFECTS OF TREE DENSITY, TREE SPECIES DIVERSITY, AND PERCENTAGE OF HARDSCAPE ON THREE INSECT PESTS OF HONEYLOCUST

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Abstract. Honeylocust (*Gleditsia triacanthos* L. var. *inermis*) trees in urban areas are attacked principally by three insect pests: honeylocust plant bug, mimosa webworm, and honeylocust spider mite. One hundred honeylocust trees on the Purdue University campus were studied to better understand the influence of landscape characteristics on the populations of these insect pests. Specifically, the amount of hardscape, defined as imperviousness under and around trees, including roads, sidewalks, parking lots, and buildings; density of honeylocust; and diversity of tree species around each tree were calculated at numerous spatial scales and correlated with insect pest abundance on honeylocust. Each of these landscape factors influenced insect pest and their natural enemy populations on honeylocust trees at a wide range of scales. No single combination of these factors was associated with lower densities of honeylocust pests.

Key Words. Honeylocust; *Gleditsia triacanthos* L. var. *inermis*; hardscape; honeylocust plant bug; mimosa webworm; honeylocust spider mite; urban tree planting; tree species diversity; geographic information systems (GIS).

Increased insect and disease problems on honeylocust (*Gleditsia triacanthos* L. var. *inermis*) in urban areas are a product of the liberal planting of this species in the past decades (Wheeler and Henry 1976). The popularity of honeylocust is due to its adaptability to urban sites, attractive appearance, rapid growth, and the aftermath of the Dutch elm disease epidemic that forced urban foresters to seek trees other than American elm for planting. Three insect and mite pests commonly encountered on honeylocust are mimosa webworm *(Homaduala anisocentra)*, honeylocust plant bug *(Diaphnocoris chlorionis)*, and honeylocust spider mite *(Platytetranychus multidigituli)* (Sadof 1997). Honeylocust plant bug and honeylocust spider mite specialize on honeylocust, while mimosa webworm is known to feed on one other plant, mimosa or silk tree *(Albizzia julibrissin)*. In rural settings, honeylocust insect pests rarely reach outbreak proportions, while in urban settings, they are common (Wheeler and Henry 1976; Hart et al. 1986).

Previous studies investigating the variability among insect pest populations in individual trees have focused primarily on factors intrinsic to the tree—cultivar, pesticide spray history, nutrition, and other factors (North and Hart 1983; Bastian and Hart 1990; Smitley and Peterson 1996, 1997; Sclar et al. 1998). A study conducted by Hart et al. (1986) involved a more extrinsic approach, investigating what was around the tree and how these factors influenced overwinter survival of only one insect pest, the mimosa webworm.

The goal of this research was to determine how landscape characteristics influence populations of the three most common insect pests of honeylocust. Specifically, levels of hardscape (imperviousness under and around the tree including roads, sidewalks, parking lots, and buildings), honeylocust density, and tree species diversity were calculated for areas of various sizes surrounding trees to determine their relation to insect pest abundance on the trees. We also sought to determine if there was a particular combination of these factors that could be associated with reduced abundance of honeylocust pests.

METHODS

Honeylocust trees on the campus of Purdue University, West Lafayette, Indiana, U.S., were used in the research because they are numerous and regularly infested with the three principal insect pests (Sadof, unpublished data). In the winter–spring of 1997–1998, all 7,600 trees on the main campus of Purdue University were inventoried. Data collected included tree species, diameter at breast height (dbh), tree health, maintenance requirements, clearance needs, crown width, and year planted. The data were entered in a geographic information system (GIS). From a total population of 387 honeylocust trees on the Purdue campus, 100 mature trees (dbh > 25 cm [9.8 in.]) were selected for study. Tree diameter ranged from 28 to 81 cm (11 to 31.8 in.) dbh with an average dbh of 44 cm (17.3 in.). Selection of trees was stratified based on a 5 × 4 × 2 randomized block factorial design with five levels of honeylocust population density (0–2.9, 2.9–3.75, 3.75–5.8, 5.8-9.2, 9.2-12 trees per ac), four levels of tree diversity (0-2.62, 2.62-2.82, 2.82-2.94, 2.94–3.5) based on the Shannon-Weiner ecological diversity index (Begon et al. 1990) and two levels of the percentage of hardscape surrounding the trees (0%–30%, 30%–100%). GIS was used to quantify the three landscape parameters.

For sampling honeylocust plant bug and honeylocust spider mite insect populations, a collecting device was assembled using a metal funnel with a 24-cm (9.4-in.) diameter opening, a sheet-metal lid, and a telescoping pole that extended to 4.5 m (5 ft) (Figure 1). A baby-food jar lid was attached to the small opening of the funnel to allow fastening of a jar to catch the insects as they fell into the funnel. The device allowed sampling groups of leaves in a tree crown for insects while standing on the ground. This was accomplished by opening the lid using a rope, then letting the spring-loaded hinge snap the lid shut on the leaves, knocking the insects into the funnel. The insects were then washed into the baby food jar with 70% ethanol and taken to the laboratory for further examination.

Figure 1. Modified funnel on extension pole used to sample insects in honeylocust trees.

One composite sample was taken from each tree by collecting within the crown at a height of 3 to 4 m (10 to 13 ft) above ground level at each of the four cardinal directions, resulting in a 0.18 m^2 (2 ft^2) area sampled from each tree. The collecting device was used to collect data from all 100 trees in the study every 2 weeks beginning May 15 and ending September 14, 1998, providing ten sets of samples. Analysis of variance (ANOVA) and Tukey's test of differences among means were used to determine significant differences between the different sampling dates for each of the two insect species.

Mimosa webworm abundance was visually estimated as the percentage of canopy infested with webs on three different occasions for each of the 100 trees in the study. This was done simultaneously by four different people to reduce the bias associated with this type of data collection. Estimates of webworm infestation were performed on July 30, August 12, and September 3, 1998. These measurements were combined into an average index (percentage value) for each of the observation dates for comparison of the relative differences between individual trees and the correlative relationship to the surrounding landscape variables.

Sticky traps were placed in each of the trees for two 1-week sampling periods, August 5 and August 19, 1998, to estimate natural insect enemies of honeylocust pests. The sticky traps were placed on the east side of the trunk of the trees 3 m (9.8 ft) above ground level. Insects captured on the traps were identified in the laboratory, the majority of them only to the family level.

Computer maps of hardscape features (roads, sidewalks, buildings, and parking lots) were obtained from Facilities Planning at Purdue. ArcView version 3.1 (www.esri.com) was used to create circular areas with radial lengths of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 100 and 150 m (lengths from 16 to 492 ft) around each of the sample trees.

The percentage of the area covered by hardscape surrounding each tree was calculated for each of the 18 radius lengths.

Tree species diversity was calculated for radius lengths of 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, and 150 m (lengths from 33 to 492 ft) using the Shannon-Weiner species diversity index, which measures both species richness and evenness (Begon et al. 1990). The Shannon-Weiner Index was calculated in ArcView by employing Avenue programming.

For this paper, we chose to interpret these data from the standpoint of an arborist. Only three spatial scales were considered for further analysis. These consisted of radius lengths of 10 m (33 ft) (the area immediately surrounding a tree), 20 m (65 ft) (the size of a backyard), and 100 m (328 ft) (an area the size of a city block). Regression analyses were conducted using a stepwise approach and an alpha of 0.05.

RESULTS

Insect Populations

A total of 12,418 insects and mites representing 35 species were collected in funnel samples. In a 1-month period beginning May 11, the number of honeylocust plant bugs declined from 19.8 to 0.54 per sample. None were collected after June 22 (Table 1). The reduction in the average number of honeylocust plant bugs sampled per tree from May to June indicates that the sampling done was sensitive enough to detect the single generation peak. In contrast, honeylocust spider mites were present throughout the season, with the peak occurring in late summer. The remaining 33 insect species found were present throughout the season when counted collectively with a slightly larger number per tree in August (Table 1).

Table 1. Average number of insects collected per tree in funnel trap samples taken at 2-week intervals from honeylocust trees.

Sampling date	Plant bugs	Spider mites	Other insects
May 11	19.81 a*	1.62 a	3.61 a
May 25	12.64 a	0.57 a	2.75 a
Jun 8	0.54 b	1.01 a	4.66 ab
Jun 22	0.04 b	4.78 b	3.22 a
Jul 6	0.0 b	5.99 bc	2.34 a
Jul 20	0.0 b	2.19 a	2.30 a
Aug 3	0.0 b	1.26 a	3.16 a
Aug 17	0.0b	13.90 c	6.65 b
Aug 31	0.0 b	12.81 c	5.10 b
Sep 14	0.0 b	10.41 bc	3.55 ab

*Values in columns followed by the same lower case letter are not significantly different at $P = 0.05$.

Mimosa webworm infestation, estimated three times between July 30 and September 3, 1998, ranged from 0 to 100%. The average percentage of the canopy infested was 26.7% on September 3, the sampling time showing maximum damage.

Natural insect enemies in sticky card samples in August were plentiful and represented a diversity of species. There were 61 different families, superfamilies, and orders identified. The vast majority of insects (67.7%) were all wasp parasitoids of the mimosa webworm. Most of these (65.9%) were *Elasmus albizziae*, with Eulophidae and Ichneumonidae representing less than 2% of insects caught on sticky traps. Mymaridae, Scelionidae, and Trichogrammatidae, known parasites of insect eggs (Borror et al. 1976), ac-counted for 19.3 % of the sample. These could be significant since honeylocust plant bug was in the egg stage at the time of these collections.

Landscape Variables

Honeylocust density and the percentage of hardscape were each computed at 18 different radius lengths, while tree species diversity was computed at 11 radius lengths. The values of landscape parameters varied depending on the radius length used. As the radius length increased from 5 or 10 to 150 m, mean values of honeylocust density decreased from 103.1 to 2.35 trees per ac, whereas mean values of the percentage of hardscape and the tree species diversity index increased from 27.2% to 50.2% and from 0.39% to 2.65, respectively (Table 2). Two examples of high (98%) and low (3%) levels of hardscape are shown in Figure 2 and Figure 3, respectively.

Table 2. Average honeylocust density, percentage of hardscape, and species diversity index at a range of radius lengths surrounding honeylocust trees sampled on the Purdue University campus.

Radius length (m)	Honeylocust density, mean (trees/ac)	Percentage of hardscape, mean	Species diversity index, mean
5	103.10	27.2	
10	25.78	38.3	0.39
15	17.18	44.1	
20	12.89	45.8	0.56
25	10.31	46.3	
30	8.59	46.0	1.45
35	7.36	45.9	
40	6.44	46.4	1.78
45	5.73	47.1	
50	5.67	47.5	2.02
55	5.11	47.8	
60	4.65	48.0	2.20
65	4.58	48.4	
70	4.21	48.8	2.33
75	3.90	49.2	
80	3.83	49.6	2.43
90			2.53
100	3.22	50.2	2.60
150	2.35	50.2	2.65

Relation of Insect Populations to Landscape Variables

For honeylocust plant bug, regression analyses show that in a 10-m radius length (area immediately surrounding a single tree scenario), none of the landscape variables is significant at the 0.05 level (Table 3). However, at the 20-m radius length resolution (backyard scenario), species diversity had a significant effect on honeylocust plant bug populations (R^2 = 0.17). At the 100-m radius length resolution (city block scenario), both tree density and species diversity were significant (R^2 = 0.46).

Regression analysis for mimosa webworm shows that at the 10-m radius length resolution, both the percentage of hardscape and honeylocust density were significantly related to insect population (R^2 = 0.23). At the 20-m resolution, only the percentage of hardscape was significant (R^2 = 0.05). At the 100-m resolution, all three variables were significantly related to infestations of mimosa webworm (R^2 = 0.28) (Table 3).

Analysis of honeylocust spider mites at the 10-m radius length showed a positive relationship between percentage of hardscape and mite populations (R^2 = 0.09). At the 20-m radius length, no landscape variables were correlated with mite populations. However, at the 100-m radius length, honeylocust density was significant (R^2 = 0.22) (Table 3).

Table 4 is a summary of these data showing the effects of an increase in each of the three landscape variables analyzed on the abundance of honeylocust plant bugs, mimosa webworms, or honeylocust spider mites at 10-, 20-, or 100-m spatial scales. For example, at the 20-m radius length, as the percentage of hardscape surrounding a tree increases, the abundance of mimosa webworm in that tree also increases.

DISCUSSION AND CONCLUSIONS

Percentage of hardscape was chosen as one of the variables to measure since it affects tree vigor and has an influence on the microclimate around a tree (Herms and Mattson 1997). Honeylocust density was chosen to test the hypothesis that areas with more honeylocust have more insect pests. Tree diversity is often stressed in urban forest management, primarily to prevent another incident like the epidemic spread of Dutch elm disease (Guntenpregen and Stearns 1983; Richards 1983, 1993; Sun 1992). The investigation of the relationship between tree species diversity and insect pest populations w1as expected to be important due to its effects on natural predators of the insect pests. The relationship between these three landscape variables and each of the three principal pests of honeylocust is discussed below.

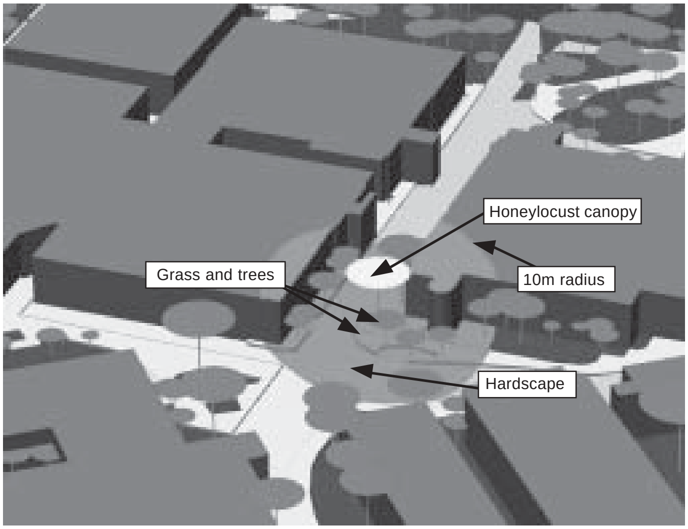

Figure 2. Illustration of a honeylocust tree surrounded by a high (98%) level of hardscape at a 10-m radius.

Mimosa Webworm

Landscape variables exerted a strong influence on mimosa webworm abundance. Both hardscape percentage and honeylocust density were found to be significant at the 10-m radius length (Table 3). Hardscape percentage was positively correlated with mimosa webworm infestation, while tree density was negatively correlated. These results suggest that as the percentage of hardscape and tree density increase, mimosa webworm populations tend to increase or decrease, respectively (Table 4). The positive correlation between the percentage of hardscape and mimosa webworm infestation is supported by other studies (Hart et al. 1986; Coffelt et al. 1993; Speight et al. 1998), whereas the negative correlation with tree density is not. Based on these results, the appropriate management practice to minimize mimosa webworm infestations is to increase tree density and reduce the amount of hardscape immediately surrounding the tree.

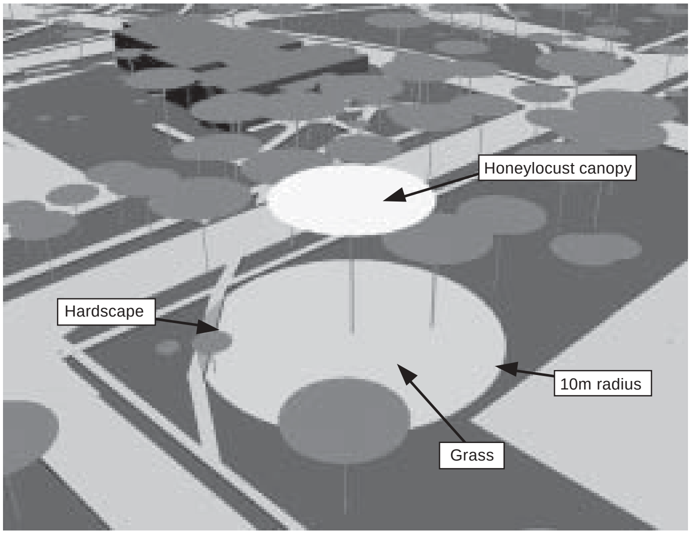

Figure 3. Illustration of a honeylocust tree surrounded by a low (3%) level of hardscape at a 10-m radius.

At the 20-m radius length, hardscape percentage continued to be a significant determinant of mimosa webworm infestation (Tables 3 and 4), while tree density no longer was. A possible explanation for the influence of hardscape percentage at both the 10- and 20-m radius length may be a combination of a heat-island effect that increased the probability of overwinter survival and tree stress due to poor soil aeration and moisture. Speight et al. (1998) found that hardscape resulted in increased temperatures, higher wind speeds, higher air pollution, and decreased soil moisture and nutrient flow. These effects translate into trees with lower vigor

Table 3. Results of forward stepwise multiple regression of honeylocust plant bug (HLPB), mimosa webworm (MWW), and honeylocust spider mite (HLSM) abundance with honeylocust density (DEN), percentage of hardscape (HARD), and species diversity index (DIV) at 10-, 20-, and 100-m radius lengths surrounding the trees.

Dependent variable	Radius length	Significant variables	Unstandardized coefficients	Standardized coefficients	Model R^2
HLPB	10 m	NONE	——	——	——
	20 m	DIV	–0.143	–0.412	0.17
	100 m	DEN	–0.0617	–0.571	
		DIV	–33.346	–0.049	0.46
MWW	10 m	HARD	34.956	0.363	
		DEN	–0.0038	–0.253	0.23
	20 m	HARD	24.374	0.222	0.05
	100 m	HARD	–40.476	–0.241	
		DEN	0.0412	0.479	
		DIV	14.919	0.287	0.28
HLSM	10 m	HARD	132.435	0.299	0.09
	20 m	NONE	——	——	——
	100 m	DEN	0.1832	0.469	0.22

than found in trees without a high percentage of hardscape surrounding them.

At the 100-m radius length, all three variables were significant, but in contrast, as hardscape increased, mimosa webworm populations decreased (Tables 3 and 4). An explanation for this contrasting response at the 100-m spatial scale could be that the percentage of hardscape no longer had the stressful effects on the trees since this scale is outside of the range of tree roots, and the function of hardscape changes to that of forming a barrier to movement of the insects.

The effect of the variable honeylocust density also was reversed when 100-m radius length was compared to the 10-m radius length (Tables 3 and 4). The results of these findings at 100 m are supported by Thomas (1989) and Davis (1975) who showed that as plant population increased, insect abundance also increased.

Our results suggest that to minimize mimosa webworm when considering a 100-m or neighborhood spatial scale, the arborist should reduce both honeylocust density and total species diversity surrounding a honeylocust.

Honeylocust Plant Bug

At the 10-m radius length (single-tree scenario), the relationship between landscape variables and honeylocust plant bug populations was not significant (Table 4). Therefore, when an area of less than 0.1 ac is the management unit under the control of the arborist, landscape variables do not need to be considered when making planting or pesticide application decisions. When the scale of analysis was expanded to 20-m radius length (backyard scenario), tree diversity was negatively significant (Table 3). As tree species diversity increased, honeylocust plant bugs decreased (Table 4). These results are in agreement with those reported by other researchers (Monteith 1960; Pimentel 1961; Fowler and Lawton, 1982). At the 100-m radius length, density and tree diversity were both negatively significant (Table 3), showing that as honeylocust density and tree species diversity increase, insect pests decrease (Table 4). The relationship between insect populations and tree species diversity was expected to be negative. However, the negative relationship between tree density and insect populations is contrary to other research results (Davis 1975; Solomon 1981; Bach 1988a, 1988b; Thomas 1989). A negative density dependent relationship suggests that as more honeylocust trees exist at the scale of 100-m radius length, honeylocust plant bug problems could decrease. The implication

Table 4. Effect of an increase in landscape variables (percentage of hardscape—HARD, honeylocust density—DEN, and tree species diversity index—DIV) on the abundance of honeylocust plant bug (HLPB), mimosa webworm (MWW), or honeylocust spider mite (HLSM) at 10-, 20-, and 100-m radius lengths surrounding honeylocust trees.

		Insect abundance		
Radius length	Landscape variable	Plant bug (HLBP)	Webworm (WWM)	Spider mite (HLSM)
10 m	HARD	No effect	Increase	Increase
	DEN	No effect	Decrease	No effect
	DIV	No effect	No effect	No effect
20 m	HARD	No effect	Increase	No effect
	DEN	No effect	No effect	No effect
	DIV	Decrease	No effect	No effect
100 m	HARD	No effect	Decrease	No effect
	DEN	Decrease	Increase	Increase
	DIV	Decrease	Increase	No effect

of the significance of these variables at the 100-m radius length, and not at the 10-m radius length, suggests that honeylocust plant bug responds to landscape variables at a more macroscopic level.

Honeylocust Spider Mite

At all three spatial levels of analysis, honeylocust spider mites show the weakest relationship between insect abundance and landscape variables, with only two variables being significant at the three scales of analysis (Table 3). At the 10-m radius length, a weak positive relationship existed between the percentage of hardscape and honeylocust spider mite populations, indicating that spider mite abundance is increased by impervious surfaces (Table 4). To minimize honeylocust spider mite populations, one should avoid planting honeylocust in areas containing a large amount of hardscape within a 10-m radius of the tree. At the 100-m radius length, a positive relationship with density was discovered, indicating that when honeylocust density is high in a neighborhood, high spider mite populations can be expected (Table 4). This is consistent with the literature concerning plant densities and insect abundance (Davis 1975; Thomas 1989).

Landscape–Insect Relationships

This study has shown that not only do landscape variables influence insect pest abundance, but that this influence differs depending on the species of insect and the scale of analysis. There does not appear to be just one combination of factors that predicts a lower abundance of all three of the principal insect pests of honeylocust. Although the mechanisms for these landscape effects are not entirely known, the relationships found in this study were consistent in some situations with the literature published on pest biology and offer a difficult challenge for future research.

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Résumé. Les féviers (*Gleditsia triacanthos* L. var. *inermis*) en milieu urbain sont attaqués principalement par trois insectes: la punaise du févier, la chenille à tente du mimosa et la tétranyque du févier. Une centaine de féviers sur le campus de l'université Purdue ont été étudiés afin de mieux comprendre l'influence de l'environnement paysager sur les populations de ces insectes parasites. De façon spécifique, la proportion de surfaces dures—définies comme tout ce qui est imperméable sous et autour des arbres comme les chemins, trottoirs, stationnements et édifices—la densité en féviers ainsi que la diversité en espèces autres d'arbres autour de chacun des féviers ont été calculées à une échelle spatiale numérique et corrélées avec l'abondance en insectes parasites sur les féviers. Chacun de ces facteurs de l'environnement paysager influence les populations d'insectes parasites ainsi que celles de ses ennemis naturels, et ce selon des échelles diverses. Aucune combinaison de ces facteurs n'a pu être associée à de plus faibles densités en insectes parasites sur les féviers.

Zusammenfassung. *Gleditsia triacanthos* L. var. *inermis* werden in urbanen Gegenden grundsätzlich von drei Insekten befallen. Auf dem Purdue Universitätscampus wurden 100 Gleditschien untersucht, um den Einfluss der Landschaftscharakteristika auf die Entwicklung der Insektenpopulation besser zu verstehen. Besonders die Menge von versiegelter Oberfläche unter und um Bäume, einschließlich Straßen, Gehwege, Parknischen und Gebäude, die Pflanzdichte von Gleditschien und die Diversität der Baumarten um die Gleditschien wurde an zahlreichen Standorten kalkuliert und mit dem Auftreten von Schadinsekten an Gleditschien korreliert. Jeder dieser Landschaftsfaktoren beeinflusste die Schadinsekten und ihre natürlichen Feinde auf einer weiten Spanne von Untersuchungsorten. Keine Kombination dieser Faktoren war mit einer geringeren Dichte von Schadinsekten assoziiert.

Resumen. Los árboles de mimosa (*Gleditsia triacanthos* L. var. *Inermis*) en áreas urbanas son atacados principalmente por tres plagas de insectos: chinches, gusanos y arañas. Cien árboles de mimosa en el campus de la Universidad de Purdue fueron estudiados para entender mejor las influencias de las características del paisaje en las poblaciones de estas plagas de insectos. Específicamente la cantidad de pavimento, definido como impermeable, debajo y alrededor de los árboles, incluyendo carreteras, aceras, lotes de estacionamiento y edificios. La densidad de mimosa y la diversidad de especies de árboles alrededor de cada árbol fueron calculadas en numerosas escalas espaciales y correlacionadas con la abundancia de insectos sobre la mimosa. Cada uno de estos factores del paisaje influyó en las plagas de insectos y sus enemigos naturales en los árboles en un rango amplio de escalas. Ninguna combinación simple de estos factores estuvo asociada con densidades bajas de plagas en la mimosa.