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The Relative Susceptibility of Tomato Cultivars to *Epilachna vigintioctopunctata* (Coccinellidae: Coleoptera) in Western Samoa

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Abstract—When the relative susceptibility of tomato cultivars to *Epilachna vigintioctopunctata* was investigated in a randomized block design experiment at Alafua campus, Western Samoa, the results showed that the tall, bushy varieties: Alafua winner (AW), Fire ball (FB), Nuu (NU), Sugar pearl (SP) and Season red (SR) attracted more beetles than Alafua large (AL) which although tall had small, less compact canopy or Alafua early (AE) which branched heavily but was comparatively shorter. However, irrespective of whether the cultivar was more or less attractive, the larvae and adults predominantly fed on apical main leaflets 3 to 9 of the cultivars. Both the reproductive biology and food ecology of *E. vigintioctopunctata* were apparently not affected by any of the cultivars, suggesting that all of them were suitable host plants.

Introduction

Tomato, *Lycopersicon esculentum,* is a new crop in Western Samoa. Several varieties currently being cultivated in the country yield well (Suavi 1991), but a community of resident phytophagous insects is rapidly being recruited to this alien plant. Of these, *Epilachna vigintioctopunctata* is threatening to become a major economic pest of tomato in the Samoan archipelago. Although *Epilachna* spp. only feed on Solanaceae and Cucurbitaceae (Waterhouse & Norris 1987 & Richards 1983), species complexes exhibit high degree of host specificity. That is, some species complexes feed predominantly on solanaceous plants while others feed exclusively on cucurbitaceous hosts (Waterhouse & Norris 1987). Tallamy (1985) demonstrated that induced cucurbitacins adversely affected feeding activities of *Epilachna borealis* on zucchini; suggesting that cucurbitacins may influence the observed feeding preference in this genus.

Host-specificity among insects is promoted by a number of factors. Preference may be due to differences in physical appearances of potential food plants or to differential capabilities of insects to circumvent chemical or physical barriers. Herbivores may circumvent such obstacles by (i) neutralizing the toxic chemicals of their food plants (Strong et al. 1984), (ii) avoiding the tissues with toxic substances (Carroll & Hoffman 1980, Dillon et al. 1983, Tallamy 1985), (iii) destroying physical obstacles protecting preferred tissues (Dillon et al. 1983) or (iv) erecting mechanical devices to avoid injury from defensive devices such as hooked trichomes (Rathcke & Poole 1974).

The ability of resident insects to circumvent the defense systems of alien plants and thus colonize them can seriously undermine efforts to develop new crops in a country. Unfortunately, such potential pest problems are seldom researched and documented, so that our knowledge of this subject is scanty and fragmented (Strong et al. 1984). As a contribution to both this topic and island biogeography at large, this paper reports the results of a study in which the relatives susceptibility of seven tomato cultivars: Alafua early (AE), Alafua large (AL), Alafua winner (AW), Fire ball (FB), Nuu (NU), Sugar pearl (SP) and Season red (SR) to *E. vigintioctopunctata* was investigated in Upolu, Western Samoa. Data on the interactions of *E. vigintioctopunctata* with these cultivars are needed to make the current recommendations for the large scale introduction of tomatoes into Western Samoa.

Materials and Methods

EXPERIMENTAL SEEDLINGS

On 31 July 1991, seeds of AE, AL, AW, FB, NU, SP and SR were sown into respective varietal nursery beds enriched with chicken manure and NPK (12:5:20, at the rate of 192 kg N/ha) worked into the soil with a roto tiller. Direct sunlight onto the beds was reduced by a plastic canopy erected about 2 m above the beds. Seeds were watered twice a day until they germinated. Fifteen days after sowing (DAS), seedlings were given a second dose of NPK (12:5:20). About 5 grams were distributed in 1 m long narrow furrows made adjacent to the rows of seedlings. Two percent malathion (25% EC) was used at 21 DAS to kill adult *Epilachna* invading seedings at the nursery.

EXPERIMENTAL LAYOUT

The study was conducted at Alafua campus on an old corn field measuring approximately 20 × 30 m. The land was ploughed, harrowed and divided into four blocks of 3 × 28.8 m. Each block was divided into 7 plots of 3 × 2.4 m. Both the blocks and plots were demarcated from each other by 1.5 m boundaries. 34 DAS, 20 seedlings of each variety were randomly assigned and planted in one plot of a given block at a spacing of 1.0 × 0.6 m (between and within the rows respectively), thus making four replicates per variety. To start off the bare-rooted seedlings, about 5 gm of NPK (12:5:20) and urea (2:1) was placed in every planting hole. Transplants were watered immediately after planting and thereafter twice daily using a sprinkler. Additional fertilizer applications were made at 41 (NPK, 5 gm per plant), 47 (urea, 5 gm per plant) and 51 (NPK, 5 gm per plant) DAS. At 14, 28 and 42 days after transplanting (DAT), the crop was manually weeded. Similarly, all but the determinate AE were stacked at 14 DAT. Plants were not pruned as commonly practised by the local farmers (Suavi 1991).

TOMATO GROWTH CHARACTERISTICS

On the day seedlings were transplanted (3 Sep. '91) the root collar diameters, heights, and number of main and side leaflets of seedlings of each cultivar (n= 20) were recorded. On 22 Oct. '91 trichomes (long hairs only) on the upper surface of leaf discs (19.6 mm^2, n = 12) of the cultivars were counted under a binocular microscope. Discs were punched with a cork borer (dia. = 5 mm) from the right centre of terminal leaves of all the main leaflets of a variety. Trichome density on the lower surface of the discs were not estimated because they formed a mat which prevented an accurate count. Remnants of punched leaves were pressed and dried onto graph paper and their outlines were later traced for the purpose of estimating varietal leaf areas. Branching traits of all the cultivars were observed on 6 separate dates. Again on 22 Oct. '91 heights of every AE, AL, AW, FB, NU, SP and SR plant from replicate 4 were estimated.

PEST POPULATION DYNAMICS

From 18.9.91 to 30.10.91 population trends of *E. vigintioctopunctata* on varietal transplants were monitored weekly. Numerical records of egg batches, larvae, pupae and adults found on the main leaflets of the plant canopy were kept separately. Eggs per batch were counted under a microscope.

DATA ANALYSIS

We used ANOVA, model I (Sokal & Rohlf 1973) to investigate whether there were any significant differences in growth characteristics of the varieties and the total number of adults, eggs, larvae and pupae of *Epilachna* associated with each of the varieties before using Duncan's multiple range test (DMRT) to establish whether some varieties were identical in certain growth traits and beetle population characteristics at a significance level of 5%. We used DMRT knowing fully well its inherent weakness and limitations as discussed by Day & Quinn (1989). Similarly, we did not transform the data to a different scale because (i) there were no reasons to suspect that the population of *Epilachna* attracted to each of the varieties was not normally distributed and (II) interpretation of analyses of transformed data is usually problematic (Day & Quinn 1989). The validity of our hypothesis that Epilachna never varied its feeding, oviposition and pupation sites, and the number of eggs it laid per batch on the various varieties under investigation was analysed using *chi-square*. Only data from the first 12 apical leaflets was used to test this hypothesis because leaflets > 13 were rarely exploited by *Epilachna* for feeding, egg laying and pupation. Most often, the relative positions of existing leaflets changed within a sampling interval as new leaflets were recruited, so that these data were cumulative totals of larvae, adults, egg batches and pupae recorded on successive leaflets attaining a given relative position on a sampling date. The weekly average number of adults and egg batches per plant (n = 6) were regressed on the mean number of branches per plant of a variety for the week. The relationship between the mean number of eggs per batch estimated on the second day of the month and the mean number of varietal branches counted on this date was also investigated using regression analysis technique.

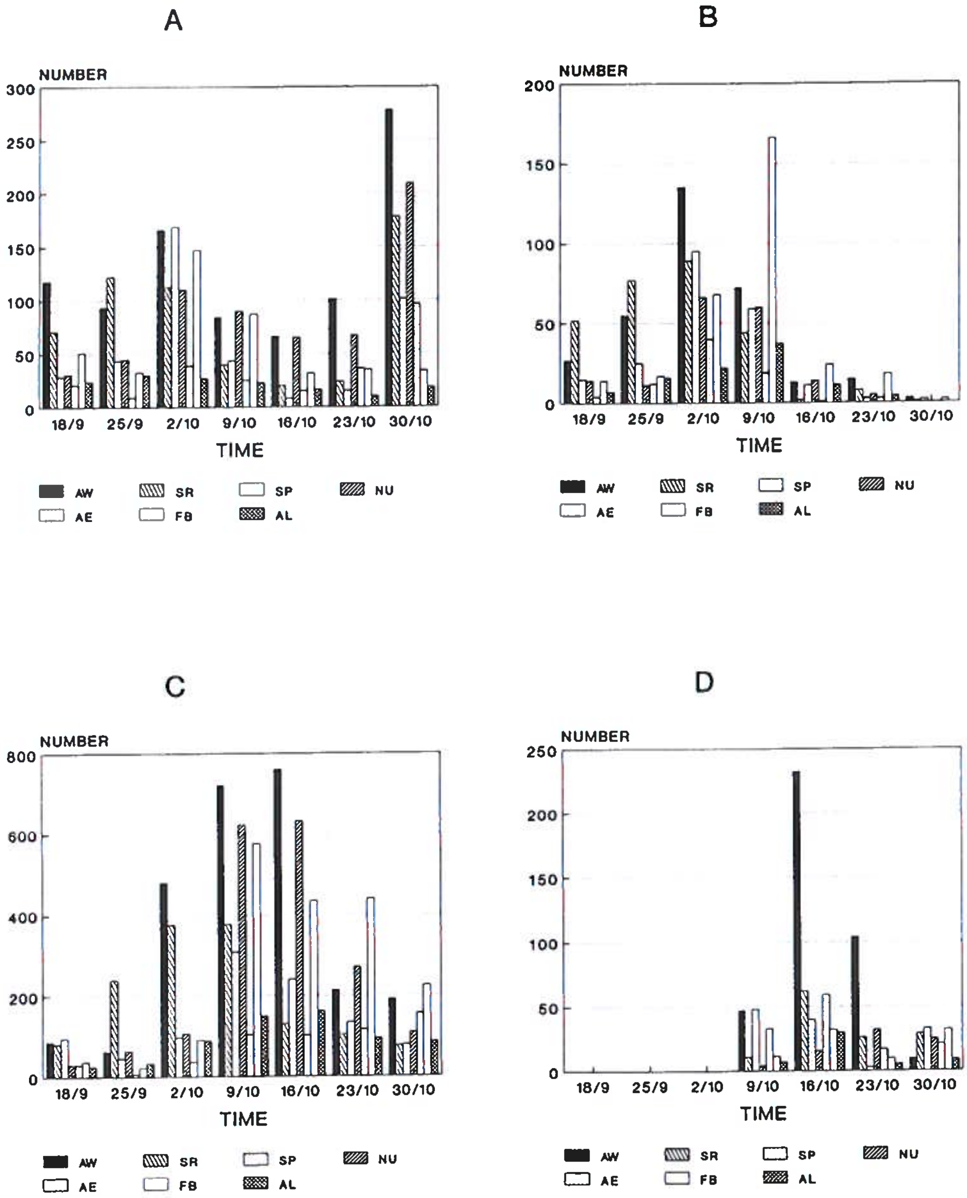

Figure 1. Temporal abundance of adults, eggs, larvae and pupae of *Epilachna vigintioctopunctata* on tomato cultivars grown at Alafua Campus, Western Samoa, 1991.

Similarly, we used regression analysis to ascertain whether the number of adults and egg batches counted on the 23rd of the month were related to the mean number of varietal trichomes estimated on the 22nd of the month. We also regressed total number of adults, egg batches, larvae, pupae and the mean number of eggs per egg batch on the "architectural rating" (=ar) (Moran 1980); which was the sum of six growth characteristics of a variety: height of mature plant, number of branches, trichomes on old leaves, main and side leaflets of seedlings; and leaf size, each measured on a score from 1 to 4. Mean varietal values of a parameter were grouped into four classes using a class interval obtained from the difference between the lowest and highest means divided by 4 before scoring them.

Results

GROWTH CHARACTERISTICS

Varietal seedlings and mature plants differed significantly in some of the characteristics we investigated. For example, the mean root collar diameters of AE, AW, NU and SR were significantly ($F_{(6, 19)}=18.6$, $P< 0.05$) higher than those of AL, FB and SP. Seedlings of AL, AW, FB, NU, SP and SR were taller than AE ($F_{(6, 19)}=65.4$, $P< 0.05$). Mature AL, SP and FB plants were taller than AW, NU and SR ($F(6, 82)= 36.8$, $P< 0.05$) while AE plants were determinate at relatively low heights. All except the seedlings of AL ($F_{(6, 19)}=29.6$, $P< 0.05$) produced similar leaf complements; except that AL produced significantly ($F_{(6, 19)}=32.8$, $P< 0.05$) fewer side leaflets. Although branch production increased as the tomato plants grew older, AL plants also produced fewer branches. Apart from extreme cases of NU (smallest, 55.0 cm^2) and SR (largest, 184.1 cm^2), the average leaf areas of the other varietal seedlings were also similar ($F_{(6, 81)}= 33.0$,

Table 1. Mean number of adults, egg batches, larvae, pupae and eggs per batch recorded on tomato varieties at Alafua Campus, 1991. (Means within the column with same letters are not significantly different, Duncan's multiple range test at 5%).

	Mean No. of				
Variety	Adults	Egg Batches	Eggs per Batch	Larvae	Pupae
AE	60.3 a	19.8 a	22.4 ab	138.5 a	33.0 ab
AL	30.8 a	24.3 a	27.2 bc	160.5 a	12.8 a
AW	226.5 b	80.0 c	24.2 abc	628.5 b	98.3 b
FB	104.8 ab	77.3 c	23.9 abc	456.5 ab	21.5 ab
NU	154.3 ab	42.5 ab	23.6 abc	459.3 ab	19.3 a
SP	95.3 ab	52.5 abc	28.3 c	226.8 ab	31.0 ab
SR	141.8 ab	68.3 bc	21.7 a	345.5 ab	32.0 ab
Fcal.	1.97	4.54	1.91	2.63	1.80
df	3,6	3,6	3,6	3,6	3,6
Significance (5%)	NS	S	NS	NS	NS

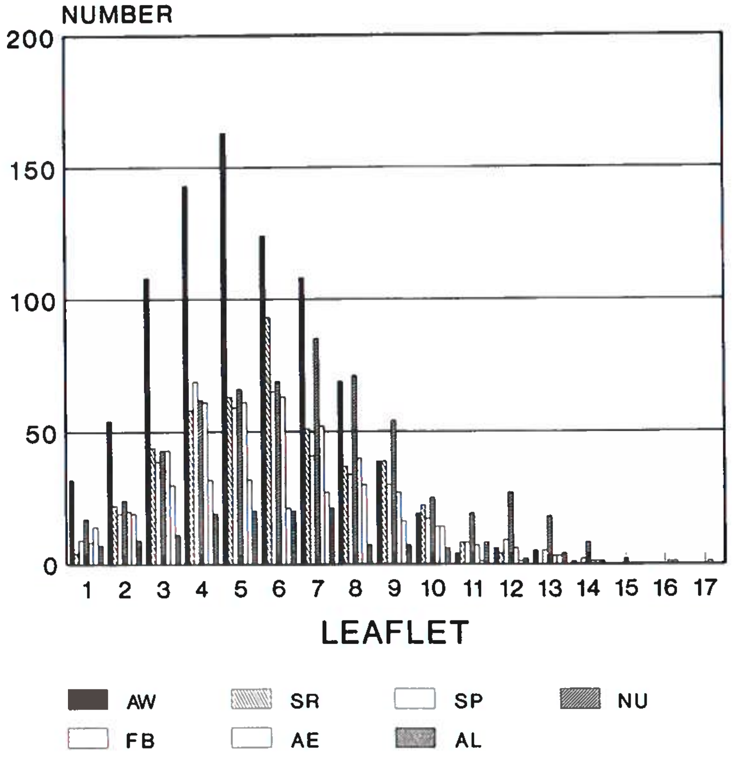

Figure 2. Spatial distribution of adult *Epilachna vigintioctopuctata* on the canopy of tomato cultivars at Alafua Campus, Western Samoa, 1991.

P< 0.05). The seedlings of AE cultivar had low number of trichomes on the upper surfaces of their leaves while leaves of SR plants has significantly (P< 0.05) higher number of trichomes. All the plants increased in size and structural complexity in time. Rated architecturally (Moran 1980 and Strong et al. 1984), the following varietal order was revealed: AL (8), AE (14), NU (15), FB (16), SP (16), AW (17) and SR (22).

TEMPORAL PEST ABUNDANCE

Except for egg batches, ANOVA established no significant differences among varietal means of adults, eggs per batch, larvae and pupae although DMRT ranked these means into 2 to 3 significantly (P< 0.05) different groups (Table 1). Thus for example, adult *E. vigintioctopunctata,* in decreasing order were significantly (P< 0.05, Table 1) more common on AW, NU, SR, FB and SP and occasionally invaded AE and AL in appreciable numbers. Adult populations peaked twice. The first peak occurred in the fourth week after transplantation on AW, FB, NU, SP and SR and FB and the second came four weeks later on AW, SP, SR, NU and AE (Fig. 1A). The second population peak was not accompanied with egg laying as was the case with the first invading population (Fig. 1B). Approximately equal number of eggs were laid in batches on the lower surfaces of the leaflets of AE, AL, AW, FB, NU, and SP (Table 1). However, egg batches laid on SR were generally smaller (Table 1). Population peaks of larvae occurred between week 5 and 6 following seedling transplanting, and of pupae between week 6 and 7 (Figs. 1 C and D). More larvae survived and pupated on AW; few survived on AE and AL (Table 1). However, at the time of peak pupation, as many larvae survived on the less attractive AL cultivar as on FB (Fig. 1D). Eight weeks after transplanting seedlings few pupae were found on any varieties. Weekly data on the various stages (Fig. 1) implied that the development time of *Epilachna* was similar on all the cultivars.

SPATIAL DISTRIBUTION PATTERNS

Adults grazed and laid eggs mainly on the first 10 apical main leaflets (Figs. 2, 3). Larvae fed anywhere between 3rd and 12th apical leaflets (Fig. 4). The chi-square analyses (Table 2) showed that regardless of the plant age, adults, eggs, larvae and pupae were invariably found at identical relative positions within the

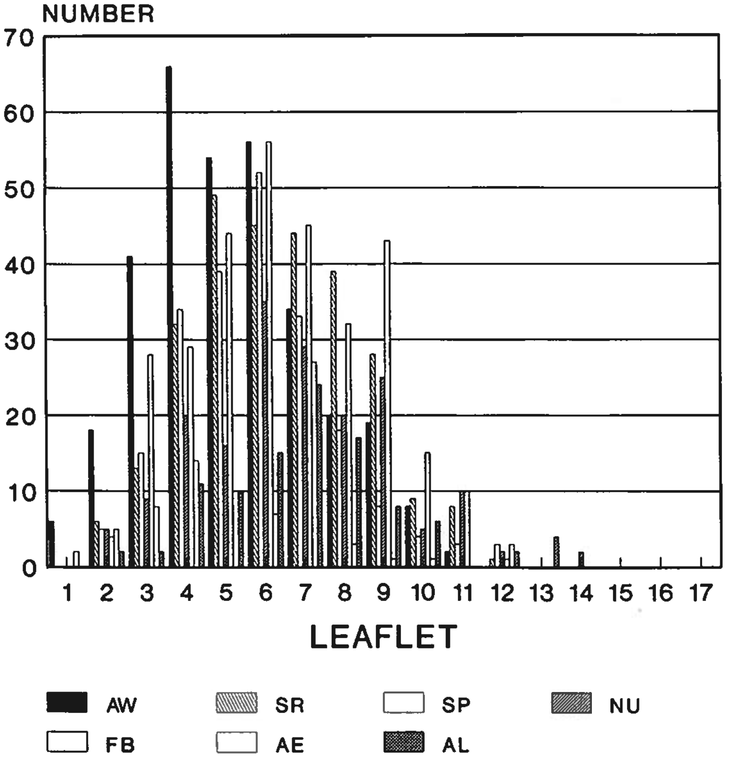

Figure 3. Spatial distribution of egg batches of *Epilachna vigintioctopunctata* on the canopy of tomato cultivars at Alafua Campus, Western Samoa, 1991.

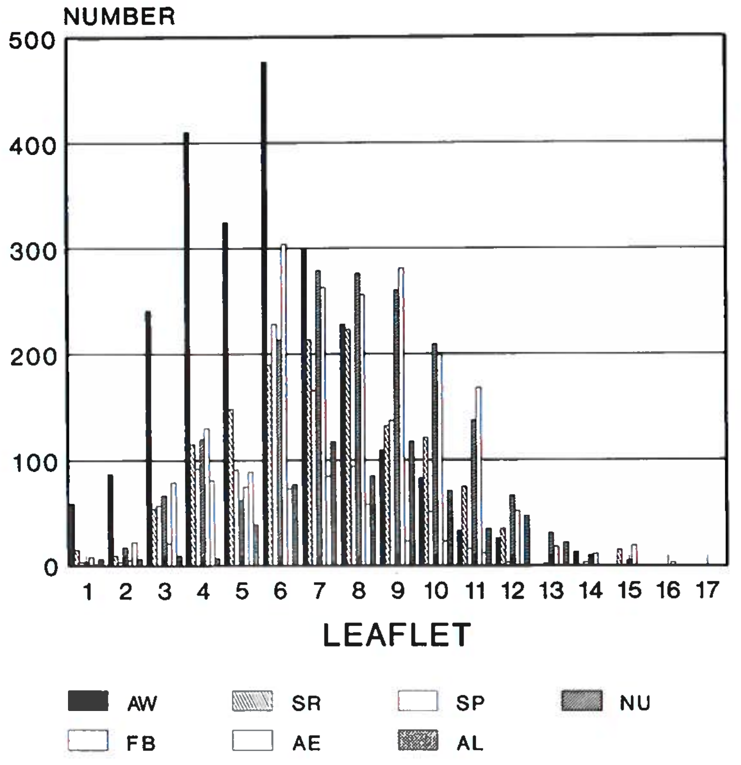

Figure 4. Spatial distribution of larvae of *Epilachna vigintioctopunctata* on the canopy of tomato cultivars at Alafua Campus, Western Samoa, 1991.

Table 2. χ^2 analysis of the distribution of life stages of *Epilachna vigintioctopunctata* on the canopies of seven tomato varieties at Alafua Campus, 1991.

Stage	χ^2	df	P
Adults	245.07	66	<0.0001
Eggs (Batches)	195.22	60	<0.0001
Larvae	1779.98	66	<0.0001
Pupae	355.96	66	<0.0001

canopies of every variety (Figs. 2, 3, 4). Most penultimate larvae pupated on the leaves they last fed on (Figs. 4, 5) although a few probably moved below and pupated on the older leaves.

VARIETAL DIFFERENCE IN LADY BEETLE ABUNDANCE

Tall bushy cultivars attracted more beetles than AL which although tall, had less compact canopy. Beetle population (adults, eggs and larvae) trend and the

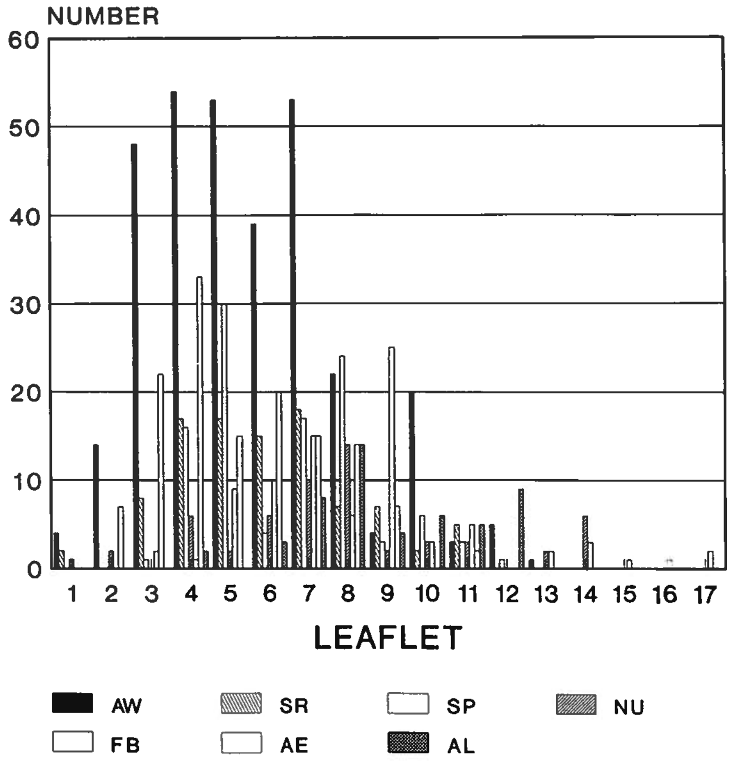

Figure 5. Spatial distribution of pupae of *Epilachna vigintioctopunctata* on the canopy of tomato cultivars at Alafua Campus, Western Samoa, 1991.

branching of the cultivars coincided although regression analysis of weekly adult average numbers on the mean number of branches did not explain adequately the invasive behavior of the beetles in time on AW, FB, NU and SP while that on AE was significantly ($P< 0.05$) a function of branching (Table 3). Marginally, branches on SR and AL appeared to have influenced the beetles as well (Table 3). Oviposition on AE, NU, SP and SR was probably also influenced by the number of branches (Table 3). Nevertheless, this was not the case on cultivars AL, AW and FB where the regression analyses indicated very low correlation between the two variables. When the number of adults, egg batches, eggs per batch and larvae recorded on 2 Oct. '91 (first population peak) was regressed on the varietal mean number of branches of the same date, about 35 to 40% of the variations in number of adults, egg per batch and larvae were explained by changes in the number of branches (Table 4). The number of egg batches the beetles laid about this time were significantly ($P< 0.05$) correlated with branching of the varieties (Table 4) while the trichomes on the upper surface of the leaves did not influence the number of adults and egg batches laid on a cultivar (Table 4). There was absolutely no correlation between adult beetle abundance and the relative

Table 3. Equations and correlation coefficients for the regression of weekly number of adults and egg batches on the mean number of varietal branches.

Variety	Equations	r^2	F	df	P
		Adults			
AE	Y = 35.2 − 1.30 X	0	0.05	1,6	0.841
AL	Y = 30.5 − 4.05 X	52.0	4.34	1,6	0.106
AW	Y = 468 − 51.9 X	25.9	1.40	1,6	0.303
FB	Y = 91 − 5.8 X	1.9	0.08	1,6	0.795
NU	Y = −192 + 45.8 X	27.9	1.55	1,6	0.281
SP	Y = 106 − 6.8 X	2.4	0.10	1,6	0.770
SR	Y = 231 − 26.8 X	60.8	6.19	1,6	0.068
		Egg Batches			
AE	Y = 87.5 − 11.8 X	73.5	11.10	1,6	0.029*
AL	Y = 22.7 − 2.97 X	10.8	0.49	1,6	0.524
AW	Y = 192 − 21.7 X	9.0	0.40	1,6	0.562
FB	Y = −45 + 17.5 X	9.8	0.44	1,6	0.545
NU	Y = 246 − 35.1 X	61.2	6.30	1,6	0.066
SP	Y = 141 − 17.3 X	41.2	2.81	1,6	0.169
SR	Y = 143 − 16.8 X	28.6	1.60	1,6	0.274

*Significant at $P < 0.05$.

heights of mature plants although for unknown reason(s), the number of eggs per batch the females laid were somewhat influenced by the branching traits of the varieties (Table 4). Similarly, architectural rating (Moran 1980) of a cultivar appeared not to determine the number of adults, egg batches or eggs per batch observed throughout this study nor did it influence the number of larvae which survived through to pupal stage (Table 4).

Discussion

Factors which influenced the beetles to choose some cultivars more often than others were complex and hard to discern in a simple study such as this one. In any case, a thorough knowledge of all the plant traits that have an important bearing on the finding of hosts by insects is still lacking (Mattson & Haak 1987). Thus far, research has focused on plant chemical properties that may affect this behavior, but there is a growing body of evidence about the significance of visual plant properties (Prokopy & Owens 1983). In our study, physical appearances of the cultivars were correlated with differential beetle attacks. The most preferred cultivars (Fig. 1) were similar in physical attributes; all had comparable architectural ratings although neither of the component physical characteristics functioned independently. For example, AE plants branched heavily, but were shorter and had fewer beetles on them. AL plants were tall but produced fewer branches and also had fewer beetles on them. Heights of mature plants, branches and trichome density appeared to have influenced egg laying independently (Tables

Table 4. Equations and correlation coefficients for regression of the number of adults, egg batches, eggs per batch, larvae and pupae on mean number of trichomes, branches, heights of mature tomato plants and architectural ratings of the cultivar.

Variety	Equations	r^2	F	df	P
		Trichomes			
Adults	Y = 275 + 64.3 x	14.8	0.87	1,5	0.395
Egg Batches	Y = 115 + 32.4 x	24.7	1.64	1,5	0.257
Eggs/Batch	Y = 29.6 − 0.9 x	30.8	2.23	1,5	0.196
Larvae	Y = 1018 + 131 x	7.5	0.41	1,5	0.552
		Branches			
Adults	Y = −21.3 + 26.4 x	37.3	2.97	1,5	0.145
Egg Batches	Y = −38.0 + 22.5 x	64.4	9.03	1,5	0.030*
Eggs/Batch	Y = 32.9 − 1.2 x	42.9	3.76	1,5	0.110
Larvae	Y = −235 + 84.0 x	42.7	3.73	1,5	0.111
		Mature Plant Heights			
Adults	Y = 470 − 0.12 x	0.0	0.0	1,5	0.982
Egg Batches	Y = 62 + 1.9 x	16.8	1.01	1,5	0.361
Eggs/Batch	Y = 21.1 + 0.08 x	43.4	3.83	1,5	0.108
Larvae	Y = 1053 + 4.4 x	1.7	0.09	1,5	0.779
		Architectural Ratings			
Adults	Y = −121 + 37.7 x	39.0	3.20	1,5	0.134
Egg Batches	Y = −43 + 16.3 x	47.8	4.58	1,5	0.085
Eggs/Batch	Y = 31.9 − 0.3 x	30.2	2.17	1,5	0.201
Larvae	Y = 158 + 80.2 x	21.8	1.39	1,5	0.291
Pupae	Y = −3 + 9.2 x	12.5	0.71	1,5	0.437

*Significant at $P < 0.05$.

3, 4). It was however difficult to tell whether AL was less suitable to *E. vigintioctopunctata* than the other varieties. The average number of eggs per batch, larval survivorship through to pupae on AL and the general similarity in developmental time of the beetles on all the cultivars suggested that AL plants were probably as suitable as the other cultivars.

Age of the leaves determined which position on the canopy the adults, eggs, larvae and pupae of *E. vigintioctopunctata* were located (Figs. 2–5). Foliar age is linked to the nutritional values of food plants (Strong et al. 1984) and is a factor in the food ecology of most phytophagous insects (Rockwood 1974, Cates 1980, 1981, Strong et al. 1984, Epila-Otara, 1986). In this study, older tomato leaves were less preferred by adults both as oviposition and feeding sites and the larvae fed predominantly on the younger leaves. We were unable to explain why adult *Epilachna* apparently never used plant heights as a cue in host finding and yet other phytophagous insects do so (Service 1984).

From the standpoint of potential pest problems, AW which Anon. (1990) reported to be high yielding and resistant to bacterial wilt disease was the most susceptible cultivar to beetle attack. Therefore we do not recommend it as the cultivar for adoption in Western Samoa. AE and AL which were also reported to be resistant to bacterial wilt (Anon. 1990) had fewer beetles than the other cultivars, suggesting that these varieties should be given priorty for use from the pest standpoint. However, yield data is needed for the varieties.

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