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BIOLOGICAL CONTROL OF THE NAVEL ORANGEWORM

AGRICULTURAL EXPERIMENT STATION PROJECT 1983 - H

ALMOND CONTROL BOARD RESEARCH PROJECT 74-F

1975 ANNUAL REPORT

prepared by

L. E. Caltagirone

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

TITLE: Biological Control of the Navel Orangeworm.

PERSONNEL:

a) Permanent (U. California funds)

L. E. Caltagirone, Project Leader (¼ time)

D. W. Meals, Staff Research Associate (full time)

b) Temporary (Almond Industry funds)

Mabel Fong, Staff Research Associate (½ time)

Alice Wu, Staff Research Associate (½ time)

I. OBJECTIVES AND GOALS: The principal objective is 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. To achieve this we have endeavored

- to determine what natural enemies of the navel orangeworm are already present and what influence these enemies have upon the pest population,
- to explore for natural enemies, including pathogens in the home environment of the pest, and to introduce these into California, and
- to evaluate the effectiveness in controlling the abundance of the navel orangeworm by such natural enemies as are successfully established.

The immediate goals were:

- to evaluate the establishment and impact of the parasite Pentalitomastix plethoricus in the areas where it had been colonized,
- to explore for additional natural enemies, and
- to gather data on navel orangeworm populations as they occur in almond orchards.

II. ABSTRACT: The parasite Pentalitomastix plethoricus, known to the almond growers as the "almond wasp", is established in almond orchards in Chico and vicinity (Butte Co.), Le Grand and Snelling (Merced Co.), and Famoso (Kern Co.). During 1975 releases of this parasite were limited to Capay (Yolo Co.) and Lost Hill (Kern Co.). It has been recovered from both localities: from Capay in only trace numbers, while samples from Lost Hill reveal a 14% parasitization of the NOW larvae at harvest time. We do not know yet whether it is definitively established in these areas.

Samples from Chico indicate that this parasite successfully overwintered in 1974-75, and that it has increased its level of destruction of navel orangeworm. Harvest time samples indicate that in some orchards 44% of the navel orangeworm population has been destroyed.

Intensive sampling in Snelling indicates that in this area the "almond wasp" is also doing extremely well. During 1974 the wasp was colonized in some 800 acres of the 1469 acres planted to almonds in the L D Properties Ranch. Samples of the overwintering navel orangeworm population (worms in the old nuts) show that the parasite has destroyed from 37% to 80% of the pest in the sections where it was colonized. Such high levels of mortality will result in fewer navel orangeworm moths in these orchards this coming season.

Two other parasites, one from Israel (Phanerotoma flavitestacea), and the other from Mexico (Parasierola sp.) were colonized in Yolo Co., Merced Co., and Kern Co. They have been recovered from the release areas, but it is too early to say whether they are established or not.

Some areas in Texas and New Mexico were explored for natural enemies of the navel orangeworm. No NOW infestations were found. One parasite that may attack NOW was found and imported to California. Its usefulness against the navel orangeworm is yet to be determined.

Based on our 1975 work, the almond wasp seems to have become an important mortality factor against the navel orangeworm. We expect to determine its capabilities to bring about economic control of the pest during the 1976 season.

III. EXPERIMENTAL PROCEDURE:

1.- Laboratory culture of parasites.

a) Pentalitomastix plethoricus.- This parasite was discovered in Mexico and imported to California. The females search for and sting navel orangeworm eggs; an egg is then laid in the NOW egg, which is not killed. The NOW larva hatches and develops apparently normally, but it carries the parasite inside. When the NOW larva has completed its development it spins a silken cocoon. At this time the parasites inside the NOW larva develop very quickly killing the host, of which only the outer skin is left. The parasites transform into adult wasps inside the dead NOW larva. This parasite is a polyembryonic one, that is, from a single egg many adults develop; in this case an average of 500 adult Pentalitomastix develop inside each parasitized NOW larva.

Based on these biological characteristics, P. plethoricus is mass cultured as follows:

-Navel orangeworm eggs are exposed to female Pentalitomastix for some 24 hours,

-These parasitized eggs are placed in 1-gallon containers ¼ full of a rearing medium consisting of a mixture of wheat bran, brewers yeast, honey, glycerine, and water.

-After the NOW larvae have spun their cocoons the parasitized larvae are collected and prepared for colonization in the field and/or for stock to continue lab culture.

b) Phanerotoma flavitestacea and P. inopinata.- Phanerotoma flavitestacea was imported from Israel where it parasitizes the carob pod moth, Ectomyelois ceratoniae. P. inopinata is native to California. Both species have similar biologies, and the culturing method is the same for both. Females search for and sting navel orangeworm eggs where and eggs is laid. The NOW larva hatches, apparently unharmed by the parasite it carries inside. After the NOW larva completes its development and spins its cocoon, the parasite develops at a fast rate consuming the host, leaving only the head capsule and part of the integument (skin). Soon after, the parasite larva spins its cocoon inside the NOW cocoon. Eventually the parasite energes as an adult cutting its way out of the two cocoons.

To culture these species, the Mediterranean flour moth, Anagasta kuehniella, is used as a factitious host. This moth is easier to culture than the navel orangeworm. The procedure is as follows:

- Mediterranean flour moth eggs are collected from oviposition units and sprinkled on wet paper. When the paper dries, the eggs remain stuck on it. These eggs are exposed to parasites for oviposition for about 24 hours.
- The parasitized eggs are placed in 1 gallon jars ¼ full of a culturing medium composed of chicken feed (starter and laying), rolled barley, raisins, and glycerine.
- When adult parasites emerge, they are collected and used for field colonization, and/or to keep the culture in the lab.

c) Paraolinx typica.- This parasite is native to California. The females search for and lay eggs on NOW larvae in the nuts; medium size to full grown larvae are preferred. Prior to laying the eggs the female parasite permanently paralyzes the host larva. Upon hatching, the parasite larvae feed on the paralyzed NOW larva, leaving only the head capsule and the integument. After reaching full size the parasite larvae turn into pupae, and soon after into adults.

To culture this parasite, nearly full grown navel orangeworm or Mediterranean flour moth larvae are exposed to the parasites. The parasitized larvae are then transferred to glass jars where the new generation adults emerge. These are collected for field colonization and/or for continuation of the colony in the lab.

d) Parasierola sp.- This species was imported from Mexico. Its biology is very similar to that of Paraolinx typica. Females search for, paralyze, and lay eggs on nearly full grown NOW larvae in the nuts. Larvae of the parasite feed on the paralyzed NOW larva.

To culture this parasite, large Mediterranean flour moth or NOW larvae are exposed to the parasite females. In this case one larva is exposed to one female, since when they are kept in large groups in a single container, the parasites interfere with each other. This results in high mortality of the parasites, and low parasitization.

2.- Colonization of parasites in the field.

Pentalitomastix plethoricus was colonized placing mummified parasitized navel orangeworm larvae in screened 2 oz. condiment plastic cups hung in the trees. Generally some 20 to 25 parasitized larvae were placed in each cup. As some 500 adult parasites develop in each parasitized larva, and allowing for a natural mortality (failure to emerge from the parasitized larva) of 28%, a total of 7200 to 9000 adults are released in each colonization point. In the 1974 season the parasite was colonized in the L D Properties Ranch in Snelling, Merced Co. at the rate of one colonization point every tenth tree every fifth row.

The other parasites were taken or sent to the orchards as adult, and were released for them to disperse themselves.

3.- Analysis of navel orangeworm populations.

The navel orangeworm spends all its developmental stages - egg, larva, and pupa - on or in the almond nuts. This makes it possible to treat each nut as a sampling unit. To assess population density, age distribution, and percentage of kernel damage, as well as the impact of navel orangeworm parasites, samples of some 200 nuts are periodically taken. Sometimes samples are smaller because of unavailability of nuts. Harvest samples consist of larger number of nuts (1000 or more). In the laboratory each nut is examined for

eggs	viable
	emerged
	parasitized by Trichogramma
larvae	viable
	parasitized by Pentalitomastix
	Parasierola
	Paraolinx
	dead due to other causes
pupae	viable
	emerged

The number in each category is recorded. The viable eggs, larvae, and pupae are reared in medium and the final status of the individuals (parasitized or unparasitized) is finally recorded. A tally of the number of nuts examined (size of the sample) and of the

number of damaged kernels is kept. Thus the level of navel orangeworm infestation, and the structure of the population of navel orangeworm and its parasites in each nut is known.

IV. RESULTS:

1.- Colonization of natural enemies.- Colonization of natural enemies, mostly parasites, was a reduced activity during the 1975 season. The different species, and the localities in which they were colonized are indicated in Table I below.

Table I. Colonization of natural enemies of the navel orangeworm in 1975.

Natural enemy	Locality	No. colonized	Total
Pentalitomastix plethoricus	Swanson Orchard, Capay Yolo Co.	2,139,264	
	Blackwell Land Co., Lost Hill, Kern Co.	8,398,512	
	Delantico Orchard, Oakley, Contra Costa	220,320	10,758,096
Phanerotoma flavitestacea	L D Properties, Snelling, Merced Co.	1,156	
	Swanson Orchard	6,498	
	Blackwell Orchard ,	5,175	12,829
Phanerotoma inopinata	L D Properties	793	
	Swanson Orchard	85	878
Paraolinx typica	Swanson Orchard	13,800	
	Blackwell Orchard	2,000	15,800
Parasierola sp.	Swanson Orchard	2,890	
	Blackwell Orchard	3,950	6,840
Haplothrips sp.*	Swanson Orchard	470	470
Total natural enemies colonized			10,794,913

* predator

2.- Establishment, and impact of Pentalitomastix plethoricus on navel orangeworm populations.- Sampling of navel orangeworm populations has confirmed that this parasite is now established in Chico and vicinity (Butte Co.), Oakley (Contra Costa Co.), Le Grand and Snelling (Merced Co.), and Famoso (Kern Co.). It was also recovered from Capay (YoloCo.) and Lost Hill (Kern Co.), but since parasites were colonized in these localities in 1975, it is premature to say whether the parasite is established there.

Harvest samples from the Blackwell Land Co. Orchard, Lost Hill, reveal that 14% of the navel orangeworm population in the colonization area has been destroyed by P. plathoricus. This level, reached during the first year of colonization is higher then the first year in Chico (7%), and Snelling (11%).

Old and new nuts were collected in the Chico area where the parasite has not been colonized since June 1974, and examined to determine parasitization. Table II contains the information gathered.

Table II. Parasitization of navel orangeworm by Pentalitomastix plethoricus in the areas indicated. All samples collected in 1975.

Orchard	Sampling date	No. nuts examined	% parasitization
Nottelmann, Hegen Rd. Chico	23 July	150*	46.2
	10 Sept.	1,168**	44.7
Nottelmann, Fimple Rd. Chico	23 July	169*	32.2
Carter, Chico	23 July	167*	52.3
Seever, Chico	23 July	226*	37.3
Hanson, Chico	23 July	222*	36.9
Decker, Durham-Dayton Rd.	23 July	220*	23.6

* old nuts

** new nuts

Analysis of the data collected in the Nottelmann Orchard on Hegen Rd., Chico, indicates that the impact of the parasite on the navel orangeworm population has been steadily increasing from 7% in 1971 to 44.7% in 1975 (Fig. 1).

Intensive sampling of the L D Properties Ranch, Snelling, where Pentalitomastix plethoricus was not released in 1975, was conducted in most of the sections of the 1469 acres planted to almonds. During the previous season (1974) the parasite was distributed in about 800 acres (Fig. 2). Analysis of the samples revealed that the parasite has become established, and that it is inflicting high percentages of parasitization in some sections. Results obtained up to this writing are presented in Table III.

Table III. Analysis of almond nuts collected in the L D Properties Ranch, Snelling. All samples collected in 1975.

Date sampled	No. nuts examined	% nuts with viable eggs, larvae and/or pupae	No. viable eggs, larvae, and/or pupae per 100 nuts	% parasitism by Pentalitomastix
		Section F-29		
10 April	440*	22.5	36.1	0
		Section F-30		
27 Feb.	160*	14.4	20.6	0
15 Dec.		pending	pending	recovered
		Section F-31		
15 Dec.	180*	pending	pending	recovered
		Section F-32		
10 April	292*	3.4	4.1	0
8 May	260*	2.3	2.3	0
		Section F-34		
25 June	93*	5.4	23.7	9.5
25 Aug.	198**	14.6	22.2	3.7
3 Nov.	200**	pending	pending	pending
		Section F-36		
27 Feb.	237*	6.8	10.6	0
15 Dec.	223**	pending	pending	pending

Table III. (continued)

Date sampled	No. nuts examined	% nuts with viable eggs, larvae and/or pupae	No. viable eggs, larvae, and/or pupae per 100 nuts	% parasitism by Pentalitomastix
		Section F-38		
8 May	293*	12.6	19.5	11.5
25 June	353*	15.6	49.0	28.5
17 Sept.	372**	pending	pending	38.5
4 Dec	198**	pending	pending	pending
		Section F-39		
8 May	218*	16.1	32.1	11.1
		Section F-41		
10 April	250*	31.6	66.0	18.1
8 May	202*	14.9	28.2	22.7
10 July	229*	21.8	60.7	34.3
7 Aug.	168*	42.3	167.9	55.3
25 Aug.	188*	31.9	83.5	58.7
25 Aug.	179**	27.4	55.9	58.4
3 Nov	202**	pending	pending	66.8 (prelim.)
		Section F-43		
10 April	263*	22.1	37.3	6.3
25 June	257*	18.3	80.9	18.9
7 Aug.	170*	30.6	114.1	29.8
25 Aug.	225*	19.1	41.8	60.0
25 Aug.	159**	6.3	11.3	33.3
17 Sept.	1048**	pending	pending	37.3
		Section F-44		
15 Dec.	209**	pending	pending	pending
15 Dec.	270**	pending	pending	80.4 (prelim.)
		Section F-45		
16 Jan.	526*	33.7	52.5	18.0
21 Feb.	361*	33.8	55.1	17.0
10 April	300*	25.0	41.3	18.1
8 May	330*	36.7	72.7	13.4
25 June	200*	35.0	13.0	35.8

Table III. (continued)

Date sampled	No. nuts examined	% nuts with viable eggs, larvae and/or pupae	No. viable eggs, larvae, and/or pupae per 100 nuts	% parasitism by Pentalitomastix
		Section F-45 (continued)		
10 July	202*	21.3	75.2	48.3
7 Aug.	200*	27.5	102.0	43.6
17 Sept.	1128**	23.9	41.3	80.2
3 Nov.	200**	pending	183.5	79.7 (prelim.)
4 Dec.	204**	pending	165.7	72.5 (prelim.)

* old nuts

** new nuts

Figure 3 depicts the progression of parasitization by Pentalitomastix in Section F-45 and F-41, L D Properties Ranch, Snelling.

3.- Establishment of other natural enemies.- Phanerotoma flavitestacea has been recovered from L D Properties, Snelling, and from Swanson Orchard, Capay. Parasierola sp. has been recovered from Blackwell Ranch, Lost Hill, and from Swanson Orchard. No statement can be made regarding the establishment of these species in these areas.

The predaceous thrips Haplothrips sp., which was released only in the Swanson Orchard, has not been recovered; presumably it did not establish itself.

4.- Exploration for natural enemies.- From 22 September to 3 October 1975 exploration in search of navel orangeworm and its natural enemies was conducted in Texas and New Mexico. Plants known to be hosts for the navel orangeworm - including almond, apple, apricot, peach, pecan, plum, walnut, fig, acacia, yucca, and soap tree - were examined in El Paso and surroundings, and Davis Mountains in Texas, and in the area from Las Cruces to Santa Rita, and Carlsbad in New Mexico. No navel orangeworm was found, but three parasites, considered to be worthy of investigation were collected and brought to California. They were processed according to quarantine regulations. Two of the parasites, both in the family Eulophidae, did not reproduce in quarantine, while the third, a species of Bethylidae in the genus Goniozus parasitized

successfully larvae of the Mediterranean flour moth. This parasite will be tested against navel orangeworm when enough number of adults are secured.

V. DISCUSSION:

We have determined that there are some 11 species of natural enemies of the navel orangeworm in California. Of these, the parasite Pentalitomastix plethoricus is the only exotic, the others are parasites of other insects that are native, or have been in California for a long time. These natural enemies do not seem to have the potential to reduce navel orangeworm populations to non economic levels on their own. The possibility to improve their effectiveness by manipulation (inundative and/or inoculative releases, additional food sources, etc.) have not been investigated.

Pentalitomastix plethoricus, on the other hand, is having a great impact on the navel orangeworm , especially in Chico and Snelling, the two areas where this parasite has been more intensively colonized. The levels of parasitization in these areas indicate that the number of parasites overwintering in the orchards is extremely high; they should have an even greater impact on the pest this coming spring. For example, in Nottelmann Orchard, Hegan Rd.,Chico, the level of parasitization is 44 percent. This means that next spring of every 100 navel orangeworm larvae, 56 will develop into adult moths, and 44 will produce parasites; but since each parasitized larva produces an average of 500 parasites, there will be 22,000 parasites, or a projected 393 adult parasites for each navel orangeworm adult. The situation in certain areas in the Snelling L D Properties Ranch is even better. In Section F-45, for example, the level of parasitization is 80 percent, or a projected 2,000 adult parasites for every navel orangeworm adult come next spring.

Pentalitomastix plethoricus disperses very slowly - ¼ to ½ mile per year - while the navel orangeworm disperses much more rapidly. This is why it has not yet been possible to determine the potential of this parasite to reduce the damage caused by the moth. To know this potential the parasite should be distributed in a large area, so that the whole resident navel orangeworm population is subjected to the effect of the parasite. This condition seems possible to occur

next season in the L D Properties Ranch in Snelling, which is a somewhat isolated orchard. Once the potential of this parasite is determined in one area, it will be possible to choose the strategy, or strategies to disperse it or to manipulate it more efficiently in other areas.

The remarkable increase in parasitization in Chico and Snelling, where no Pentalitomastix were released in 1975, suggests that this species has become well adapted in these areas. We do not discount the possibility that an adaptation of this parasite to California conditions has occurred, or is occurring. The logical step to take is to move this parasite from Chico, Snelling, and Le Grand to other areas, especially to those in which the parasite was released in past years, but where we have failed to recover it.

Intensive monitoring of the navel orangeworm and Pentalitomastix populations in Chico, Le Grand, Snelling, and Lost Hill - to the extent permitted by the resources available -, and transfer of parasites from these to other locations in California should be the main activity of this project for the coming season.

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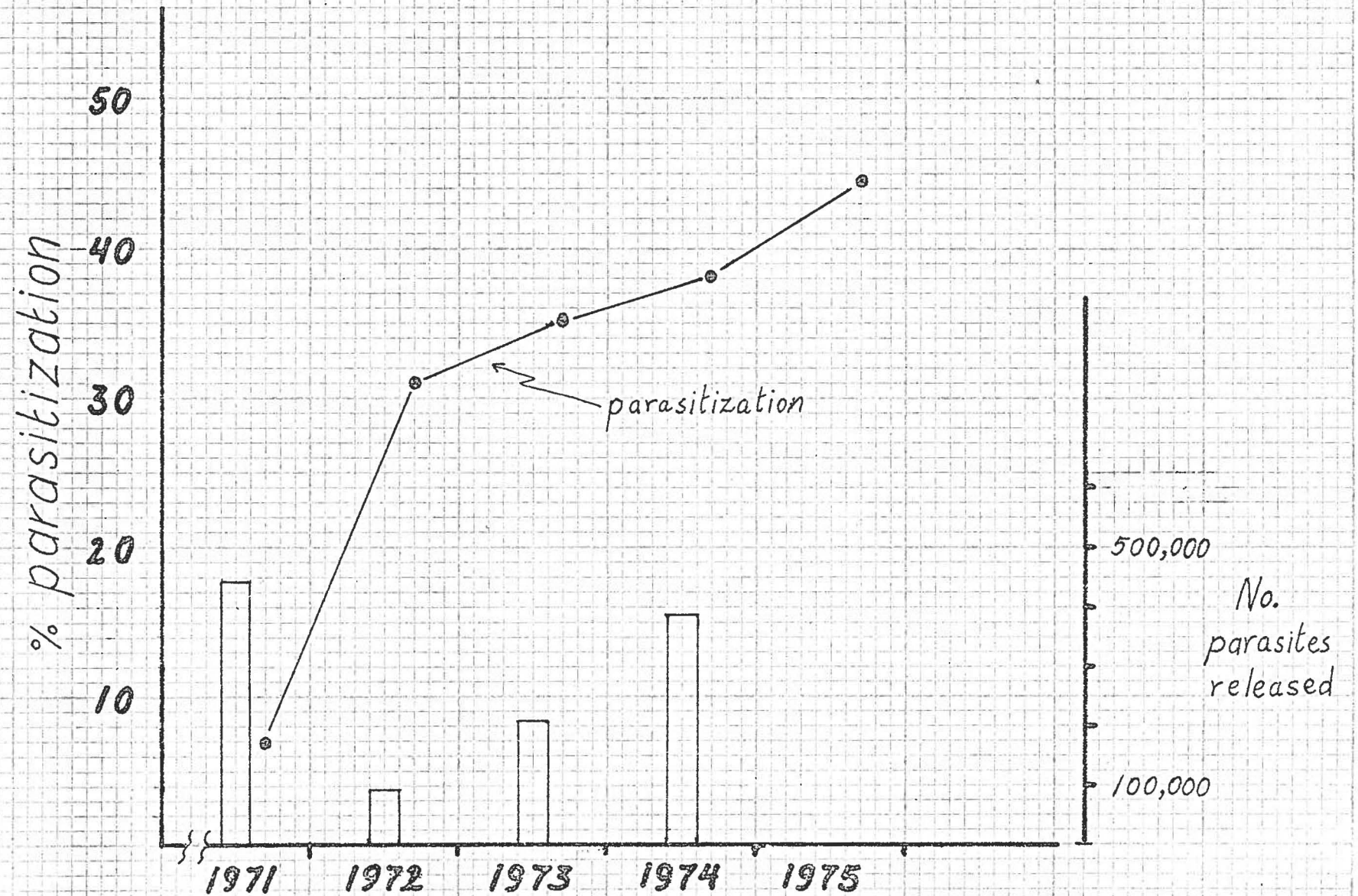

Fig. 1.- Percentage parasitization of navel orangeworm, Paramyelois transitella by the parasite Pentalitomastix plethoricus. Nottelmann Orchard, Hegan Rd., Chico, Butte Co. Samples taken at harvest time.

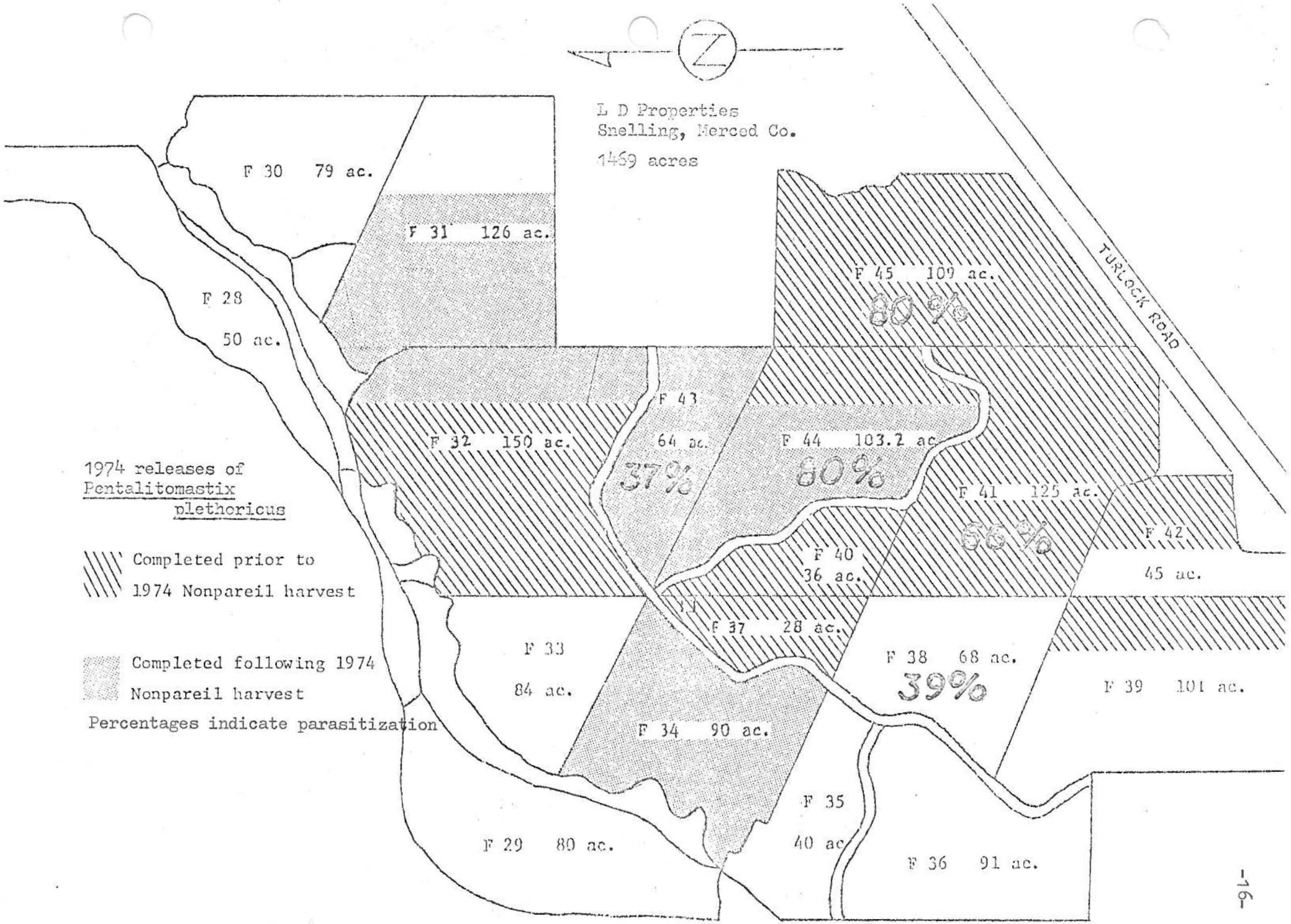

Fig. 2.- Colonization of Pentalitomastix plethoricus, and its parasitization of navel orangeworm in some of the sections in the L D Properties Ranch, Snelling.

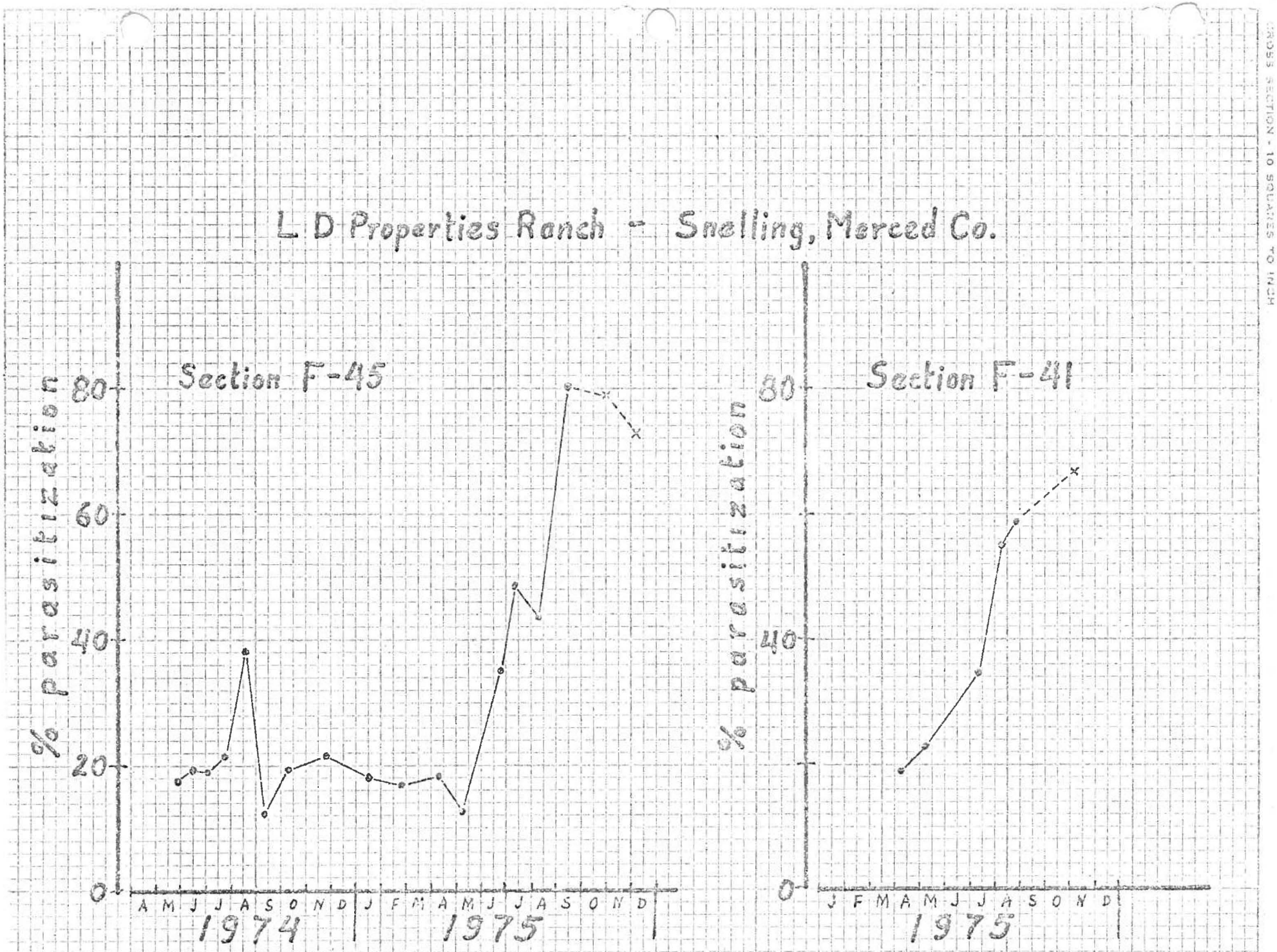

Fig. 3.- Parasitization of navel orangeworm by the parasite Pentalitomastix plethoricus