Distribution of *Stethorus punctum*[1] in Relation to Densities of the European Red Mite[2,3,4]

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ABSTRACT

The distributional patterns of *Stethorus punctum* (LeConte) in relation to densities of the European red mite, *Panonychus ulmi* (Koch), were investigated within an apple orchard and within an apple tree. *S. punctum* adults have the ability to find increasing mite populations on trees in an orchard. A prey population averaging 2–3 motile mites/leaf is sufficient to enable the predator population to reproduce and increase in size. Temperature was found to influence the ability of *S. punctum* to find its prey. Within the tree, distribution showed that *S. punctum* adults search out areas of the tree where the mite populations were the highest. *S. punctum* larvae also were found feeding in these areas. Mite populations increased within the row where the leaves were not as heavily hit by spray.

The ability of a predator to occupy the same habitat as its prey may influence its suppressive effect on the prey. For a predator to exert a maximum effect it should be present and active in all places inhabited by the prey (Chant 1960).

Knowledge of the distribution of *Stethorus punctum* (LeConte) vs. the European red mite, *Panonychus ulmi* (Koch), (ERM), is important in further improving the Pennsylvania integrated mite control program, which is based upon the interaction of the predator *S. punctum* with ERM. This experiment was designed to determine if the distribution of *S. punctum* is closely associated with that of its spider mite prey within an apple orchard and within an apple tree under conditions similar to Pennsylvania's commercial apple orchards.

Materials and Methods

Distribution within an Orchard

This study was conducted in an orchard owned and operated by the Pennsylvania State University near Arendtsville, PA. The orchard contained 7 rows of apple trees of the following apple cultivars: York Imperial (Y), Rome Beauty (R), Golden Delicious (G), Stayman Winesap (S), and Delicious (D). Air temp records were taken from a United States Weather Bureau Station located within the orchard.

Three trees were selected from each row in the orchard for counting mites; 1 tree near each end of the row and 1 tree in the middle. There were a total of 21 trees selected from 7 rows (Fig. 1).

Ten randomly selected leaves of approximately equal size were picked from the lower periphery of each tree. The leaves were transported back to the laboratory in labeled 1-qt plastic bags. Leaves were examined with aid of a stereoscopic microscope at 10× magnification for all stages of ERM.

Fifty-seven trees scattered throughout the 137 tree orchard were chosen for monitoring the seasonal movement of *S. punctum*. A 3-min examination of each tree was made by slowly walking around the periphery and recording the number of adults and larvae observed as described by Asquith and Colburn (1971). These trees included the ones monitored for mite populations.

In order to minimize any effect by pesticides on the interaction between *S. punctum* and ERM, the chemicals chosen for the seasonal spray program were selected on the basis of their low toxicity to both predator and prey.

Distribution within a Tree

Four apple trees of the cultivar 'Stayman Winesap' were selected for this experiment. Each tree was part of a 4-tree plot in a larger randomized complete block experiment. The size of the trees, which were in full production, was controlled by mechanical cutting. Each tree was divided into 2 levels for sampling purposes. The lower level was the area at the 4–6 ft height above the ground and the upper level was the zone at the 8–10 ft height above the ground. Each zone was further divided into 4 sections according to the cardinal points of the compass. The trees were divided by the use of wire strapping coated with fluorescent orange paint. The strapping was attached to 4 wooden poles located at each corner of the tree and to 1 pole rising from the center of the tree.

Examination of a tree for *S. punctum* adults and larvae was conducted by a trained observer as follows. First, a 1-min examination in a modification of the method described previously in the within orchard distribution study was made of each quadrant in the lower level. Next, a 1-min examination was made of the upper level of each quadrant using a hydraladder. An additional 10 sec was added to the time spent in each upper quadrant to allow for posi-

[1] Coleoptera: Coccinellidae.

[2] Acarina: Tetranychidae.

[3] Authorized for publication on Sept. 12, 1975 as Journal Series paper number 4932 of the PA Agric. Exp. Stn. This publication was supported in part by the National Science Foundation and the Environmental Protection Agency, through a grant (NSF BMS75-04223) to the Univ. of Calif. The findings, opinions, and recommendations expressed herein are those of the authors and not necessarily those of the Univ. of Calif., the NSF or the EPA. Received for publication Jan. 6, 1976.

[4] Part of a thesis to be submitted by the 1st author in partial fulfillment of the requirements for the Ph.D. degree at the Penn. State Univ., University Park, PA.

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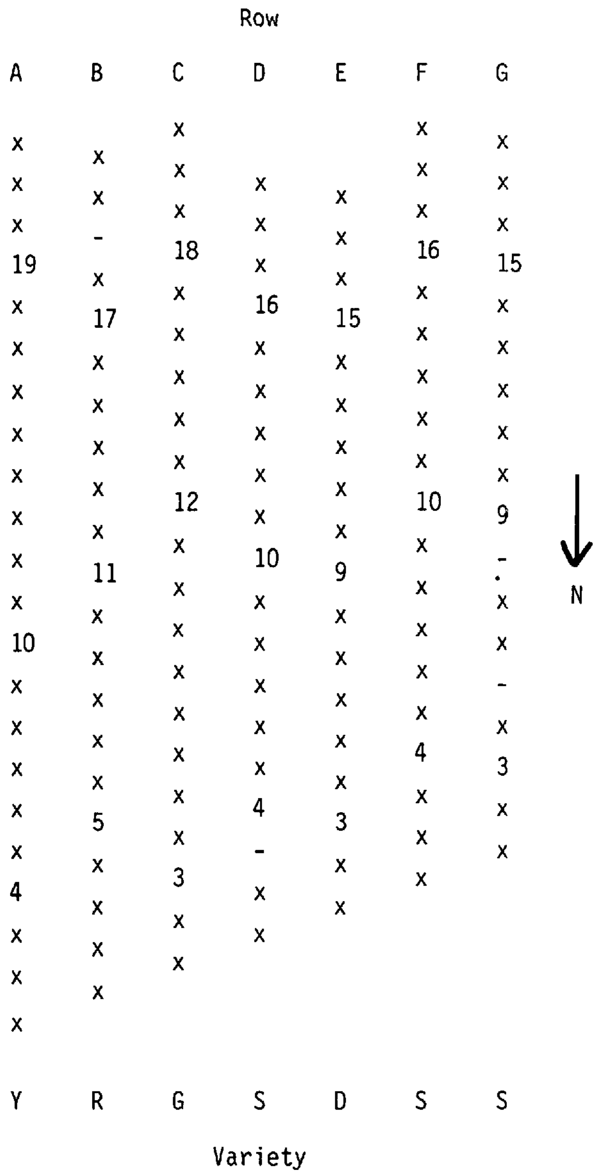

FIG. 1.—Design used to study the distributional patterns within an orchard of the predator *Stethorus punctum* and its prey *Panonychus ulmi* at Arendtsville, PA. The row letter and tree number correspond to those trees sampled for *S. punctum* and *P. ulmi* found in Table 1.

tioning the hydraladder. Third, samples of 10 leaves were collected from both upper and lower quadrants and placed in labeled 1-qt plastic bags for transport to the laboratory. Counts were made in the same manner as previously described for the within orchard distribution study with the addition of counting *S. punctum* eggs.

All 4 trees were sprayed with 2 oz AI of azinphosmethyl WP 50 and 1.341 lb AI of lead arsenate WP 94/acre/alternate side application. On Aug. 12, phosalone WP 25 at the rate of 4 oz/acre/alternate side was substituted for lead arsenate. Asquith and Hull (1973) reported that at these concentrations, the insecticides showed low enough toxicity to *S. punctum* for use in the Pennsylvania integrated pest management system for apples. Two fungicide treatments were applied with 2 trees receiving captan WP 50 and sulfur WP 95 and 2 receiving Dikar® WP 80, 74% a coordination product of zinc ion and manganese ethylene bisdithio-carbamate + 6% dinocap. These fungicides are standard treatments in Pennsylvania's integrated pest management program (1975 Pennsylvania Tree Fruit Production Guide). The trees were sprayed by the alternate side technique as described by Lewis and Hickey (1967). The trees were sprayed with 6X concentrate mixtures from the north and south sides by means of a Friend Airmaster 393 sprayer.

Results and Discussion

Distribution within an Orchard

Since Colburn and Asquith (1970) demonstrated that *S. punctum* was significantly attracted to the European red mite, a correlation analysis was used to determine the response of *S. punctum* to various sized mite populations in different areas of the orchard. Even though 57 trees were monitored for *S. punctum*, only those trees on which counts were made for both predator and prey were used in the analysis. *S. punctum* adults and larvae were correlated with ERM using a lag period of 6–10 days, except on one occasion where the interval was 15 days. This lag period, which is characteristic of *S. punctum* in response to mite populations, was demonstrated by Colburn and Asquith (1971). The data and the results of the analysis are given in Table 1.

Even though *S. punctum* were found overwintering in the orchard, there were no significant correlations between *S. punctum* and mite populations early in the season (Table 1). During this time of the season, the density of ERM follows a characteristic pattern. The mites hatch from overwintering eggs and settle on the small basal leaves where they complete their development. Rapid foliage expansion occurs and the developing adult mites rapidly disperse over it. Thus the population of mites/leaf tends to decrease for a period of 2–3 weeks. It is during this time that *S. punctum* adults are searching for localized pockets of mites. The overwintered adults are sluggish early in the season because of low food reserves and the cool spring temperatures which keep them from dispersing rapidly. Hull (1974 unpubl.) found that the overwintered adults do not functionally respond to increasing mite densities as compared with 2nd and 3rd generation adults. The combination of these factors probably contributes to the poor predator-prey interaction early in the season.

S. punctum larvae began appearing in the trees (May 27) as a result of egg deposition by *S. punctum* females in response to increasing mite populations in certain areas of the orchard. Table 1 shows that trees A-4, A-10, and G-3 had increasing ERM populations and by June 5, these trees had the highest *S. punctum* populations. This response to ERM populations, ranging from 1.8–3.2 motile mites/leaf,

Table 1.—Within orchard distributional patterns of *Stethorus punctum* adults and larvae/3-min observation with respect to its prey, *Panonychus ulmi* on apple trees at Arendtsville, PA.

Row & tree no.	5/7-[a] 5/13[a]		5/13- 5/20		5/20- 5/27		5/27- 6/5		6/4- 6/10		6/10- 6/20		6/20- 6/26	
	S[b]	M[b]	S	M	S	M	S	M	S	M	S	M	S[b]	M[b]
A-4	15	1.8	8	0.9	1	0.2	12	1.8	4	1.3	10	7.4	6	1.5
A-10	3	1.6	4	0.3	6	0.1	5	1.8	2	1.0	0	4.1	2	0.5
A-19	12	1.5	5	0.3	9	0.1	1	0.0	5	1.4	2	2.1	1	2.5
B-5	2	0.4	1	0.2	0	0.0	0	0.0	0	1.5	0	0.7	0	0.2
B-11	0	1.0	1	0.2	0	0.1	0	0.5	0	0.6	0	0.2	1	0.1
B-17	1	1.1	1	0.1	0	0.0	0	0.5	1	0.6	0	0.1	0	0.7
C-3	7	0.5	4	0.2	1	0.1	3	0.1	3	1.2	0	0.5	0	0.3
C-12	4	1.2	3	0.2	1	0.0	3	0.0	0	0.4	0	0.9	1	0.1
C-18	6	0.5	4	0.4	5	0.0	2	0.3	0	0.2	0	0.3	1	0.3
D-4	11	2.1	0	1.1	1	0.1	0	0.5	0	0.2	0	1.2	0	1.0
D-10	5	1.4	2	3.0	1	0.1	1	0.9	1	0.0	2	1.6	0	0.5
D-16	17	2.0	4	1.2	5	0.0	0	0.3	0	1.0	0	1.3	2	0.9
E-3	4	0.6	3	1.4	1	0.0	0	0.1	0	0.3	0	0.7	2	0.5
E-9	1	0.3	2	0.5	0	0.1	0	0.0	1	0.1	0	0.6	0	0.3
E-15	1	0.3	4	0.0	2	0.2	2	0.2	1	0.4	0	0.5	0	0.0
F-4	7	3.5	5	2.5	3	0.1	4	0.3	1	2.4	0	4.5	2	4.4
F-10	7	6.5	11	0.8	1	0.4	0	0.1	2	2.5	2	2.3	0	1.3
F-16	1	4.4	11	1.8	1	0.4	2	0.0	3	2.6	5	1.2	4	0.7
G-3	7	7.4	9	2.7	7	0.5	8	3.2	6	3.5	7	5.0	6	1.1
G-9	8	4.0	12	1.1	6	0.3	2	0.4	3	3.9	3	1.9	5	1.3
G-15	6	2.4	20	1.6	11	0.2	2	0.9	4	0.5	3	2.0	6	1.0
R[c]	0.19 NS		0.33 NS		0.23 NS		0.73**		0.57**		0.72**		0.25 NS	

Row & tree no.	6/24- 7/3		7/2- 7/9		7/11- 7/19		7/24- 8/2		8/5- 8/12		8/29- 9/4		9/9- 9/24	
	S	M	S	M	S	M	S	M	S	M	S[b]	M[b]	S	M
A-4	31	10.0	38	10.5	173	8.2	27	2.5	7	0.0	9	0.2	2	0.3
A-10	0	1.6	2	1.5	20	0.2	15	2.0	18	0.8	16	0.6	23	3.3
A-19	3	5.2	12	0.8	12	1.8	3	1.2	2	1.5	28	4.9	22	6.3
B-5	0	1.3	0	1.3	2	0.7	14	4.5	12	1.1	17	1.0	12	1.5
B-11	0	0.1	0	1.9	0	0.0	1	0.5	8	1.2	13	1.1	83	5.3
B-17	0	0.3	0	0.1	0	0.0	0	0.2	5	0.7	9	3.6	88	12.7
C-3	0	1.6	1	1.2	0	1.0	30	0.3	41	3.2	67	12.6	26	1.2
C-12	1	1.3	0	0.0	1	0.1	5	0.6	4	2.5	37	6.7	91	6.4
C-18	0	0.2	0	0.1	0	0.0	3	1.1	7	1.6	47	9.3	65	2.2
D-4	0	1.3	3	2.3	2	0.4	22	6.8	21	2.9	13	0.4	65	5.7
D-10	0	3.0	1	2.0	8	0.0	14	2.0	14	0.6	11	1.0	23	5.0
D-16	1	2.2	0	0.3	1	0.5	7	2.2	1	0.5	9	2.4	78	1.6
E-3	0	0.3	0	0.6	3	0.0	48	7.0	25	3.3	20	0.4	31	1.1
E-9	0	3.5	1	0.4	4	0.3	17	2.1	15	1.7	32	2.3	70	3.1
E-15	1	1.1	0	1.8	5	0.5	19	6.0	24	2.9	24	0.5	43	1.9
F-4	1	5.3	0	1.9	8	0.4	26	4.3	6	1.5	22	4.7	27	3.2
F-10	2	2.9	0	1.8	2	0.3	3	3.0	11	0.7	11	5.0	73	3.2
F-16	5	2.7	1	2.0	1	1.2	16	2.9	9	0.1	4	0.1	14	2.1
G-3	5	13.3	2	4.9	3	0.2	23	1.4	28	4.2	61	12.4	44	10.7
G-9	4	4.8	1	1.1	3	0.1	6	0.7	10	1.5	27	2.8	50	15.3
G-15	1	3.7	1	3.0	2	0.1	9	1.6	16	2.9	63	3.5	31	0.5
R[c]	0.62**		0.83**		0.97**		0.61**		0.69**		0.79**		0.38 NS	

[a] ERM counts (top dates) were correlated with the *S. punctum* counts (bottom dates) using a 6–10 day lag period.
[b] S = *S. punctum* adults and larvae/3-min observation; M = European red mites/leaf.
[c] Correlation coefficient; NS, *, ** — Nonsignificant and significant at 5 and 1% level respectively.

indicates that this predator does not lack the ability to respond quickly to low prey densities. Putman (1955) reported the average minimum density of ERM necessary to sustain a population of *S. punctillum* Weise adults on peach trees was 1 mite/leaf, but very few larvae reached maturity at this prey density.

From June 10–26, *S. punctum* populations remained low throughout the orchard. During this time ERM populations began to increase in certain areas (Table 1). Due to their rate of increase along with the number of mite eggs and the size of the *S. punctum* population, we felt it necessary to apply 2 separate acaricidal applications of 3 oz/acre of Plictran® (50% tricyclohexyltin hydroxide) on June 18 and 27. The combined effect of the 1st acaricide spray, which resulted in fairly even mite populations throughout the orchard, and the low *S. punctum* population probably caused the non-significant correlation between the mite count of June 20 and the *S. punctum* count of June 26 (Table 1). The 2nd application of acaricide did not seem to affect the interaction between predator and prey. This is attributed to a high number of mite eggs, which were as high as 62 eggs/leaf on some trees. These eggs kept the motile mite population equal to or above the density level before the application of acaricide.

Tree A-4 (Table 1) is a good example of how well *S. punctum* can respond to a building mite population in a certain locale of the orchard. Near the end of June, the mite population began increasing rapidly on this tree. Within a short period of time, *S. punctum* responded numerically to this increase and near the middle of July, 173 adults and larvae could be found in a 3-min count. During the remainder of the season, ERM populations built-up on different trees and subsequently *S. punctum* dispersed to these trees and exerted a controlling effect. The predatory mite, *Amblyseius fallacis* (Garman), was found on most of the trees and assisted in controlling ERM.

Since the results (Table 1) show that most of the high correlations between *S. punctum* and ERM populations occurred during the warm summer months, it was decided to run a regression analysis of the correlation coefficients on the mean temperatures to determine if temperature affected the response of *S. punctum* to mite populations (Fig. 2). The mean temperatures were calculated by averaging the daily temperatures recorded from the time the mite count was made to the time the *S. punctum* count was made. The results of a t-test of the slope coefficient in Fig. 2 was significant at the 1% level. This indicates a possible relationship between temperature and the ability of *S. punctum* to find its prey.

Distribution within a Tree

The data from each fungicide treatment were analyzed separately using a 2 factor (level and quadrant) fixed effect analysis of variance model. The log transformation was used to stabilize the variance and to make the data more normally distributed. The raw means of the data are given in Table 2.

The build-up of ERM in different sections of the tree and the response of *S. punctum* adults and larvae to these populations is shown graphically in Fig. 3. The ERM populations on the captan treated trees began to increase earlier than on the Dikar treated trees. The suppressing effect of Dikar® on ERM populations can be seen by the number of mites/leaf on July 8 for each fungicide treatment (Table 2). On the captan-treated trees 3 oz AI/acre of Plictran® WP was applied to both sides of the trees on July 15. On July 24, 2 oz AI/acre of Plictran® WP was applied to both sides of the Dikar-treated trees. The decision to apply an acaricide was based upon the size of ERM and *S. punctum* populations and the rate at which each was increasing. Disruption of the distribution of both predator and prey caused by the

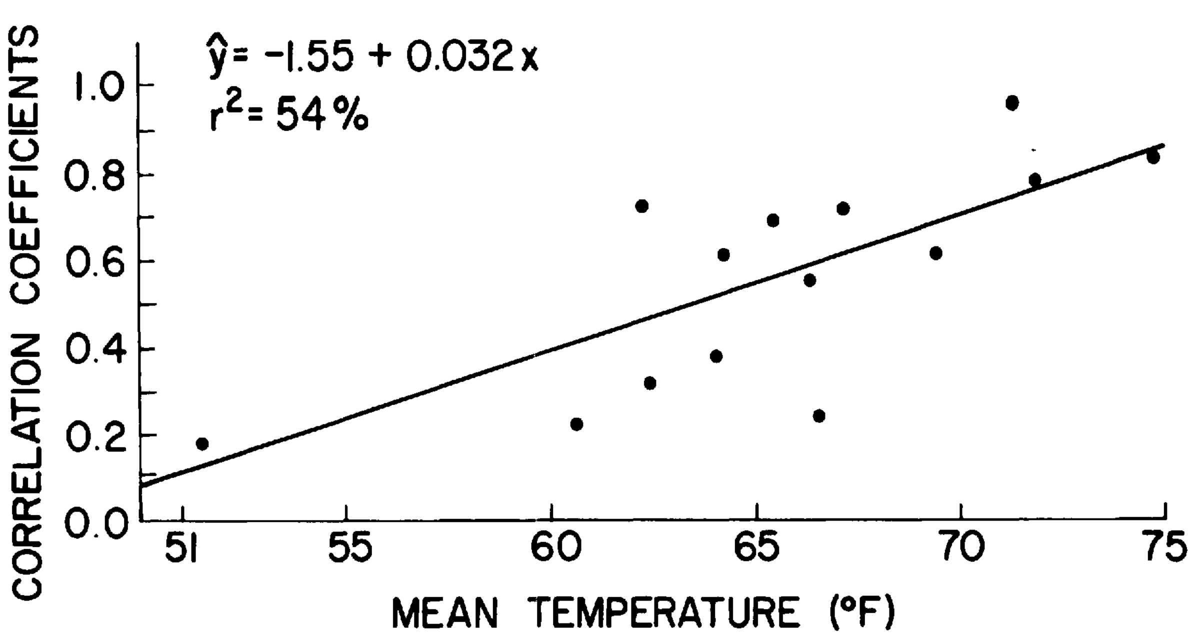

FIG. 2.—Regression analysis showing the correlations coefficients between European red mite and *Stethorus punctum* vs. the mean temperatures at Arendtsville.

Table 2.—Mean number of *Stethorus punctum* adults and larvae/1-min observation and *Panonychus ulmi*/leaf within apple trees under different fungicide programs.

		S. punctum			*S. punctum*			*S. punctum*	
Quadrant[a]	ERM[be]	Ad.[ce]	Lar.[ce]	ERM	Ad.	Lar.	ERM	Ad.	Lar.
				CAPTAN - SULFUR					
	July 8			July 16			July 23		
1	5.0	0.3	0.0	2.5	0.5ab	0.0	5.9	0.0b	0.0b
2	8.8	0.0	0.0	8.6	1.3ab	2.3	5.6	0.8ab	0.5ab
3	7.2	0.0	0.0	5.7	0.0b	0.3	3.1	0.0b	0.0b
4	11.1	0.0	0.3	8.2	2.3a	1.0	8.1	1.8a	1.0a
Top[d]	5.0b	0.0	0.1	6.4	1.0	0.5	6.7	0.6	0.4
Bottom	11.3a	0.1	0.0	6.1	1.5	1.3	4.7	0.6	0.4
				DIKAR					
1	1.5	0.3	0.0	11.7b	0.5ab	0.3	15.6b	1.0b	0.0
2	1.9	0.0	0.0	8.4b	0.0b	0.0	18.1b	0.0b	0.5
3	1.9	0.0	0.3	11.9b	0.0b	0.3	12.3b	0.3b	0.0
4	4.3	0.0	0.0	27.8a	1.5a	0.5	36.5a	2.3a	0.5
Top	2.4	0.0	0.1	17.9	0.8	0.5	26.5a	1.1	0.4
Bottom	2.4	0.1	0.0	11.4	0.3	0.0	14.7b	0.6	0.1
				CAPTAN - SULFUR					
	July 31			August 8			August 19		
1	2.3	1.0b	0.5	1.4	1.3	0.0	3.3	1.8	0.3
2	5.0	2.3ab	1.8	5.7	2.8	0.5	4.8	3.8	1.8
3	3.4	0.0c	1.0	2.7	0.3	0.3	5.7	4.3	2.0
4	5.9	3.3a	5.5	4.5	1.8	0.8	8.1	5.8	0.3
Top	5.1	2.0	1.8	4.1	1.8	0.3	6.5	3.9	1.5
Bottom	3.2	1.3	2.4	3.0	1.3	0.5	4.4	3.9	0.6
				DIKAR					
1	7.5bc	1.5ab	1.5b	4.7bc	1.5b	1.3b	4.5	9.8	2.0
2	7.7ab	2.8ab	0.3bc	8.3ab	1.8b	3.5a	3.6	11.3	0.3
3	3.5c	1.0b	0.0c	4.0c	1.8b	0.5b	2.1	7.5	0.5
4	19.9a	5.3a	4.5a	12.7a	8.0a	8.0a	4.9	16.0	2.3
Top	13.5a	3.0	1.4	9.1a	3.8	3.6	5.6a	12.9	0.9
Bottom	5.9b	2.3	1.8	5.7b	2.8	2.8	1.9b	9.4	1.6

[a] Quadrant 1 = South side (upper and lower); Quadrant 2 = West side (upper and lower); Quadrant 3 = North side (upper and lower); Quadrant 4 = East side (upper and lower).
[b] ERM = Motile European red mites/leaf.
[c] Ad. = *S. punctum* Adults/1-min observation; Lar. = *S. punctum* Larvae/1-min observation.
[d] Top = Average no./8 upper sections of 2 trees (4 sections/tree); Botton = Avg no./8 lower sections of 2 trees (4 sections/tree).
[e] Means followed by the same letter are not significantly different at the 5% level, as determined by Duncan's Least Significant Difference Test (Waller and Duncan 1969). Absence of letters following a series of means indicates that no significant differences were found.

applications of acaricide was expected because this experiment was designed to follow the distributional patterns of *S. punctum* vs. ERM under an integrated pest management program with acaricides supplementing predation in the control of ERM.

Even though there was a variation of time in the population development of both *S. punctum* and ERM caused by the use of different fungicides and the timing of acaricide application, the distributional patterns within all 4 trees were similar for both predator and prey. The ERM populations on the Dikar-treated trees were allowed to reach higher densities than on the captan-treated trees, and the movement of *S. punctum* adults into the trees paralleled this difference in mite density (Table 2). The ERM populations increased faster within the row (quadrants 2 and 4) where the leaves were not directly hit by spray. This possibly provided a haven for ERM to survive and increase in numbers.

As the mite populations increased on all 4 trees, *S. punctum* adults responded and began laying eggs. The eggs were found in all sections of the tree, but usually the greatest numbers were found in quadrants 2 and 4, where the mite populations were the highest. There were not enough eggs found to warrant a statistical test. The adults deposited more eggs on the Dikar-treated trees than on the captan-treated trees. This was determined by the number of *S. punctum* larvae found on the Dikar-treated trees (Fig. 3) especially on Aug. 8 in quadrant 4 (lower) where 10 larvae/1 min observation were found. Putman (1955) reported similar findings for *S. punctillum*. The adult females deposited their eggs in the midst of mite colonies.

On the last sampling date, Aug. 19, ERM had a fairly uniform distribution throughout the trees except for a significant difference between levels on the Dikar-treated trees. *S. punctum* reacted to this distribution of mites by spacing itself around the tree in a similar manner (Fig. 3). A number of factors can be cited that account for this type of predator-prey distribution. Hull (1974 unpubl.) found that both *S. punctum* adults and larvae functionally respond to increasing mite density. Thus through an increased functional and numerical response by *S. punctum*, more mites were eaten in those areas of the trees where their populations were the highest. Another contributing factor was the predatory mite, *Amblyseius fallacis* (Garman). It was found feeding on ERM populations during the month of August with densities ranging from 0.04–0.27/leaf.

Conclusions

The above analyses indicate that the distribution of *S. punctum* is closely associated with that of ERM. *S. punctum* adults first have the ability to find those trees in an orchard where the mite populations are increasing. Once they find these trees *S. punctum* further maximize their efficiency as predators by responding to areas of the tree where the mite populations are highest. This response of an *S. punctum* population to the changing distribution of a European red mite population is very important to the success of the Pennsylvania Integrated Pest Manage-

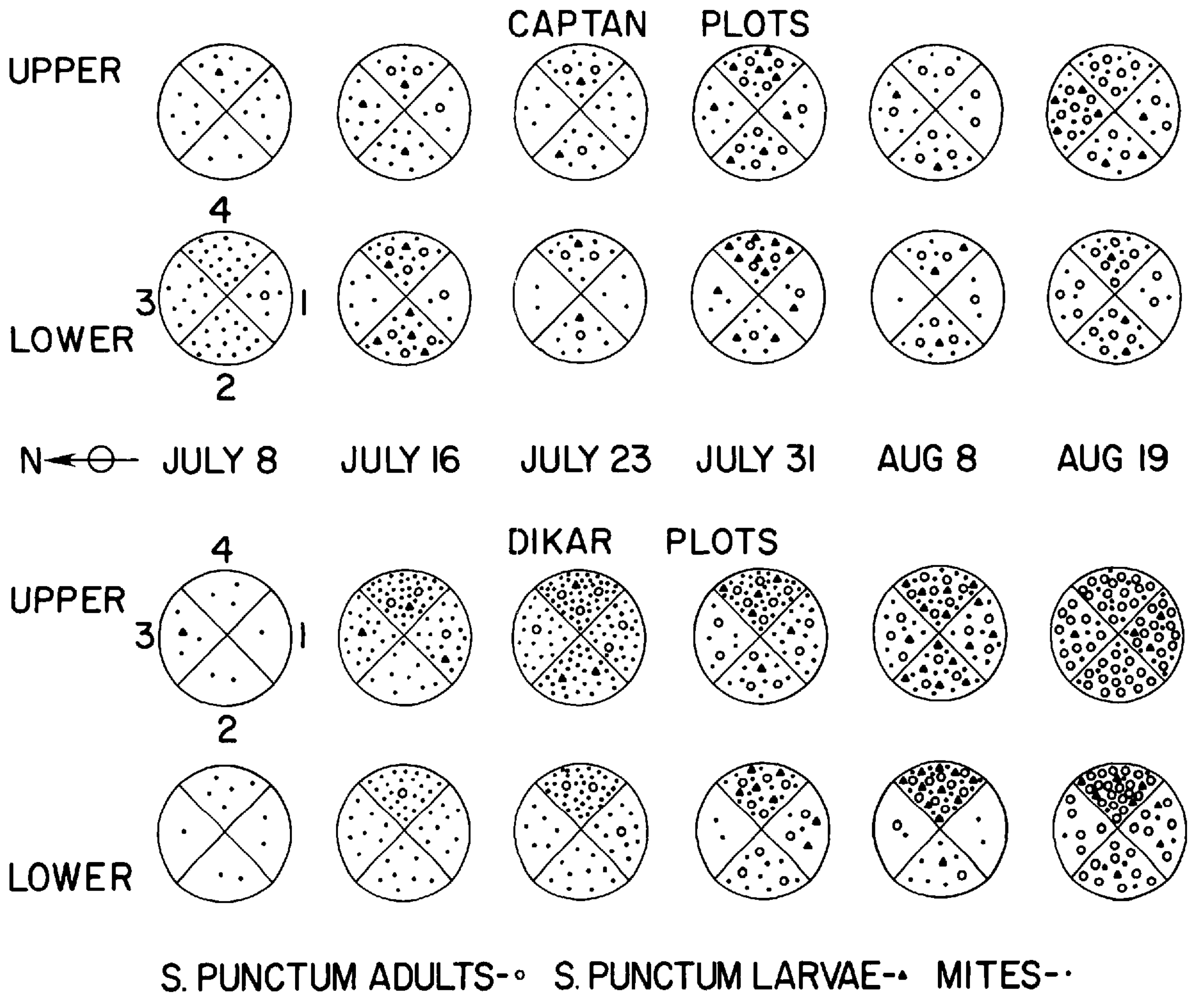

FIG. 3.—Distributional patterns of *Stethorus punctum* adults and larvae with respect to its prey, *Panonychus ulmi* within apple trees. Each circle represents the number of *S. punctum* adults and larvae (per 1-min observation) and *P. ulmi* (per leaf) on each section of a Stayman apple tree.

ment Program because *S. punctum* females deposit eggs on apple tree leaves on which prey is present.

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