lethal mutations in insects by ionizing radiation and chemicals as related to the sterile-male technique of insect control, p. 617–50. *In* J. W. Wright and R. Pal [ed.] Genetics of Insect Vectors of Disease. Elsevier, Amsterdam, The Netherlands.
LaChance, L. E., C. H. Schmidt, and R. C. Bushland. 1967. Radiation-induced sterilization for insect control. *In* W. W. Kilgore and R. L. Doutt [ed.] Biological, Physical and Advanced Chemical Methods of Pest Control. Academic Press, N.Y.
Lea, D. E. 1962. Action of Radiation on Living Cells. Cambridge Univ. Press.
Lindquist, D. A., L. J. Gorzycki, M. S. Mayer, A. L. Scales, and T. B. Davich. 1964. Laboratory studies on sterilization of the boll weevil with apholate. J. Econ. Entomol. 57: 745–50.
Miksche, J. P., and S. Shapiro. 1964. Use of neutron irradiation in the Brookhaven mutations programme. *In* Biological Effects of Neutron and Proton Irradiations, Vol. I. International Atomic Energy Agency, Vienna.
Monesi, V. 1962. Relation between X-ray sensitivity and stages of the cell cycle in spermatogonia of the mouse. Radiat. Res. 17: 809–38.
Muller, J. H. 1954. The nature of the genetic effects produced by radiation, p. 351–473. *In* A. Hollaender [ed.] Radiation Biology, Vol. I. McGraw-Hill Book Co., Inc., New York.
Murakami, A. 1966. Relative biological effectiveness of 14 Mev neutrons to gamma-rays for inducing mutations in mature sperm of the silkworm. Jap. J. Genet. 41 (1) : 17–26.
Nakanishi, Y. H., T. Iwasaki, and H. Kato. 1964. Cytological studies on the radiosensitivity of spermatogonia of the silkworm. Jap. J. Genet. 40 (Suppl) : 49–67.
Oakberg, E. F., and R. L. DiMinno. 1960. X-ray sensitivity of primary spermatocytes of the mouse. Int. J. Radiat. Biol. 2: 196–209.
Reinecke, L. H., W. Klassen, and J. F. Norland. 1969. Damage to testes and recovery of fertility in boll weevils fed chemosterilants. Ann. Entomol. Soc. Amer. 62: 511–25.
Riemann, J. G., and H. M. Flint. 1967. Irradiation effects on the midguts and testes of the adult boll weevil, *Anthonomus grandis*, determined by histological and shielding studies. Ann. Entomol. Soc. Amer. 60: 298–308.
Sado, T. 1961. Spermatogenesis of the silkworm and its bearing on radiation-induced sterility. Jap. J. Hum. Genet. 36 (Suppl.) : 136–51.
1963. Spermatogenesis of the silkworm and its bearing on radiation-induced sterility. II. J. Fac. Agr., Kyushu Univ. 12: 387–404.
Smith, H. H., and H. H. Rossi. 1966. Energy requirements and relative biological effectiveness of producing a cytogenetic phenomenon in maize by irradiating seeds with X-rays and monoenergenic neutrons. Radiat. Res. 28: 302–21.
Sparrow, A. H. 1961. Types of ionizing radiation and their cytogenetic effects, p. 55–120. *In* Symposium on mutation and plant breeding. Nat. Acad. Sci. Res. Counc., Washington, D.C.
Sugai, E. 1964. Studies on the propagation of spermatogonia and the function of apical cells in the silkworm *Bombyx mori* L. Zool. Mag. (Tokyo) 73: 219–22.
Sugai, E., and C. Hirano. 1965. Studies on the male sterility in the silkworm, *Bombyx mori* L., induced by apholate. Jap. J. Genet. 40: 357–63.
Vanderzant, E. S., and T. B. Davich. 1958. Laboratory rearing of the boll weevil: A satisfactory larval diet and oviposition studies. J. Econ. Entomol. 51: 288–91.
Zirkle, R. E. 1954. The radiobiological importance of linear erengy transfer, p. 315–50. *In* A. Hollaender [ed.] Radiation Biology. Part I. McGraw-Hill Book Co., Inc., New York.

Experiments to Determine Effects of Mass Releases of *Stethorus picipes*[1] on the Level of Infestation of the Avocado Brown Mite[2,3]

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ABSTRACT

Studies on the effects of mass releases of *S. picipes* Casey on populations of *O. punicae* (Hirst) were conducted in 3 avocado orchards in southern California. Multiple releases were made in 16-tree plots in each orchard at a rate totaling 400 to 500 adult beetles per tree. Releases were started when the avocado brown mite population averaged about 10 active stages per leaf in 2 of the orchards and nearly 50 per leaf in the third. In each orchard there was an earlier buildup of the *S. picipes* population, a lower peak population of *O.* punicae, and a lower percentage of heavily bronzed leaves in the release plots compared with check plots receiving no predator releases.

Avocado orchards in southern California generally receive no pesticide applications. Most of the arthropod pests remain at innocuous levels, this condition being attributed largely to the action of predators, parasites, and pathogens (Fleschner 1954, Fleschner et al. 1955) . However, the avocado brown mite, *Oligonychus punicae* (Hirst), sometimes reaches high numbers, causing bronzing to the upper surfaces of the leaves and, in some cases, even partial defoliation (Ebeling 1959, McMurtry and Johnson 1966) . Therefore, it is important to reduce the incidence of these heavy infestations. As spraying could upset the favorable situation that generally exists, as well as induce resistance in the mite population, it would be more desirable to use biological control.

A long-term study of *O. punicae* and its natural enemies in several avocado orchards in southern California was conducted earlier (McMurtry and Johnson 1966) . Usually only 2 species of predators were abundant: the phytoseiid mite *Amblyseius hibisci* (Chant) and the coccinellid beetle *Stethorus picipes* Casey. *A. hibisci* usually failed to show a numerical response soon enough to overtake an increasing population of

[1] Coleoptera: Coccinellidae.
[2] Acarina: Tetranychidae.
[3] This study was supported in part by contributions made through the Avocado Section, San Diego County Farm Bureau. Appreciation is expressed to the many contributors. Accepted for publication Mar. 27, 1969.
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O. punicae even if they outnumbered the latter species early in the season. *S. picipes* appeared to be the most important predator. When this species showed a marked numerical response to increases of *O. punicae* while the latter was still at low to moderate densities, control resulted before severe bronzing occurred. On the other hand, in all observed cases where severe bronzing occurred the predator had been slow to increase in response to increases of the mite population. Subsequent data (unpublished) have given similar indications of the importance of *S. picipes* in avocado orchards. Even though it requires large numbers of mites for reproduction and does not exert a suppressive effect until the spider mite population has reached a relatively high level, *S. picipes* can be of value, because avocado trees can apparently tolerate fairly high densities of *O. punicae* without suffering heavy bronzing or defoliation (Fleschner et al. 1955, McMurtry and Johnson 1966).

Since *S. picipes* sometimes appeared to be the main factor in controlling *O. punicae* at a tolerable level, studies were initiated to determine if mass releases could hasten the natural buildup of this predator in situations where heavy infestations of *O. punicae* occurred. A preliminary experiment was conducted in 1966 (McMurtry and Johnson 1967). Adult *S. picipes* were released in small plots (4–6 trees) in each of 4 orchards at rates varying from 500/tree in 1 orchard to more than 1000/tree in another. Although there was much variation between sample trees, results indicated that the releases resulted in an earlier buildup of the *Stethorus* populations and a lower peak in the *O. punicae* populations.

The results suggested also that to be most effective, releases should be started when the *O. punicae* population averaged about 10 active stages/leaf. If released too early, the beetles left the plots, and if released too late, they could not multiply rapidly enough to overtake the abundant mite population before severe leaf damage occurred.

Since the indications were sufficiently encouraging to warrant further testing, a large-scale experiment with replicated plots was conducted in 1967. The results are reported here.

Methods.—The experiment was conducted in 3 orchards of the 'Hass' variety: (1) the Chaikin orchard, (2) the Sleeping Indian Road orchard, and (3) the Von Normann orchard, all in the vicinity of Fallbrook in San Diego County, Calif. This area has a large portion of the total acreage planted with avocados. The 3 orchards, hereafter referred to by number, had a history of high populations of *O. punicae*.

In each orchard, two 16-tree blocks were selected, 1 for a release plot and 1 for a check plot. The plots were divided into 4 subplots (replicates) of 4 trees each. Release and check plots were selected for uniformity of conditions, insofar as possible, and were all surrounded by at least several rows of trees. Plots in Orchard 1 were situated on somewhat uneven terrain and were separated by 6 rows of trees. Those in Orchards 2 and 3 were on level terrain, the release and check plots being separated by 5 rows of trees in the former and by 9 rows plus a driveway in the latter.

Mite and predator populations were sampled weekly after the plots were established, in early or midsummer. The mite populations were sampled by picking 40 leaves/replicate (10 leaves at random from around each tree), placing the leaves in bags and transporting them to the laboratory in a refrigerated chest. The samples were prepared for counting by washing the mites from the leaves in each replicate in an air-agitated water bath, similar to the technique described by Scriven and McMurtry (in preparation).[5] The leaves were placed in a 10-gal container with 3 gal of water and 3 drops of wetting agent (Tween 80® or Alconox®). A perforated copper tube connected to the laboratory air supply was placed in the bottom of the container. By means of this air flow, the leaves were agitated in the water for 10 min and removed. The solution was then poured through a series of graduated fine-mesh screens to remove particles larger and smaller than mite eggs and adults. The screens trapping the mites were washed off and the solution was poured through a vacuum-operated Büchner funnel. The mites were deposited on 11-mm filter-paper discs marked off in 9 radial sections. The discs containing the mites were stored in petri dishes and refrigerated until counted, usually a few hours after preparation. All active stages of *O. punicae* and phytoseiids were counted. During the period of very high populations, *O. punicae* counts were made on only ⅓ of the total area of the discs, whereas the entire area was always examined for phytoseiids. Preliminary trials made before the technique was adopted indicated a random distribution of mites between radial sections and a consistent recovery of 65–70% of the mites counted directly on the leaves before washing.

S. picipes populations were sampled in the field by the visual-count method used in previous studies (McMurtry and Johnson 1966). A 10-min count was made on 2 trees of each replicate (8 trees/plot), 1 of which was the inside corner tree of the replicate.

An analysis of variance was made on the counts of *O. punicae* and *S. picipes* for each sampling date to determine if differences in population densities between release and check plots were significant.

It seemed possible that the 4 inside trees of release plots, being surrounded by trees having *S. picipes* releases, would be less influenced than any of the other 12 by mite populations outside the plot (where no releases were made). Therefore, to reduce the possible influence of an "edge effect," an additional sample was taken on only the 4 inside trees from each 16-tree plot (check as well as release) picking 10 leaves/tree and counting mites directly on the leaves with a binocular microscope in the laboratory, as in previous studies (McMurtry and Johnson 1966). The data were analyzed for each date, single trees being considered as replicates in this case.

The *S. picipes* were released as adults and were obtained mainly from insectary cultures. The supply was supplemented by field-collected beetles which were fed mites in the laboratory for at least 2 days before they were released. The adults were collected by vacuum aspirator in lots of 25 into plastic straws stoppered with corks and transported to the field in a refrigerated chest. The beetles were liberated by removing the stopper from a straw container, tapping some of the beetles onto the foliage and then attaching the straw to a leaf by a paper clip. In a given orchard equal numbers were liberated on each tree on each release date.

[5] G. T. Scriven and J. A. McMurtry. Some techniques for large-scale production of *Tetranychus* mites and their predators. (In preparation).

In Orchard 1, an initial release of 50/tree was made Aug. 9, 1967, when the density of *O. punicae* averaged about 11 active stages/leaf. Releases were continued at weekly intervals at a rate of 100/tree for 4 more weeks (a total of 450/tree). In Orchard 2, *O. punicae* reached the relatively high density of over 50/leaf before the 1st release of 100/tree was made Aug. 30. Two additional releases, of 200/tree each, were made 6 and 13 days later (a total of 500/tree). In Orchard 3, the initial release (100/tree) was made Aug. 2 when the *O. punicae* population density in the plot averaged about 12/leaf. Three additional releases of 100/tree were made at weekly intervals (a total of 400/tree).

A damage-rating system was devised, to have some means of comparing the amount of bronzing of the foliage between release plots and check plots. After the mite population began to decline, 3 weekly samples of 160 leaves/plot (40/replicate) were taken in the same manner as the mite population sample. The 3 samples were pooled, resulting in 480 leaves/plot and 120 leaves/replicate. For an additional check, 160 leaves were taken for 3 consecutive weeks from a 3rd block of 16 trees in each orchard. These trees were situated either on the opposite side of the release plot or formed a triangle between the release and regular check plots and were approximately the same distance as the latter from the release plots.

These leaves were inspected in the laboratory and placed into 1 of the following damage categories: *light*-bronzing on only a small portion of the upper surface, usually only along the midrib or main veins; *medium*-bronzing more widespread than limited areas along midrib or main veins, but still having definite green areas with little or no stippling; *heavy*-bronzing over all or nearly all of upper surface. Unless heavily bronzed on the upper surface, there is usually little or no bronzing on the lower side, as the mites rarely feed there unless the upper side has been rendered unfavorable (McMurtry and Johnson 1966). Depending upon environmental conditions, some or many of the heavily damaged leaves may drop from the tree. Therefore, the percentage of leaves receiving heavy bronzing is probably a critical factor, and a significant reduction in the percentage of heavily-bronzed leaves resulting from *S. picipes* releases should be beneficial. The data on heavily damaged leaves were thus used for the analysis of variance.

RESULTS.—*Orchard 1.*—The *O. punicae* population in the *S. picipes* release plot peaked at a lower level and started declining 1 wk sooner than it did in the check plot (Fig. 1). However, there was too much variation among replicates for the differences between plots to be statistically significant, even on Sept. 11, when the difference was greatest ($F = 5.78$, required F for 5% level $= 10.13$). The *S. picipes* population increased sooner and peaked somewhat higher in the release plot than in the check, the difference between the 2 plots being significant on 4 consecutive dates (Fig. 1). A definite response from the releases was apparent on Aug. 21, just after the 2nd release.

On the sample from the 4 inside trees of the 16-tree plots, the trends were similar to those in the whole plots (Table 1). The average number of adult *O. punicae*/10 leaves was significantly lower on the release trees at the peak on Sept. 5. The *S. picipes* count was significantly higher on the release trees on Aug. 21 and Sept. 5, indicating an earlier buildup as a result of the predator releases.

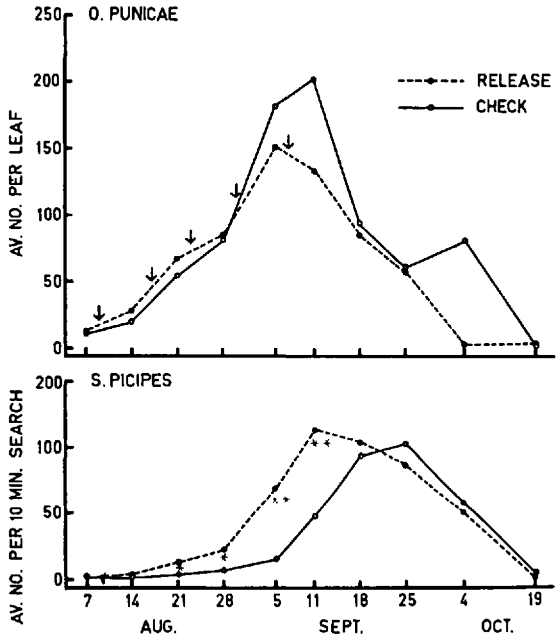


FIG. 1.—Population trends of *O. punicae* and *S. picipes* in *S. picipes* release plots and check plots in Orchard 1. Arrows indicate dates of *S. picipes* releases. Asterisks indicate dates on which there were statistically significant differences between populations in release and check plots (* = 5% level; ** = 1% level).

The leaf-damage ratings from Orchard 1 showed the lowest percentage of heavily damaged leaves in the release plot, although it was not significantly different from that of the check plot (Table 2). However, the additional check area situated on the opposite side of the release plot had an extremely heavy infestation, exceeding 40% heavily damaged leaves. The release area had also been heavily damaged in previous years, but in this case there was no leaf drop, and the infestation in the release plot could be considered tolerable. The main check plot showed slight leaf drop in limited areas of certain trees.

Orchard 2.—Even though the population of *O. punicae* became greater than anticipated before the *S. picipes* releases were started, the releases apparently had a marked effect (Fig. 2). The peak in the population of *O. punicae,* on Sept. 18, was lower in the release than in the check plot, although this difference was not statistically significant ($F = 6.43$, required F for 5% level $= 10.13$). The decline to low numbers occurred sooner in the release plot and showed significant differences from the check on Oct. 2 and 9. The buildup of the *S. picipes* population started considerably sooner in the release plot with numbers noticeably higher on Sept. 11, 4 days after the 2nd release was made. On this date 72% of the *S. picipes* counted in the release plot were adults. By the following week (Sept. 18) there were high numbers of *S. picipes* in the release plots, although the adult count was actually lower and comprised only 16% of the total counted, indicating that the increase was due to reproduction. Differences in numbers of *S. picipes* between release and check plots were significant on 4 consecutive dates. High numbers were never reached in the check.

The samples from the 4 inside trees of the plots showed trends similar to those in the plots as a whole (Table 1). There was considerable between-tree variation in the *O. punicae* populations; therefore, the differences between release and check trees were not statistically significant, even on Sept. 18 ($F = 7.54$, required F for 5% level = 10.13). Consequently, there was also much variation in numbers of *S. picipes*, but the analysis showed significant differences between the release and check on 2 dates.

Leaf-damage ratings showed that the main check plot had a significantly higher percentage of heavily damaged leaves (Table 2). The block used as an additional check for damage ratings had twice the percentage of heavily damaged leaves as the check, but the difference was not statistically significant.

Orchard 3.—The *O. punicae* population in the release plot peaked at an average density of only about ½ that in the check plot (Fig. 3). The peak of 282 mites/leaf in the check was the highest of the 3 orchards, and the population densities exceeded 200/leaf for 3 wk. *S. picipes* increased sooner in the release plot, being significantly higher than in the check plot on 4 consecutive dates. A response from the releases was evident after the 2nd release.

Table 1.—Population trends of *O. punicae* and *S. picipes* on the 4 inside trees of 16-tree blocks where *S. picipes* were released and on the inside trees in the check blocks receiving no releases. Fallbrook, Calif. 1967.

	No. *O. punicae*[a]		No. *S. picipes*[b]	
Date	Release trees	Check trees	Release trees	Check trees
		Orchard 1		
July 24	7	9	0	0
31	24	33	0	0
Aug. 7	87	49	0	0.5
14	69	58	2	.7
21	198	220	17*c	3
28	374	436	22	12
Sept. 5	480*c	867	65**c	15
11	268	323	112	51
18	113	335	97	111
25	94	123	76	128
Oct. 4	10	21	51	72
19	1	0	2	7
		Orchard 2		
Aug. 28	202	215	0	0
Sept. 11	372	497	24	.2
18	389	1080	66	16
25	536	759	106	26
Oct. 2	62	611	161*c	39
9	11	146	113*c	47
16	5	16	32	20
23	1	2	12	29
		Orchard 3		
July 19	31	31	0	.2
26	39	27	0.2	0
Aug. 2	56	64	0	0
9	115	257	2	.7
17	243**c	567	14	1
23	475**	1178	48	4
30	415	389	107*c	24
Sept. 7	329	807	154*	52
13	215	335	208*	87
20	76	154	194	192
28	34	6	162	168
Oct. 11	0	0	7	5

[a] Avg. no. adult females/10-leaf sample.
[b] Avg no. active stages/10-min search.
[c] Significant differences between release and check trees (* = 5% level; ** = 1% level).

Table 2.—Mite damage ratings of leaf samples taken from *S. picipes* release plots and check plots in 3 avocado orchards. Fallbrook, Calif. 1967.[a]

	% of leaves in each category[b]		
Plot	Light	Medium	Heavy
	Orchard 1		
Release	32.5	55.0	12.5
Check	23.1	55.4	21.5
Additional check[d]	12.5	47.3	40.2**c
	Orchard 2		
Release	42.7	49.6	7.7
Check	19.2	51.1	29.7*c
Additional check[d]	33.3	50.4	16.3
	Orchard 3		
Release	34.4	60.0	5.6
Check	15.6	55.9	28.5**c
Additional check[d]	12.8	58.1	29.1***

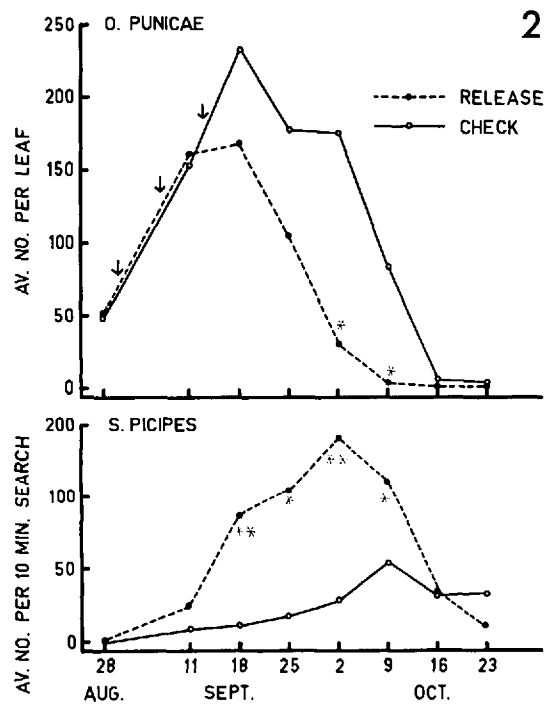
[a] Composite of 3 samples totaling 480 leaves/plot.
[b] Light damage = bronzing confined to only a small area, usually along midrib or main veins; Medium damage = some parts of upper surface still unbronzed; Heavy damage = all or most of upper surface heavily bronzed.
[c] Differences significant from release plot (* = 5% level; ** = 1% level; *** = 0.1% level).
[d] Block of trees in different area of orchard, but about same distance from release plot as main check plot. Mite and predator populations not sampled.

Samples from the 4 inside trees showed similar trends, with highly significant differences between *O. punicae* populations on Aug. 17 and 23 (Table 1). Differences in numbers of *S. picipes* were significant on the 3 subsequent sampling dates, but not on previous dates, since 1 of the trees in the release plot had low numbers at first.

Leaf damage ratings (Table 2) indicated significantly lower percentages of damaged leaves in the release plot than in the check plot (1% level of significance) and the additional check in another area of the orchard (0.1% level). The damage sustained to the foliage of the trees in the release plot could be considered tolerable, while that of the check plots was quite severe with considerable leaf drop. Thus the effect of the *S. picipes* releases was clear.

DISCUSSION.—Population trends and peak numbers of phytoseiid mites were similar to those observed in San Diego County in previous studies (McMurtry and Johnson 1966). There were no consistent differences in numbers between the check plots and those in which *S. picipes* was released.

Results of these experiments show that mass releases of *S. picipes* can improve the suppression of populations of *O. punicae*. The data tend to support previous conclusions of McMurtry and Johnson (1966) that, under certain conditions, *S. picipes* can control populations of this mite. Though there was much variation among replicates, differences between release and check plots were statistically significant in the 16-tree blocks in 2 of the 3 orchards, and in the other orchard there were statistically significant differences between plots in the samples taken from only the 4 inside trees. The release plots in all 3 orchards had lower peaks of *O. punicae* than any of the check plots. Variation in mite populations between trees



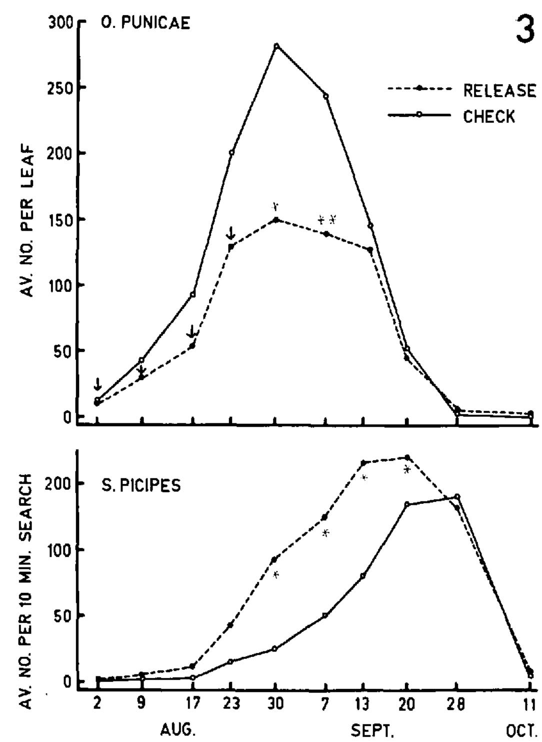


Fig. 2, 3.—Population trends of *O. punicae* and *S. picipes* in *S. picipes* release plots and check plots in Orchards 2 and 3. Arrows indicate dates of *S. picipes* releases. Asterisks indicate dates on which there were statistically significant differences between populations in release and check plots (* = 5% level; ** = 1% level).

and locations within an orchard seems to be inherent, so conditions for the experiment were probably as favorable as could be expected.

McMurtry and Johnson (1966) indicated that it was not known why *S. picipes* was sometimes slow to increase in response to increasing populations of *O. punicae* and suggested that it might be due either to lack of sufficient numbers migrating into the infested orchard or to conditions within the orchard that are unfavorable to rapid increase. The fact that *S. picipes* did build up more rapidly in release plots suggests that the former possibility is more likely than the latter. Thus by adding additional predators at a critical time, the natural buildup was effectively hastened.

It could not be determined what percentage of the released beetles remained in the release plots. Attempts to investigate this by means of releasing marked beetles were not successful, because time limitations precluded marking large numbers of beetles and making extensive recovery efforts. About 500 beetles were marked with a spot of paint and released on 2 trees in Orchard 2. One week later 30 marked individuals were observed on 1 tree and 12 on the other, mostly in the same areas of the trees where they were released. No marked beetles were seen on adjacent trees. General observations indicated that trees immediately adjacent to release plots had more heavily damaged leaves than release trees, which fact suggests that the rate of dispersal was not rapid under these conditions where prey was abundant.

It was shown that releases of *S. picipes* can reduce the amount of leaf damage and resulting defoliation by *O. punicae*. Leaf bronzing still occurred, but leaf drop was generally prevented. Although it is not known what constitutes an economic infestation of *O. punicae*, there is no evidence that a moderate amount of bronzing on the upper surfaces of the foliage is harmful. Whether larger releases would result in better control is open to speculation. Although it is probable that releasing larger numbers could allow for more latitude in timing the releases, the nature of *S. picipes* predation, e.g., multiplying only at relatively high prey densities, suggests that a moderate amount of leaf bronzing would occur under most conditions.

The possibility for using mass releases of *S. picipes* as a control program on avocados cannot yet be predicted. Two difficult problems are evident from these studies. (1) The timing of releases is extremely critical. If made either too soon or too late, releases would be of no value (McMurtry and Johnson 1967). Therefore, extremely close supervision would be necessary in any large-scale program. Additional studies are needed to determine the most effective timing of the releases. (2) There is presently no inexpensive method of mass-producing *S. picipes*. The rate of 400 beetles/tree would be equivalent to about 32,000/acre, and obviously millions would be needed for release over a large area. Possibly, this rate could be lowered without reducing the effectiveness. It would be important to try lower numbers per tree over a larger area. These aspects are presently being explored.

Acknowledgments.—We gratefully acknowledge the special interest and cooperation of C. D. Gustafson, Farm Advisor, San Diego County; W. Beck, A. Chaikin, J. Diamond, and A. von Normann, avocado growers; and the Avocado Section of the San Diego County Farm Bureau. Appreciation is expressed also to Ronald Weseloh, graduate student, Department of Biological Control, University of California, Riverside, for technical assistance.

REFERENCES CITED

Ebeling, W. 1959. Subtropical fruit pests. Univ. California Div. Agr. Sci. 436 p.

Fleschner, C. A. 1954. Biological control of avocado pests. California Avocado Soc. Yearbook. 38: 125–9.

Fleschner, C. A., J. C. Hall, and D. W. Ricker. 1955. Natural balance of mite pests in an avocado grove. California Avocado Soc. Yearbook. 39: 155–62.

McMurtry, J. A., and H. G. Johnson. 1966. An ecological study of the spider mite *Oligonychus punicae* (Hirst) and its natural enemies. Hilgardia 37 (11): 363–402.

1967. Preliminary studies on releasing *Stethorus* beetles for control of the avocado brown mite. California Avocado Soc. Yearbook 51: 173–6.

Seasonal Life Cycle of *Fiorinia externa* in Maryland[1]

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ABSTRACT

F. externa Ferris on hemlock in Maryland has 2 generations per year. Crawlers hatch continuously from late April until early November. The largest egg hatch is in early May when the new growth is approximately ½ inch long. The second largest hatch occurs in September. There is a great deal of overlapping of the generations especially during the second generation. From 91 to 96 days are required for first-generation development. Second-generation development was longer because of cold and other unfavorable environmental conditions.

The *Fiorinia* hemlock scale *F. externa* Ferris was first reported in the United States by Sasscer (1912) from material collected on Long Island, N.Y. in 1908. At that time Sasscer identified this scale as *F. japonica* Kuwana. Ferris (1942) re-examined Sasscer's material and additional material collected at Baltimore, Md. by the late H. S. McConnell and renamed this pest of *Tsuga* sp., *Fiorinia externa,* n. sp.

Little has been reported in the literature in regard to the seasonal life cycle. Several authors have made observations and notes (Duda 1957, Davidson and McComb 1958, Bray 1958). Wallner (1964) found that in New York, the *Fiorinia* hemlock scale has 1 full and a partial 2nd generation each year. He stated that females require a minimum of 100 days to mature and that females may lay as many as 16 eggs during their lifetime. He noted that egg laying was delayed during the winter but was resumed in the spring.

The purpose of this study was to investigate the seasonal life cycle of this scale insect in Maryland. The study was started at Pikesville in the spring of 1963.

Methods and Materials.—The seasonal life cycle of *F. externa* was studied on heavily infested, 20- to 25-ft-tall Canadian and Carolina hemlocks. Samples were collected from these trees at periodic intervals or as needed throughout the year. Each sample consisted of at least a 6-in. twig, which contained 2 years' growth. All samples were random. A dissecting microscope was used to study and record the development of males and females. Permanent mounts were made in Canada balsam.

Seasonal Life Cycle.—The seasonal life cycle of *F. externa* was found to be complicated and not easily defined. This was due to the continuous hatching of eggs through the growing season, which resulted in much overlapping of stages, particularly at the beginning of the 2nd generation. Thus, only the progeny of females hatching in May was followed in detail.

First Generation.—In late April and early May the buds of Canadian and Carolina hemlock begin to swell in Maryland. At this time eggs of the scale begin to hatch and the crawlers settle on year-old needles. When the new growth is about ½ in. long, crawlers begin to migrate and settle on new needles. On May 15, 1963, and May 8, 1964, crawlers were first observed moving freely on the surface of the new needles and had settled on the underside of them.

On June 12, 1963, and June 4, 1964, approximately 20–28 days after the 1st crawlers were observed on the new growth, 2nd-instar females were observed. Starting with these dates, the number of 2nd-instar females increased steadily.

Third-instar females first appeared July 8, 1963, and June 25, 1964. This was 20–28 days after 2nd-instar females were first observed. Third-instar females pass through 2 phases: a prefertilization and a postfertilization phase.

The prefertilization phase was characterized by the 3rd-instar female completely filling the outer covering. Mating took place at this time. The female scale then contracted to the upper half of the outer covering. Eggs were laid in 2 rows with their anterior ends meeting alternately along the longitudinal axis of the vacated posterior part of the covering.

By July 30, 1963, and by July 29, 1964, a period that covered 22 and 30 days, respectively, females had completed the prefertilization phase. Oviposition did not occur immediately. In 1963 the 1st eggs were laid 20 days after contraction. In 1964 the period was 16 days.

With egg deposition at this time the 1st generation of *F. externa* was nearly complete. From the time the 1st crawlers were seen in May until the 1st egg was deposited in August, 91 days had elapsed in 1963 and 96 days in 1964. This was the development time for the 1st generation of this scale under Maryland conditions. The females present at this time continued

[1] Maryland State Board of Agriculture Contribution no. 12. This paper is a portion of a thesis submitted to the Graduate School of the University of Maryland by the senior author in partial fulfillment of the requirements of the M.S. degree. Accepted for publication Apr. 29, 1969.

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