Correct Project Number

78-A4

PROJECT NO. - 78-A5 - Navel Orangeworm Research
Ballico Project

COOPERATOR:
USDA, SEA/AR
Stored-Product Insects Research Laboratory
5578 Air Terminal Drive
Fresno, California 93727

PROJECT LEADER: Dr. Charles E. Curtis

PERSONNEL: Jimmy D. Clark

I. OBJECTIVES: (1) To evaluate the data developed during the three year Ballico/Famoso project. (2) To determine the impact of the project on getting growers to practice orchard sanitation, insecticidal control of the peach twig borer, and early and rapid harvest for navel orangeworm control in almond orchards. (3) To determine the degree of success that growers have with proper or improper use of these control methods. (4) To compare progression of infestation and damage due to navel orangeworm at harvest time in almonds on the tree, spread out on the ground, and in winrows.

II. INTERPRETIVE SUMMARY: "Should I leave my almonds on the tree or knock them to the ground if harvest is going to be delayed by insufficient huller capacity?", asks a grower. What the grower wants to know, is whether or not navel orangeworm (NOW) damage will increase more rapidly in nuts on the tree or in nuts on the ground. Tests were made in 1978 in an orchard near Clovis to answer these questions.

Three different tests were made with Nonpareil almonds: 1) nuts not knocked, 2) nuts left spread out on ground, 3) nuts winrowed to a depth of about 3 nuts. Samples were taken at weekly intervals beginning on August 11 and ending on Sept. 1.

Results:

(1) No eggs were laid on nuts on the ground (spread out or winrows).

(2) Egg counts for nuts on the trees ranged from 30-60 per 100 nuts throughout the test.

(3) NOW damage remained at 10% in nuts on the ground throughout the test.

(4) NOW damage increased from 9% to 19% in nuts on the tree.

These results show that almonds on the ground are safe from egg laying. Also, there was no evidence that larvae did additional damage by moving from nut to nut in the winrow. About 70% of the larvae and pupae in the nuts spread out on the ground and 90% of those in winrowed nuts were killed by heat, especially if the nuts were exposed to the sun for a few hours. The test orchard had rows running east and west, and the trees were small enough to allow several hours of sun penetration to a six-foot wide strip of ground between rows. This killing of NOW would probably not happen in an orchard with a full canopy.

One caution to growers, especially those that would not have their almonds on the ground or in winrows exposed to the sun, is that NOW moths would emerge over a period of time and lay eggs on any almonds remaining in the trees. This factor and the possibility of rain would make picking up the nuts and tarping and fumigating them an important alternative.

Even though NOW damage increased in nuts on the tree and not in nuts on the ground, there was no statistically significant increase in total worm damage which remained at about 16% in nuts on the ground and on the tree. This was because peach twig borer (PTB) damage remained at about the same level throughout the tests with nuts on the ground but decreased from 6% to 0% in nuts on the tree. The nuts on the tree evidently became too dry for small NOW larvae to enter unless another NOW or a PTB had already damaged the kernel. This is shown by the survival rate for eggs which was 13% for undamaged nuts, 32% for nuts with NOW damaged hulls and 38% for nuts with NOW or PTB damaged kernels. Also more eggs were laid on damaged almonds than on undamaged almonds — 1.1 Eggs per meat on nuts with no damage, 2.1 on nuts with PTB damaged hulls, 4.4 on nuts with NOW damaged hulls, 14 on nuts with NOW or PTB damaged meats.

Remember that these data are for one variety - one year - one grower. We know from a great amount of data from other situations that NOW damage can easily double in a two week period with very little PTB damage being present and can increase as much as seven times under extreme conditions such as rain.

III. EXPERIMENTAL PROCEDURE: (1) About 2500 computer work sheets of Ballico Project data have been stored on disks on our Wang 2200T-4 computer. Programs have been written to process the data on NOW and PTB damage in the kernel and hull, egg counts and placement, hull maturity and other data concerning insects and quality factors. Also, programs have been written to process grower records to show dollar loss per acre and dollar loss per ton of meats for all varieties taking into account direct losses of damaged nuts, quality adjustments and huller losses.

(2) Work was begun to determine the impact of the Ballico Project on getting growers to practice orchard sanitation, PTB control and early and rapid harvest. Mummy nut counts were made during late February and early March, 1978, in 69 Test-Area orchards and in 54 Check-Area orchards. Five trees of each variety present in a given orchard were selected at random for making mummy counts. Fully developed nuts were distinguished from shriveled-sticktight type nuts. No questionnaires have been sent out to determine what all growers in the Ballico Test and Check areas did for NOW and PTB control for the 1978-crop, but personal contact has been made with several growers in those areas to gain this information.

(3) In early August, 100 Nonpareil variety almonds were sampled from each of 6 Cortez area orchards and 30 Ballico area orchards. Also, 100 Nonpareil variety almonds were sampled from each of 5 sites in each of 2 Fresno area orchards. These samples were examined for NOW and PTB

damage to kernels and hulls as well as other types of defects. A determination of 1978-crop rejects for all of the Ballico Test and Check area growers will not be done until early 1979 at which time we will have received all the grade sheets from the various handlers. We do have some information based on the small number of samples that we took in August and on personal contact with some growers.

(4) A Clovis area grower cooperated with us in an experiment set up to determine whether or not almonds become more infested and damaged by navel orangeworm when (1) left on the tree (2) spread out on the ground or (3) in winrows at harvest time. The test was set up as follows:
Two adjacent rows of Nonpareil trees were selected. Each treatment was replicated 5 times. Each replication consisted of 4 trees, 2 adjacent trees in each row directly across the middle from one another. Alternate trees within a row have been pruned upright and narrow because of the close planting, so each pair of trees consisted on one upright tree plus one normal shaped tree. This pruning method, the light crop (ca. 400 pounds/acre) and the desire to have a good representation of infestation account for why 4 trees instead of 1 tree were used in each replication. Four trees in each replication were left unshook. The other trees in the replication were shook on August 8. Winrows (0.5 x 8.0 m) were constructed on August 10 using the almonds that fell in the middle between the 2 Nonpareil rows. Winrows were about 15 cm deep (generally 2-3 nuts deep) and were equidistant from the tree rows on either side of the middle. Nuts not placed in winrows were left spread out such that they covered an area 6 x 9 m between the 2 tree rows.

The first samples (100 nuts/replication/test) were taken on August 11, and other samples were taken at weekly intervals through September 1 resulting in 4 sets of samples. Tree samples were taken to represent all sides of trees and several elevations within the tree. Winrow samples represented the entire length, width and depth of a winrow. The spread out almonds were taken so that the south, middle and north areas between the 2 tree rows were represented. This was especially important as the rows ran east and west and the sun penetrated the tree canopy such that some almonds just north of the middle were exposed to direct sunlight for several hours each day.

IV. RESULTS: (1) The data processing of Ballico Project data is still in progress. The dollar loss for each year (1971-1978) for each variety for each grower is being calculated for Test-area and Check-area growers along with the costs of any dormant season cleanup so these data may be presented to each individual grower involved in the Ballico Project. Figure 1 shows the reduction in total rejects and NOW rejects for the Nonpareil variety for the years prior to the Project (1971-1974) and the years during the Project (1975-1977). There was a 50% reduction of NOW rejects in the Test over the Check area when using an average for the 3 Project years (3.1% for Nonpareil) corrected for what had existed in prior years, the fact that Check-area rejects were always lower than Test-area rejects. Similar values for other varieties were 3.6% (a 48% reduction) for Merced, 5.2% (an 84% reduction) for Thompson and 2.0% (a 20% reduction) for Neplus.

(2) Table 1 shows mummy nut counts for 1978 were as low or lower than those during the Project years (1975-1977) for Test-area growers. Mummy nut counts for Check-area growers were about the same (4.3/tree) as those for Test area growers (4.7/tree) in 1978. During the Project years the Check area (29.2 mummys/tree) generally had ca. 6 times more mummys than did the Test area (5.2 mummys/tree). These values are calculated based on a hypothetical 2:1 planting of the most prevalent varieties that are susceptible to NOW infestation (6/9 Nonpareil, 1/9 Neplus, 1/9 Merced, 1/9 Thompson). The data indicate that many growers in both areas did clean their orchards and that a good natural cleanup by birds and wet weather did occur in most orchards. Many growers in the Ballico, Delhi and Cortez areas are known to have cleaned their orchards very thoroughly during December 1977, doing a good job of removing mummys from trees and destroying mummys on the ground. A determination by questionnaires covering what Ballico-Project (Test and Check area) growers did for NOW and PTB control has not been done. This should be accomplished in early 1979.

(3) We had hoped that the 1978-crop grower grade sheets would show the degree of success that growers had with various control methods. However, we know that the grade sheets will show very high total rejects for the Ballico and Cortez area even though both areas were very clean. Most of the rejects were due to PTB and gummy and shrivel meats early in the season (Figure 2). NOW damage was only 1.2% in the Ballico area and 0.8% in the Cortez area in early August. We know that most of the PTB damage was covered up by NOW damage by harvest time and that the PTB damaged kernels greatly encouraged the NOW infestation. Most of the shrivels were probably blown out at the huller so they would not contribute much to the reject values found on growers' grade sheets. However, they were obviously a large direct loss to growers.

Fresno #1 grower (Figure 2) had a dormant spray for PTB control but had high mummy nut counts in August, especially on the Neplus and Thompson varieties. This resulted in high NOW and high PTB damage showing the need for a clean orchard and, in the case of the 1978-crop year, a May spray for PTB control. Fresno #2 grower had a clean orchard and no dormant spray yielding a low NOW infestation and 25% PTB meat damage showing the need for a dormant spray and perhaps a May spray for PTB control.

Table 2 shows the 1978-crop results compared to previous crop years for a grower discussed in the 1977 Annual Report. This grower had a dormant spray - 400 gallons per acre at 2 miles per hour applying Parathion® at 2 pounds active ingredient and 8 gallons of superior grade oil per acre. He cleaned his orchard by dormant tree shaking and destruction of nuts on the ground. He applied Guthion® (2 pounds active ingredient per acre) and Plictran® at 60 days before harvest as a dilute spray (400 gallons per acre at 2 miles per hour). He started Nonpareil harvest on September 10 and finished Merced harvest on September 23 which is early for Merced county growers. Even with the much smaller crop in 1978 and the high PTB damage in many Merced county orchards, this grower had only 3.0% rejects in his Nonpareil, 3.8% in Neplus and 6.3% in Merced. The 1977- and 1978-crops for which the grower took action in controlling NOW and PTB had about 70% fewer rejects than did the 1975- and 1976-crops. Merced county reject figures have increased about 50% when comparing these same years.

(4) In tests to compare the progression of infestation and damage due to NOW at harvest time in almonds on the tree, spread out on the ground, and in winrows, no eggs were laid on nuts on the ground (winrows or spread out). Table 3 shows that throughout the test egg counts for nuts on the tree were 30-60 per 100 nuts, no statistical differences between any of the sample means. Data for small larvae also show that practically no small larvae were present in nuts on the ground but that large numbers were present in nuts on the tree with significant increases between 8/11 and 8/18 and between 8/25 and 9/1. The last set of data in Table 3 shows the total numbers of larvae and pupae did not increase on nuts on the ground, but they did increase in nuts on the tree. Also, there was ca. 90% mortality in winrowed nuts, 70% mortality in spread out nuts and very little mortality in tree nuts for half-grown to full-grown larvae. There was some mortality for first instar larvae in tree nuts, but this was not recorded as these small larvae were very difficult to find when dead and dried out.

Table 4 shows that there was significantly less NOW damage in nuts on the ground than in nuts on the tree after the 8/11 sample date. Also there was a significant increase in NOW damage in tree nuts between the 8/11 and 8/18 sample dates. There was no such increase in nuts on the ground. However, there was no significant difference between the combined damage by NOW and PTB for nuts on the ground or nuts on the tree. Also, there was no significant difference between any of the sample dates for a given treatment. This is explained, at least in part, by the last part of Table 4 which shows a significant drop in PTB damage and a significant increase in NOW damage in nuts on the tree. The NOW alone and PTB alone damage levels remained the same through time in nuts on the ground, but the PTB alone and dually damage kernels on the tree became so damaged by NOW that only evidence of NOW damage could be found on the 8/18, 8/25 and 9/1 sample dates. Figure 3 shows the same thing in that the PTB alone damage goes from 27% of the damage on 8/11 to 0% on 9/1 in nuts on the tree but remains at 28% of the damage for both dates in almonds on the ground (combined data for winrow and spread almonds).

Figure 4 shows that NOW females are more stimulated to lay eggs and that larval survival is much greater on previously infested almonds. These data are for the 9/1 sample date at which time only one PTB damage kernel was found. It had 16 eggs and 75% survival of eggs. From the values printed by each point, one can see that the percentage of nuts with eggs was 46% for nuts with no damage, 70% for nuts with PTB damage in hull and 100% for nuts with NOW hull or NOW meat damage.

Figure 5 also shows that NOW females are more stimulated to lay eggs on previously infested nuts than on noninfested nuts. The total counts per nut for live eggs on all samples dates are higher on NOW and on PTB damaged meats than those on NOW and on PTB damaged hulls. All these counts are higher than the average count for eggs on undamaged nuts.

V. DISCUSSION: The Ballico Project did result in a 50% or more reduction for most varieties of almonds involved in the dormant season cleanup. The reductions may be even greated when data for growers in the test area that did not spray for PTB and those in the check area that did cleanup during some of the Project years are stratified out in the final analysis.

A guide line of leaving no more than an average of 5 mummy nuts per tree in a cleanup program seems to be an achievable goal based on the results of the 3 Project years and for 1978 when many growers did their own cleanup.

The results for the 1978-crop will not be very helpful in evaluating the impact that growers had in using orchard cleanup for NOW control. The PTB damage levels were very high, even in many orchards where growers used a phosphate insecticide in a dormant spray. The growers with the lowest levels of total rejects and PTB damage were generally those that applied a May spray of Guthion®. One grower in Merced county which we discussed in our 1977 Annual Report as being successful in controlling NOW and PTB was able to hold his total rejects to 3.0% in Nonpareil, 3.8% in Neplus and 6.3% in Merced by using dormant tree shaking plus Parathion® in his dormant spray plus Guthion® in a spray 60 days before harvest plus a timely harvest.

The important findings in our harvest tests in Fresno county agree closely with what Bob Curtis and Keith Andrews found in Kern county. No eggs were laid on nuts spread out on the ground or in winrows. NOW damage did not increase in nuts on the ground. Also, 70-90% of NOW larvae and pupae were killed by heat in nuts on the ground.

More eggs were laid on nuts with NOW or PTB damaged kernels than on nuts with damaged hulls than on nuts with no damage. Also, the survival of larvae was much greater on NOW or PTB damaged nuts than on undamaged nuts. Fortunately, the NOW invests most of its reproductive potential in nuts that already have insect damage, particularly those already infested by NOW larvae.

VI. PUBLICATIONS:

Curtis, C. E., and J. D. Clark. Responses of navel orangeworm moths to attractants evaluated as oviposition stimulants in an almond orchard. Accepted for publication in Environmental Entomology.

FIGURE 1 -- Comparison of total rejects and navel orangeworm rejects in Nonpareil variety for the Ballico Test and Check areas. Project years for dormant season cleanup were 1975-1977.

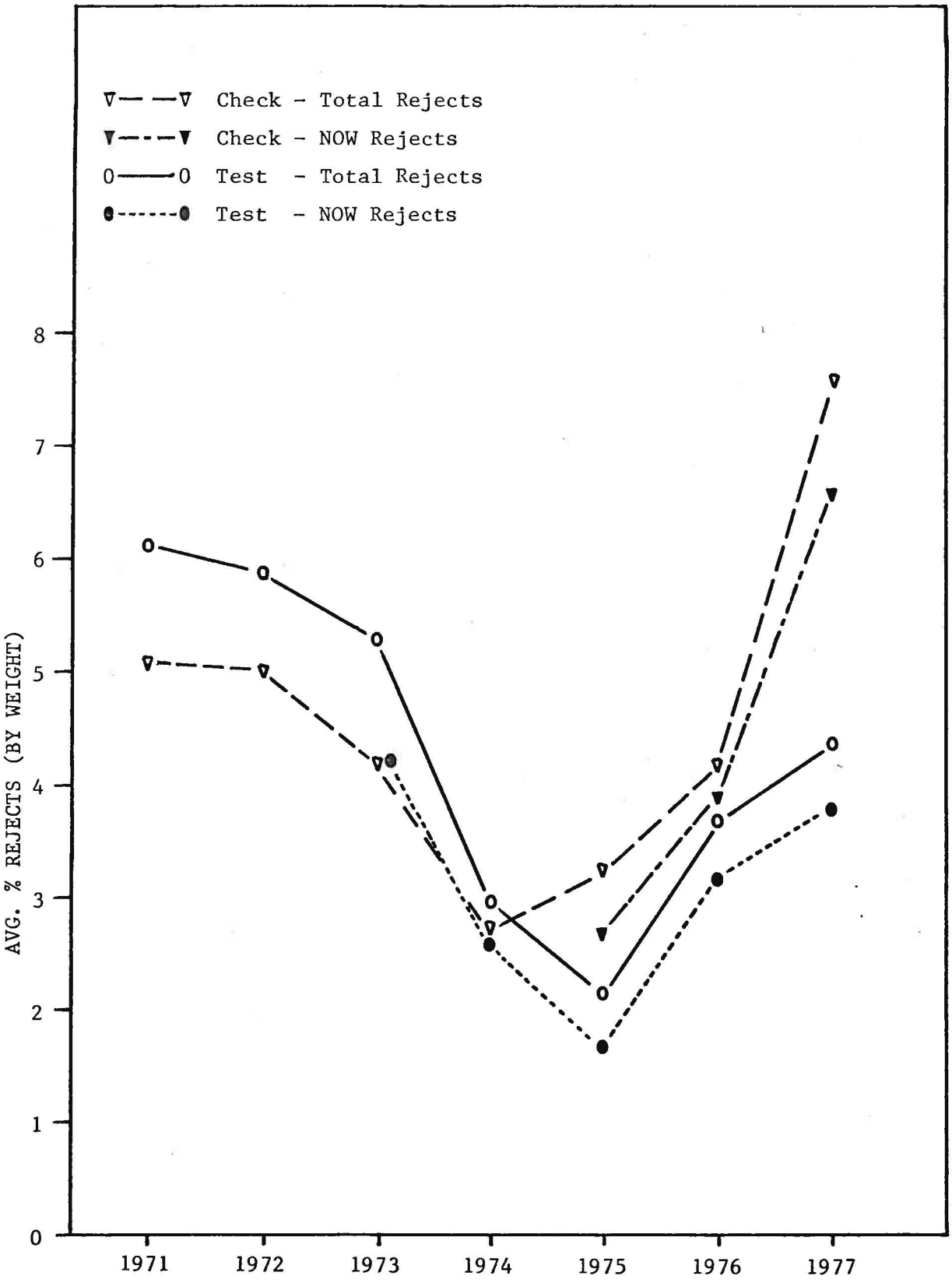
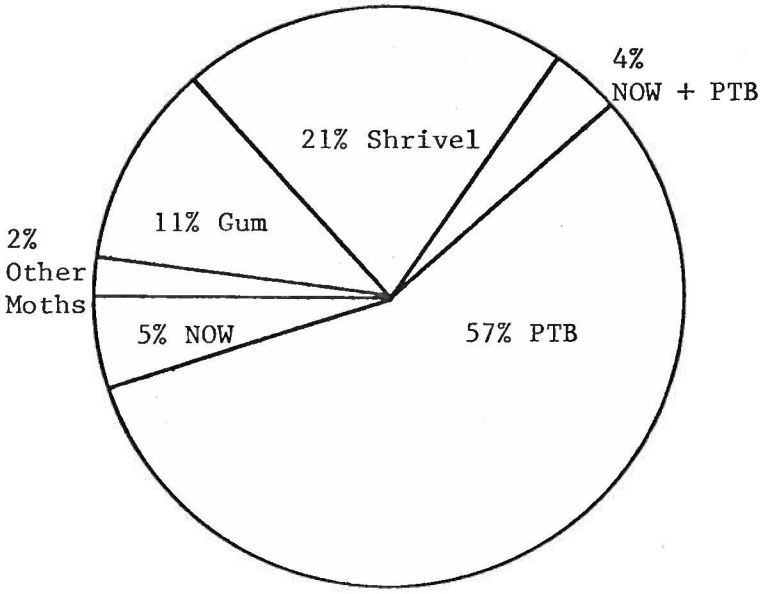
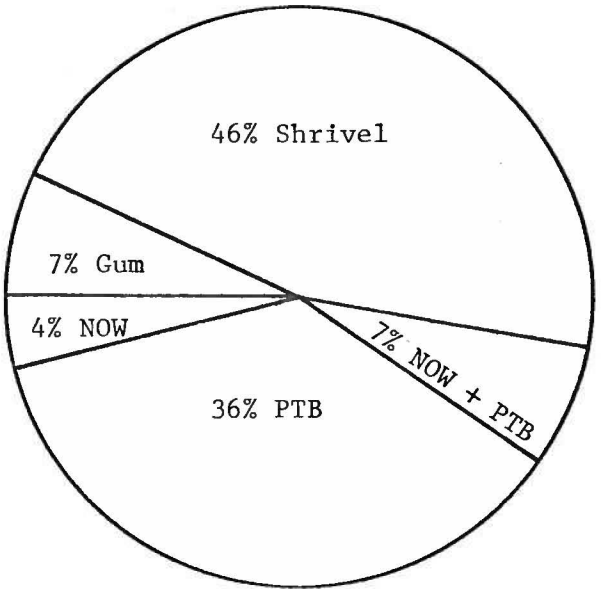


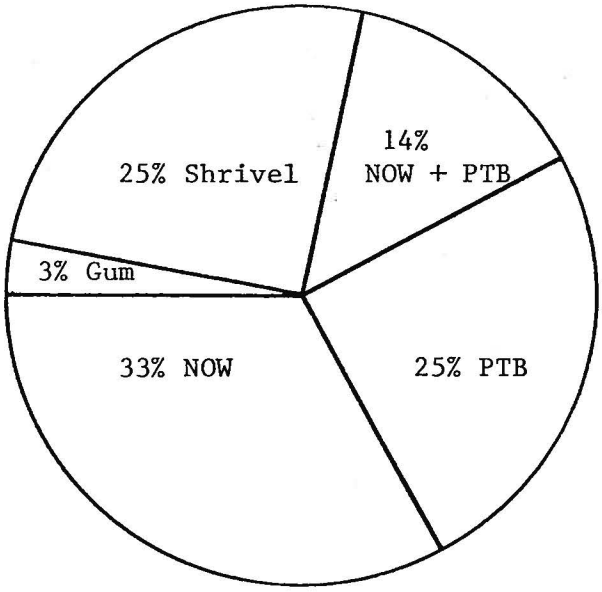
FIGURE **2** -- Some examples of the extent of peach twig borer (PTB) kernel damage in the Nonpareil variety for 1978-crop. Each graph shows total percent rejects (by count) and the percentage distribution of rejects according to type of damage.



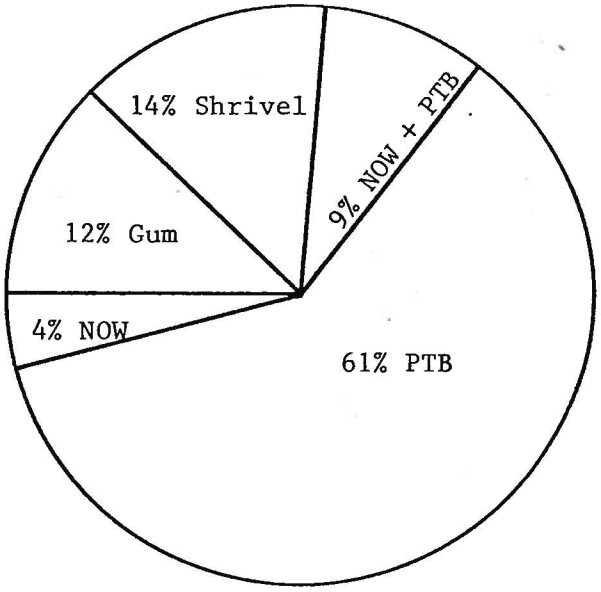
Ballico (Avg. of 30 growers)
8/8/78 Samples
Avg. of 24% rejects



Cortez (Avg. of 5 growers)
8/15/78 Samples
Avg. of 19% rejects

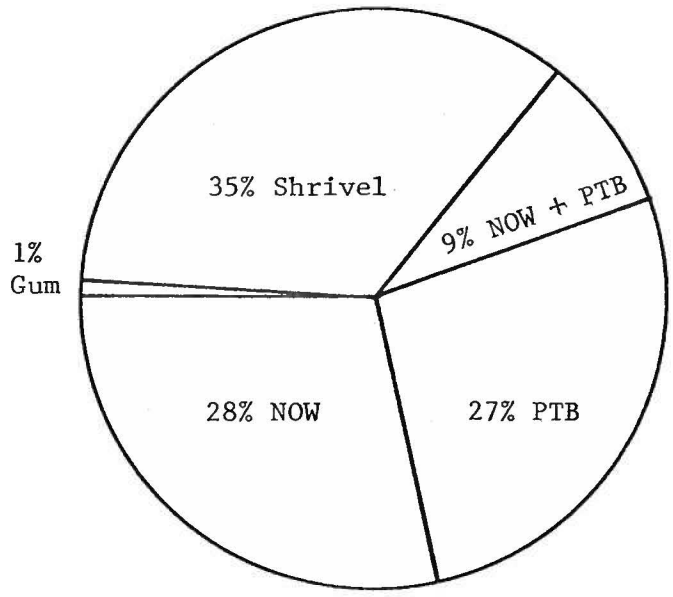


Fresno #1 grower
8/1/78 Samples
27 % rejects

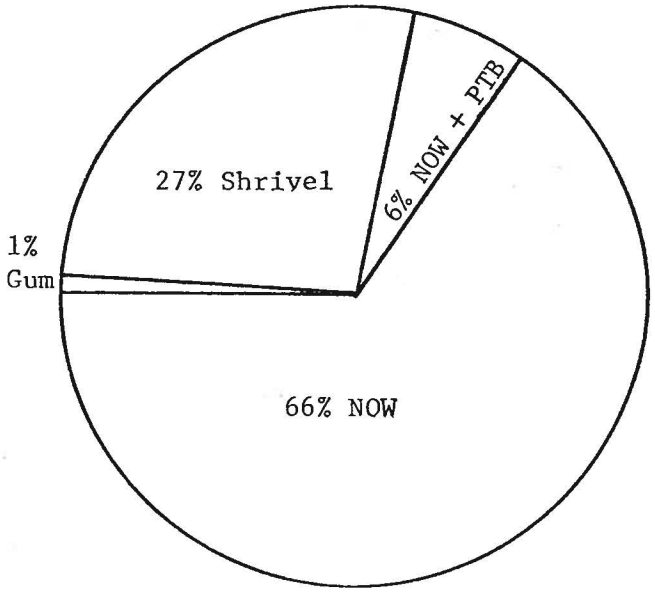


Fresno #2 grower
8/2/78 Samples
41% rejects

FIGURE 3 -- Change in percentage distribution of rejects according to type of damage in the harvest tests for Nonpareil variety for 1978-crop in Fresno. Samples were taken at weekly intervals beginning 8/11/78 and ending 9/1/78 from the tree and from the ground (data for winrow and spread almonds grouped).

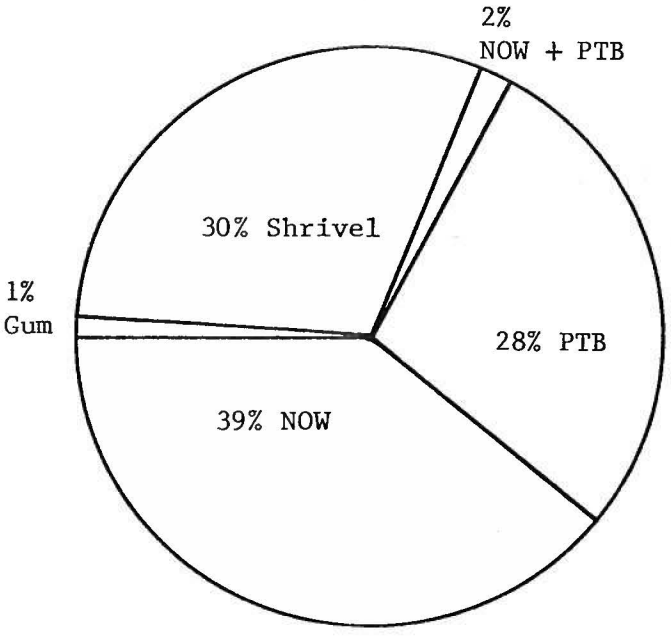


8/11/78 Begin test
22% rejects

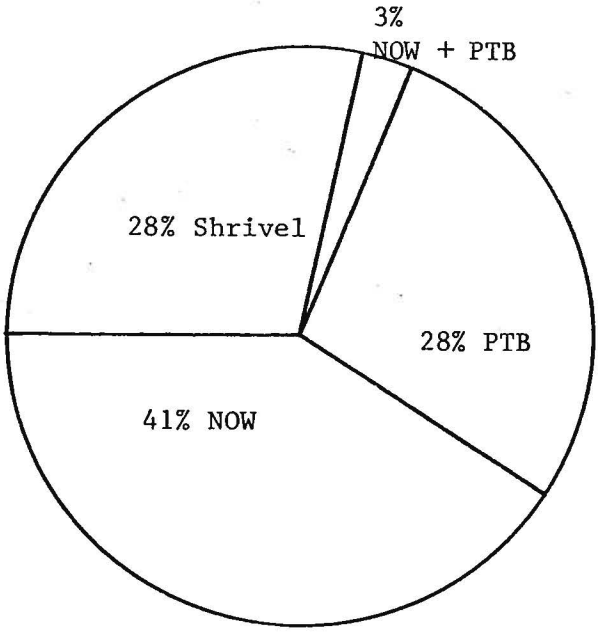


9/1/78 End test
25% rejects

TREE STORED ALMONDS



8/11/78 Begin test
22% rejects



9/1/78 End test
22% rejects

GROUND STORED ALMONDS

FIGURE 4 -- Total number of eggs (live + dead + chorions) and percent survival of eggs (live larvae + pupae + pupal cases / dead eggs + chorions) as influenced by type of damage to almond nut. Nonpareil variety of the 1978-crop collected in harvest test on 9/1/78.

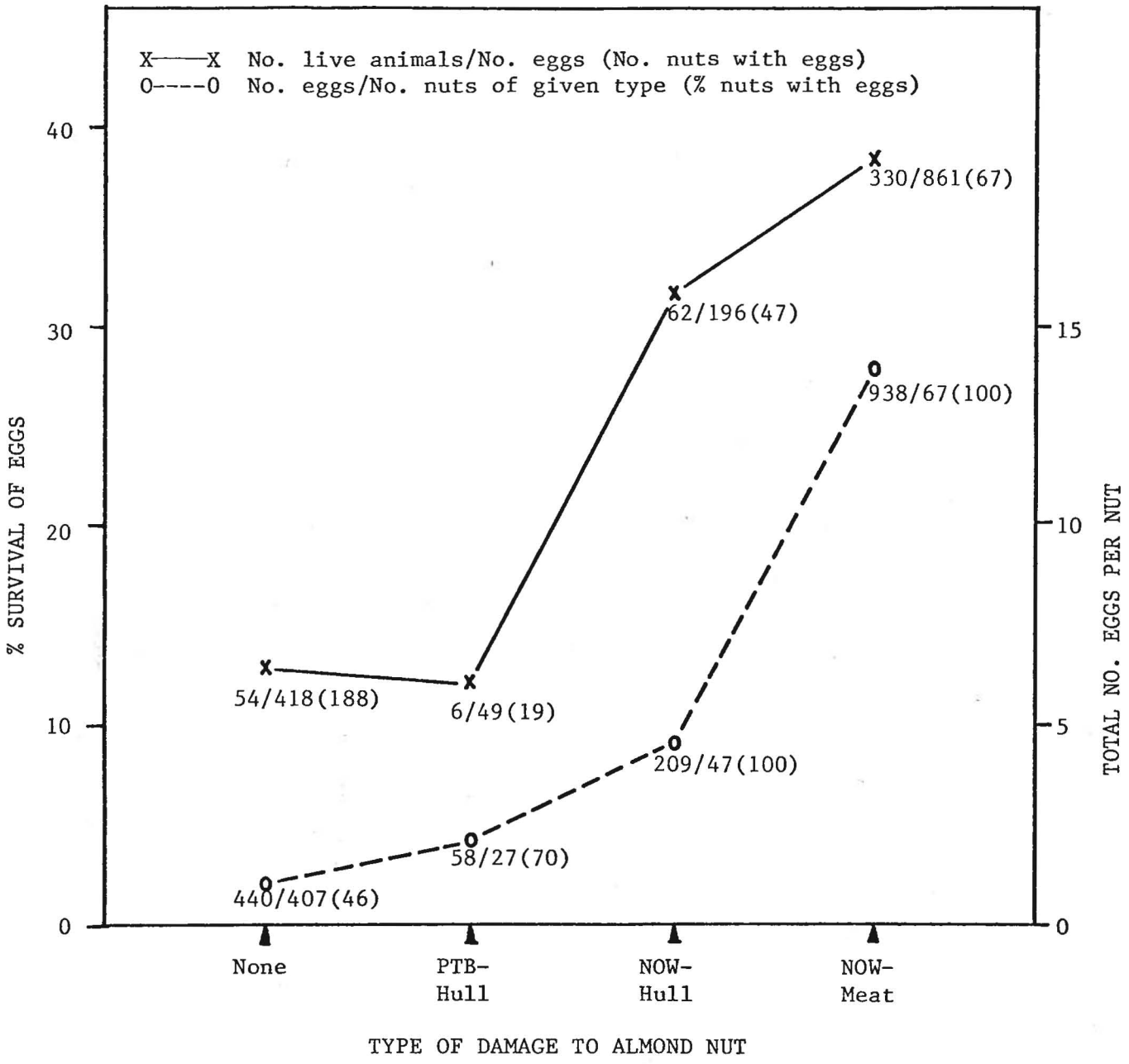


FIGURE 5 -- Total number of live eggs per nut with a given type of damage. Nonpareil variety of the 1978-crop collected in harvest tests of 8/11/78 through 9/1/78. Number by each point on graph is the number of nuts with a given type of damage on a given date.

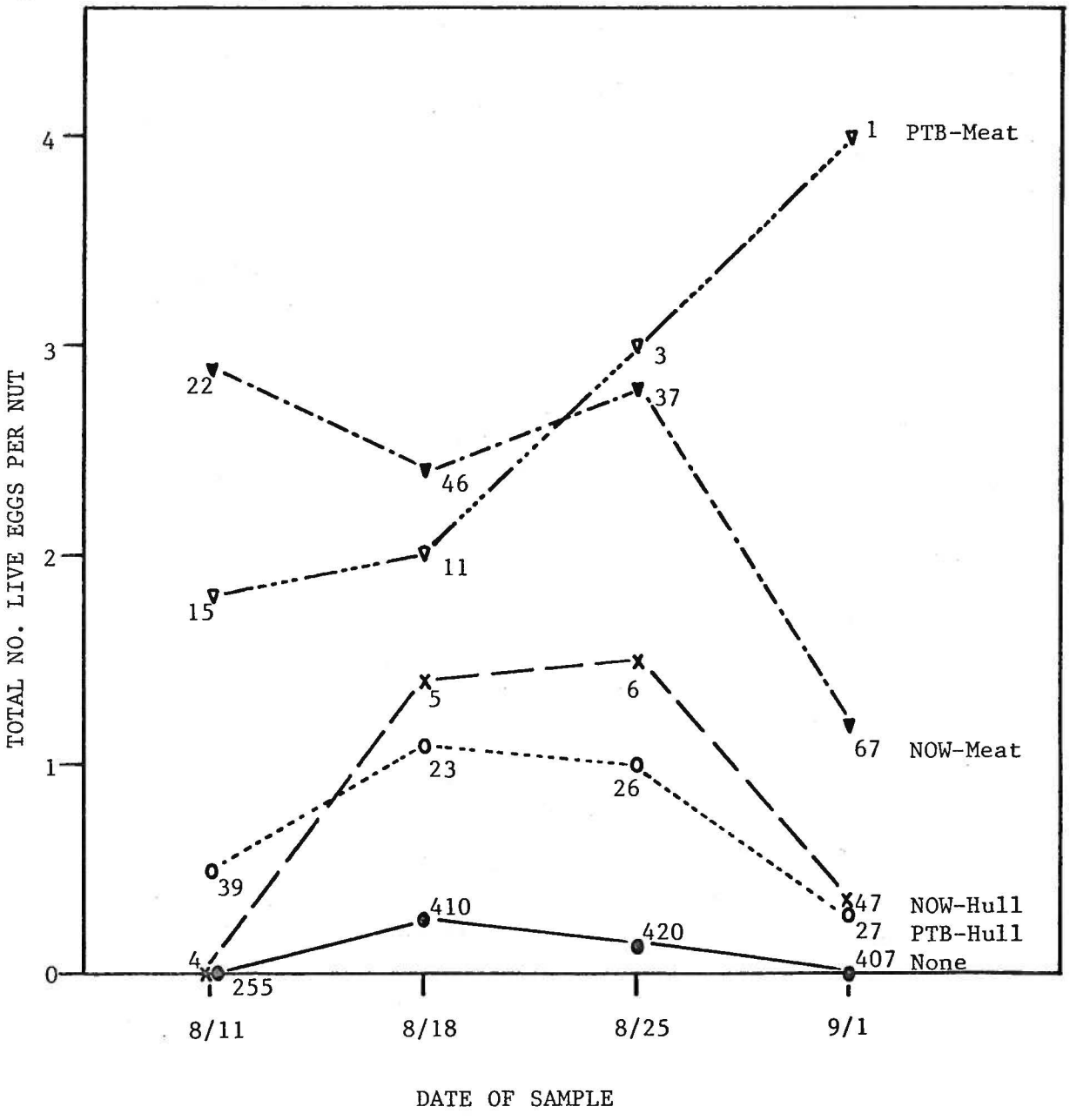


Table 1.--Number of mummy nuts per tree for the Ballico Test and Check areas. Comparisons of the 1975-1976-1977 Project years with the 1978-crop year in which some growers did their own dormant season cleanup.

	Test				Check			
	1975	1976	1977	1978	1975	1976	1977	1978
Neplus	<1	4	2	2	16	21	22	2
Nonpareil	2	8	4	3	22	25	33	2
Merced	3	13	9	6	34	48	50	9
Thompson	3	9	17	17	21	65	34	14
Drake	18	20	5	15	275	332	178	1
Davey	17	88	44	51	--	302	412	14
Mission	33	27	11	14	49	79	81	20

Table 2.--Merced County - grower example showing results of dormant spray for PTB plus winter cleanup plus one Sevin® spray after hull-split plus inhull fumigation of all varieties. (1977) — Dormant spray for PTB plus winter cleanup plus one Guthion® spray ca. 60 days before harvest plus no inhull fumigation (began Nonpareil harvest Sept. 10 and finished Merced harvest Sept. 23) (1978).

	% Total rejects by almond variety		
Crop Year	Nonpareil	Neplus	Merced
1978	3.0	3.8	6.3
1977	2.5	2.2	8.4
1976	9.9	9.5	15.9
1975	7.0	4.3	12.1
1974	3.6	6.1	10.2
1973	2.5	4.8	5.5
1972	5.8	3.3	4.2
1971	4.2	—	11.0

	Meat Pounds by almond variety					
	Nonpareil		Neplus		Merced	
Crop Year	Good + Reject	Reject	Good + Reject	Reject	Good + Reject	Reject
1978	28,148	846	4374	165	4128	258
1977	57,389	1438	12,653	279	12,817	1077
1976	53,310	5328	9658	927	12,476	1995
1975	42,054	2976	7246	313	11,832	1432
1974	33,998	1241	6655	406	9398	963
1973	24,187	628	3490	168	7289	403
1972	25,958	1506	4520	149	9442	397
1971	22,687	953	—	—	6459	710

Table 3.--Number of eggs, larvae and pupae as measures of infestation in almonds stored on the tree, in winrows, and spread out on the ground for Nonpareil variety for 1978-crop in Fresno.

Avg. no. viable NOW eggs/100 nuts[a]

	8/11	8/18	8/25	9/1
Tree	38a	59a	43a	31a
Winrow	5	<1	0	0
Spread	4	0	0	0

Avg. no. live small NOW larvae/100 nuts[a]

Tree	2a	30b	31b	48c
Winrow	0	<1	<1	0
Spread	0	1	<1	0

Avg. no. NOW larvae + pupae/100 nuts[a]

	Live	Dead	Live	Dead	Live	Dead	Live	Dead
Tree	10a	0	39b	<1	39b	<1	70c	2
Winrow	9	6	1	8	1	8	1	10
Spread	8	6	3	4	1	6	3	7

[a] Averages within a row followed by the same letter are not significantly different ($P > 0.05$) from each other using Duncan's multiple range test.

Table 4.--Percent rejects (by count) for various combinations of navel orangeworm (NOW) and peach twig borer (PTB) kernel damage in almonds stored on the tree, in winrows, and spread out on the ground for Nonpareil variety for 1978-crop in Fresno.

	Avg.[a] % kernel damage by (NOW) + (NOW + PTB)[b]			
	8/11	8/18	8/25	9/1
Tree	9.2a	17.2a	15.6a	18.6a
Winrow	10.6a	9.6b	9.6b	9.8b
Spread	9.4a	8.0b	11.4ab	10.6b

	Avg.[a] % kernel damage by (NOW) + (PTB) + (NOW + PTB)[b]			
Tree	15.4a	18.0a	16.0a	18.6a
Winrow	17.0a	15.0a	14.0a	16.8a
Spread	15.2a	15.2a	15.8a	16.2a

	Avg.[a] % kernel damage by NOW alone and PTB alone							
	NOW	PTB	NOW	PTB	NOW	PTB	NOW	PTB
Tree	7.0a	6.2a	11.8a	0.8a	11.8a	0.4a	16.8a	0a
Winrow	10.2a	6.4a	7.6b	5.2b	9.6a	4.4b	9.4b	7.0b
Spread	9.0a	5.4a	5.8b	7.0b	10.0a	4.4b	9.6b	5.4b

[a] Averages within a column followed by the same letter are not significantly different ($P > 0.05$) from each other using Duncan's multiple range test.

[b] Dual infestation by NOW and PTB.