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BIOLOGICAL CONTROL OF THE NAVEL ORANGEWORM

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prepared by

L. E. CALTAGIRONE

University of California
Department of Entomological Sciences
Division of Biological Control
Albany

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Objectives

To control the navel orangeworm by means of natural enemies - parasites and predators - so as to reduce as much as possible its economic importance as a pest.

Interpretive Summary

Mortality of navel orangeworm as a result of parasitization by the imported wasp Pentalitomastix plethoricus continues to increase in the almond orchards where it has become established. The information so far gathered suggests that the mortality P. plethoricus is inflicting on navel orangeworm populations may contribute to make other complementary methods of control more effective. This parasite is steadily, though slowly, spreading itself from the orchards in which it was originally colonized. A forced dispersal could accelerate the realization of this parasite's potential in those NOW-infested areas suitable for its establishment.

The dispersal of Pentalitomastix plethoricus could be accelerated by gathering old nuts attacked by NOW from orchards where parasitism is substantial, and distributing them in orchards with NOW but with no parasites. The old nuts can be gathered during the winter, placed in containers (large, empty coffee cans make good, cheap ones) covered with 1/16" mesh wire screen secured in place with wire or strong twine. The cans with nuts should be stored for the rest of the winter in a shady place protected from rain, but exposed to outside temperature. The following spring the cans should be distributed in the orchards. The parasites will complete development and fly out through the screen, while the moths (from larvae which were not parasitized) will remain in the cans, unable to cause any damage. The cans should be somehow sheltered to avoid waterlogging of the nuts in case of rain.

During June 1976 a trip was made to Baja California, México, to explore for navel orangeworm and its natural enemies in an almond orchard in Valle de la Trinidad. No navel orangeworm was found. According to reports from people connected with the operation of that orchard, this pest has never been found there.

In September 1976, search for navel orangeworm and its natural enemies was conducted in the State of Sonora, México. Two parasites, on of which is Pentalitomastix plethoricus, were found. Next season they will be colonized in California orchards. The Sonoran Pentalitomastix may be better adapted to certain California conditions than the already established material, which originally came from Monterrey, Oaxaca, and Tehuantepec, México.

Experimental Procedure

To monitor the populations of navel orangeworm and its natural enemies, the procedure described in the 1975 Annual Report was followed. Samples of nuts -- 200 nuts for pre- and post-harvest, and more than 1000 nuts for harvest samples -- were taken periodically from the L D Properties Snelling Ranch orchard. The samples were taken to the laboratory and each nut was examined for:

eggs	viable (alive)
	emerged (chorion only)
	parasitized by Trichogramma
	dead due to undetermined cause
larvae	alive
	parasitized by Pentalitomastix
	Parasierola
	Paraolinx
	other
	dead due to undetermined cause
pupae	alive
	emerged (empty)

The numbers in each category were recorded. The viable (alive) eggs and larvae were reared in a medium consisting of a mixture of bran, glycerine, honey, water, and yeast hydrolyzate. By rearing these specimens it was possible to determine whether they were parasitized or not. The viable pupae were kept in containers where they completed their development; eventually the adult moths, or if they were parasitized,the adult parasites emerged. A tally of the number of nuts examined (size of the sample) and of the number of damaged kernels was kept. Thus the level of navel orangeworm infestation, the age distribution of the population of navel orangeworm and its parasites in each nut was determined.

The procedure to collect natural enemies of the navel orangeworm abroad involved search for possible host plants; once these were found, the fruits were carefully examined. If navel orangeworm, or a similar larva was found, as many fruits as possible were collected. These were examined, one by one, under the microscope for navel orangeworm specimens which were placed in containers with rearing medium. Specimens that were obviously parasitized were placed in separate containers. Prior to crossing the border back to the United States, all of the

collected material was placed in metal containers or glass vials, these were placed in heavy cardboard boxes which were then wrapped and sealed. The material was taken to the Biological Control Quarantine Facility at Albany where it was kept until the adults (moths or natural enemies) emerged. The moths were immediately destroyed, while the natural enemies were identified and cultured for at least one generation under quarantine conditions. Only those species proved to be primary natural enemies of the navel orangeworm were released from quarantine, and transferred to the insectary for mass culturing.

Results

Monitoring of the navel orangeworm and Pentalitomastix plethoricus in the L D Properties Ranch, Snelling.- Analyses of the samples indicate that P. plethoricus continues to spread to the sections which did not receive parasites in 1974, and that the percentage of navel orangeworm destroyed by this parasite is substantial in most of the sections (Fig. 1). Figure 2 depicts the progression of parasitism in Section F-45 since 1974.

Table I below indicates the results obtained to date.

Table I. Analysis of almond nuts collected in the L D Properties Ranch, Snelling, CA. All samples collected in 1976.

Date sampled	No. nuts examined	% nuts with viable eggs, larvae and/or pupae	No. viable eggs, larvae, and/or pupae/100 nuts	% parasitism by Pentalitomastix	% kernel damage
			Section F - 30		
14 Mar.	49	12.2	16.3	14.3	14.3
			Section F - 31		
20 Oct.	304		11.8	pending	3.3
			Section F - 32		
19 Jan.	256	56.3	194.5	20.8	41.8
25 Aug.	222 (new nuts)		0.5		0.9
24 Sept.	2765 (harvest)	----	----	pending	4.7
			Section F - 33		
19 Jan.	214	76.6	288.3	14.1	50.5
2 Apr.	240		139.2	27.3	49.6
21 June	164		140.2	63.3	37.8
11 Aug.	20 (old nuts)		75.0	82.4	40.0
11 Aug.	121 (new)		13.2	9.1	4.1
10 Sept.	1503 (harvest)	----	----	pending	3.2

Table I (Continued)

Date sampled	No. nuts examined	% nuts with viable eggs, larvae and/or pupae	No. viable eggs, larvae, and/or pupae/100 nuts	% parasitism by Pentalitomastix	% kernel damage
			Section F - 34		
23 Feb.	220	51.8	179.5	10.8	39.1
16 Apr.	111		106.3	13.9	36.9
16 Apr.	154		101.9	11.6	35.1
10 Sept.	1522 (harvest)	----	----	pending	5.2
			Section F - 35		
19 Jan.	210	76.2	304.8	7.6	56.7
11 Aug.	100 (new)		2.0	100.0	1.0
20 Sept.	320 (harvest subsample)		8.4	pending	2.8
			Section F - 36		
3 May	87		73.6	18.2	20.7
20 Sept.	1955(harvest)	----	----	pending	4.1
			Section F - 37		
7 Jan	210	78.1	284.8	37.0	45.7
15 Oct.	722(harvest)	----	----	pending	7.2
			Section F - 38		
23 Feb.	204	52.0	145.6	54.2	39.7
16 Apr.	162		76.5	62.5	45.1
25 Aug.	238 (new)		0.8	----	0.0
5 Oct.	259 (harvest subsample)		3.1	pending	1.2
			Section F - 39		
4 Feb.	210	40.0	102.9	24.0	25.7
3 May	104		71.2	57.4	26.0
20 Oct	1184(harvest)	----	----	pending	3.0
			Section F - 40		
7 Jan.	215	63.7	194.4	59.2	37.7
15 Oct.	395 (harvest subsample)			pending	8.6
			Section F - 41		
4 Feb.	203	63.1	191.1	46.6	42.4
24 March	218	53.2	136.7	75.2	50.9
12 July	226		28.8	69.6	41.6
5 Oct.	2780(harvest)	----	----	pending	4.3

Table I (Continued)

Date sampled	No. nuts examined	% nuts with viable eggs, larvae and/or pupae	No. viable eggs, larvae, and/or pupae/100 nuts	% parasitism by Pentalitomastix	% kernel damage
			Section F - 42		
7 Jan.	235	71.5	286.0	29.9	43.4
			Section F - 43		
7 Jan.	207	69.1	193.7	74.9	29.5
24 March	226	53.5	136.7	74.5	51.3
26 July	220		30.5	77.1	31.8
10 Sept.	1883	----	----	pending	2.9
			Section F - 44		
23 Feb.	200	55.5	130.5	67.8	31.0
23 Feb.	144 (ground)	25.0	38.9	25.5	46.5
2 Apr.	223		71.3	70.3	32.7
21 June	209		73.7	68.5	33.0
20 Sept.	3112(harvest)	----	----	pending	3.1
			Section F - 45		
4 Feb	210	61.4	165.7	80.9	32.9
4 March	209	45.0	101.9	75.0	29.2
2 Apr.	282		137.2	68.0	39.7
16 Apr.	89 (top of trees)		102.2	78.6	36.0
16 Apr.	230 (bottom of trees)		135.5	63.4	43.9
3 May	240		308.3	84.9	37.5
19 May	349		420.9	71.3	41.8
4 June	206		198.1	77.1	40.3
21 June	203		109.4	72.0	35.0
12 July	222	45.5	125.7	72.8	39.2
26 July	184		116.8	81.3	42.4
25 Aug.	160 (old)		64.4	63.0	40.0
25 Aug.	220 (new)	(1 Pentalitomastix brood, 0 moths)			0.9
20 Sept.	428		23.4	36.3	7.5
15 Oct.	2497(harvest)	----	----		6.7

Foreign exploration.- From 12 to 21 June 1976 a trip was made to Baja California, Mexico, with the purpose of exploring for navel orangeworm and its natural enemies in an almond orchard in Valle de la Trinidad, a locality some 75 mi. SE of Ensenada on Hwy. 16 to San Felipe. This large mountain valley, 2400 ft above sea level, is the dividing area between Sierra Juarez on the north and the even taller San Pedro Martir range on the south. There are some 1465 acres planted to almonds. These orchards are managed by Empacadora del Cid, S. A of Tijuana. The varieties planted are Non Pareil, Mission, Merced, Thompson, and Marcona. The oldest trees in the valley were planted in 1967. The managemen has the goal to plant approximately 2000 trees a year. The great majority of the nursery stock has been imported from California.

The survey conducted, and the information provided by the field manager and other residents in the valley suggest that the navel orangeworm is not present in this area. The only pest problems noticed in the field or reported by management were peach twig borer, brown almond mite, bud failure, and a leaf beetle. Most probably the first three pests were introduced with the trees from California; the beetle may be native. There has been loss of trees due to bud failure; the other pests do not seem to be causing much damage, except occasionally the beetle which damages the terminals in nursery stock and newly planted trees. Loss of crop due to severe frosts in April and early May seems to be the most important problem.

Further exploration was conducted in Sonora, Mexico, from 6 to 23 September 1976. The areas around Magdalena and Santa Ana, Carbo, Hermosillo, Ures, Guaymas, and Alamos were explored for navel orangeworm and their natural enemies. Navel orangeworm was found in the area north of Hermosillo to Santa Ana along Hwy. 15, and in the vicinity of Alamos in the southern tip of the state. The localities and host plants on which navel orangeworm was found were:

Locality: Km 111 on Hwy 15 north of Hermosillo
Host plants: Pithecellobium sp. probably undulatum
Parkinsonia aculeata

Locality: Ejido "El Sabino", on road from Alamos to Guirocoba
Host plants: Sapindus saponaria
Jacquinia pungens

Locality: on road from Alamos to Yocojihua, between Piedras Blancas and Yocojihua
Host plant: Jacquinia pungens

All these plants, except Sapindus saponaria, are new records as hosts

for navel orangeworm. Larvae of navel orangeworm were collected in fruits of these plants; no eggs were found. The larvae were prepared as explained under "Experimental Procedure" above. Some of the larvae were evidently parasitized. A few days after the material was placed in quarantine, adults of Pentalitomastix plethoricus and Paraolinx typica emerged. These species are already present in California. The Sonoran P. plethoricus may be better adapted to certain California conditions than the material being used for colonization until last fall (1976). The material that has already been colonized in California originated in Monterrey, Mante, Oaxaca, and Tehuantepec.

Discussion.

Of the five species of parasites that have been manipulated against the navel orangeworm -- Pentalitomastix plethoricus, Parasierola sp., Paraolinx typica, Phanerotoma flavitestacea and Phanerotoma inopinata -- only P. plethoricus has demonstrated capabilities to inflict substantial mortality on navel orangeworm on a sustained basis. Areas such as Chico, Le Grand, Snelling, and more recently Lost Hills, are specially favorable to this parasite. It is my conviction that the controlling potential of this beneficial species will be realized when it is distributed in all areas where the conditions are favorable to its establishment. One of the methods of accomplishing this by growers and other interested individuals has been indicated in the "Interpretive Summary" above. No additional research effort from this project will be devoted to this activity.

The large area of distribution of the navel orangeworm -- from California and North Carolina in North America, to Lima, Peru,; Recife, Brasil, and probably to northern Argentina in South America -- suggest that there must be other natural enemies there. I feel that additional effort to look for these natural enemis, and to import them to California is amply warranted.

Natural enemies of closely related species, such as the carob pod moth, Ectomyelois ceratoniae, should be looked for, imported and tested against the navel orangeworm in California. The carob pod moth is a species that occur in the Mediterranean area and Middle East in climatic conditions similar to those in California. Exploration for natural enemies of this species will be conducted in one of the areas where it occurs, Iran, in 1977.

Publications.

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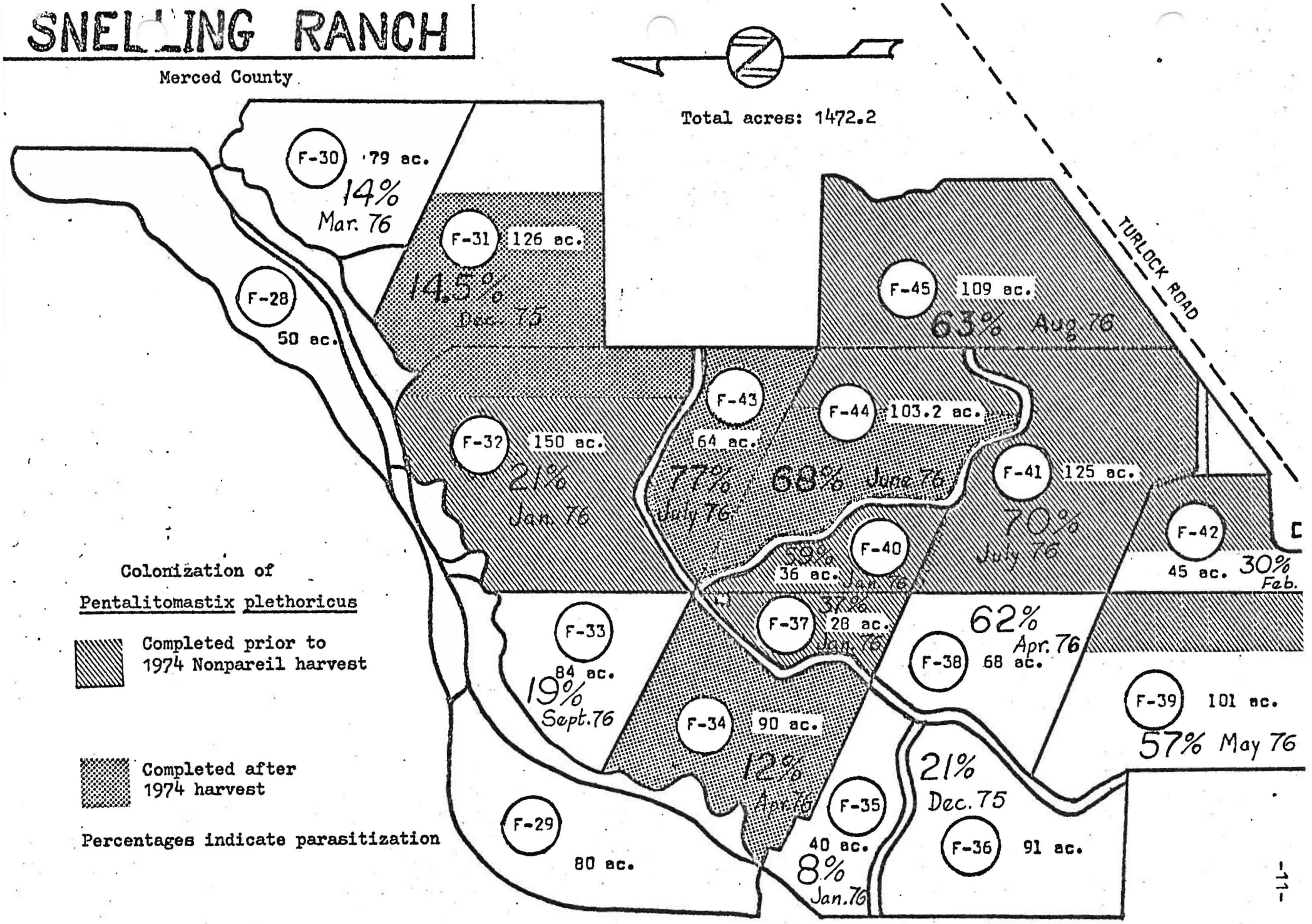

Fig. 1.- Colonization of Pentalitomastix plethoricus and its parasitization of navel orangeworm in the I. D Properties Ranch. Snelling.

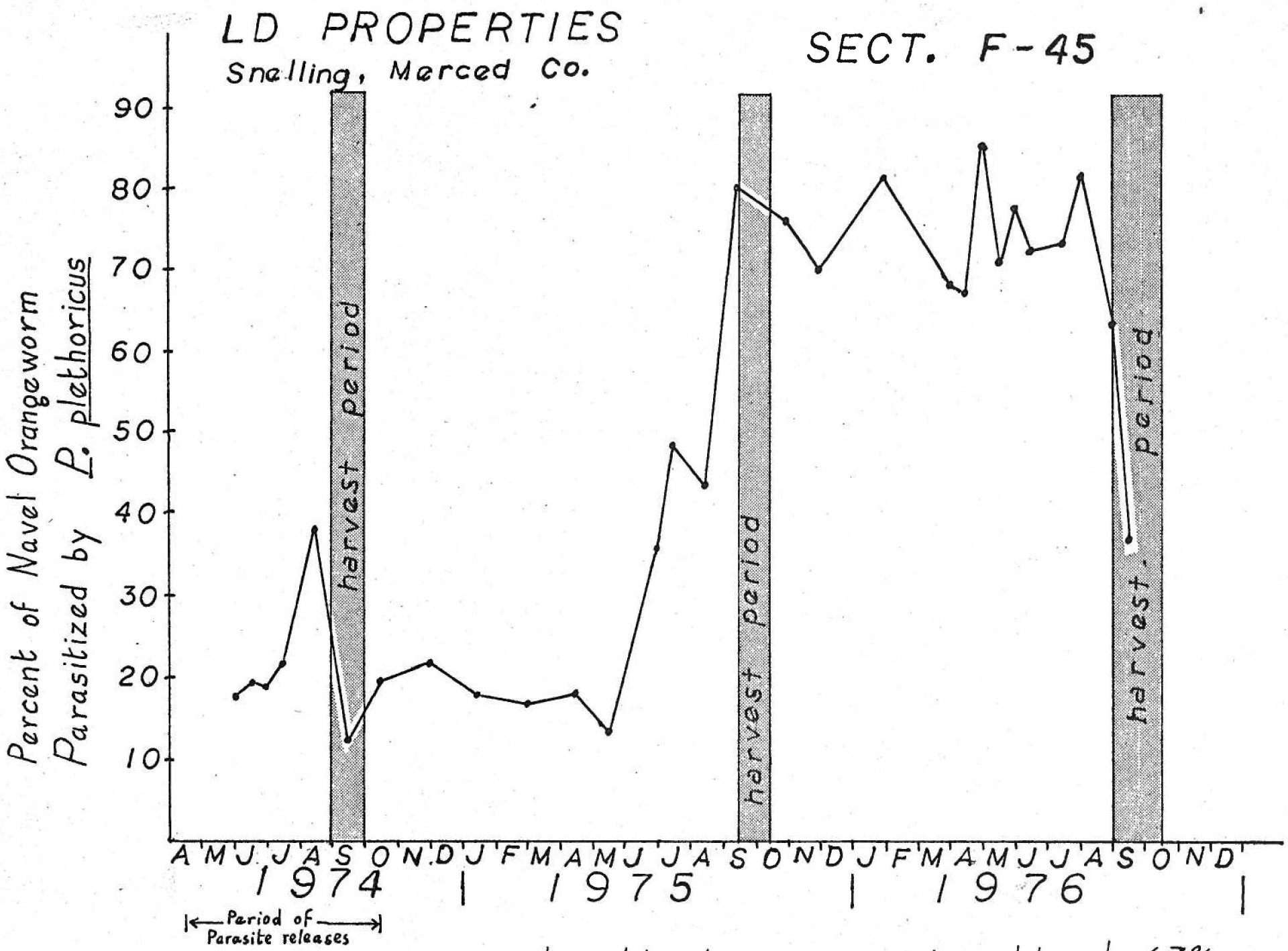

Fig. 2.- Progression of parasitization by Pentalitomastix plethoricus