April 25, 1986

Final Report (1985-1986)

BIOLOGICAL CONTROL OF NAVEL ORANGEWORM

Project No. 85-E12

E. F. Legner and L. E. Caltagirone

Divisions of Biological Control
University of California
Berkeley and Riverside

ABSTRACT

An integrated management scheme seems possible for navel orangeworm and peach twig borer in soft-shelled almonds. It entails maximizing the role of four imported parasitic insects by establishing a minimum overwintering mummy reservoir density and inundative releases with an egg parasite as a back-up for disruptions in the synchrony of other imported parasites with their hosts, caused primarily by unpredictable weather patterns. The acquisition of such data would require a minimum of 4 additional research years. Plans beyond June 30, 1986 are uncertain because of the unavilability of funds from any source.

[End of Abstract]

SUMMARY

Populations of navel oranageworm in six orchards (Paso Robles, Hilmar, Chowchilla, Selma, Wesley and Atwater) have been followed in an attempt to determine impact of the parasites Goniozus legneri, Goniozus sp. nr. emigratus and Copidosomopsis (= Pentalitomastix) plethoricus. A clear drop in the average density of NOW in the Paso Robles orchard is coincident with the establishment of Goniozus legneri. Data suggest that a similar relationship occurs at Hilmar and Chowchilla. Insufficient data are available for the other sites sampled.

Techniques to mass rear Trichogrammatoidea annulata and its laboratory host the Mediterranean flour moth (Anagasta kuehniella) have been improved. A total of 7,867,800 adults of T. annulata were released in almond orchards in the counties of Butte (4,036,000), San Joaquin (3,531,800) and San Luis Obispo (300,000). In addition, 3,610 adults of Goniozus legneri from northern Argentina were released in San Joaquin County.

Pre-release samples from a new release orchard in Butte Co. (Ballard Orchard) revealed the absence of Copidosomopsis and Goniozus; native Trichogramma californicum was present. Trichogrammatoidea annulata was released there. Harvest samples revealed 6.28% kernel damage in almonds from outside the release

plot (5 x 5 trees) while only 2.33% damage was found inside the plot. Transect sampling outside and through the plot in north-south and east-west directions showed that within and two rows beyond the plot area only Trichogrammatoidea annulata was present; while beyond two rows, only Trichogramma californicum was detected. T. annulata has been recovered also from the San Joaquin release sites.

During the last 4 to 6 years, a steady decline in the incidence of navel orangeworm parasites has been noticed, except in orchards where practices favor their persistence. Parasites such as Liotryphon nucicola, Scambus sp., Anachaetopsis tortricis, and Paraolinx typica that were commonly reared from NOW a few years ago, are now seldom collected.

Copidosomopsis plethoricus and Goniozus legneri, and to a lesser extent Goniozus sp. nr. emigratus overwinter in release orchards year after year. However, only Copidosomopsis can consistently be recovered at all times of the year. The Goniozus species are not recovered in significant numbers until early summer.

Goniozus legneri has been reared from codling moth and oriental fruit moth in peaches in the Paso Robles area in addition to NOW from almonds. Field data suggest that a certain number of old nuts (mummies) is necessary to maintain a desirable synchrony of these parasites with NOW to produce the lowest average densities (below 4% damage at harvest).

Future Research Emphases & Recommendations.--

1. A reappraisal of overwintering mummy density is essential. Empirical data indicate that two mummies/tree in February is too low for maximum carry-over of parasites to the next cropping period. An adequate reassessment will require that a minimum of 20 random trees from three orchards, <40 acres each, be sampled beginning in December and extending until mid July. An estimation of total mummies per tree will have to be made, and an aliquot sample of mummies be incubated under controlled laboratory conditions in screened vials for the emergence of living NOW and parasites. The incubation period will require a minimum of 4 months. It seems that the most critical periods for mummy presence in the tree scaffold will be in September-October and May-July, when outdoor temperatures are favorable for the reproduction of key imported parasites. Thus, instead of delimiting a certain number of mummies per tree in February, it may be necessary to determine a minimum number both in autumn and spring. Depending on weather after February, the number of mummies in the critical parasite reproductive months of May-July may or may not correlate with those found in mid-winter.

2. Almond mummies that fall to the ground over the winter should be gathered into screened containers and located in rain-protected areas within the orchards only if the number of boreal mummies falls below the minimum as determined in #1 above.

Hanging such containers in trees is not recommended because exposure there to wind, desiccation and low temperatures causes greater mortality.

3. New parasitic strains which have evolved in a few orchards through rapid natural selection, should be spread directly without culture to other parts of the state. This would accelerate the impact of climatically adapted strains statewide. Evolution of similar strains in other orchards would be expected to occur, but in an undefined length of time based on a number of random and nonrandom events.

4. _Trichogrammatoidea_ _annulata_ is one of the extremely rare effective boreal trichogrammatid parasites known to science. Additionally, its ability to effectively kill lepidopterous eggs in the small size range typified by NOW, makes it unique. Its potential in inundative biological control may be great; and it is cost competitive with insecticides. Further research emphasis ought to be given to this parasite for integration into the almond pest management scheme. It could prove especially valuable in years when inclement weather interferes with parasite winter survival.

DETAILED POPULATION TRENDS

Following are details of data gathered from 6 central California Nonpareil almond orchards in which Copidosomopsis plethoricus, Goniozua legneri and Goniozus sp. nr. emigratus have been established.

Navel Orangeworm Density--There is a clear drop in the average density of NOW in the Paso Robles area coincident with the establishment of Goniozus species (Figs. 1 & 2). A similar relationship is apparent at Hilmar (Fig. 4) and Chowchilla (Fig 11). However, at Selma (Fig. 5) insufficient data has been gathered since parasite introduction to establish trends; and at Wesley and Atwater (Figs. 7 & 9) the data are confounded with a high incidence of peach twig borer attacking almonds at harvest (due to inadequate dormant sprays).

The relationship between total Nonpareil rejects and yields at harvest is significantly negative only at Hilmar and Atwater (see Tables). In all other orchards, either there is no correlation or a trend exists for a positive correlation, probably indicating the importance of neighboring NOW reservoirs on these orchards. In Atwater the high 25.66% rejects at the 1983 harvest (Fig. 9) occurring after Goniozus establishment may be a function of an especially low yield in that year (Table 5).

Parasite Overwintering.--Copidosomopsis plethoricus and

Goniozus legneri overwinter in release orchards year after year. However, only *C. plethoricus* can always be detected year round by sampling mummies. *Goniozus* is not recovered in significant numbers after December or before early summer (following several weeks of warm weather) (Table 2). Thus, it appears that *Goniozus* either reduces its population density drastically every winter, or it migrates to another habitat or environment for the colder months. The bark of trees is one favored overwintering site.

Alternate Hosts.--*Goniozus legneri* has now been reared from codling moth and oriental fruit moth in peaches in the Paso Robles area. *Goniozus* sp. nr. *emigratus* has been found capable of reproduction on the peach twig borer in the laboratory. Field recoveries of parasites were verified by cross-mating with laboratory cultures.

Importance of Overwintering Mummies.--A high number of overwintering mummies may be essential to produce the lowest NOW densities in orchards where imported parasites are established. This is evidenced by the situation in Orchard No. 1 at Paso Robles which yearly averages high mummy densities per tree (100-1000+), and where many Nonpareil trees are never harvested. All other orchards in the current study had partial to thorough mummy removal (2 mummies/tree) rendered either by inclement weather or by manual labor. In such orchards *Goniozus* are unable to build-up to significant numbers during May-July. Recolonization from neighboring orchards is of prime importance in those areas.

Influence of Neighboring Walnuts.--Most walnuts sustain a low incidence of NOW (usually below 2% infested mummies by August). Since new-crop walnuts are still green at this time, it seems probable that the NOW population, unable to find suitable oviposition sites, migrates to neighboring hull-cracking almonds in July and August. *Goniozus* is capable of overwintering in walnut groves, and in the Riverside area has reduced high NOW infestations from <20% in October to >0.5% at two sites.

Proportion of Peach Twig Borer in Almond Rejects.--An estimate of the damage caused by the peach twig borer, *Anarsia lineatella* Zeller, has been made whenever possible at the time of harvest. The information obtained is printed on the top of each graph as a percentage of total rejects. Almond processing plants have just begun to cooperate in furnishing this data, although varieties are not clearly distinguished. It is apparent that in some orchards the twig borer constituted a significant proportion of the the total rejects. *Goniozus* can attack twig borer while it occurs in the almond, but is incapable of locating this insect on the bark and twigs and in the June drops. Thus, until now twig borer has been able to escape significant parasitism. A new import from Pakistan, *Goniozus pakmanus* Gordh, may have a greater capacity to reduce twig borer in its peculiar niche, but field experiments with this species have yet to be extended.

FIG. 1. Estimates of Nonpareil rejects at harvest at Orchard #1 in the Paso Robles area.

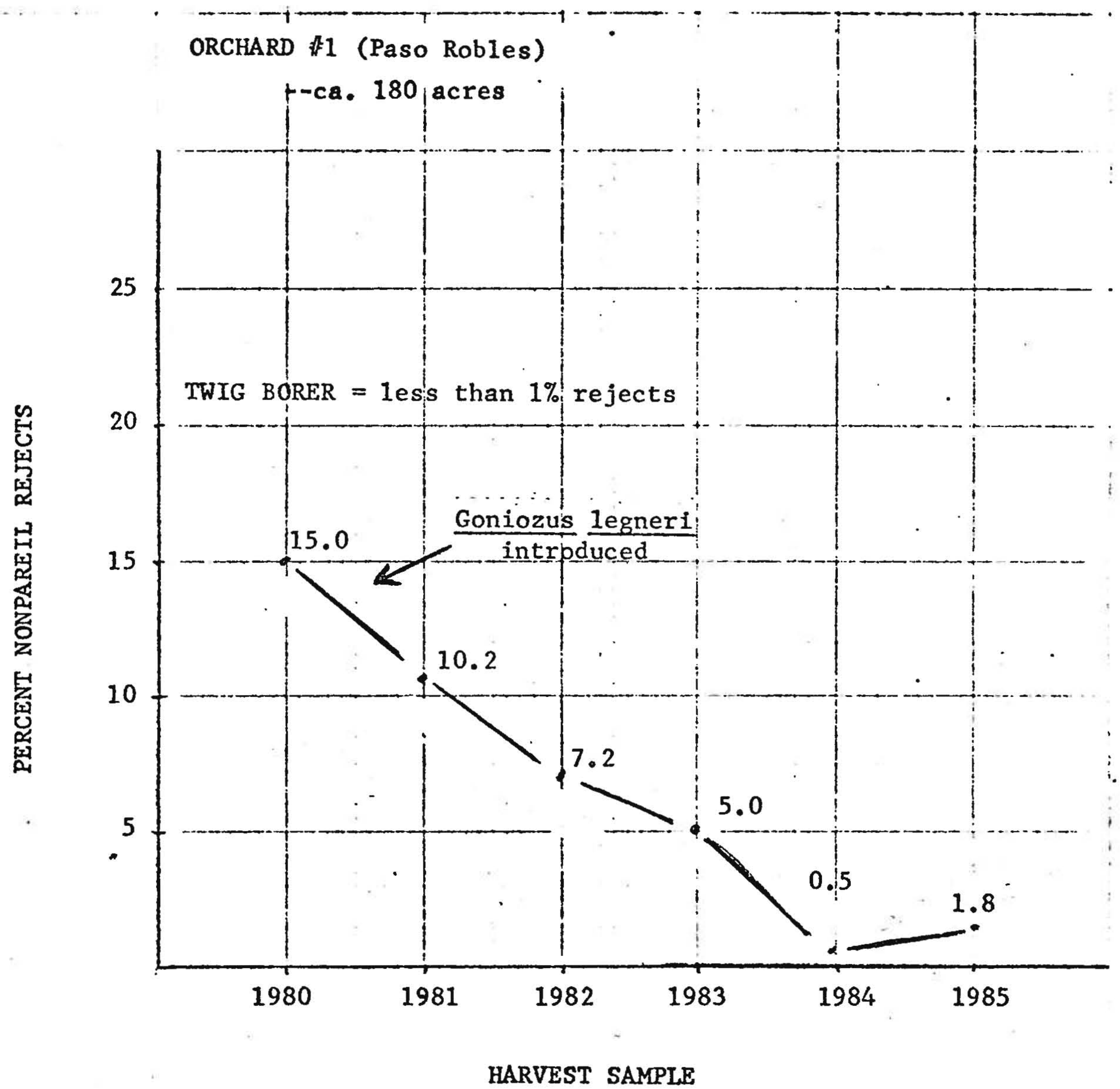


FIG. 2. Percent infested Nonpareil mummies sampled in the first week of December at Orchard #1 in the Paso Robles area.

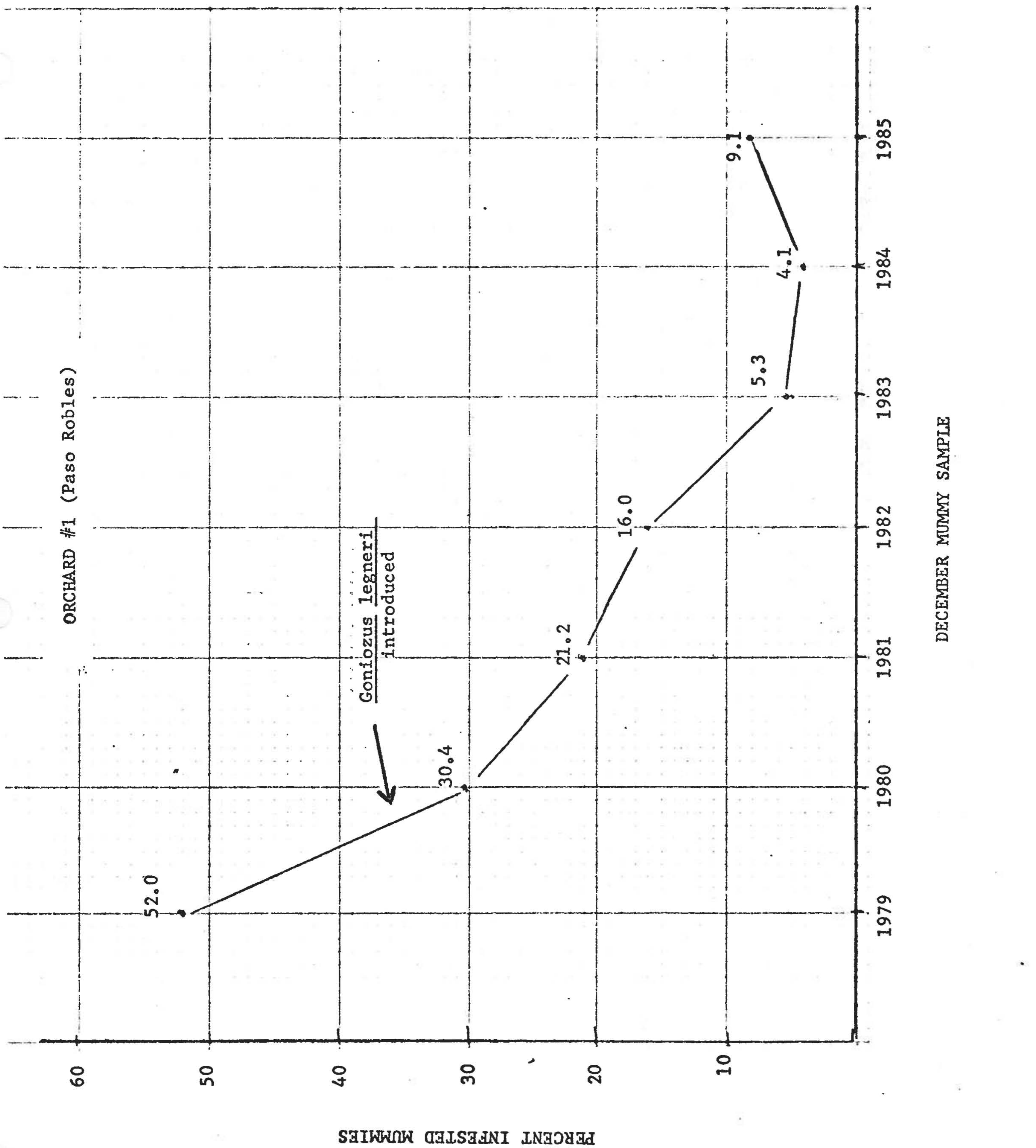


FIG. 3. Relationship between % Nonpareil rejects and orchard yield at Orchard #1 in the Paso Robles area.

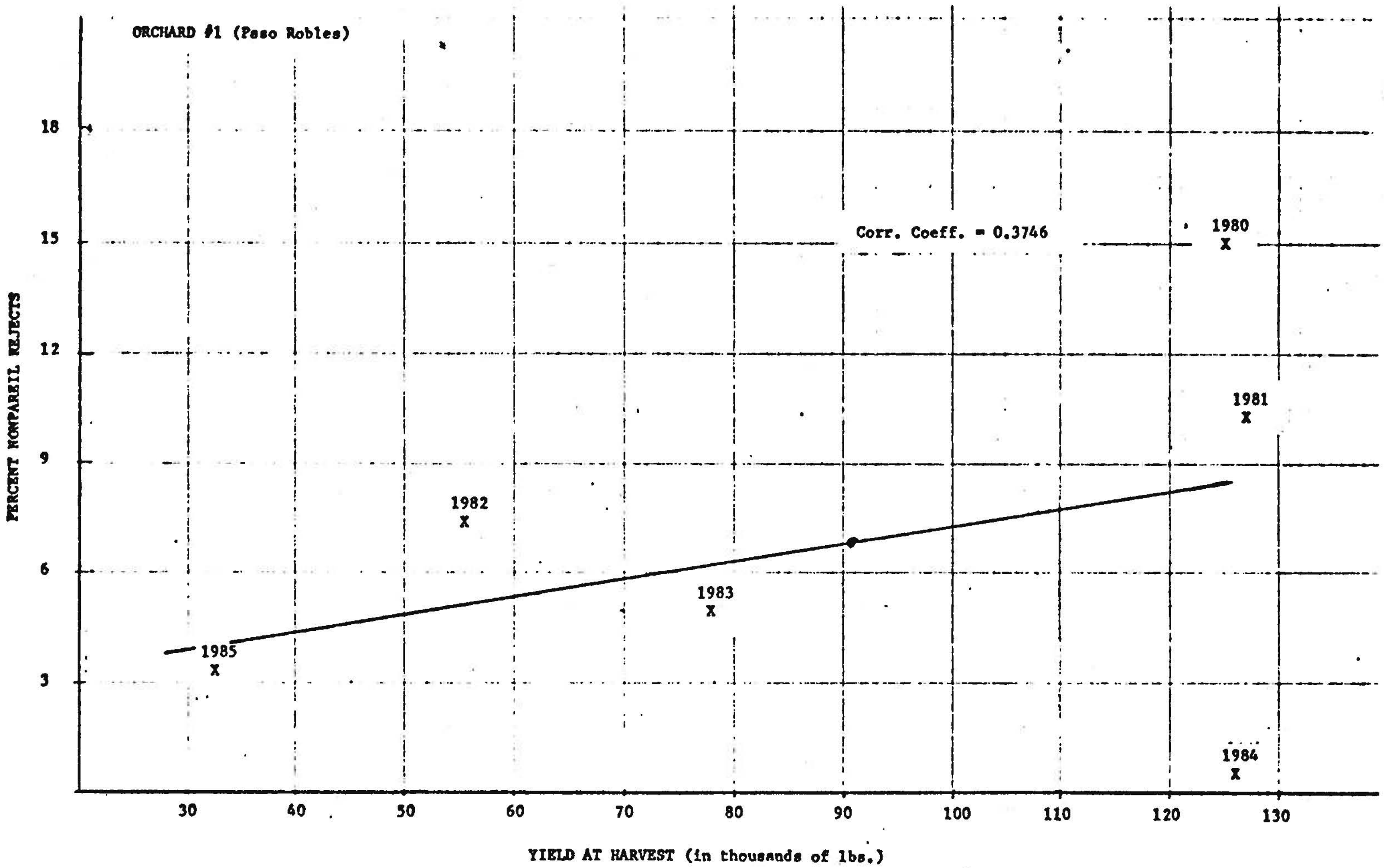


Table 1. Data for Figure 3.

ORCHARD #1 (Paso Robles)

X = estimate of total good meats (lbs.)
Y = total rejects

X	Y	
125000.000	15.000	1980
126000.000	10.200	1981
55000.000	7.200	1982
78000.000	3.000	1983
125000.000	0.500	1984
32000.000	3.300	1985

NUMBER PAIRS = 6
MEAN OF X = 90166.66 OF Y = 6.866667
SLOPE = 4.710948E-05 (= b)
Y-INTERCEPT = 2.618963 (= a)

SUM-OF-SQUARES

TOTAL	417.02
MEAN	282.9067
SLOPE	18.81709
RESIDUAL	115.2962

STANDARD DEVIATIONS

X	41179.68
Y	5.17906
ERROR	5.368803
Y-BAR	2.191805
SLOPE	5.83055E-05
Y-INTER.	3.695813

F-RATIO FOR SLOPE = .6528261
t-TEST FOR SLOPE = .8079766 df = 4
CORRELATION COEFFICIENT = .3745763

COORDINATES FOR REGRESSION LINE

Y1 = 6.866667 for X = 90166.66 (= original computed intercept)

Y2 = 4.742815 for X = 45083.33
Y3 = 6.017126 for X = 72133.33
Y4 = 7.716208 for X = 108200
Y5 = 8.565748 for X = 126233.3

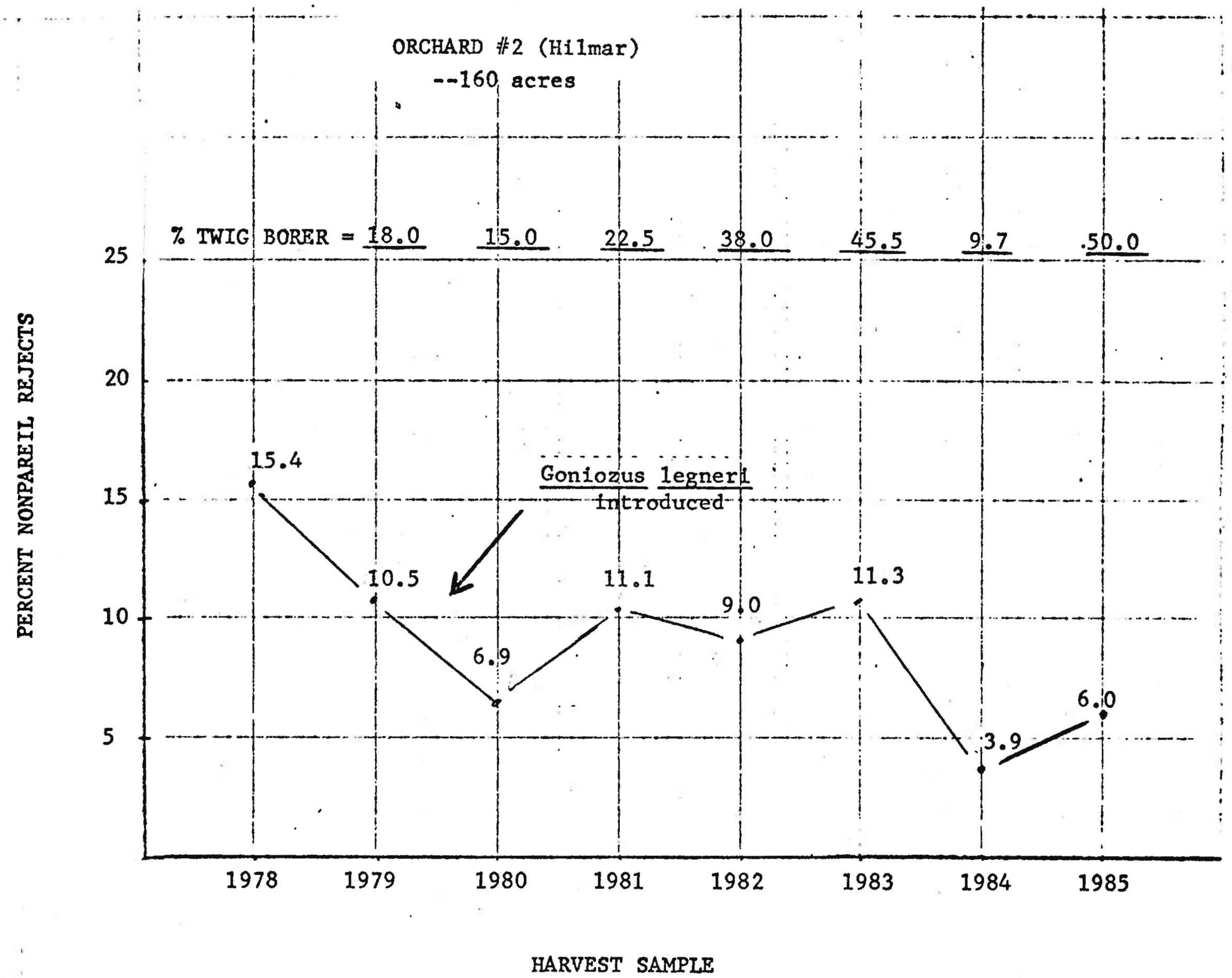
Table 2. Nonpareil mummies sampled in spring 1985 at Orchard #1 in the Paso Robles area, and parasitization by two principal parasites.

ORCHARD #1 (Paso Robles)

Spring Mummy Sample (1985)

SAMPLE SIZE	% Infested Mummies	% Navel Orangeworm Parasitized	
		Pentalitomastix	Goniozus
16 May 1985			
2,000	4.89	4.72	0
26 June 1985			
2,800	1.39	3.85	26.92

FIG. 4. Nonpareil rejects at harvest at Orchard #2 in the Hilmar area.



ORCHARD #2 (Hilmar)

X = total good meats (lbs.)
Y = % rejects

X	Y	
88987.000	15.400	1978
54439.000	10.500	1979
79978.000	6.900	1980
75689.000	11.100	1981
102338.000	9.000	1982
32586.000	11.300	1983
195360.000	3.900	1984
125379.000	6.000	1985

NUMBER PAIRS = 8
MEAN OF X = 94344.5 OF Y = 9.262501
SLOPE = -4.956087E-05 (= b) Y-INTERCEPT = 13.9383 (= a)

SUM-OF-SQUARES

TOTAL	778.1301
MEAN	686.3514
SLOPE	42.29924
RESIDUAL	49.47945

STANDARD DEVIATIONS

X	49599.62
Y	3.620945
ERROR	2.871685
Y-BAR	1.015294
SLOPE	2.188313E-05
Y-INTER.	2.300696

F-RATIO FOR SLOPE = 5.129309
t-TEST FOR SLOPE = 2.264798 df = 6
CORRELATION COEFFICIENT = -.6788837

COORDINATES FOR REGRESSION LINE

Y1 = 9.262501 for X = 94344.5 (= original computed intercept)

Y2 = 11.6004 for X = 47172.25
Y3 = 10.19766 for X = 75475.6
Y4 = 8.327341 for X = 113213.4
Y5 = 7.392183 for X = 132082.3

FIG. 5. Nonpareil rejects at harvest at Orchard #3 in the Selma area.

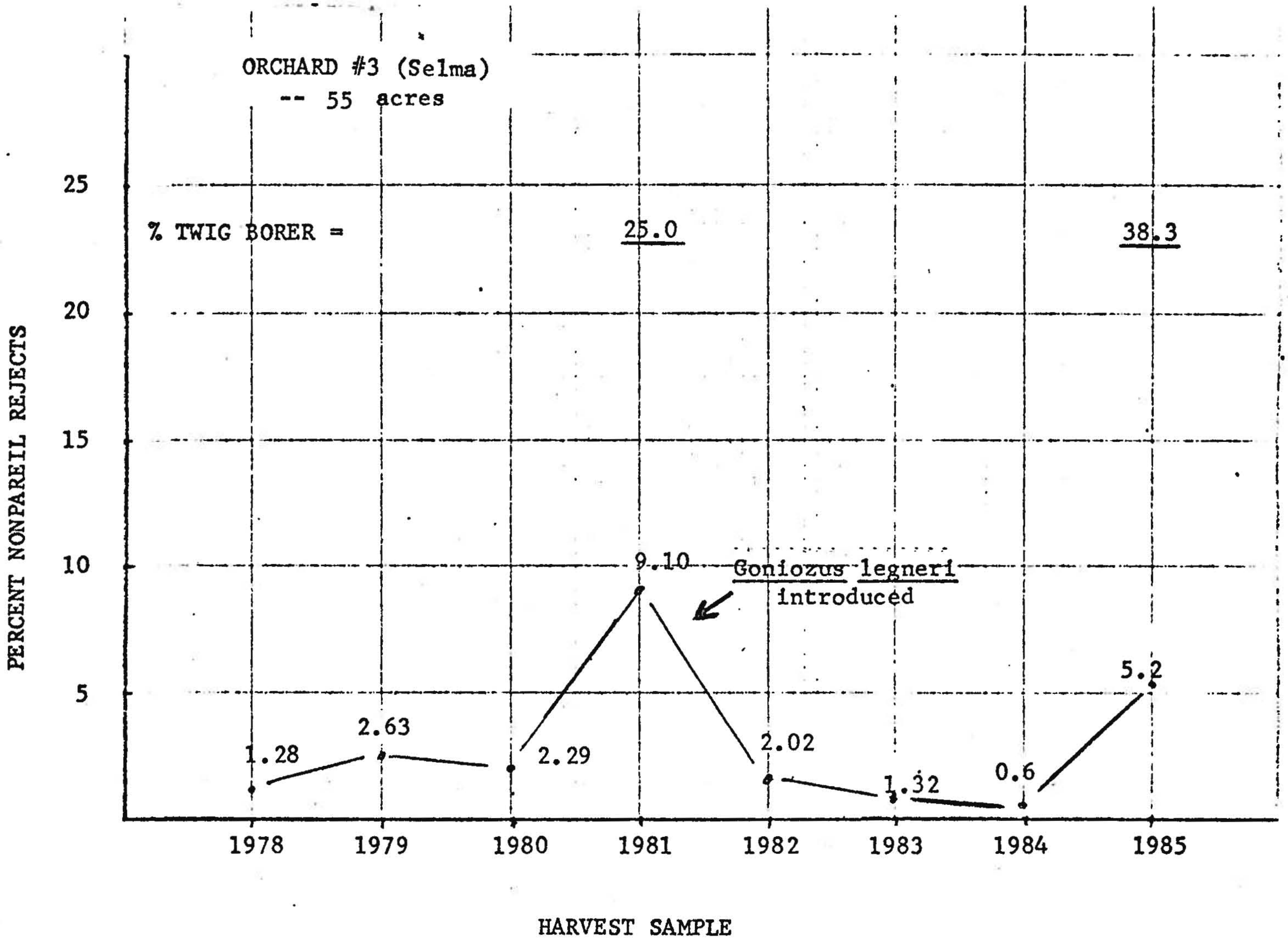


FIG. 6. Relationship between % Nonpareil rejects and orchard yield at Orchard #3 in the Selma area.

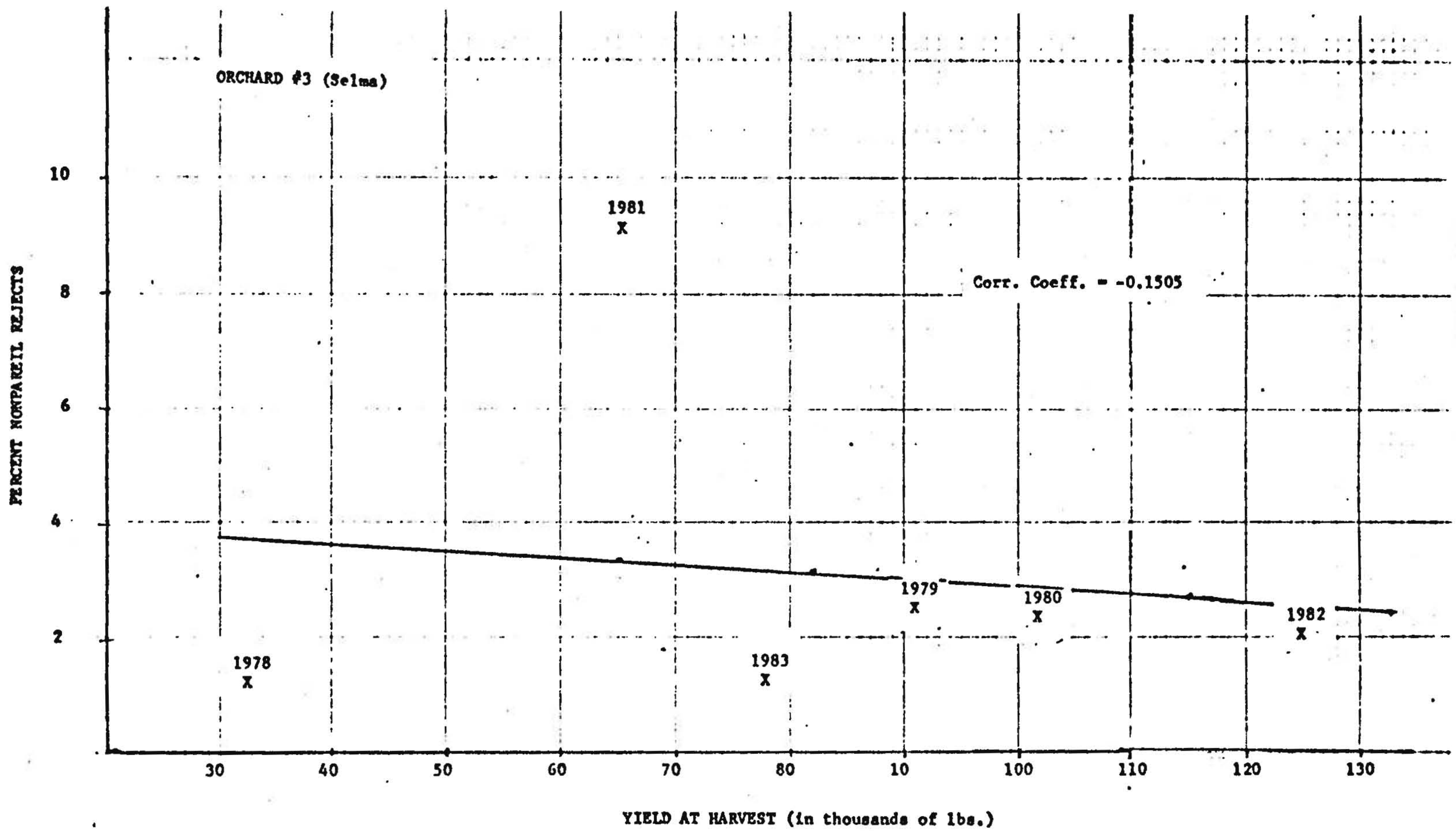


Table 3. Data for Figure 6.

ORCHARD #3 (Selma)

X = total good meats (lbs.) .
Y = % rejects

X	Y	
32798.000	1.280	1978
90191.000	2.630	1979
101538.000	2.290	1980
65130.000	9.100	1981
125210.000	2.020	1982
78203.000	1.320	1983

NUMBER PAIRS = 6
MEAN OF X = 82178.34 OF Y = 3.106667
SLOPE = -1.41519E-05 Y-INTERCEPT = 4.269647
(= b) (= a)

SUM-OF-SQUARES

TOTAL	102.4322
MEAN	57.90827
SLOPE	1.008509
RESIDUAL	43.51543

STANDARD DEVIATIONS

X	31735.11
Y	2.984089
ERROR	3.298311
Y-BAR	1.34653
SLOPE	4.648006E-05
Y-INTER.	4.030049

F-RATIO FOR SLOPE = 9.270356E-02
t-TEST FOR SLOPE = .3044726 df = 4
CORRELATION COEFFICIENT = -.1505023

COORDINATES FOR REGRESSION LINE

Y1 = 3.106667 for X = 82178.34 (= original computed intercept)

Y2 = 3.688157 for X = 41089.17
Y3 = 3.339263 for X = 65742.68
Y4 = 2.874071 for X = 98614.01
Y5 = 2.641475 for X = 115049.7

FIG. 7. Nonpareil rejects at harvest at Orchard #4 in the Wesley area.

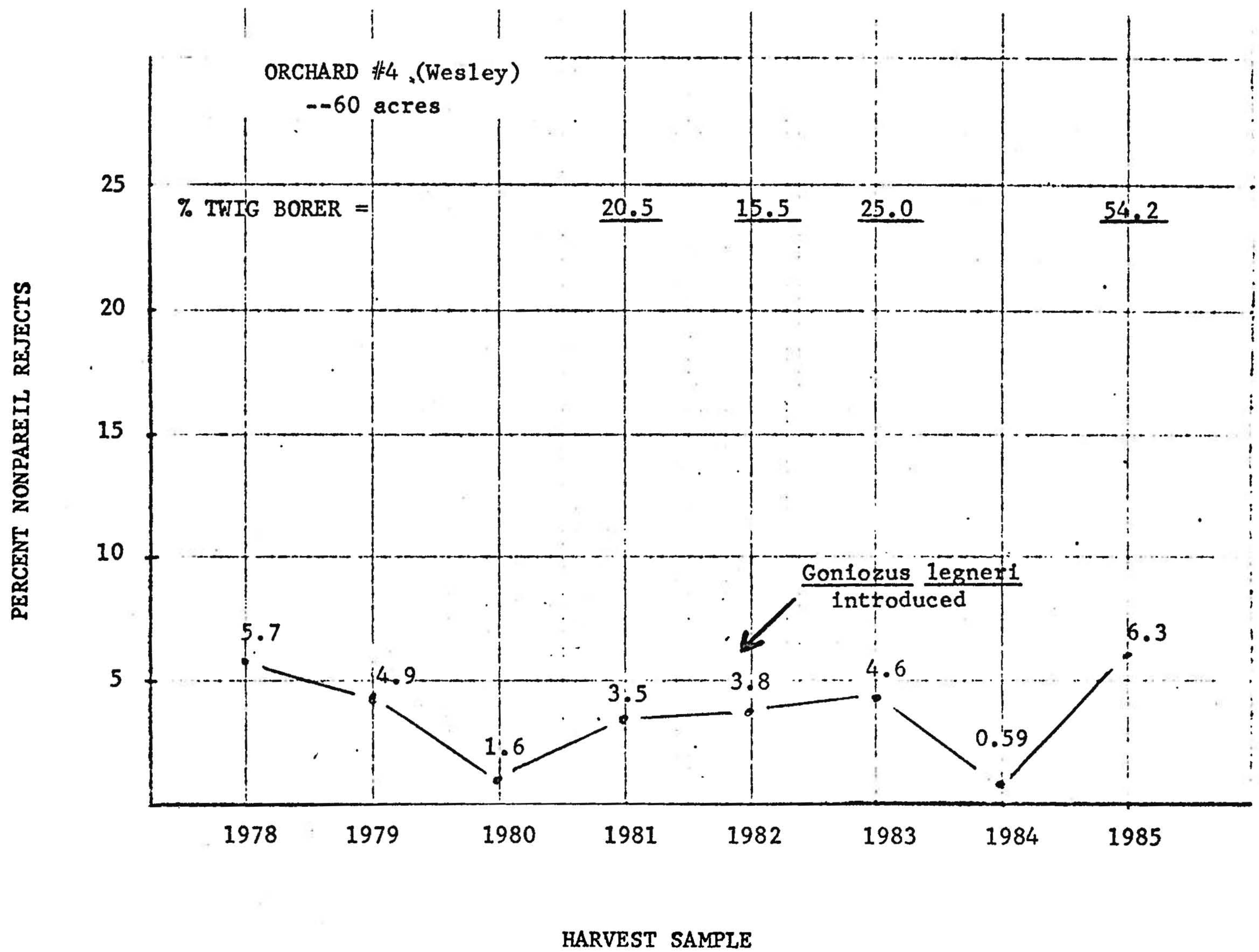


FIG. 8. Relationship between % Nonpareil rejects and orchard yield at Orchard #4 in the Wesley area.

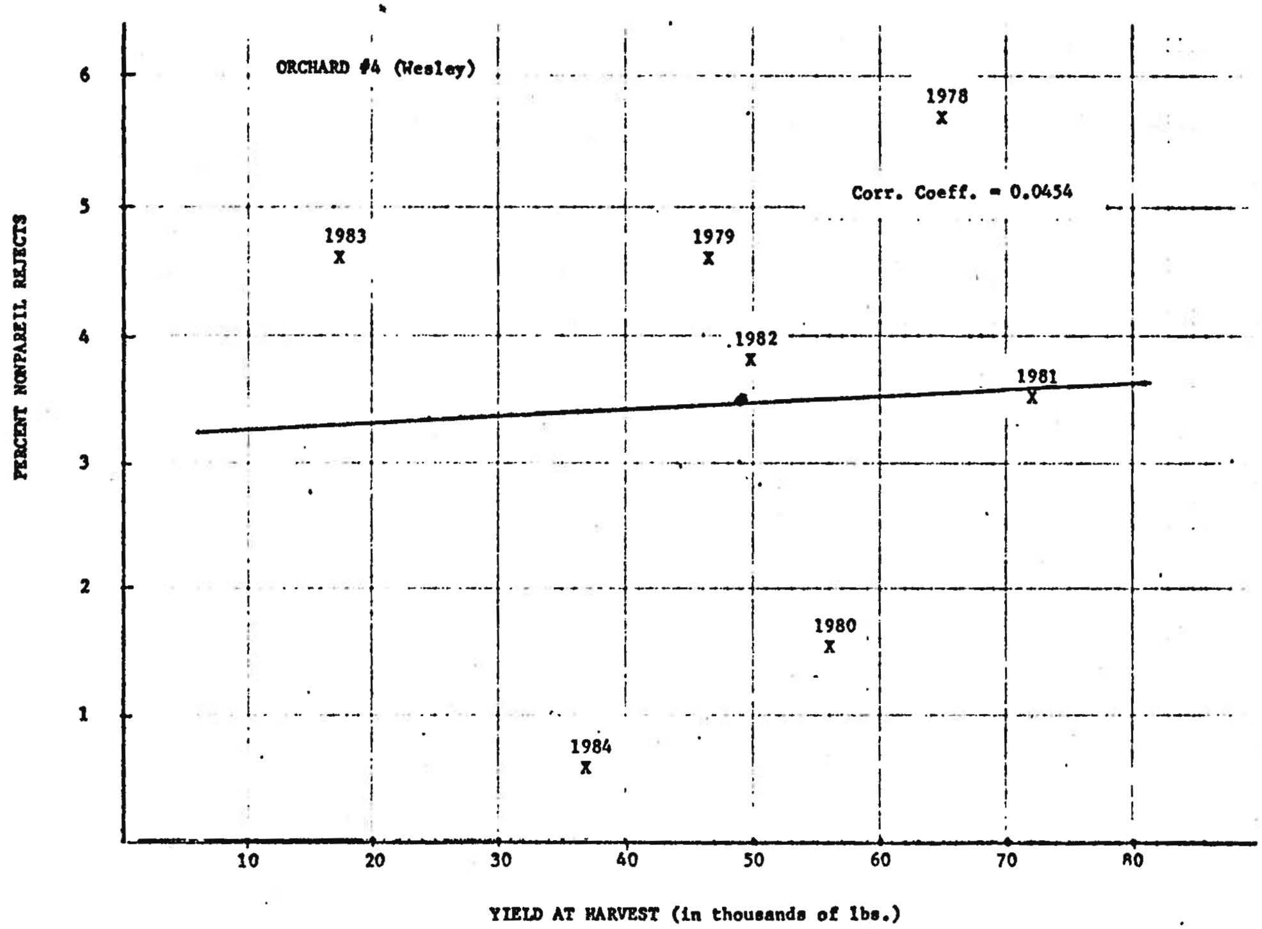


Table 4. Data for Figure 8.

ORCHARD #4 (Wesley)

X = total good meats (lbs.)
Y = % rejects

X	Y	
60518.000	5.700	1978
46237.000	4.600	1979
56052.000	1.600	1980
71653.000	3.500	1981
49918.000	3.800	1982
17296.000	4.600	1983
37195.000	0.590	1984

```
NUMBER PAIRS =  7
MEAN OF X =  48409.86          OF Y =  3.484286
SLOPE =  4.653136E-06                          Y-INTERCEPT =  3.259028
 (= b)                                          (= a)

SUM-OF-SQUARES
               TOTAL          104.4081
               MEAN           84.98172
               SLOPE          3.997102E-02
               RESIDUAL       19.38641

STANDARD DEVIATIONS
                X             17540.88
                Y             1.799369
               ERROR          1.969081
               Y-BAR          .7442428
               SLOPE          4.582862E-05
               Y-INTER.       2.340063

F-RATIO FOR SLOPE =  1.030903E-02
t-TEST FOR SLOPE =  .1015334    df =  5
CORRELATION COEFFICIENT =  4.536038E-02

COORDINATES FOR REGRESSION LINE

Y1 =  3.484286 for X =  48409.86  (= original computed intercept)

Y2 =  3.371657 for X =  24204.93
Y3 =  3.439234 for X =  38727.88
Y4 =  3.529337 for X =  58091.83
Y5 =  3.574389 for X =  67773.8
```

FIG. 9. Nonpareil rejects at harvest at Orchard #5 in the Atwater area.

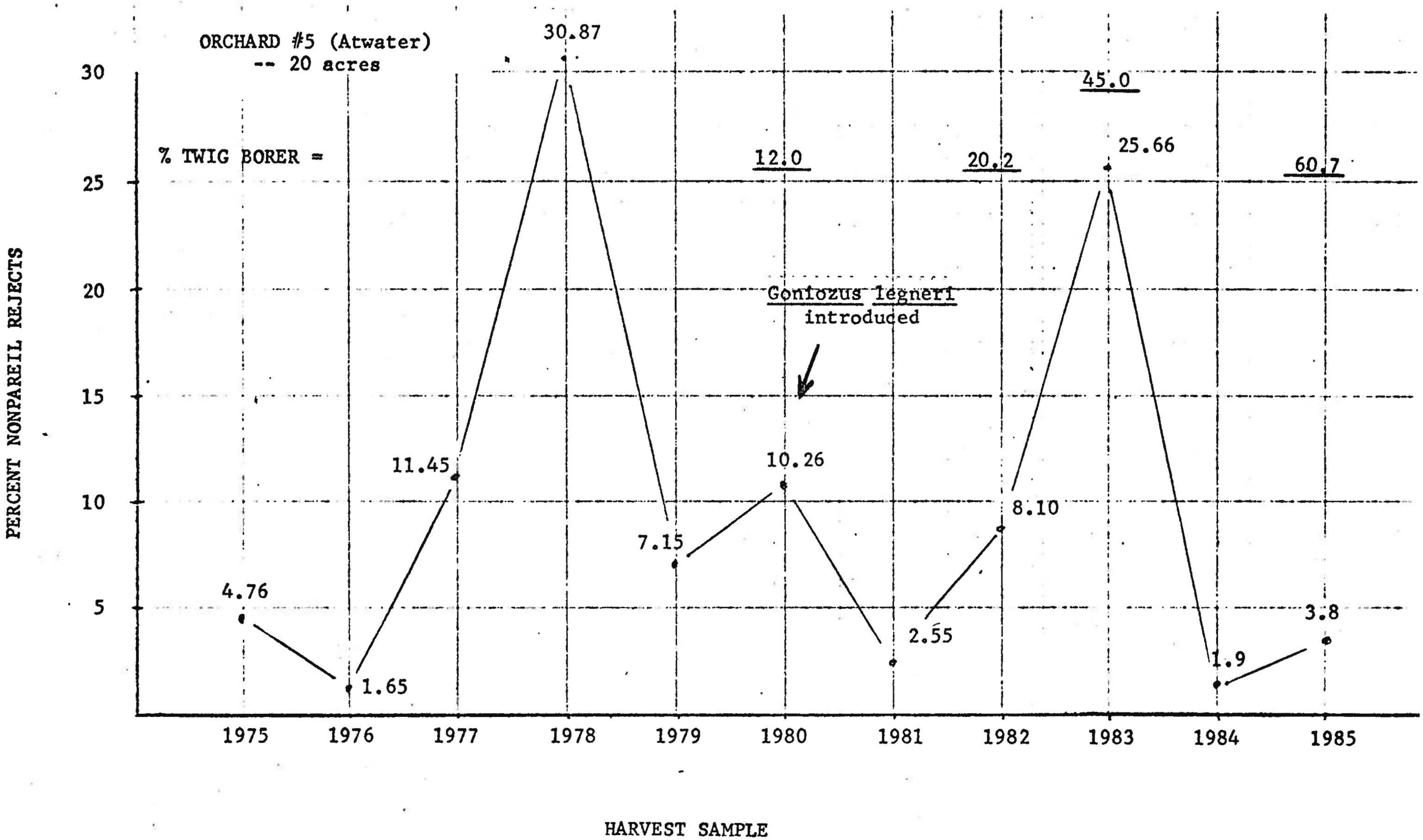


FIG. 10. Relationship between % Nonpareil rejects and orchard yield at Orchard #9 in the Atwater area.

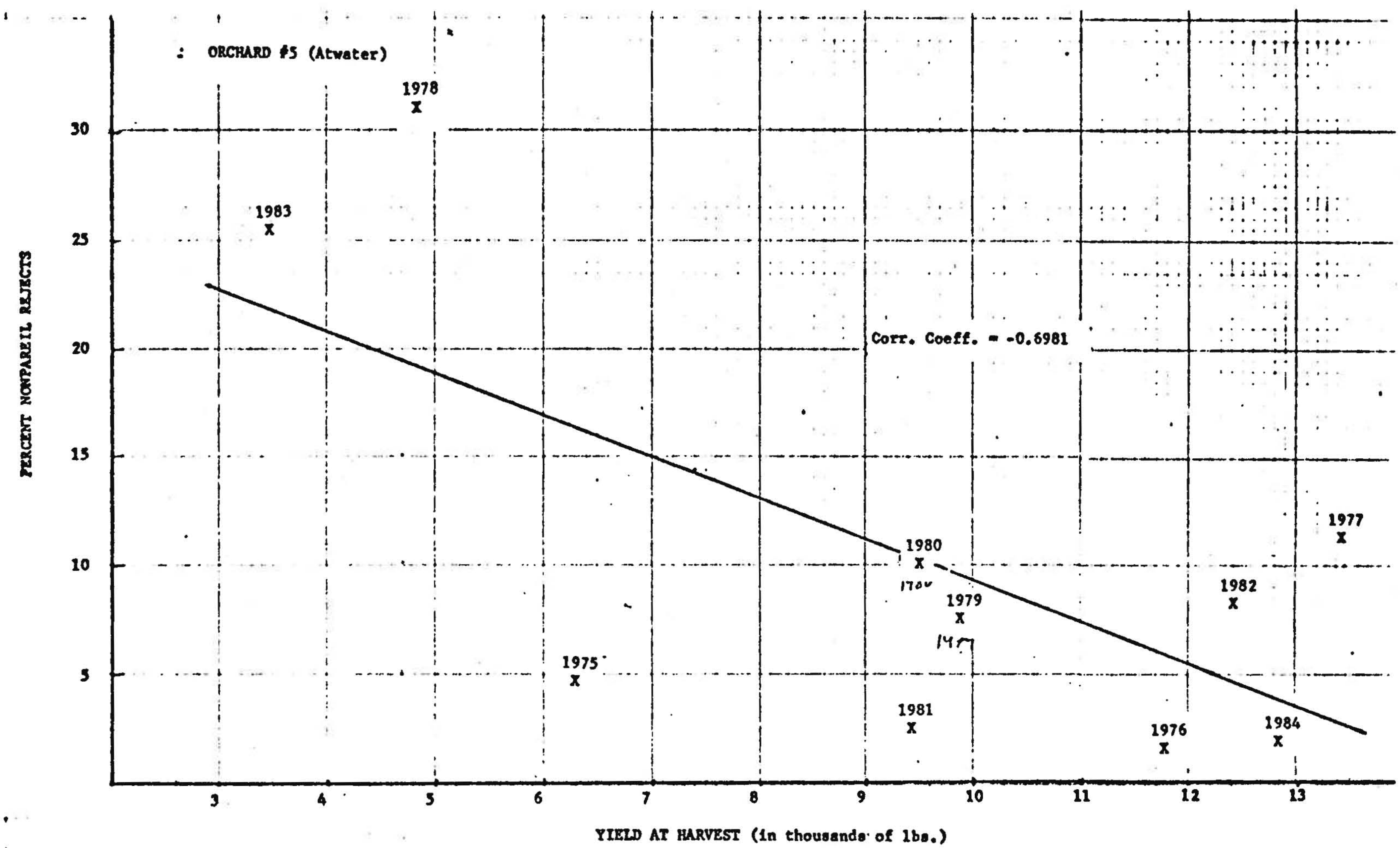


Table 5. Data for Figure 10.

ORCHARD #5 (Atwater)

X = total good meats (lbs.)
Y = % rejects

X	Y	
6238.000	4.760	1975
11846.000	1.650	1976
13488.000	11.450	1977
4830.000	30.870	1978
9847.000	7.150	1979
9411.000	10.260	1980
9423.000	2.550	1981
12477.000	8.100	1982
3476.000	25.660	1983
12839.000	1.900	1984

NUMBER PAIRS = 10
MEAN OF X = 9387.5 OF Y = 10.435
SLOPE = -2.007564E-03 (= b) Y-INTERCEPT = 29.28101 (= a)

SUM-OF-SQUARES

TOTAL	1999.987
MEAN	1088.892
SLOPE	444.0001
RESIDUAL	467.0952

STANDARD DEVIATIONS

X	3498.652
Y	10.06145
ERROR	7.641132
Y-BAR	2.416338
SLOPE	7.280071E-04
Y-INTER.	7.24876

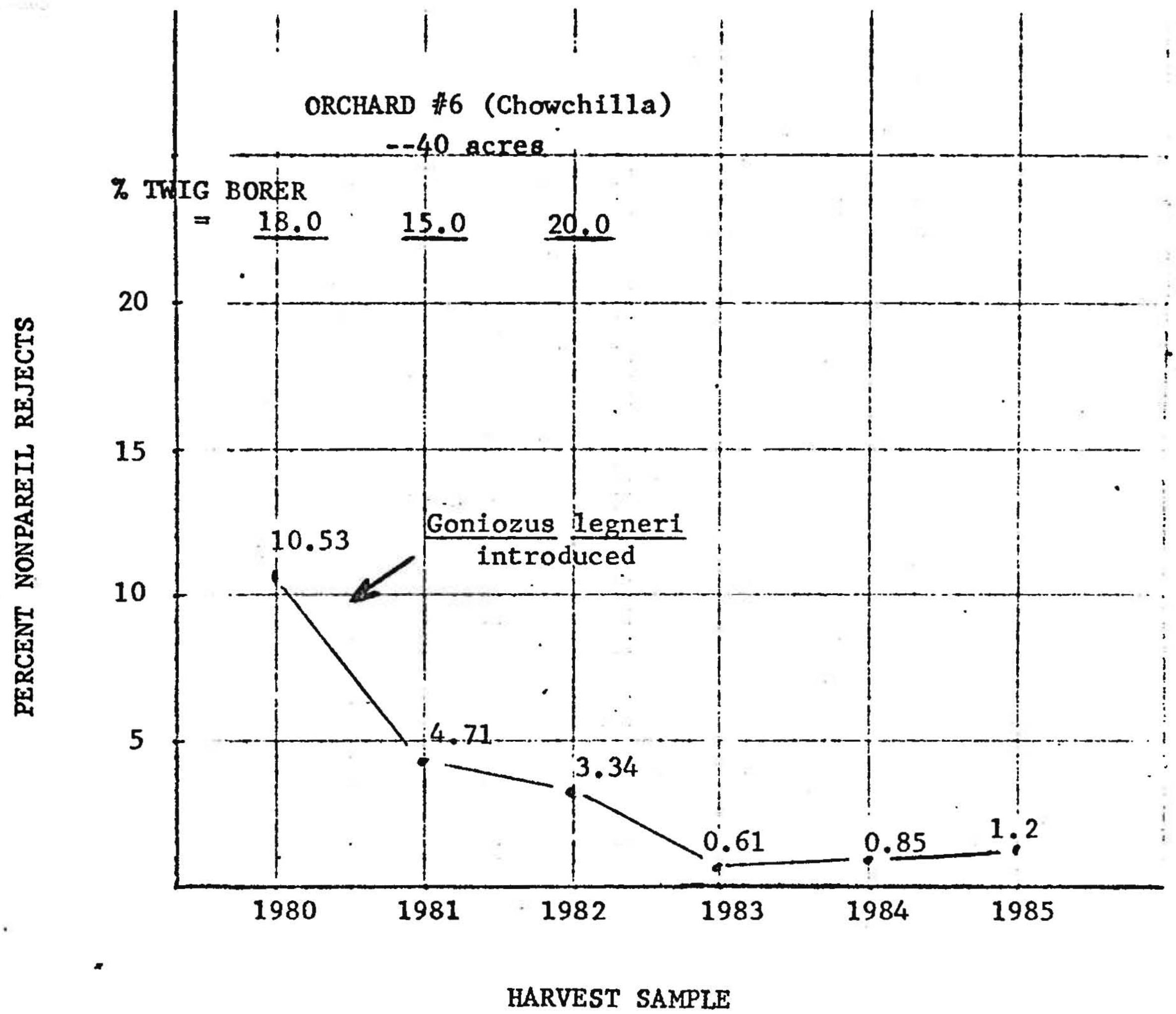
F-RATIO FOR SLOPE = 7.604448
t-TEST FOR SLOPE = 2.757616 df = 8
CORRELATION COEFFICIENT = -.6980871

COORDINATES FOR REGRESSION LINE

Y1 = 10.435 for X = 9387.5 (= original computed intercept)

Y2 = 19.85801 for X = 4693.75
Y3 = 14.2042 for X = 7510
Y4 = 6.665798 for X = 11265
Y5 = 2.896595 for X = 13142.5

FIG. 11. Nonpareil rejects at harvest at Orchard #6 in the Chowchilla area.



BIOLOGICAL CONTROL OF NAVEL ORANGEWORM

Semi-annual Report

December 1985

PREPARED BY E.F. LEGNER

Project No. 85-E12 - Navel Orangeworm, Mite and Insect Research
Biological Control of Navel Orangeworm
(Continuation of Project No. 84-E11)

Project Leaders: Dr. E. F. Legner (714) 787-5709 or 787-4674
Division of Biological Control
University of California
Riverside, CA 92521

Dr. L. E. Caltagirone (415) 642-4230
Division of Biological Control
University of California
Berkeley, CA 94720

Objectives: (1) Assess the impact of established parasites, with the goal of determining if the action of firmly established natural enemies will lead to acceptable harvest time orangeworm damage in orchards with higher mummy levels. (2) Further explore management tactics like caging mummy almonds which would make biological control more compatible with navel orangeworm control practices like orchard sanitation. (3) Continue mass production and release of natural enemies which are established and are having an apparent impact on navel orangeworm. (4) Exploration for additional parasites will be a secondary activity.

Project 85-E12

Biological Control of Navel Orangeworm

E. F. Legner and L. E. Caltagirone
Project Leaders

SUMMARY REPORT

Populations of navel orangeworm in six orchards (Paso Robles, Hilmar, Chowchilla, Selma, Wesley and Atwater) have been followed in an attempt to determine impact of the parasites Goniozus legneri and Copidosomopsis (=Pentalitomastix) plethoricus. A clear drop in the average density of NOW in the Paso Robles orchard is coincident with the establishment of Goniozus legneri. Data suggest that similar relationship occurs at Hilmar and Chowchilla. No sufficient data are available for the other sites sampled.

Techniques to mass rear Trichogrammatoidea annulata and its laboratory host the Mediterranean flour moth (Anagasta kuehniella) heve been improved. A total of 7 867 800 adults T. annulata were released in almond orchards in the counties of Butte (4 036 000), San Joaquin (3 531 800) and San Luis Obispo (300 000). In addition 3 610 adults of Goniozus legneri of Argentinian origin were released in San Joaquin County.

Pre-release samples from a new release orchard in Butte Co. (Ballard Orchard) revealed absence of Copidosomopsis and Goniozus; native Trichogramma californicum was present. Trichogrammatoidea annulata was released here. Harvest time samples revealed 6.28% kernel damage in nuts from outside the release plot (5 x 5 trees) while 2.33% was detected inside the plot. Transect sampling outside and through the plot in N-S and E-W directions revealed that within and two rows beyond the plot area only Trichogrammatoidea annulata was present, while beyond two rows only Trichogramma californicum was detected. T. annulata has been recovered also from the San Joaquin release sites.

During the last 4 to 6 years a steady decline in the insidence of navel orangeworm parasites has been noticed, except in orchards where practices that favor the persistency of natural enemies have been implemented. Parasites such as Liotryphon nucicola, Scambus sp., Anachaetopsis tortricis, and Paraolinx typica that were commonly reared from navel orangeworm a few years ago, are now seldom, if ever collected.

Copidosomopsis plethoricus and Goniozuz legneri overwinter in release orchards year after year. However, only Copidosomopsis can consistently be recovered at any time of the year, Goniozus is not recovered in significant numbers until early summer.

G. legneri has been reared from codling moth and oriental fruit moth in peaches in the Paso Robles area, in addition to NOW from almonds.

Field data suggest that a certain number of old nuts is necessary to maintain a desirable density of natural enemies such as G. legneri and C. plethoricus.

Future work will concentrate in colonization of T. annulata and in manipulating populations of resident NOW natural enemies.

BIOLOGICAL CONTROL OF NAVEL ORANGEWORM

--E. F. Legner research

RESULTS:

The following summarizes data gathered from six central California Nonpareil almond orchards in which both Pentalitomastix plethorica and Goniozus legneri have been established. Data through 1985 will be added as it becomes available:

Navel Orangeworm Density.--

There is a clear drop in the average density of NOW in the Paso Robles area coincident with the establishment of Goniozus legneri (Figs. 1 & 2). Apparently, a similar relationship is evident at Hilmar (Fig. 4) and Chowchilla (Fig. 11). However, at Selma (Fig. 5) insufficient data has been gathered since parasite introduction to establish trends; and at Wesley and Atwater (Figs. 7 & 9) the data are confounded with a high incidence of peach twig borer attacking almonds at harvest (due to inadequate dormant sprays).

The relationship between total Nonpareil rejects and yields at harvest is significnatly negative only at Atwater (Fig. 10). In all other orchards either there is no correlation or a trend exists for a positive correlation, indicating the importance of neighboring reservoir areas on these orchards. In Atwater the high value of 25.66% rejects at the 1983 harvest (Fig. 9) occurring after Goniozus legneri establishment may be a function of an especially low yield in that year (Table 5).

Overwintering of Parasites.--

Pentalitomastix plethorica and Goniozus legneri overwinter in release orchards year after year. However, only Pentalitomastix can always be detected by sampling mummies at any time of year. Goniozus is not recovered in significant numbers until early summer, after several weeks of warm weather (Table 2). Thus, it appears that Goniozus either reduces its population density drastically every winter, or it migrates to another habitat or environment for the colder months.

Alternate Hosts.--

Goniozus legneri has now been reared from codling moth and oriental fruit moth in peaches in the Paso Robles area. Goniozus sp. nr. emigratus has been found capable of reproduction on the peach twig borer in the laboratory. Field recoveries of parasites were verified by crossing with laboratory cultures.

Importance of Overwintering Mummies.--

A high number of overwinter mummies may be essential to produce the lowest NOW densities in orchards where both parasites are established. This is evidenced by the situation in Orchard #1 at Paso Robles which averaged high mummy densities per tree (100-1000+) and where many Nonpareil trees are never harvested. All other orchards in the current study had partial to thorough mummy removal (2 mummies/tree) rendered either by inclement weather or by manual labor. Such orchards cannot sustain a build-up of *Goniozus legneri* in significant numbers in June and July.

Influence of Neighboring Walnuts.--Most walnuts sustain a low incidence of NOW (usually below 2% infested mummies by August). Since walnuts are still green at this time, it seems possible that the NOW population, unable to find suitable oviposition sites, migrates to neighboring hull-cracking almonds in July and August. *Goniozus legneri* is capable of overwintering in walnut groves, and in the Riverside area has reduced high NOW infestations from ca. 20% in October to under 0.5% at two sites.

Proportion of Twig Borer in Harvest Rejects.--An estimate of the damage caused by the twig borer, *Anarsia lineatella* Zeller has been made whenever possible at the time of harvest. The information obtained is printed on the top of each graph as a percentage of the total rejects. The processing plants have recently begun to cooperate in furnishing this data, although varieties are often not distinguished. It is apparent that in some orchards the twig borer constituted a significant proportion of the total rejects. *Goniozus legneri* attacks twig borer while it occurs in the almond, but is incapable of locating this insect on the bark and in twigs and June drops. Thus, it is able to escape significant parasitism.

FIG. 1. Estimates of Nonpareil rejects at harvest at Orchard #1 in the Paso Robles area.

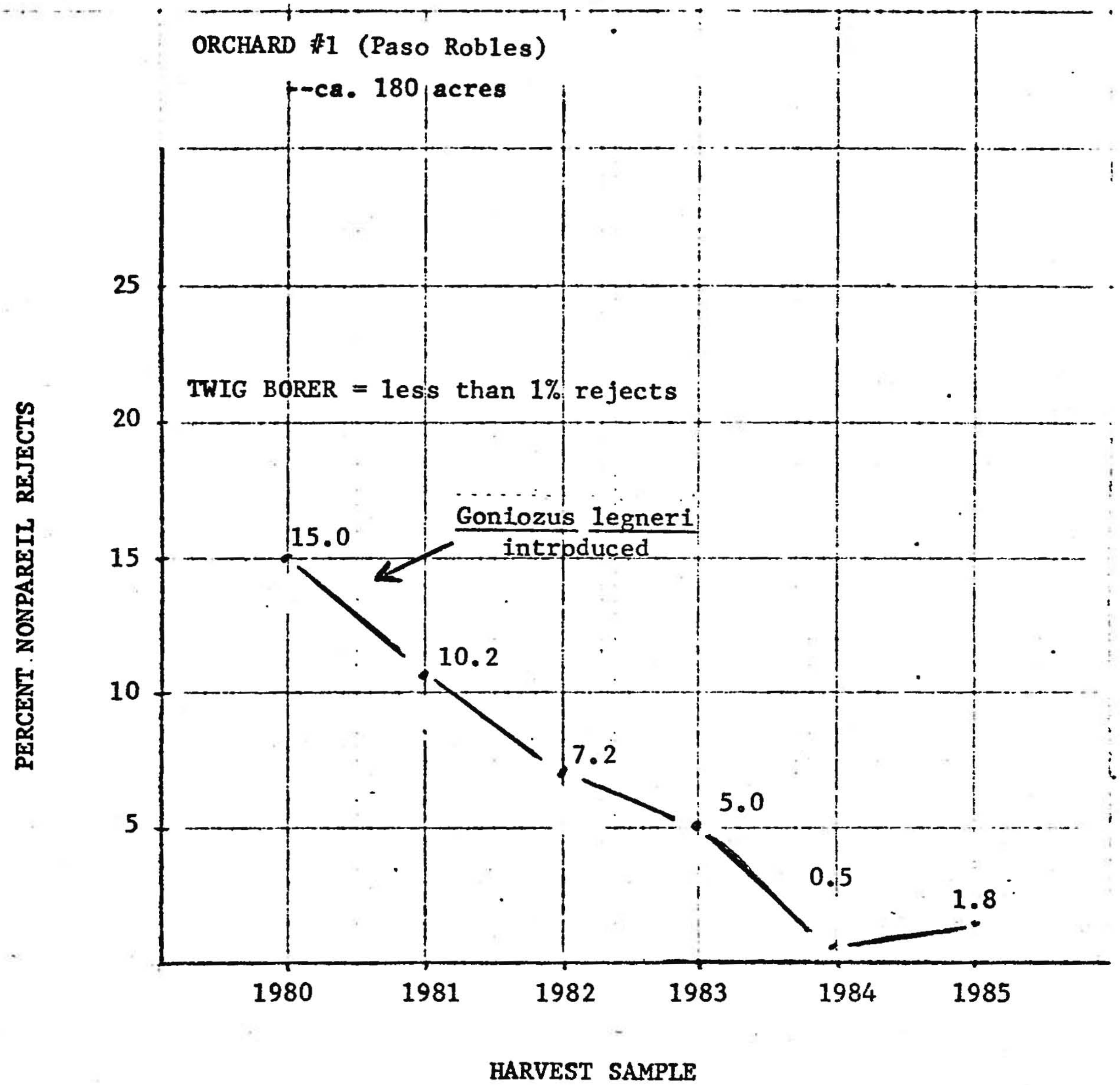


FIG. 2. Percent infested Nonpareil mummies sampled in the first week of December at Orchard #1 in the Paso Robles area.

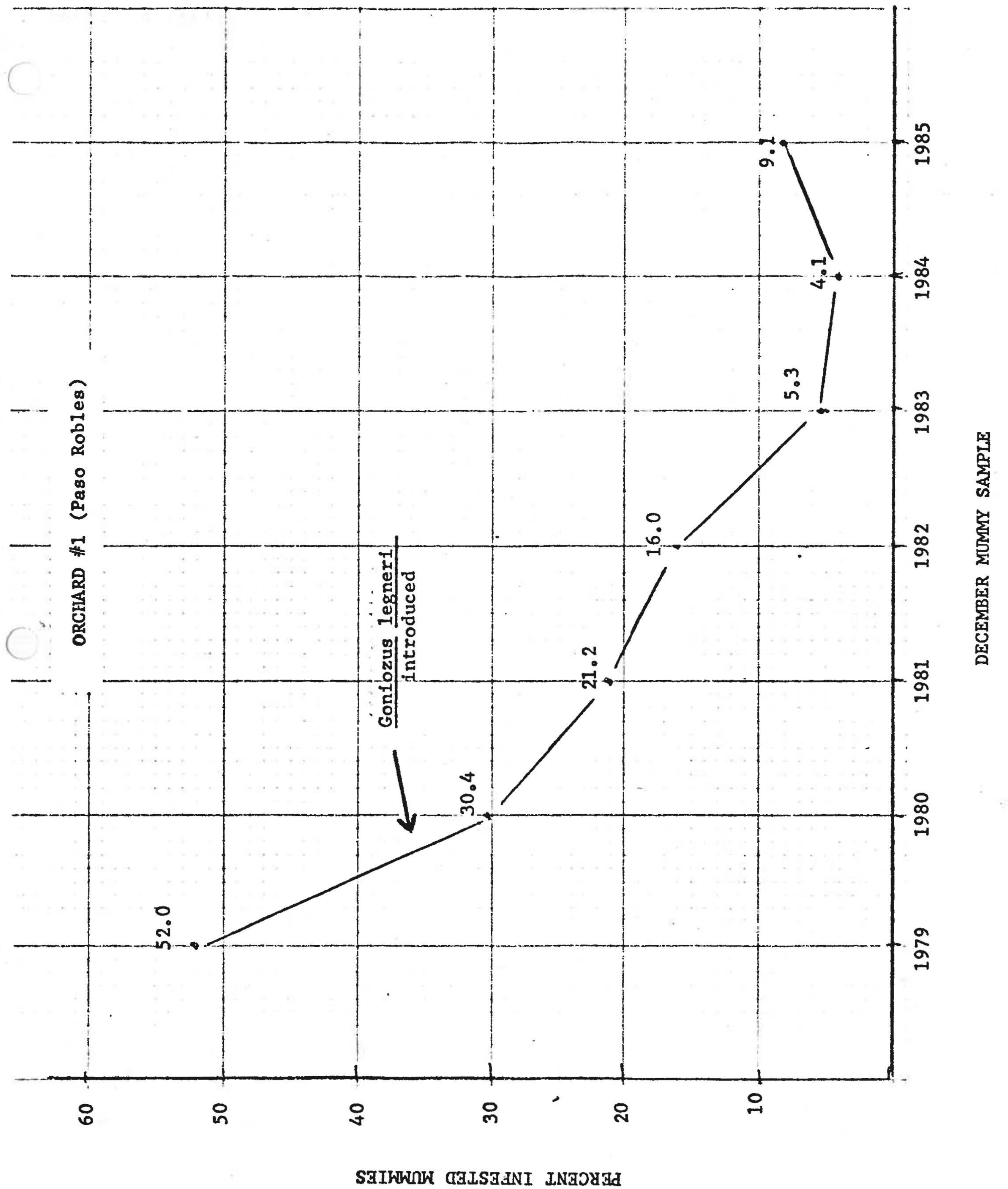


FIG. 3. Relationship between % Nonpareil rejects and orchard yield at Orchard #1 in the Paso Robles area.

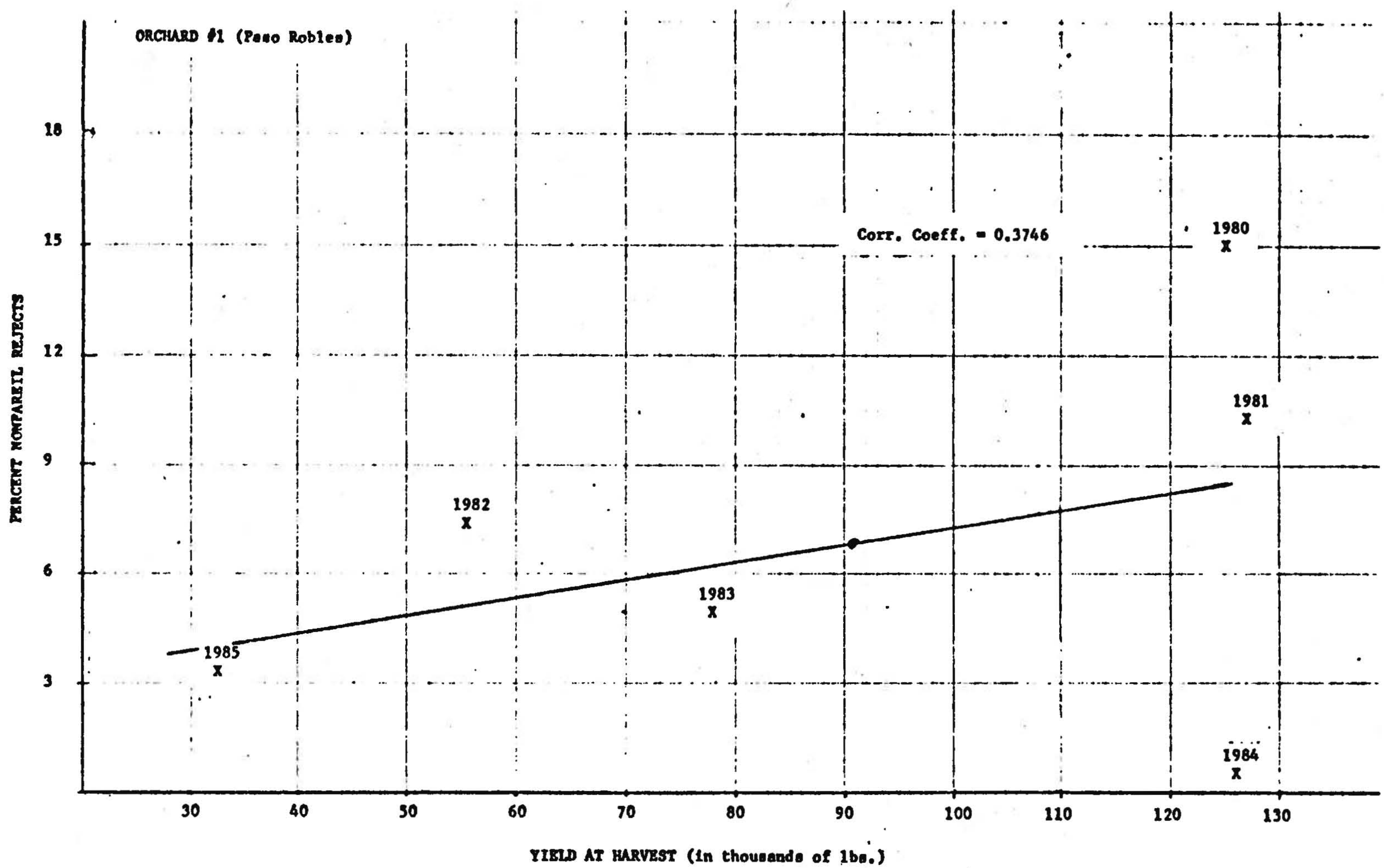


Table 1. Data for Figure 3.

ORCHARD #1 (Paso Robles)

X = estimate of total good meats (lbs.)
Y = total rejects

X	Y	
125000.000	15.000	1980
126000.000	10.200	1981
55000.000	7.200	1982
78000.000	5.000	1983
125000.000	0.500	1984
32000.000	3.300	1985

```
NUMBER PAIRS =  6
MEAN OF X =  90166.66          OF Y =  6.866667
SLOPE =  4.710948E-05                         Y-INTERCEPT =  2.618963
 (= b)                                          (= a)

SUM-OF-SQUARES
              TOTAL          417.02
              MEAN           282.9067
              SLOPE          18.81709
              RESIDUAL       115.2962

STANDARD DEVIATIONS
              X              41179.68
              Y              5.17906
              ERROR          5.368803
              Y-BAR          2.191805
              SLOPE          5.83055E-05
              Y-INTER.       5.695813

F-RATIO FOR SLOPE =  .6528261
t-TEST FOR SLOPE =  .8079766     df =  4
CORRELATION COEFFICIENT =  .3745763

COORDINATES FOR REGRESSION LINE

Y1 =  6.866667 for X =  90166.66  (= original computed intercept)

Y2 =  4.742815 for X =  45083.33
Y3 =  6.017126 for X =  72133.33
Y4 =  7.716208 for X =  108200
Y5 =  8.565748 for X =  126233.3
```

Table 2. Nonpareil mummies sampled in spring 1985 at Orchard #1 in the Paso Robles area, and parasitization by two principal parasites.

ORCHARD #1 (Paso Robles)

Spring Mummy Sample (1985)

SAMPLE SIZE	% Infested Mummies	% Navel Orangeworm Parasitized	
		Pentalitomastix	Goniozus
16 May 1985			
2,000	4.89	4.72	0
26 June 1985			
2,800	1.39	3.85	26.92

FIG. 4. Nonpareil rejects at harvest at Orchard #2 in the Hilmar area.

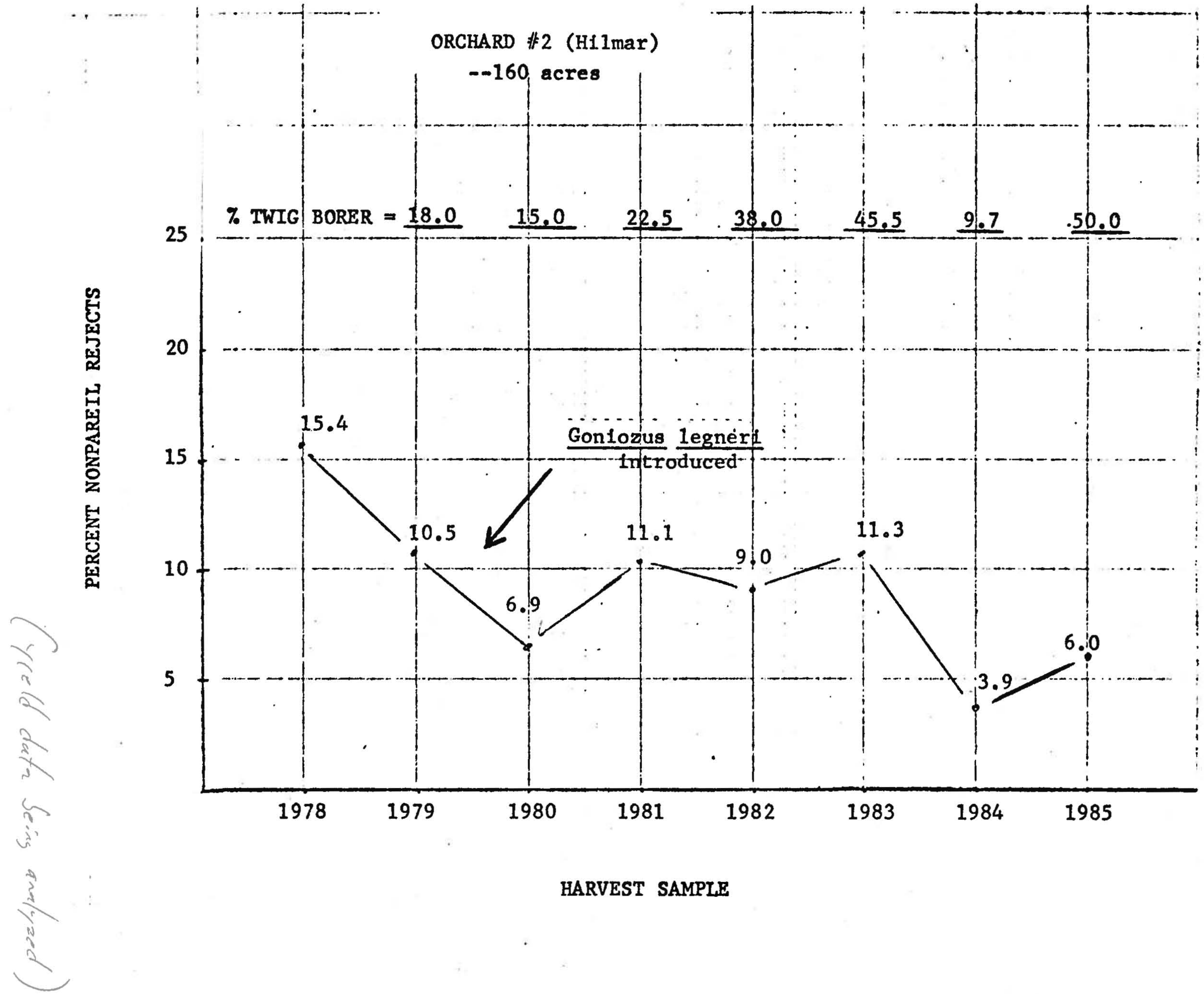


FIG. 5. Nonpareil rejects at harvest at Orchard #3 in the Selma area.

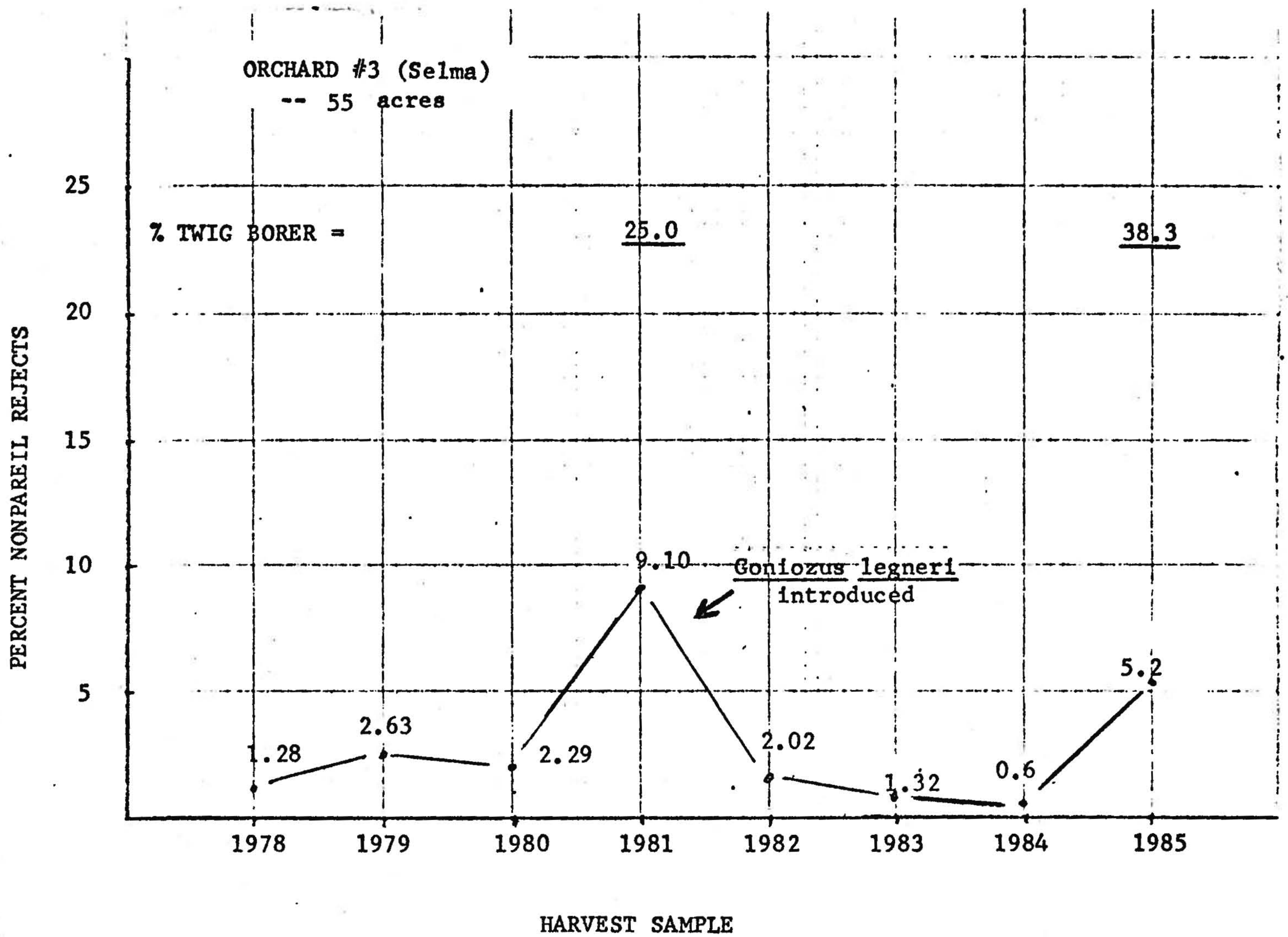


FIG. 6. Relationship between % Nonpareil rejects and orchard yield at Orchard #3 in the Selma area.

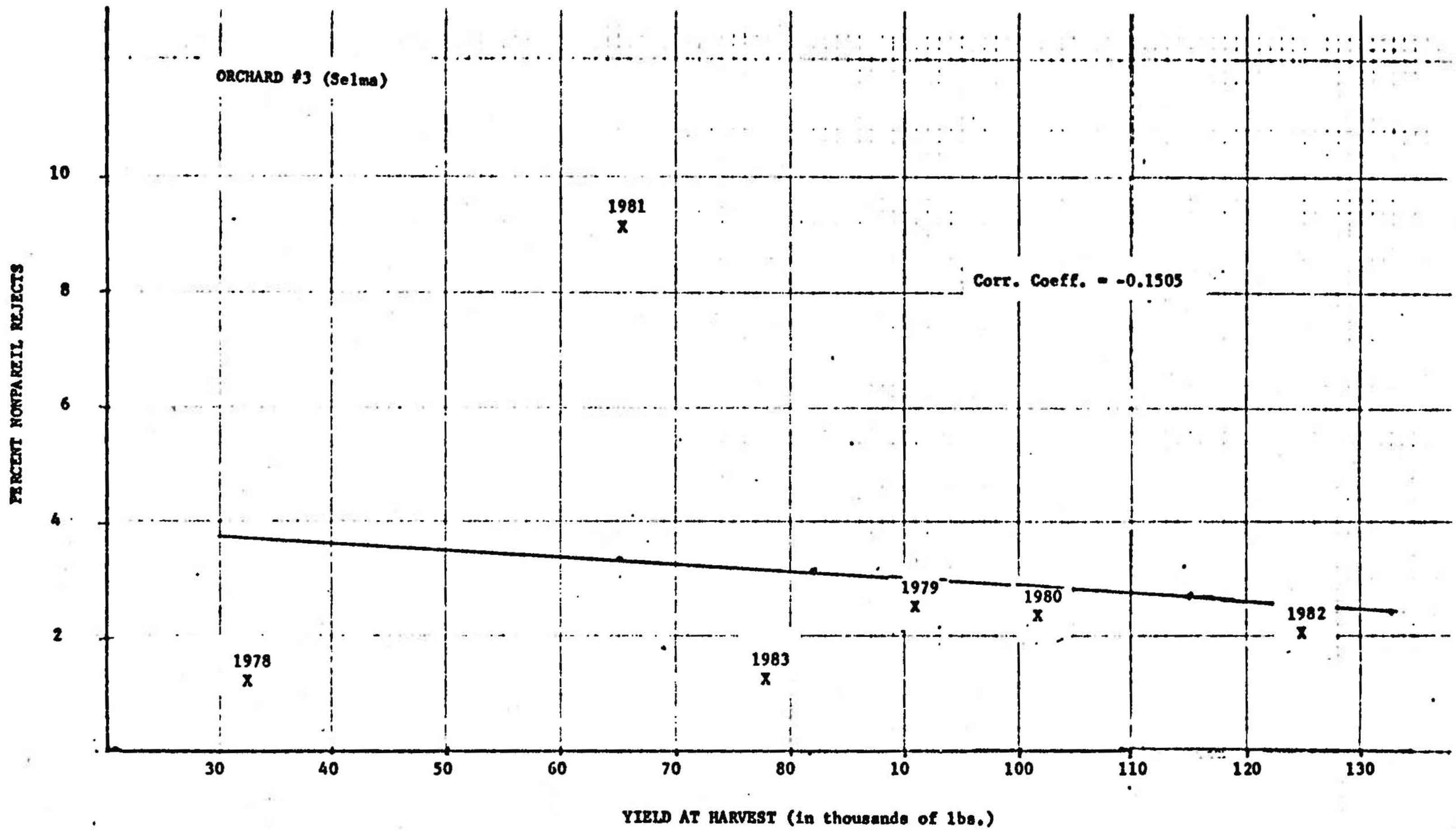


Table 3. Data for Figure 6.

ORCHARD #3 (Selma)

X = total good meats (lbs.)
Y = % rejects

X	Y	
32798.000	1.280	1978
90191.000	2.630	1979
101538.000	2.290	1980
65130.000	9.100	1981
125210.000	2.020	1982
78203.000	1.320	1983

NUMBER PAIRS = 6
MEAN OF X = 82178.34 OF Y = 3.106667
SLOPE = -1.41519E-05 Y-INTERCEPT = 4.269647
(= b) (= a)

SUM-OF-SQUARES

TOTAL	102.4322
MEAN	57.90827
SLOPE	1.008509
RESIDUAL	43.51543

STANDARD DEVIATIONS

X	31735.11
Y	2.984089
ERROR	3.298311
Y-BAR	1.34653
SLOPE	4.648006E-05
Y-INTER.	4.050049

F-RATIO FOR SLOPE = 9.270356E-02
t-TEST FOR SLOPE = .3044726 df = 4
CORRELATION COEFFICIENT = -.1505023

COORDINATES FOR REGRESSION LINE

Y1 = 3.106667 for X = 82178.34 (= original computed intercept)

Y2 = 3.688157 for X = 41089.17
Y3 = 3.339263 for X = 65742.68
Y4 = 2.874071 for X = 98614.01
Y5 = 2.641475 for X = 115049.7

FIG. 7. Nonpareil rejects at harvest at Orchard #4 in the Wesley area.

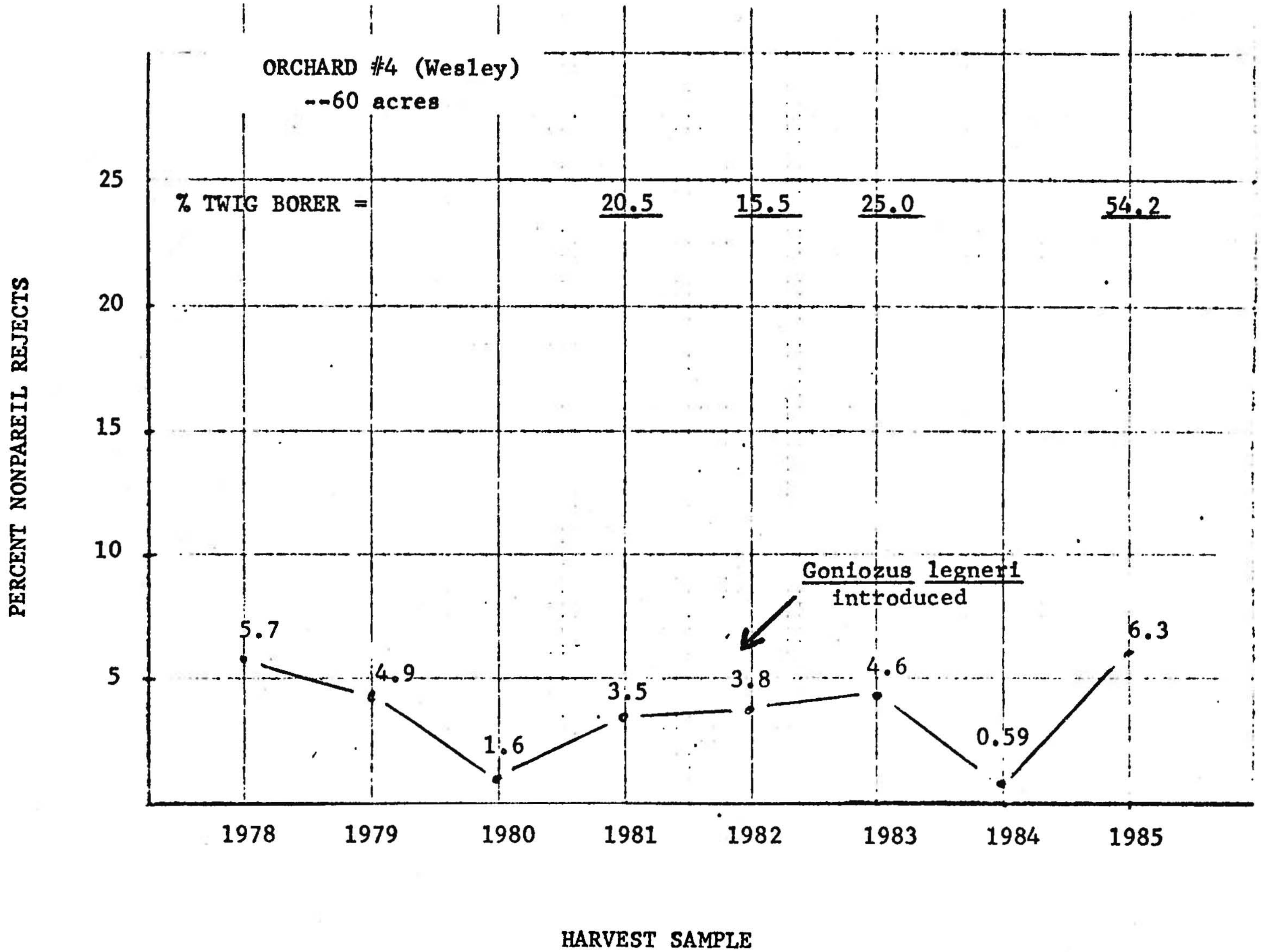


FIG. 8. Relationship between % Nonpareil rejects and orchard yield at Orchard #4 in the Wesley area.

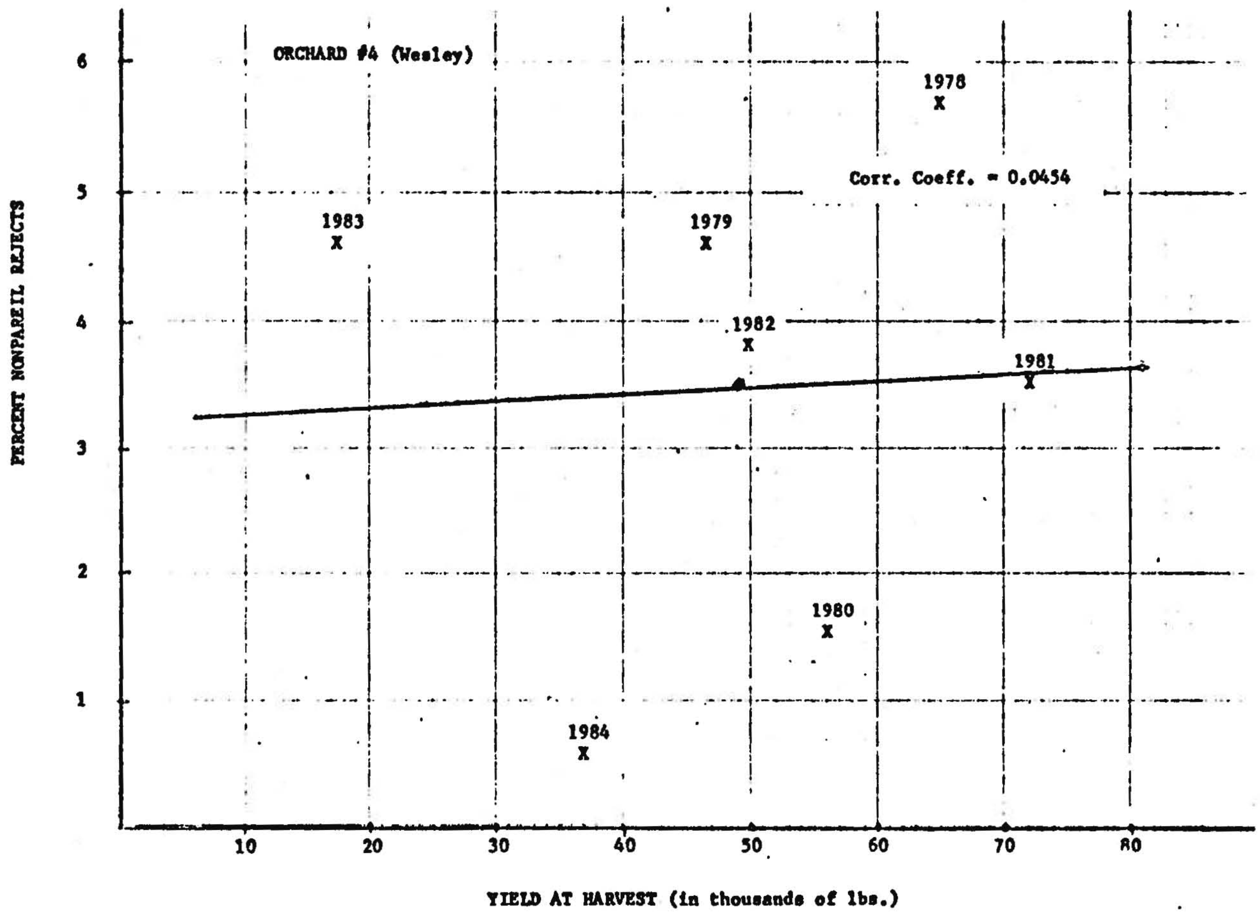


Table 4. Data for Figure 8.

ORCHARD #4 (Wesley)

X = total good meats (lbs.)
Y = % rejects

X	Y	
60518.000	5.700	1978
46237.000	4.600	1979
56052.000	1.600	1980
71653.000	3.500	1981
49918.000	3.800	1982
17296.000	4.600	1983
37195.000	0.590	1984

NUMBER PAIRS = 7
MEAN OF X = 48409.86 OF Y = 3.484286
SLOPE = 4.653136E-06 Y-INTERCEPT = 3.259028
(= b) (= a)

SUM-OF-SQUARES

TOTAL	104.4081
MEAN	84.98172
SLOPE	3.997102E-02
RESIDUAL	19.38641

STANDARD DEVIATIONS

X	17540.88
Y	1.799369
ERROR	1.969081
Y-BAR	.7442428
SLOPE	4.582862E-05
Y-INTER.	2.340063

F-RATIO FOR SLOPE = 1.030903E-02
t-TEST FOR SLOPE = .1015334 df = 5
CORRELATION COEFFICIENT = 4.536038E-02

COORDINATES FOR REGRESSION LINE

Y1 = 3.484286 for X = 48409.86 (= original computed intercept)

Y2 = 3.371657 for X = 24204.93
Y3 = 3.439234 for X = 38727.88
Y4 = 3.529337 for X = 58091.83
Y5 = 3.574389 for X = 67773.8

FIG. 9. Nonpareil rejects at harvest at Orchard #5 in the Atwater area.

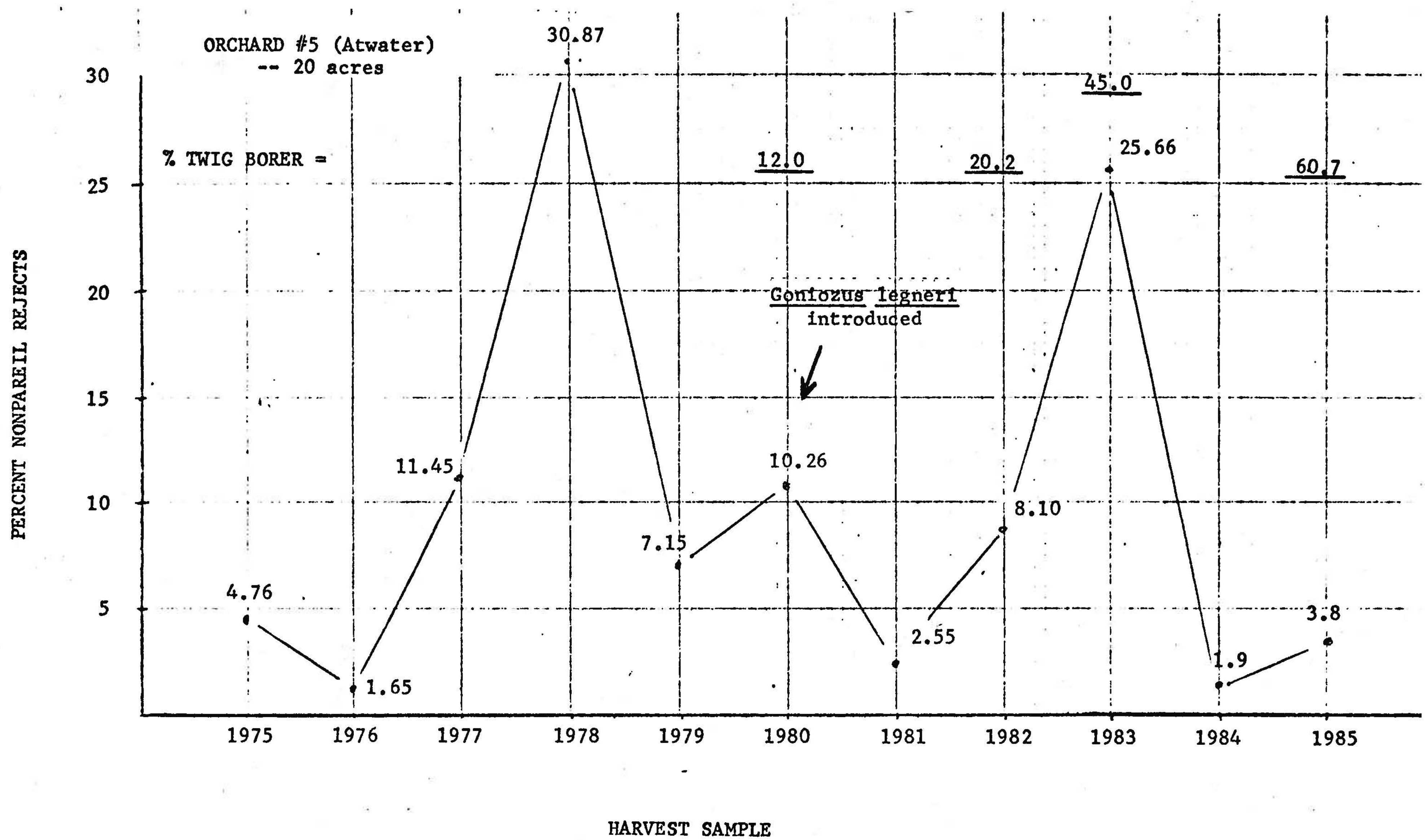


FIG. 10. Relationship between % Nonpareil rejects and orchard yield at Orchard #9 in the Atwater area.

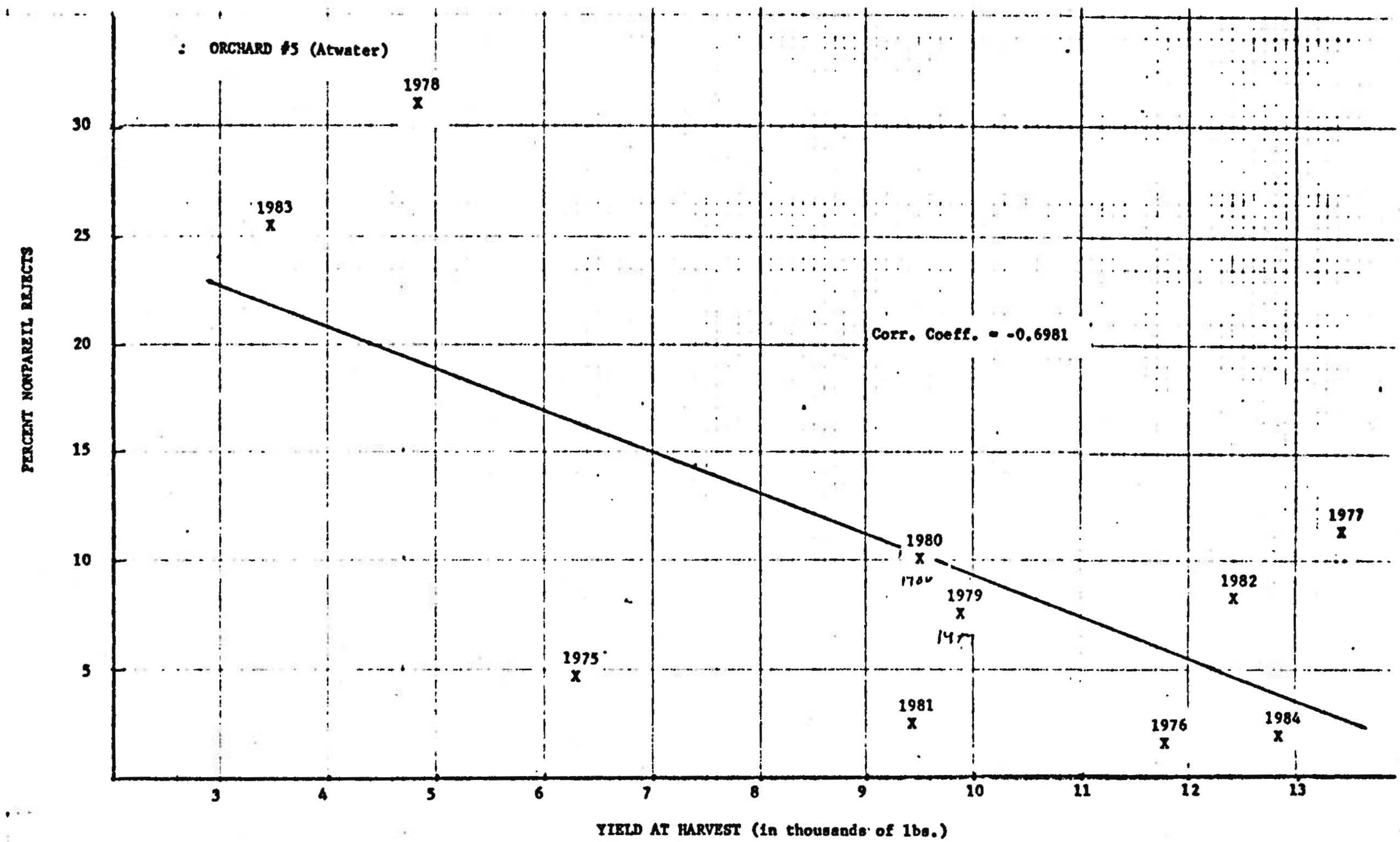


Table 5. Data for Figure 10.

ORCHARD #5 (Atwater)

X = total good meats (lbs.)
Y = % rejects

X	Y	
6238.000	4.760	1975
11846.000	1.650	1976
13488.000	11.450	1977
4830.000	30.870	1978
9847.000	7.150	1979
9411.000	10.260	1980
9423.000	2.550	1981
12477.000	8.100	1982
3476.000	25.660	1983
12839.000	1.900	1984

NUMBER PAIRS = 10
MEAN OF X = 9387.5 OF Y = 10.435
SLOPE = -2.007564E-03 Y-INTERCEPT = 29.28101
(= b) (= a)

SUM-OF-SQUARES

TOTAL	1999.987
MEAN	1088.892
SLOPE	444.0001
RESIDUAL	467.0952

STANDARD DEVIATIONS

X	3498.652
Y	10.06145
ERROR	7.641132
Y-BAR	2.416338
SLOPE	7.280071E-04
Y-INTER.	7.24876

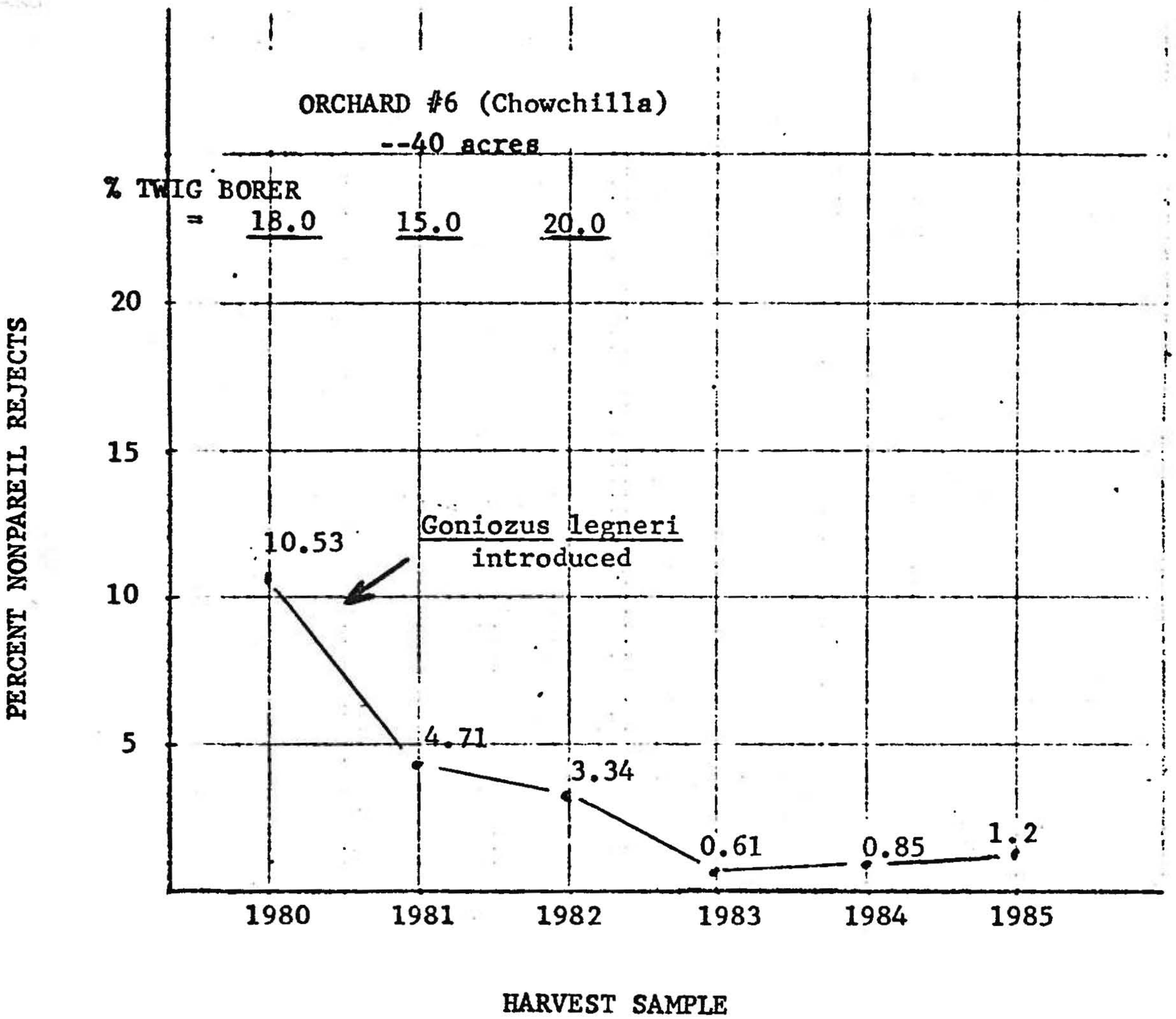
F-RATIO FOR SLOPE = 7.604448
t-TEST FOR SLOPE = 2.757616 df = 8
CORRELATION COEFFICIENT = -.6980871

COORDINATES FOR REGRESSION LINE

Y1 = 10.435 for X = 9387.5 (= original computed intercept)

Y2 = 19.85801 for X = 4693.75
Y3 = 14.2042 for X = 7510
Y4 = 6.665798 for X = 11265
Y5 = 2.896595 for X = 13142.5

FIG. 11. Nonpareil rejects at harvest at Orchard #6 in the Chowchilla area.



(yield data forthcoming)

Project 85-E12

Biological Control of Navel Orangeworm

ANNUAL REPORT

December 1985

prepared by

Leopoldo E. Caltagirone
Division of Biological Control
University of California
Berkeley

Project Leaders: Leopoldo E. Caltagirone
Division of Biological Control
University of California
1050 San Pablo Ave.
Albany, CA 94706 Tel. (415) 642-4230

E. Fred Legner
Division of Biological Control
University of California
Riverside, CA 92521 Tel. (714) 787-5709

Cooperators: William W. Barnett
Cooperative Extension
9240 S. Riverbend Ave.
Parlier, CA 93648

Frank G. Zalom
Integrated Pest Management Implementation Group
2101 Wickson
University of California
Davis, CA 95616

Personnel: D. W. MEALS, Staff Research Associate (UCB): mass culture, colonization and evaluation of *Trichogrammatoidea annulata*; sampling and evaluation of other natural enemies of navel orangeworm.

R.W. WARKENTIN, SRA (UCR): colonization and evaluation of natural enemies of NOW in southern San Joaquin Valley and Paso Robles areas.

M. FONG, SRA (UCB): mass culture of mediterranean flour moth for culture of *T. annulata* and other NOW natural enemies.

K. M. DAANE, Research Assistant (UCB): colonization and evaluation of NOW natural enemies in the Sacramento Valley.

1. OBJECTIVES

A. To mass culture, colonize, and evaluate the recently introduced parasite *Trichogrammatoidea annulata*.

B. To evaluate the established parasites *Goniozus legneri* and *Copidosomopsis* (=*Pentalitomastix*) *plethorica* and other resident natural enemies of NOW.

C. To manipulate NOW natural enemies to maximize their impact in an IPM program for almonds.

2. INTERPRETIVE SUMMARY

Techniques to mass culture *Trichogrammatoidea annulata* and its laboratory host the Mediterranean flour moth (*Anagasta kuehniella*) have been improved. A total of 7 867 800 adults of *T. annulata* were released in almond orchards in the counties of Butte (4 036 000), San Joaquin (3 531 800) and San Luis Obispo (300 000). In addition 3 610 adults of *Goniozuz legneri* of Argentinian origin were released in San Joaquin County.

Pre-release samples from a new release orchard in Butte Co. (Ballard Orchard) revealed absence of *Copidosomopsis* and *Goniozus*; native *Trichogramma californicum* was present. *Trichogrammatoidea annulata* was released here. Harves time samples showed 6.28% kernel damage in nuts from outside the release plot (5 x 5 trees) while 2.33% was detected inside the plot. Transect sampling outside and through the plot in N-S and E-W directions revealed that within and two rows around the plot area only *T. annulata* was present, while beyond two rows only *Trichogramma californicum* was detected. *T. annulata* has been recovered also from the San Joaquin release sites.

Populations of navel orangeworm in six orchards (Paso Robles, Hilmar, Chowchilla, Selma, Wesley, and Atwater) have been followed in an attepmt to determine impact of the parasites *G. legneri* and *C. plethorica*. A definite drop in the average density of NOW in the Paso Robles orchard is coincident with the establishment of *G. legneri*. Data suggests that similar relationship occurs at Hilmar and Chowchilla. No sufficient data are available for the other sites sampled.

C. plethorica and *G. legneri* overwinter in release orchards year after year. However, only *Copidosomopsis* can consistently be recovered at any time of the year. *Goniozus* is not recovered in significant numbers until early summer.

G. legneri has been reared from codling moth and oriental fruit moth in peaches in the Paso Robles area, in addition to NOW from almonds.

Field data suggest that a cretain number of old nuts is necessary to maintain a desirable density of natural enemies such as *G. legneri* and *C. plethorica*.

During the last 4 to 6 years a steady decline in the incidence of navel orangeworm parasites has been noticed, except in orchards where practices that favor the persistence of natural enemies have been implemented. Parasites such as *Liotryphon nucicola*, *Scambus* sp., *Erynnia* (= *Anachaetopsis*) *tortricis*, and *Paraolinx typica*, which were commonly reared from navel orangeworm a few tears ago are now seldom, if ever, collected. Sampling in representative orchards in the Central Valley has been started to determine the status of the differen NOW natural enemies.

Future work wil concentrate in colonization of *T. annulata* and in manipulating populations of resident NOW natural enemies.

3. EXPERIMENTAL PROCEDURE

A. Mass culture of Trichogrammatoidea annulata has been standardized using Mediterranean flour moth as host. This entails mass culture of the moth using rolled oats as food which is placed in half-gallon glass containers, and seeded with moth eggs. After the moth larvae complete their development they are transferred to emergence cages where adult moths are collected and placed in oviposition units. These units consist of cages with screen bottoms. The moths oviposit through the screen and the eggs are collected daily. Part of the eggs are used to continue moth production, while the majority is destined to culture of Trichogrammatoidea.

The use of glass containers to rear the moth larvae has the drawback of having to wash and disinfect them after each cycle. This involves a significant amount of work and loss of containers because of breakage. We are in the process of modifying this system toward using disposable units to rear moth larvae. We feel that with modified units our operation will be more efficient. The prototype units will be tested in full this coming season.

The moth eggs destined to culture T. annulata are frozen (the embryo is killed) and then they are used to produce parasites. Frozen eggs are suitable for the parasites, and those that are not parasitized will not develop into larvae, thus loss of parasites through being eaten by emerging caterpillars is avoided. The parasites are cultured in plastic boxes (13.5 x 13 x 3.8 cm) each of which yield ca 25 000 adult parasites.

To determine whether T. annulata has the capability to parasitize NOW eggs under field conditions a group of 25 Nonpareil trees (5 x 5) was selected in the Ballard Orchard in Butte County. When the trees were selected (early winter 1985) old nuts were in large enough numbers (15+ per tree), many of the infested with NOW. As a result of wind, bird activities, and other undetermined factors, the old nuts were practically eliminated from the orchard by the middle of February. Because we needed oviposition sites for NOW so that we could test T. annulata, two Zoecon NOW egg traps baited with almond meal were hung in each tree in the plot. After the parasite release program started, one half of the traps were removed one weeks after the release; the removed traps were replaced with fresh ones. The removed traps were taken to the laboratory, the NOW eggs on them were counted and held until their development was sufficiently advance to determine if they were parasitized. Parasites were allowed to develop to adult stage and identified. Immediately prior to the next release of parasites, the other half of the traps was removed and processed as already indicated.

To measure natural dispersal of T. annulata new crop, susceptible nuts (after hull split) were collected along two transects (N-S and E-W) that went through the parasite release plots. These nuts were brought to the laboratory and examined for NOW eggs; these were counted and reared through to determine level of parasitization either by T. annulata or the native Trichogramma californicum.

B. Monitoring of the Burris Orchard, San Joaquin Co. has continued. Samples of nuts were taken and processed in the laboratory to determine levels of infestation and incidence of natural enemies.

C. Samples of ca 400 nuts each were taken from a series of representative orchards in the Central Valley shortly after harvest. These nuts were examined; those that were infested with NOW were isolated individually in plastic containers and left to develop. The purpose of this sampling was to determine the kinds of natural enemies in these orchards and their abundance as a preliminary step to manipulating these natural enemies.

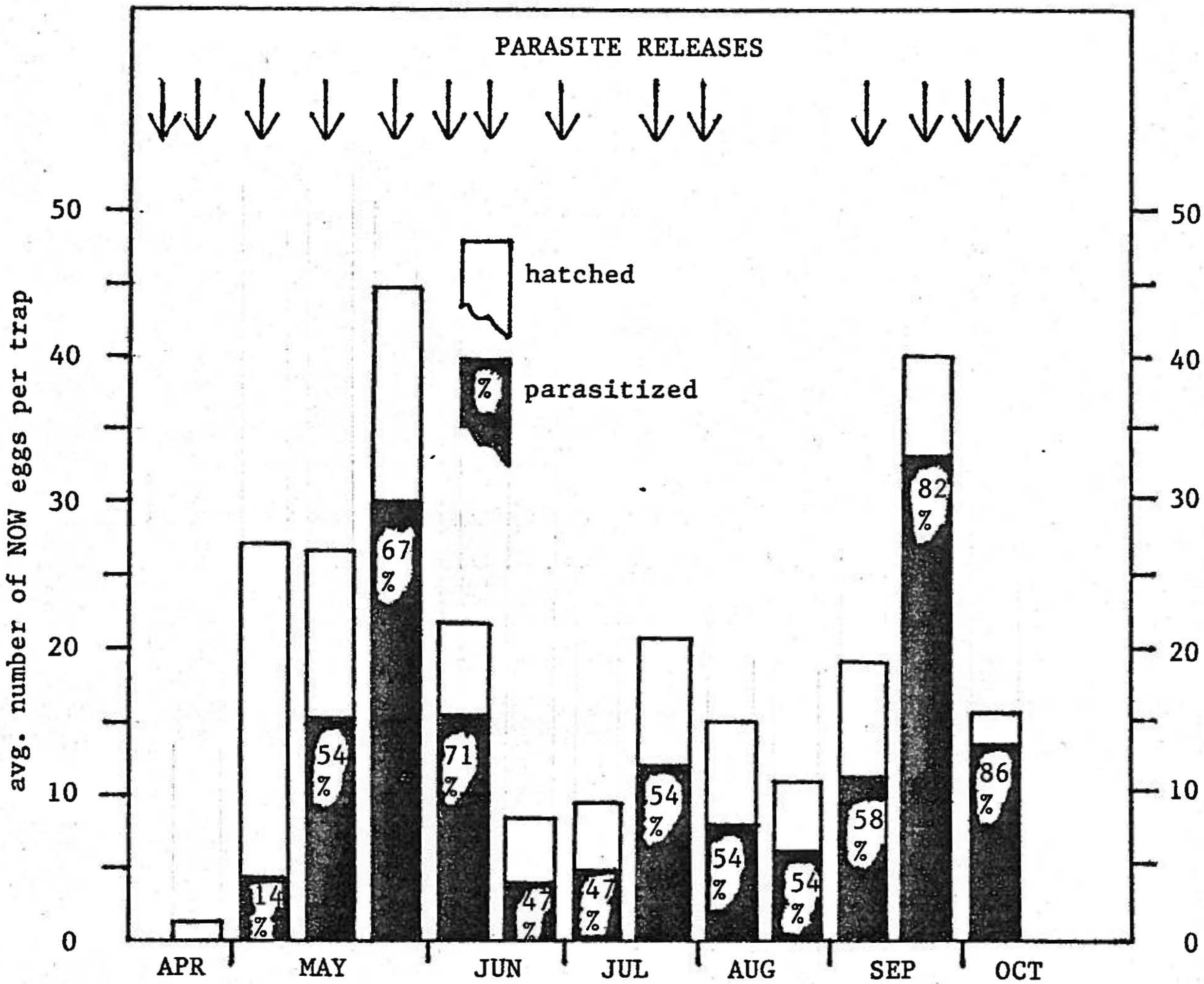
4. RESULTS

A. A total of 7 867 800 adult Trichogrammatoidea annulata were released in almond orchards as follows:

county	no. released
Butte	4 036 000
San Joaquin	3 531 800
San Luis Obispo	300 000

In addition 915 000 T. annulata were released in walnut orchards in Solano county.

Evaluation of the impact of the impact of T. annulata in Ballard Orchard, Butte Co. revealed that from May through October this parasite destroyed between 47 and 86 percent of the Navel Orangeworm eggs. The figure below indicates that the peaks of parasitization (67 - 71% and 82 - 86%) occurred during the peaks of NOW oviposition.

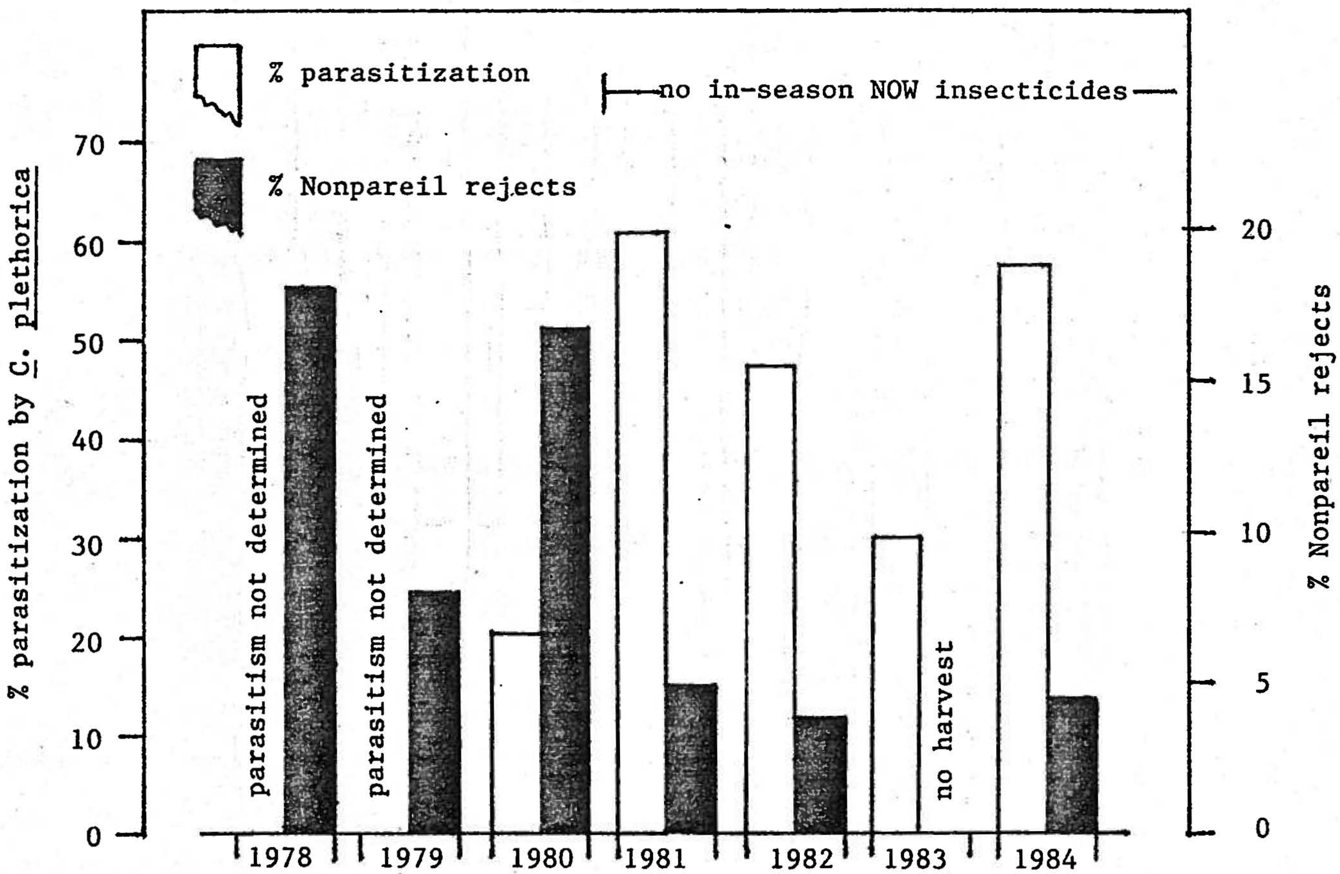


parasitization of NOW eggs by Trichogrammatoidea annulata
Ballard Orchard, Butte Co.
1985

Natural dispersal of T. annulata in the Ballard Orchard plot, as determined by transect sampling, is slow; the parasite was recovered within and as far as two rows beyond the release plot.

Sampling for kernel damage at harvest within the release plot indicated a 2.33% loss (kernel unit basis, not weight), while outside the plot the loss was 6.28%.

B. The figure below represents the data on parasitization by C. plethorica and kernel damage obtained since 1978 in the Burris Orchard, San Joaquin county. Data for the 1985 season is not yet available.



Effect of Copidosomopsis plethorica on NOW

Burris Orchard, San Joaquin Co.

C. The isolated NOW-infested nuts collected in various orchards in the Central Valley are being processed in the laboratory. Results will not be available until all rearings are completed.

5. DISCUSSION

Trichogrammatoidea annulata is capable of destroying a significant proportion of NOW eggs. Because parasitism is higher during the periods of high host density, it is now desirable to test impact os selective periodic releases, limiting them to those periods. It would be necessary to determine dose response by testing various concentrations of parasites (e.g., 500, 1 000, 2 000 parasites per tree). Impact on NOW population, effect on kernel damage at harvest time, and cost should be determined.

Data on the impact of Copidosomopsis plethorica in Burris Orchard indicates that there is a correlation between increasing percentage parasitization with decreasing kernel damage at harvest. This trend has continued since 1980. In this orchard there has been no in-season applications of insecticides or acaricides. Harvest has started 8 - 10 days earlier than in the neighboring orchards. It would be desirable to determine the effect of early harvest alone on the incidence of NOW. This could be done by establishing plots some of which should be harvested early and the rest at the time considered normal. Determination of parasitism and kernel damage in the two situations should shed light on the effect of the two factors: early harvest and parasitism.

Our extended sampling of NOW populations in various commercial orchard situations has revealed a steady decline in the incidence of navel orangeworm parasites. In addition to the established exotic parasites Copidosomopsis plethorica and Goniozus legneri there are other species which are normally parasites of other moths and which have adopted the NOW as a host. Included among them are Trichogramma californicum, Erynnia (= Anachaetopsis) tortricis, Liotryphon nucicola, Paraolinx typica, and Scambus sp. Each one of these parasites adds mortality to the NOW population. The systematic sampling of representative orchards in the Central Valley will indicate the level at which these species occur, and on that basis we should device methods to manipulate them in the orchards to maximize their effect on NOW and to include them in an IPM program for almonds.

6. PUBLICATIONS

Caltagirone, L. E. 1985. New Copidosomopsis (Hymenoptera: Encyrtidae) from California, with Comments on the Genus. Ann. Entomol. Soc. Am. 78: 705-708

31 December 1985

APPENDIX

The following is a report of research conducted by Dr. E. F. Legner. It was submitted by him to the Almond Board of California on 22 October 1985. It is included here because it is an integral part of Project 85-E12.

UNIVERSITY OF CALIFORNIA, RIVERSIDE

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO | SANTA BARBARA • SANTA CRUZ

COLLEGE OF NATURAL AND
AGRICULTURAL SCIENCES
CITRUS RESEARCH CENTER AND
AGRICULTURAL EXPERIMENT STATION
DEPARTMENT OF ENTOMOLOGY

DIVISION OF BIOLOGICAL CONTROL
RIVERSIDE, CALIFORNIA 92521
(714) 787-4674

22 October 1985

RE: Contract No. ABC/LEG/E19

Mr. Robert Curtis
Almond Board of California
PO Box 15920
Sacramento, CA. 95813

Dear Bob:

Responding to your request for an early run-down of project activity during the past season, the attached semi-annual report is submitted. We are still incubating our October samples and gathering further yield information from a few orchards, but the trends are probably established by now. Leo Caltagirone will submit his results shortly also.

This will be my last year involvement with the biological control of navel orangeworm project, as I feel I can wrap up my appraisal with the December and spring mummy samples. The investigation of direct control of NOW eggs with Trichogrammatoidea seems well worth continued effort.

Sincerely yours,

E. F. LEGNER
Entomologist

Incl.

cc: L. Caltagirone
W. Barnett
F. Zalom
UC Research Office

BIOLOGICAL CONTROL OF NAVEL ORANGEWORM

--E. F. Legner research

The following summarizes data gathered from six central California Nonpareil almond orchards in which both Pentalitomastix plethorica and Goniozus legneri have been established. Data through 1985 will be added as it becomes available:

Navel Orangeworm Density.--

There is a clear drop in the average density of NOW in the Paso Robles area coincident with the establishment of Goniozus legneri (Figs. 1 & 2). Apparently, a similar relationship is evident at Hilmar (Fig. 4) and Chowchilla (Fig. 11). However, at Selma (Fig. 5) insufficient data has been gathered since parasite introduction to establish trends; and at Wesley and Atwater (Figs. 7 & 9) the data are confounded with a high incidence of peach twig borer attacking almonds at harvest (due to inadequate dormant sprays).

The relationship between total Nonpareil rejects and yields at harvest is significnatly negative only at Atwater (Fig. 10). In all other orchards either there is no correlation or a trend exists for a positive correlation, indicating the importance of neighboring reservoir areas on these orchards. In Atwater the high value of 25.66% rejects at the 1983 harvest (Fig. 9) occurring after Goniozus legneri establishment may be a function of an especially low yield in that year (Table 5).

Overwintering of Parasites.--

Pentalitomastix plethorica and Goniozus legneri overwinter in release orchards year after year. However, only Pentalitomastix can always be detected by sampling mummies at any time of year. Goniozus is not recovered in significant numbers until early summer, after several weeks of warm weather (Table 2). Thus, it appears that Goniozus either reduces its population density drastically every winter, or it migrates to another habitat or environment for the colder months.

Alternate Hosts.--

Goniozus legneri has now been reared from codling moth and oriental fruit moth in peaches in the Paso Robles area. Goniozus sp. nr. emigratus has been found capable of reproduction on the peach twig borer in the laboratory. Field recoveries of parasites were verified by crossing with laboratory cultures.

Importance of Overwintering Mummies.--

A high number of overwinter mummies may be essential to produce the lowest NOW densities in orchards where both parasites are established. This is evidenced by the situation in Orchard #1 at Paso Robles which averaged high mummy densities per tree (100-1000+) and where many Nonpareil trees are never harvested. All other orchards in the current study had partial to thorough mummy removal (2 mummies/tree) rendered either by inclement weather or by manual labor. Such orchards cannot sustain a build-up of Goniozus legneri in significant numbers in June and July.

Influence of Neighboring Walnuts.--Most walnuts sustain a low incidence of NOW (usually below 2% infested mummies by August). Since walnuts are still green at this time, it seems possible that the NOW population, unable to find suitable oviposition sites, migrates to neighboring hull-cracking almonds in July and August. Goniozus legneri is capable of overwintering in walnut groves, and in the Riverside area has reduced high NOW infestations from ca. 20% in October to under 0.5% at two sites.

FIG. 1. Estimates of Nonpareil rejects at harvest at Orchard #1 in the Paso Robles area.

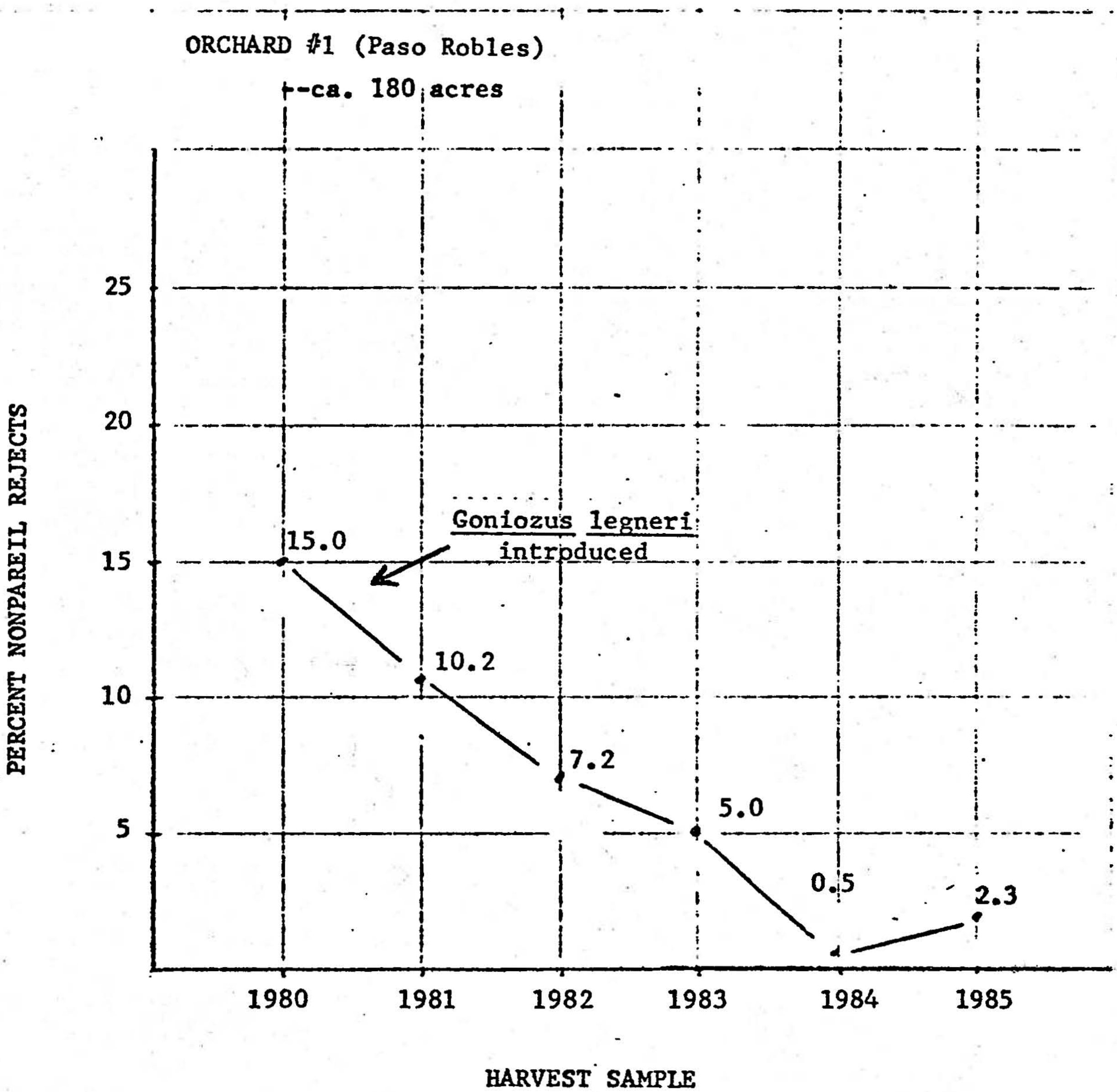


FIG. 2. Percent infested Nonpareil mummies sampled in the first week of December at Orchard #1 in the Paso Robles area.

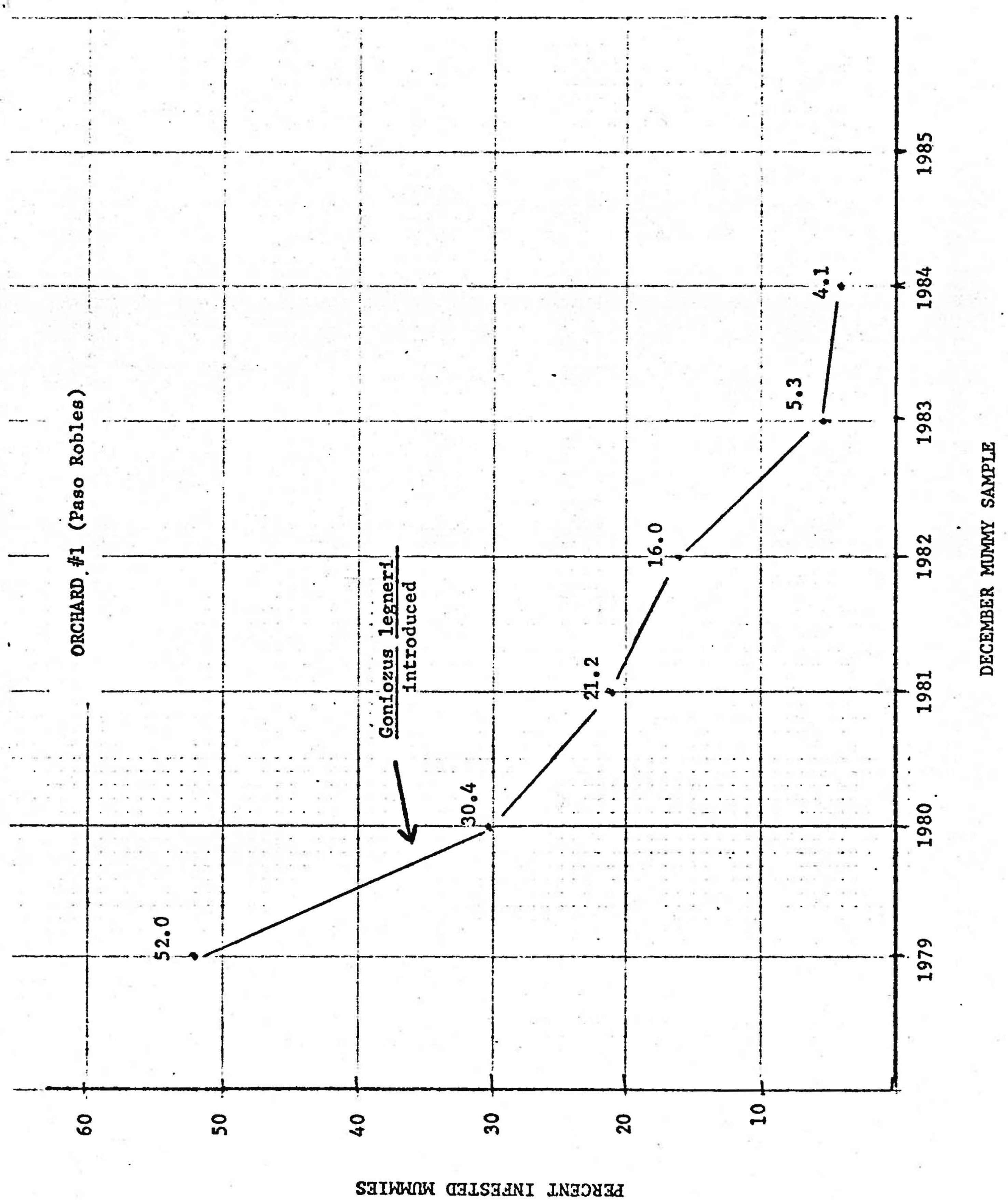


FIG. 3. Relationship between % Nonpareil rejects and orchard yield at Orchard #1 in the Paso Robles area.

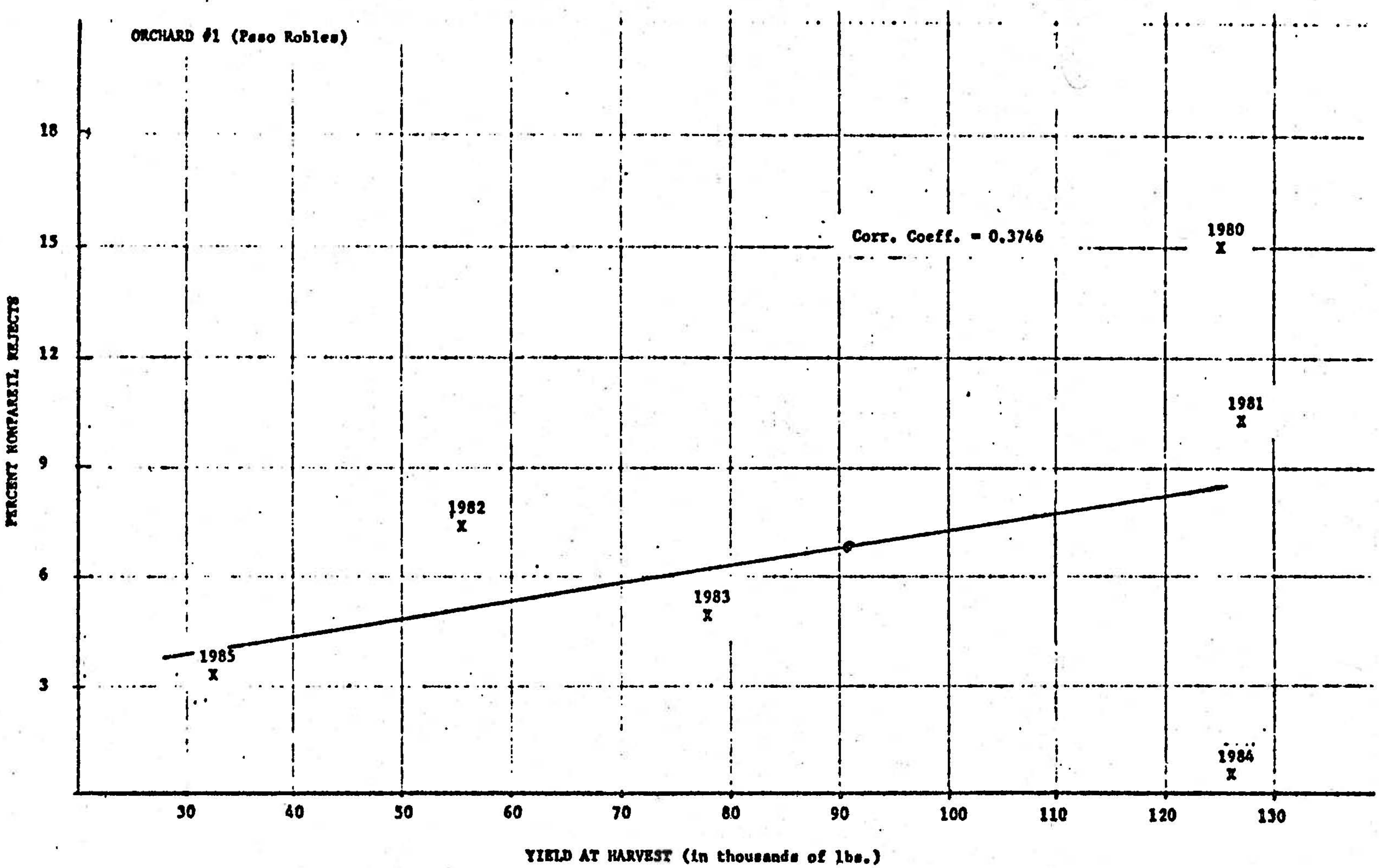


Table 1. Data for Figure 3.

ORCHARD #1 (Paso Robles)

X = estimate of total good meats (lbs.)
Y = total rejects

X	Y	
125000.000	15.000	1980
126000.000	10.200	1981
55000.000	7.200	1982
78000.000	5.000	1983
125000.000	0.500	1984
32000.000	3.300	1985

NUMBER PAIRS = 6
MEAN OF X = 90166.66 OF Y = 6.866667
SLOPE = 4.710948E-05 Y-INTERCEPT = 2.618963
(= b) (= a)

SUM-OF-SQUARES

TOTAL	417.02
MEAN	282.9067
SLOPE	18.81709
RESIDUAL	115.2962

STANDARD DEVIATIONS

X	41179.68
Y	5.17906
ERROR	5.368803
Y-BAR	2.191805
SLOPE	5.83055E-05
Y-INTER.	5.695813

F-RATIO FOR SLOPE = .6528261
t-TEST FOR SLOPE = .8079766 df = 4
CORRELATION COEFFICIENT = .3745763

COORDINATES FOR REGRESSION LINE

Y1 = 6.866667 for X = 90166.66 (= original computed intercept)

Y2 = 4.742815 for X = 45083.33
Y3 = 6.017126 for X = 72133.33
Y4 = 7.716208 for X = 108200
Y5 = 8.565748 for X = 126233.3

Table 2. Nonpareil mummies sampled in spring 1985 at Orchard #1 in the Paso Robles area, and parasitization by two principal parasites.

ORCHARD #1 (Paso Robles)

Spring Mummy Sample (1985)

SAMPLE SIZE	% Infested Mummies	% Navel Orangeworm Parasitized	
		Pentalitomastix	Goniozus
16 May 1985 2,000	4.89	4.72	0
26 June 1985 2,800	1.39	3.85	26.92

FIG. 4. Nonpareil rejects at harvest at Orchard #2 in the Hilmar area.

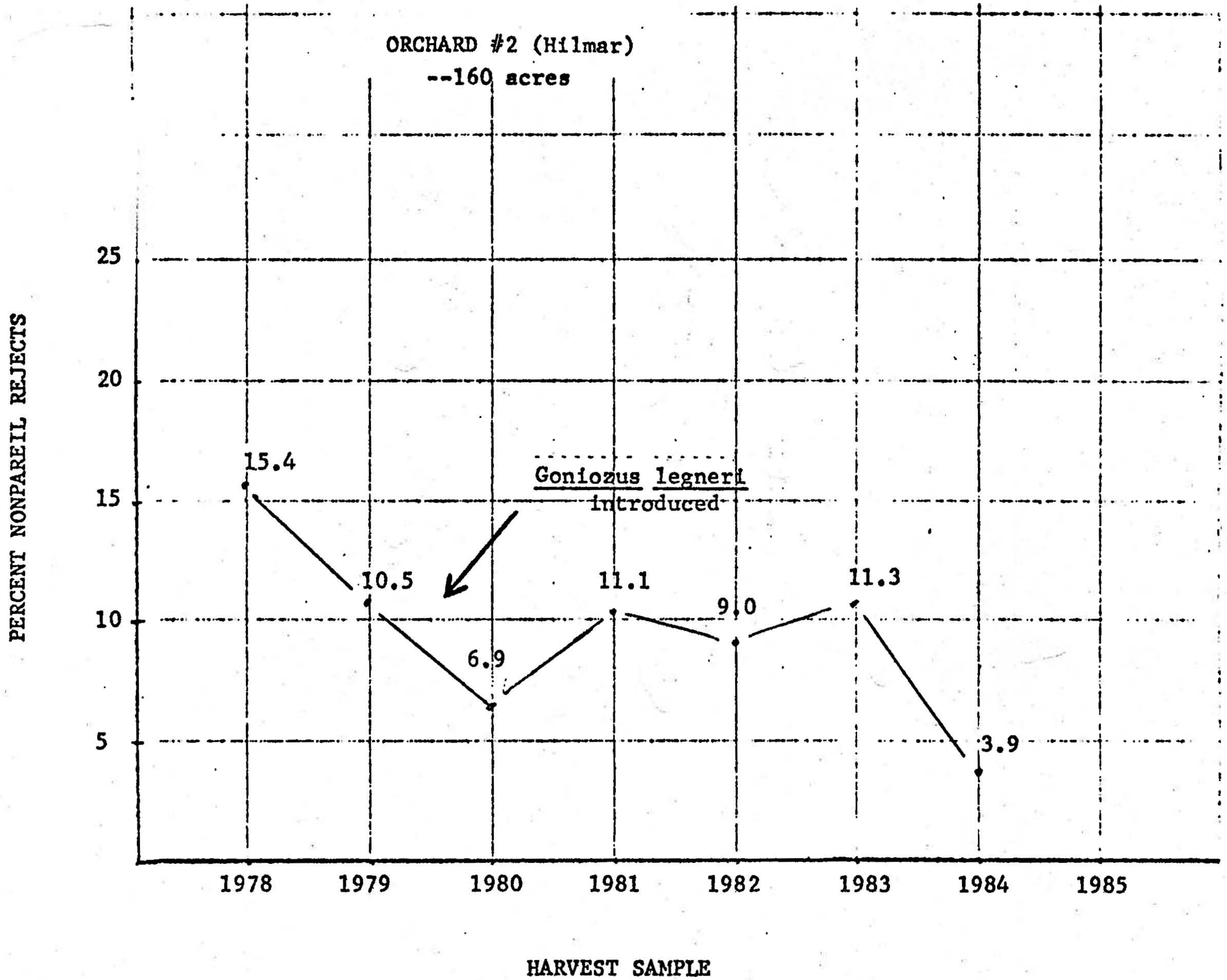


FIG. 5. Nonpareil rejects at harvest at Orchard #3 in the Selma area.

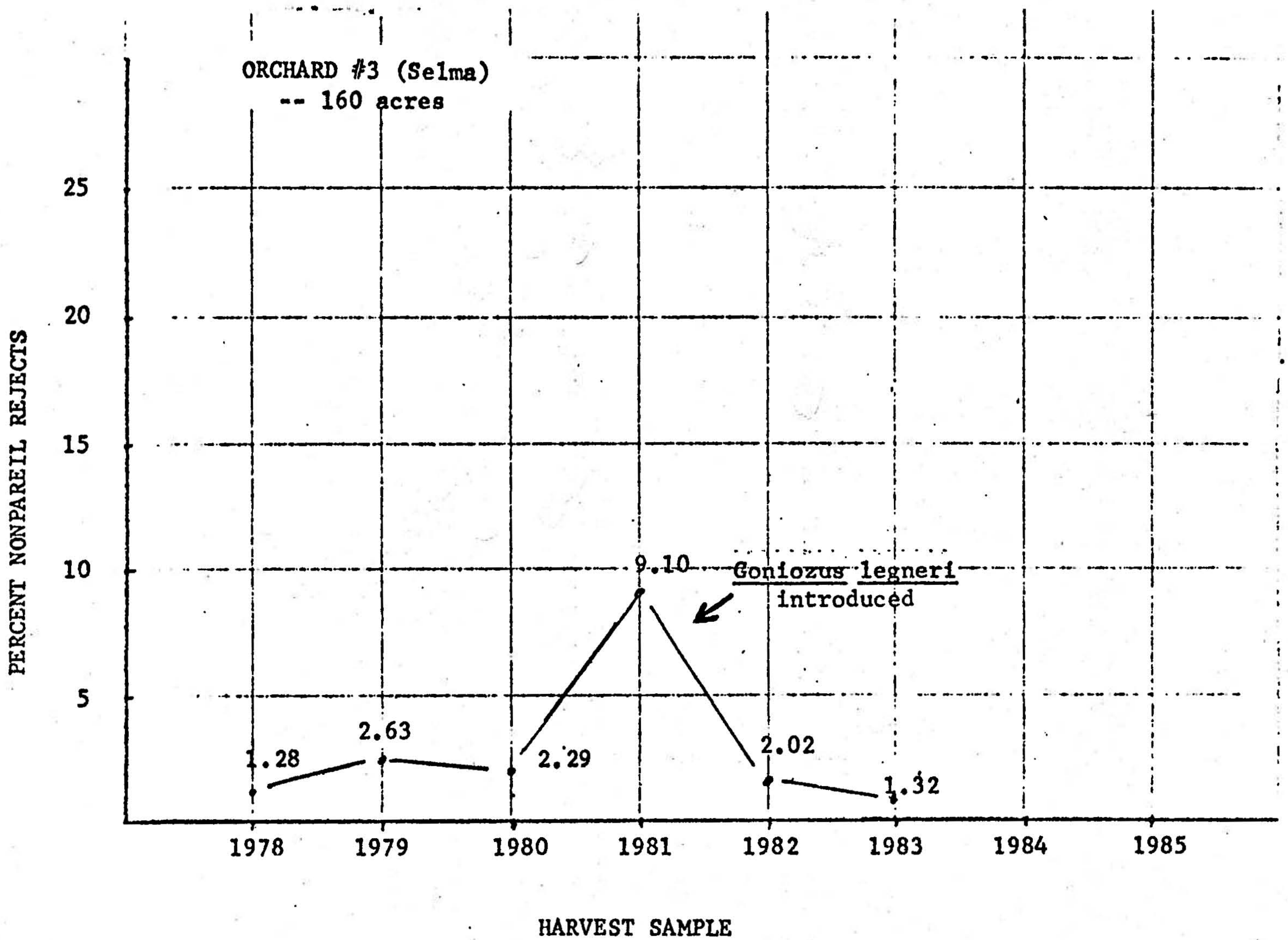


FIG. 6. Relationship between % Nonpareil rejects and orchard yield at Orchard #3 in the Selma area.

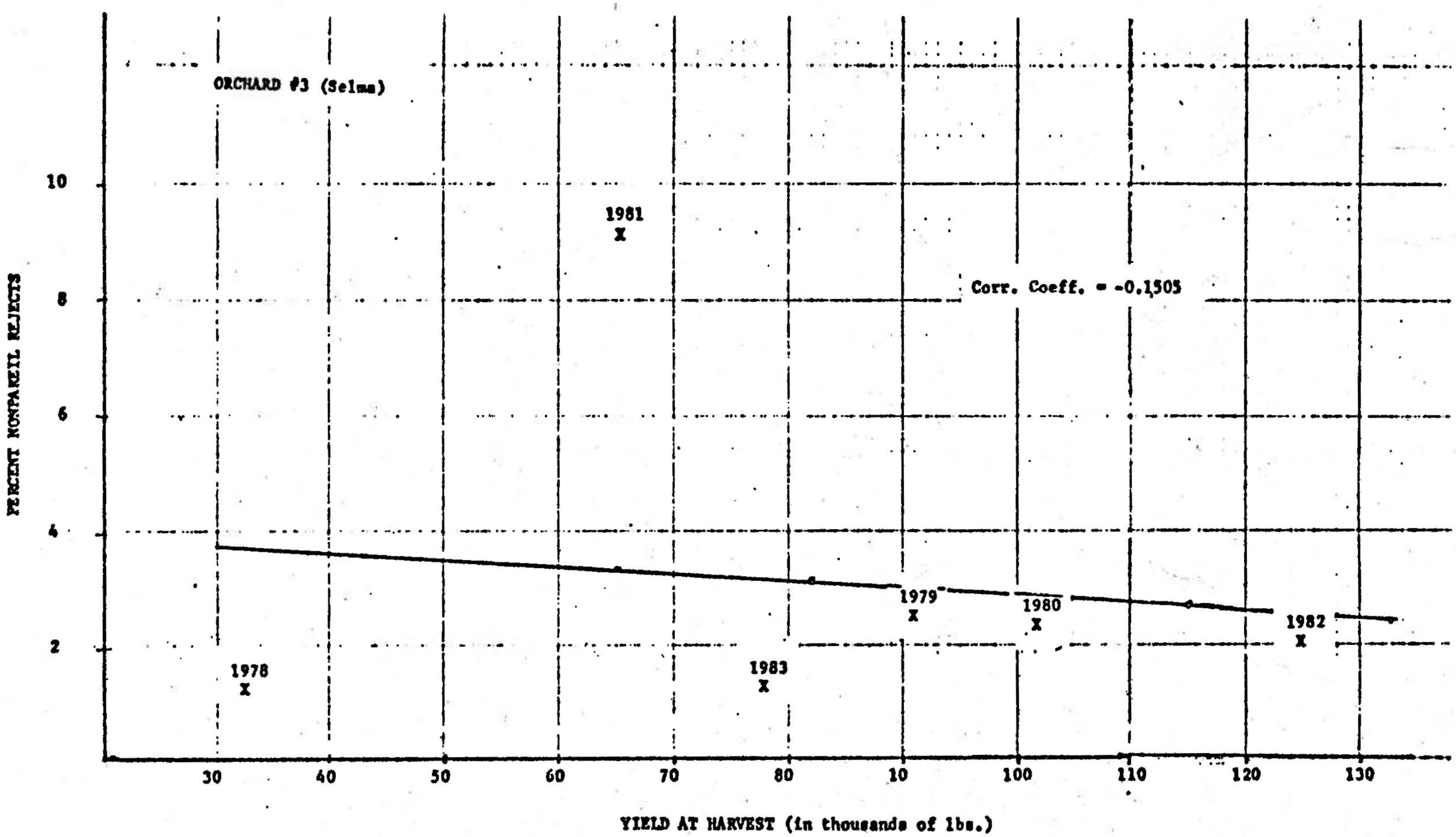


Table 3. Data for Figure 6.

ORCHARD #3 (Selma)

X = total good meats (lbs.)
Y = % rejects

X	Y	
32798.000	1.280	1978
90191.000	2.630	1979
101538.000	2.290	1980
65130.000	9.100	1981
125210.000	2.020	1982
78203.000	1.320	1983

NUMBER PAIRS = 6
MEAN OF X = 82178.34 OF Y = 3.106667
SLOPE = -1.41519E-05 (= b) Y-INTERCEPT = 4.269647 (= a)

SUM-OF-SQUARES

TOTAL	102.4322
MEAN	57.90827
SLOPE	1.008509
RESIDUAL	43.51543

STANDARD DEVIATIONS

X	31735.11
Y	2.984089
ERROR	3.298311
Y-BAR	1.34653
SLOPE	4.648006E-05
Y-INTER.	4.050049

F-RATIO FOR SLOPE = 9.270356E-02
t-TEST FOR SLOPE = .3044726 df = 4
CORRELATION COEFFICIENT = -.1505023

COORDINATES FOR REGRESSION LINE

Y1 = 3.106667 for X = 82178.34 (= original computed intercept)

Y2 = 3.688157 for X = 41089.17
Y3 = 3.339263 for X = 65742.68
Y4 = 2.874071 for X = 98614.01
Y5 = 2.641475 for X = 115049.7

FIG. 7. Nonpareil rejects at harvest at Orchard #4 in the Wesley area.

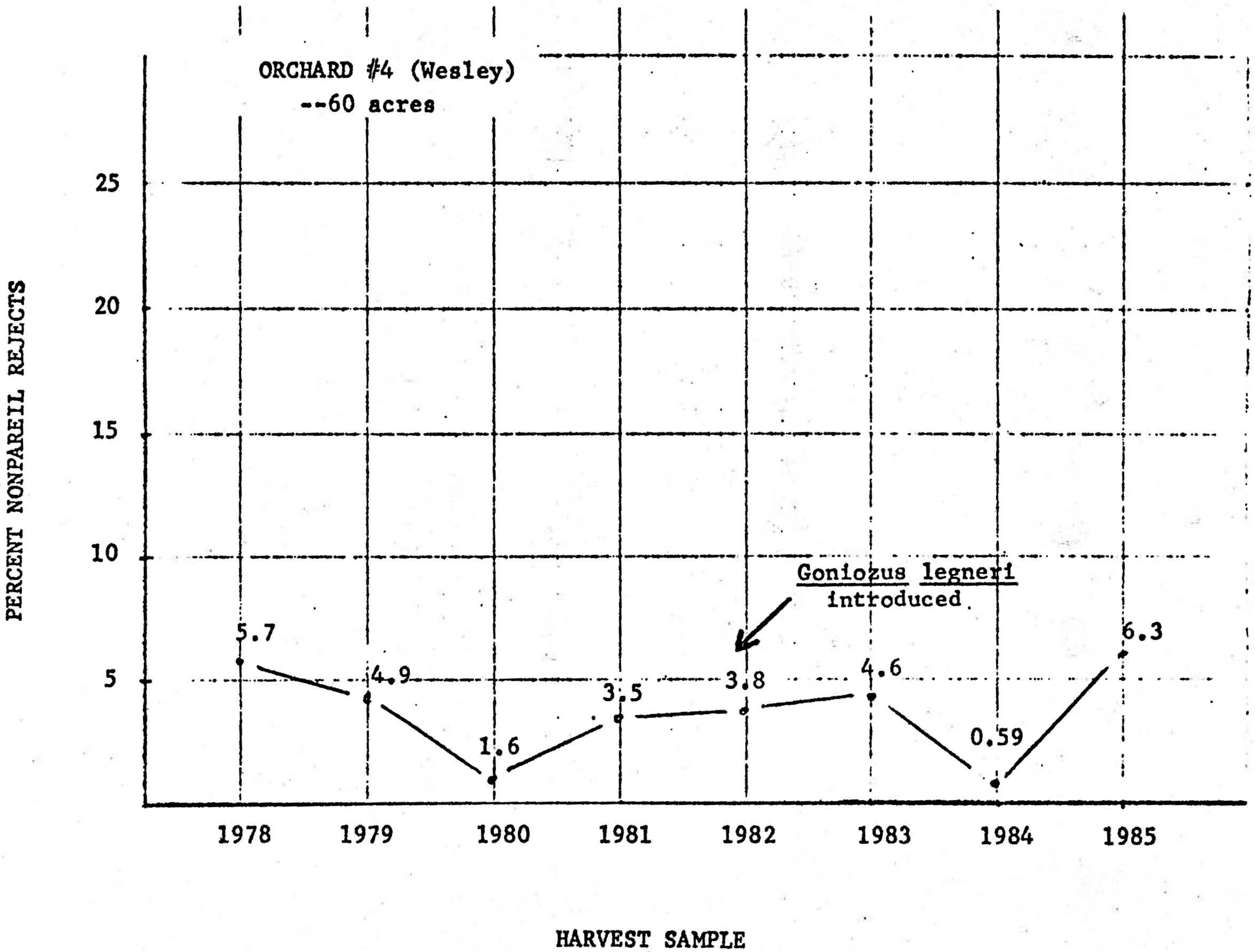


FIG. 8. Relationship between % Nonpareil rejects and orchard yield at Orchard #4 in the Wesley area.

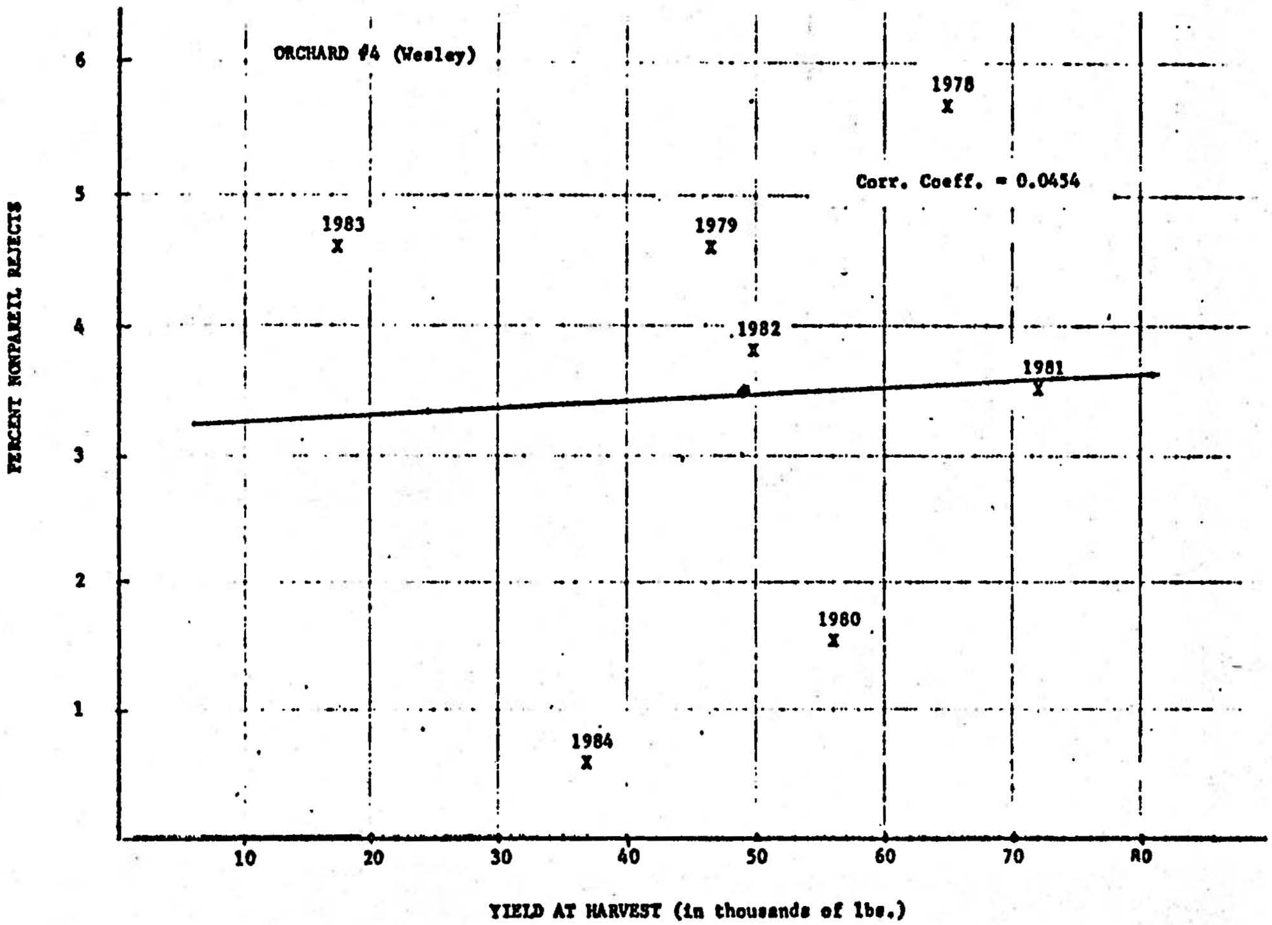


Table 4. Data for Figure 8.

ORCHARD #4 (Wesley)

X = total good meats (lbs.)
Y = % rejects

X	Y	
60518.000	5.700	1978
46237.000	4.600	1979
56052.000	1.600	1980
71653.000	3.500	1981
49918.000	3.800	1982
17296.000	4.600	1983
37195.000	0.590	1984

NUMBER PAIRS = 7
MEAN OF X = 48409.86 OF Y = 3.484286
SLOPE = 4.653136E-06 (= b) Y-INTERCEPT = 3.259028 (= a)

SUM-OF-SQUARES

TOTAL	104.4081
MEAN	84.98172
SLOPE	3.997102E-02
RESIDUAL	19.38641

STANDARD DEVIATIONS

X	17540.88
Y	1.799369
ERROR	1.969081
Y-BAR	.7442428
SLOPE	4.582862E-05
Y-INTER.	2.340063

F-RATIO FOR SLOPE = 1.030903E-02
t-TEST FOR SLOPE = .1015334 df = 5
CORRELATION COEFFICIENT = 4.536038E-02

COORDINATES FOR REGRESSION LINE

Y1 = 3.484286 for X = 48409.86 (= original computed intercept)

Y2 = 3.371657 for X = 24204.93
Y3 = 3.439234 for X = 38727.88
Y4 = 3.529337 for X = 58091.83
Y5 = 3.574389 for X = 67773.8

FIG. 9. Nonpareil rejects at harvest at Orchard #5 in the Atwater area.

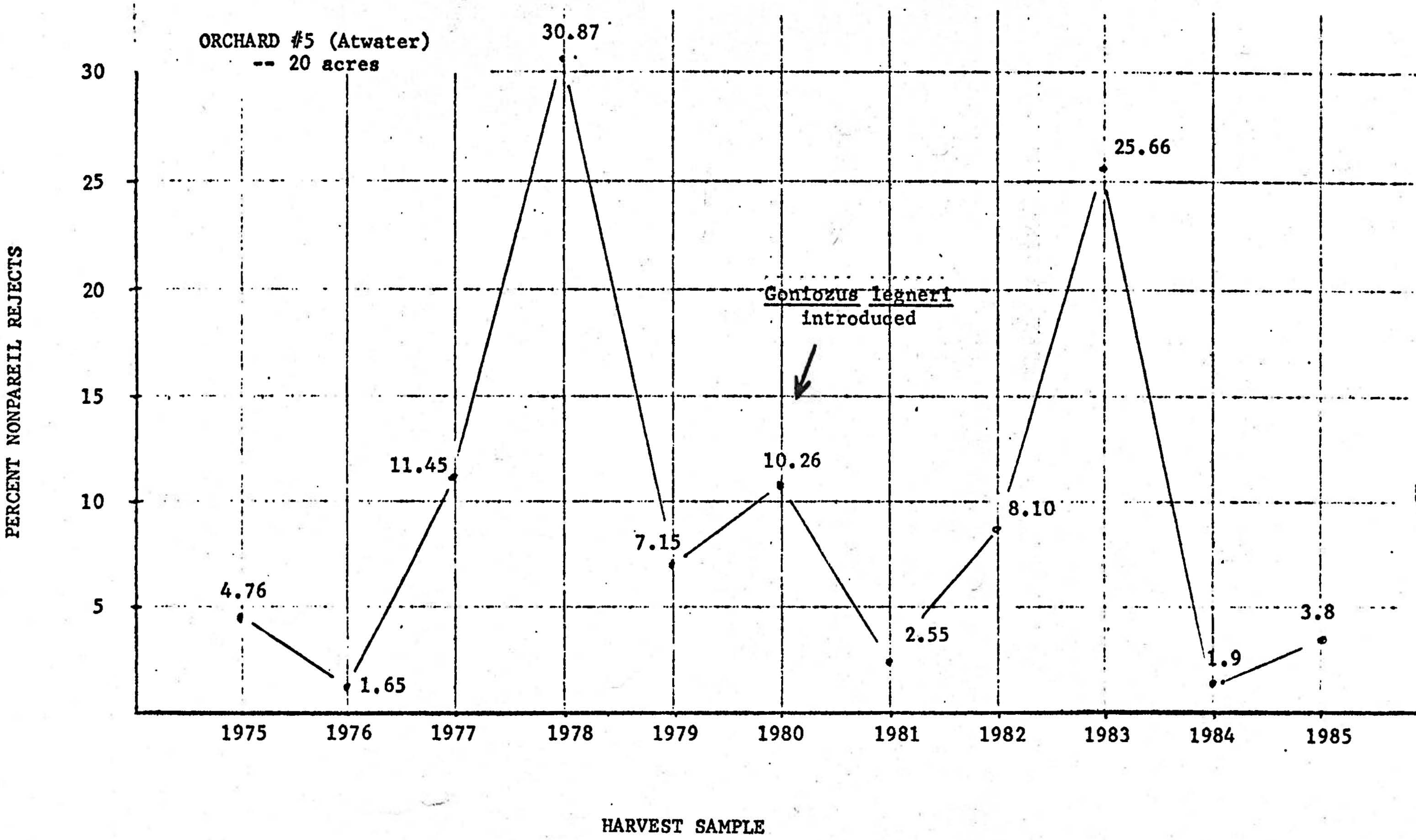


FIG. 10. Relationship between % Nonpareil rejects and orchard yield at Orchard #9 in the Atwater area.

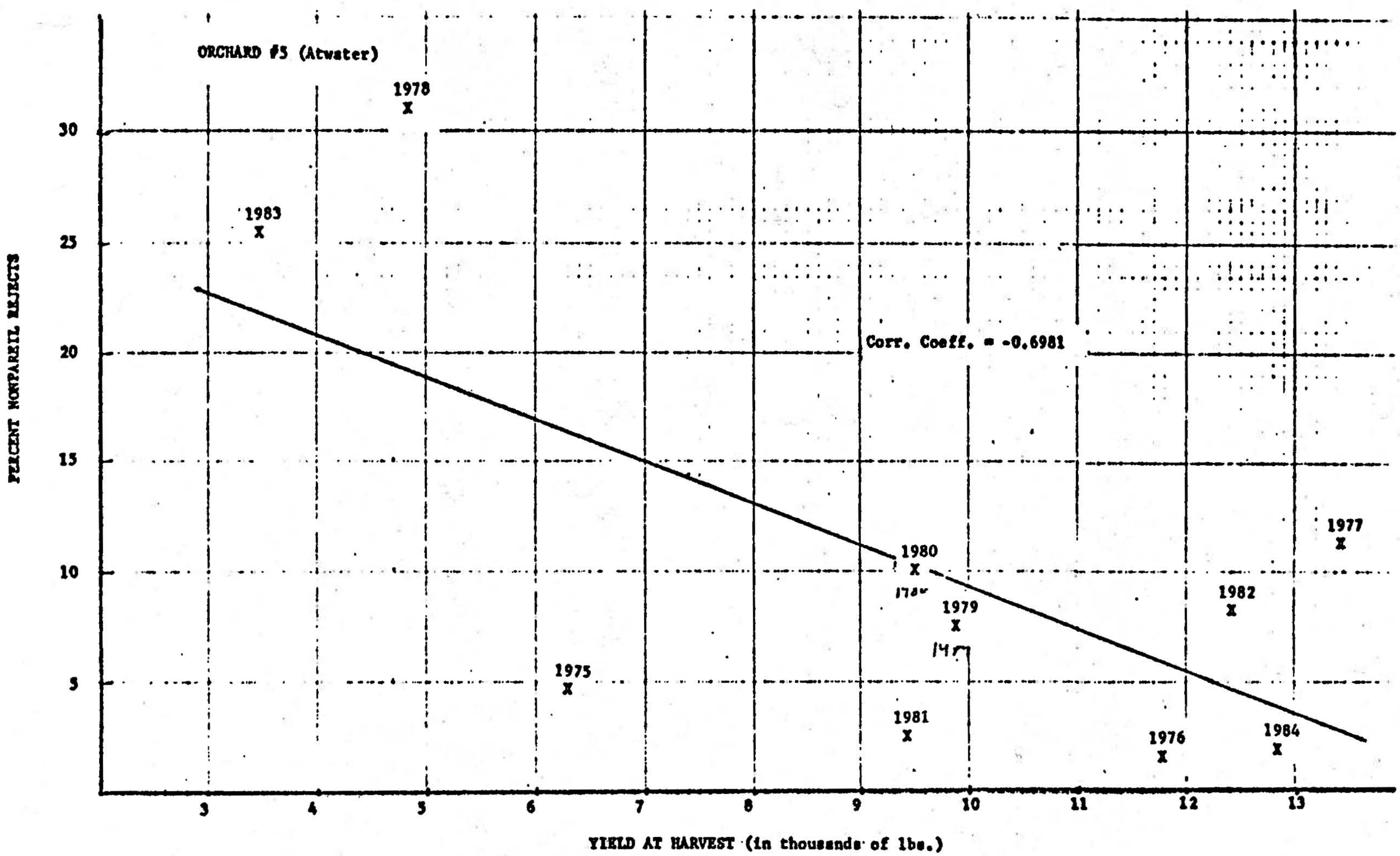


Table 5. Data for Figure 10.

ORCHARD #5 (Atwater)

X = total good meats (lbs.)
Y = % rejects

X	Y	
6238.000	4.760	1975
11846.000	1.650	1976
13488.000	11.450	1977
4830.000	30.870	1978
9847.000	7.150	1979
9411.000	10.260	1980
9423.000	2.550	1981
12477.000	8.100	1982
3476.000	25.660	1983
12839.000	1.900	1984

NUMBER PAIRS = 10
MEAN OF X = 9387.5 OF Y = 10.435
SLOPE = -2.007364E-03 (= b) Y-INTERCEPT = 29.28101 (= a)

SUM-OF-SQUARES

TOTAL	1999.987
MEAN	1088.892
SLOPE	444.0001
RESIDUAL	467.0952

STANDARD DEVIATIONS

X	3498.652
Y	10.06145
ERROR	7.641132
Y-BAR	2.416338
SLOPE	7.280071E-04
Y-INTER.	7.24876

F-RATIO FOR SLOPE = 7.604448
t-TEST FOR SLOPE = 2.757616 df = 8
CORRELATION COEFFICIENT = -.6980871

COORDINATES FOR REGRESSION LINE

Y1 = 10.435 for X = 9387.5 (= original computed intercept)

Y2 = 19.85801 for X = 4693.75
Y3 = 14.2042 for X = 7510
Y4 = 6.665798 for X = 11265
Y5 = 2.896595 for X = 13142.5

FIG. 11. Nonpareil rejects at harvest at Orchard #6 in the Chowchilla area.