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INTERSPECIFIC ASSOCIATIONS AMONG *APHIS GOSSYPII*, *MENOCHILUS SEXMACULATUS* AND *CAMPONOTUS COMPRESSUS* IN A GUAVA ECOSYSTEM

A. VERGHESE and P.L. TANDON*

The interspecific associations among *Aphis gossypii* Glover (Aphididae: Homoptera), *Menochilus sexmaculatus* (Fabricius) (Coccinellidae: Coleoptera) and *Camponotus compressus* Fabricius (Formicidae: Hymenoptera) were studied in an unsprayed guava ecosystem under natural conditions. The predator (*M. sexmaculatus*) and the ant (*C. compressus*) were positively associated with the aphid (*A. gossypii*), while a negative association was recorded between the predator and the ant. For quantifying these associations in terms of overlapping and exclusion, spatial interspecific association analysis was carried out. Between aphid and predator, and aphid and ant, partial overlapping (γ = 0.44 and γ = 0.55, respectively) was obtained. Thus, although the association between aphid and predator was positive, it did not seem to be strong. Between the aphid and ant it was suggestive of mutualism, without obligate interdependence. Moreover, the predator and ant showed a tendency to independent occurrence with respect to the aphid when the spatial correlations were calculated. The predator and ant showed spatially almost complete exclusion.
KEY WORDS: Aphis gossypii; Menochilus sexmaculatus; Camponotus compressus; interspecific association; guava ecosystem.

INTRODUCTION

The aphid *Aphis gossypii* Glover (Aphididae: Homoptera) is a polyphagous pest on many agricultural crops such as cotton, brinjal, okra, gingelly, chilli, etc., and is a

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*Div. of Entomology and Nematology, Indian Institute of Horticultural Research, Hesseraghatta Lake P.O., Bangalore 560 089, India.

serious pest on guava, especially on the new leaves (10). It is cosmopolitan in distribution and a vector of many virus diseases (7). The coccinellid *Menochilus sexmaculatus* (Fabricius) (Coccinellidae: Coleoptera) is an important predator of *A. gossypii* (10) and is particularly abundant in the months of June-July on guava in Bangalore. The ant *Camponotus compressus* Fabricius (Formicidae: Hymenoptera) was recorded attending the aphid.

Interspecific association is defined as the tendency of species to occur together more (or less) often than to be expected on the basis of chance alone and, when quantified, can serve as a useful tool for the ecologist (4). The objective of this study was to identify and measure the association among species which would help in improving our understanding of the role played by the predator and the ant – under natural conditions – with reference to the aphid, in an unsprayed guava ecosystem.

MATERIALS AND METHODS

The present study was carried out in the guava orchard of the Horticultural Experiment Station, Hesseraghatta, Bangalore, in June-July, 1986, when populations of *A. gossypii* and *M. sexmaculatus* reached their peaks.

Sampling method

In order to establish a convenient sampling plan, a preliminary count on seven

TABLE 1

DISTRIBUTION OF THE *APHIS GOSSYPII* APHID POPULATION ON GUAVA

Direction	Tree no. *1*	*2*	*3*	*4*	*5*	*6*	*7*	*Mean*
	Average per leaf							
East	36.80	5.90	4.80	6.90	265.50	240.80	113.60	96.61
West	87.00	1.40	24.60	10.00	25.30	250.80	121.80	74.41
North	9.60	20.10	62.30	58.70	242.00	345.00	129.30	113.54
South	0.40	0.10	121.00	59.80	98.80	129.30	161.50	81.56
Mean per leaf/tree	33.45	6.88	30.25	35.35	157.85	242.00	113.30	
Variance	4972.92	363.04	1992.96	4027.16	38341.00	42450.26	16899.39	n.s.
SEM								38.43

randomly selected trees was made. From each tree ten new leaves from each direction, *viz.*, north, south, east and west, were randomly selected and aphids were counted on 25 and 26 June 1986. These data were subjected to analysis of variance, and no significant difference was found between the directions (Table 1). Therefore, sampling was conducted from all over the canopy. Ten infested guava trees were selected from a highly infested orchard. From each tree 50 new leaves were taken at random for intensive sampling of *A. gossypii, M. sexmaculatus* and *C. compressus*. These trees were kept free of insecticidal sprays. As it was found in the preliminary sampling that *in situ* counting of aphids was tedious and time consuming, with a possibility of underestimation (2), a scoring method was adopted based on the extent of aphid coverage on the leaf surface as follows: no coverage, 0; 1-25%, 1; 26-50%, 2; 51-75%, 3; and 76-100% coverage, 4.

The data on the three species were recorded concurrently on the same leaf. As ants were mobile, they were counted first, followed by predators (adults and larvae) and then aphids. Samplings were carried out on 11, 14 and 15 July 1986, when the predator was most abundant. After July, the predators became scarce in the guava

TABLE 2

MEANS (ON A PER-LEAF BASIS) AND VARIANCES OF THE COUNTS OF APHID, PREDATOR AND ANT ON GUAVA

Tree no.	*Aphid* (A. gossypii)*		*Predator (M. sexmaculatus)*		*Ant (C. compressus)*	
	Mean	Variance	Mean	Variance	Mean	Variance
1	2.10	11.5	0.86	1.39	0.22	0.21
2	1.74	1.18	0.56	0.41	0.52	0.50
3	2.08	1.54	0.48	0.38	0.56	0.46
4	1.36	1.26	0.60	0.37	0.44	0.50
5	2.16	0.99	0.34	0.27	0.48	0.42
6	2.10	1.03	0.28	0.37	0.94	0.42
7	1.58	1.27	0.68	0.51	0.56	0.37
8	1.82	1.33	0.76	0.76	0.42	0.33
9	1.42	0.90	0.64	0.32	0.36	0.27
10	1.08	0.27	0.86	0.20	0.22	0.22

*Based on scored data.

ecosystem. The means and variances of these data for the three species are presented in Table 2. When variances were higher or lower than their respective means in the majority of the sets, the distribution was considered aggregated or underdispersed, respectively (9).

2x2 Contingency table analysis

A 2x2 contingency table as suggested by Southwood (13) was used to determine the type of association between aphid and predator, aphid and ant, and predator and ant. The χ^2 test of independence was used to test whether the null hypothesis of independence should be accepted or rejected, as it makes the fewest assumptions on the type of distribution of the insects. The basic table for species X (more abundant) and species Y was as follows:

Species Y	*Species X*		
	Present	Absent	
present	a	b	a+b
absent	c	d	c+d
	a+c	b+d	n = a+b+c+d

In the 2x2 contingency table, the association is positive (affinity) if *ad* is greater than *bc*, and negative (repulsion) if *ad* is less than *bc* (13).

Iwao's spatial association analysis

To quantify the associations further, the data were subjected to Iwao's (5) analytical method. The interspecies mean crowding values (m^*_{xy}, and m^*_{yx}, *i.e.* mean crowding on species X by species Y, and vice versa, were calculated employing the following formulae:

$$m^*_{xy} = \frac{\sum_{j=1}^{Q} \chi_{xj}\,\chi_{yj}}{\sum_{j=1}^{Q} \chi_{xj}} \quad \text{and} \quad m^*_{yx} = \frac{\sum_{j=1}^{Q} \chi_{xj}\,\chi_{yj}}{\sum_{j=1}^{Q} \chi_{yj}}$$

where χ_{xj} and χ_{yj} are the numbers of individuals of species X and species Y in the jth leaf.

Next, the degree of overlapping index (γ and $\gamma_{(ind)}$) was calculated per tree and averaged employing the following formulae:

$$\gamma = \sqrt{\frac{m^*_{xy}\, m^*_{yx}}{(m^*_x+1)(m^*_y+1)}} \quad \text{and} \quad \gamma_{(ind)} = \sqrt{\frac{m_x\, m_y}{(m^*_x+1)(m^*_y+1)}}$$

where m_x and m_y and m^*_x and m^*_y are the mean density and mean crowding values of species X and Y, respectively, and (ind) is independent. $\gamma_{(ind)}$ is calculated when the two species are distributed independently.

Finally, the degree of spatial correlations (ω) was calculated among the three species, per tree, and averaged, using the following equations:

$$\omega+ = \frac{\gamma - \gamma_{(ind)}}{1 - \gamma_{(ind)}}, \text{ when } \gamma \geqslant \gamma_{(ind)}$$

or

$$\omega- = \frac{\gamma - \gamma_{(ind)}}{\gamma_{(ind)}}, \text{ when } \gamma \leqslant \gamma_{(ind)}$$

Iwao's γ index provides a measure of association in terms of degree of overlapping. A value of 1.00 indicates complete overlapping, while zero indicates complete exclusion. According to Iwao this index is identical to Pianka's (11) measure of niche overlap, which is derived from Levin's (8) index of alpha. The ω value provides a measure of spatial correlation between two species (or the degree of overlapping relative to the independent occurrence). Its value changes from the maximum +1.0 for complete overlapping through zero for independent occurrence to the minimum −1.0 for complete exclusion. Based on these, the interspecific associations among the three species of insects in a guava ecosystem are discussed.

RESULTS AND DISCUSSION

Association between *A. gossypii* and *M. sexmaculatus*

The 2x2 contingency analysis (Table 3) showed that there was a positive association between these two species, as may be expected since the predator preys on the aphids. However, the extent of association (Table 4) is reflected in the degree of overlapping given by γ index, which had an average value of 0.44, with a range of 0.31

to 0.70 among the ten guava trees. The spatial correlation value of –0.21 indicated a tendency to independent occurrence, probably because of the tendency of aphids to aggregate (Table 1, variance exceeded the mean) while predators were underdispersed (Table 2, variance less than the mean). Therefore, even though the association is positive, it does not seem to be strong.

TABLE 3

INTERSPECIFIC ASSOCIATION BASED ON A 2x2 CONTINGENCY TABLE

Interspecific association, Species X – species Y	*Components of 2x2 contingency table*				χ^2	*Type of association**
	a	b	c	d		
Aphid – Predator	217	0	252	31	23.49	ad >bc, Positive
Aphid – Ant	210	0	281	9	4.99	ad >bc, Positive
Predator – Ant	7	212	241	40	332.37	ad >bc, Negative

χ^2 at 5%, one degree of freedom = 3.84.
*According to Southwood (13).

TABLE 4

SPATIAL ASSOCIATION BETWEEN THE APHID *APHIS GOSSYPII* AND THE PREDATOR *MENOCHILUS SEXMACULATUS*

Tree no.	m^*_{xy}	m^*_{yx}	γ	$\gamma(ind)$	ω
1	0.70	1.72	0.43	0.53	–0.18
2	0.44	1.36	0.44	0.56	–0.21
3	0.38	1.63	0.42	0.53	–0.21
4	0.34	0.77	0.31	0.54	–0.43
5	0.27	1.71	0.39	0.50	–0.22
6	0.27	2.00	0.36	0.38	–0.05
7	0.53	1.24	0.44	0.56	–0.21
8	0.64	1.53	0.47	0.55	–0.15
9	0.45	1.00	0.44	0.63	–0.30
10	0.76	0.95	0.70	0.79	–0.11
Mean			0.44		–0.21

Association between *A. gossypii* **and** *C. compressus*

The ant showed a positive association with the aphid (Table 3). The degree of overlap was greater than that of the aphid with the predator (average $\gamma = 0.55$, Table 5). Ant populations were less dense than aphid populations (0.22 to 0.94/leaf), underdispersed (Table 2, variance less than the mean), and tended to independent occurrence with a spatial correlation value of 0.10 (Table 5). This seemed to be suggestive of mutualism, without any evidence of obligate interdependence. In this study, although the ant was dependent on aphids for honeydew, the overlapping was partial, probably because of the presence of the guava scale, *Chloropulvinaria psidii* (Maskell), which was also attended by *C. compressus*, presumably of the same colony. Some studies have shown that the attention given by soil nesting ants to aboveground homopterans is usually discontinuous (3,16). This sort of discontinuous behavior seemed to be true in the case of *C. compressus*, which is also a soil-nesting ant with a tendency from almost complete exclusion ($\omega = -0.04$) to partial overlapping ($\omega = 0.42$), as evident in Table 5. The results tend to conform to Way's (14) views that most homopterans seem to have the ability to live independently, and that they are not physiologically dependent on ants.

TABLE 5

SPATIAL ASSOCIATION BETWEEN THE APHID *APHIS GOSSYPII* AND THE ANT *CAMPONOTUS COMPRESSUS*

Tree no.	m^*_{xy}	m^*_{yx}	γ	$\gamma(ind)$	ω
1	0.17	1.64	0.29	0.38	–0.24
2	0.48	1.62	0.47	0.50	–0.06
3	0.60	2.21	0.59	0.55	+0.09
4	0.71	2.18	0.66	0.41	+0.42
5	0.53	2.38	0.60	0.54	+0.13
6	0.90	2.02	0.71	0.74	–0.04
7	0.66	1.86	0.65	0.55	+0.22
8	0.44	1.90	0.52	0.49	+0.06
9	0.51	2.00	0.66	0.47	+0.36
10	0.22	1.09	0.39	0.38	+0.02
Mean			0.55		+0.10

Association between *M. sexmaculatus* **and** *C. compressus*

A negative association between the two species was demonstrated (Table 3) which was substantiated by the value obtained for the γ index (0.042), with an average ω value of –0.88, indicating an almost complete exclusion (Table 6). The range of overlap (0 – 0.12) was almost negligible.

Opinion is divided on the relationship between an ant and a predator, in association with a homopteran. For instance, El-Ziady and Kennedy (1) reported that the ant *Lasius niger* Linnaeus attacked the coccinellid predators of the aphid *Aphis fabae* Scopoli, but Herzig (3) and Wichmann (15) reported the opposite. In the present study there was no evidence of *C. compressus* attacking or driving away *M. sexmaculatus*. A possibility exists of the ants being repelled by the regurgitorial secretions of the coccinellids, as reported by Kloft (6). A comparable instance is the defensive secretions of hemipteran predators, which guard them from ants and enable both to coexist in an aphid-infested (including *A. gossypii*) cotton agroecosystem (12).

TABLE 6

SPATIAL ASSOCIATION BETWEEN THE PREDATOR *MENOCHILUS SEXMACULATUS* AND THE ANT *CAMPONOTUS COMPRESSUS*

Tree no.	m^*_{xy}	m^*_{yx}	γ	$\gamma_{(ind)}$	ω
1	0.00	0.00	0.00	0.26	–1.00
2	0.07	0.08	0.05	0.39	–0.87
3	0.08	0.07	0.06	0.39	–0.85
4	0.07	0.09	0.06	0.27	–0.78
5	0.12	0.08	0.08	0.33	–0.76
6	0.00	0.00	0.00	0.34	–1.00
7	0.06	0.07	0.05	0.47	–0.89
8	0.00	0.00	0.00	0.39	–1.00
9	0.00	0.00	0.00	0.42	–1.00
10	0.07	0.27	0.12	0.38	–0.68
Mean			0.042		–0.88

From the management point of view, this study has provided a better understanding of the association among the aphid, predator and ant in a guava ecosystem. Although the predator and ant are positively associated with the aphid, the degree of overlapping is only partial, probably because of their lower numbers and regular (underdispersed) distribution, as compared with the contagious distribution of the aphid. Ants showed a better degree of overlap, probably because of their greater mobility than predators. However, both showed a tendency toward independent occurrence. The almost total exclusion between predator and ant suggests some repulsion or avoidance mechanism between the two.

In this study it was found that a 2x2 contingency table and Iwao's interspecific spatial associations were adequate tools to understand and quantify the associations among the aphid, predator and ant in the guava ecosystem.

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