FINAL REPORT TO THE CALIFORNIA AIR RESOURCES BOARD

UNDER AGREEMENT ARB-287

DEVELOPMENT OF A SYSTEM FOR EVALUATING AND REPORTING ECONOMIC CROP LOSSES CAUSED BY AIR POLLUTION IN CALIFORNIA

I. QUALITY STUDY

by

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CHAPTER I - INTRODUCTION

The need for development of accurate air pollution crop assessment methodology has increased with public concern over our pressing environmental problems. In order to keep pace with the demands of our increasing population, great efforts have been made to increase agricultural production. Yet, Federal, State, and County agencies have been unable to make an adequate assessment of crop losses caused by air pollutants. The lack of basic information relative to the effects of air pollutants on crops has prevented standardization of assessments and has raised questions as to the accuracy and value of past efforts.

Some of the major problems confronting attempts to assess the extent of air pollution-induced losses have been: 1) controlling the number of variables introduced by the geographical size of agricultural production areas, 2) the lack of sufficient research on agricultural crop varieties to determine loss criteria applicable to field conditions, and 3) the enormous expense of establishing and maintaining controlled experiments under field conditions.

Formidable as these and other related problems are, two general approaches to relieve the need for economic crop loss assessments have emerged.

Chamber Studies

Several investigators have, independently and in cooperation, initiated field studies of selected crops utilizing a variety of sophisticated chambers designed to duplicate field conditions (2, 5, 6, 7, 9). These experiments have provided a good deal of useful information but have not succeeded in developing crop loss criteria applicable to field-grown crops. In each case, the use of "chambers" has significantly influenced the plants within them, either in the selection of diminutive varieties compatible with the size limitations of chambers, or in growth reaction to the chamber's environment. Open top chambers have succeeded in closely approximating ambient climatological conditions, but do not eliminate ambient pollutants in control chambers. Control plants may be affected by the pollutants and the reference for comparing pollution-exposed plants is lost.

Field Observation Assessments

Several surveys have been undertaken utilizing field observations for evaluation of pollution-damaged crops (1, 3, 4, 8). The structural design of these studies has varied but all essentially rely on one individual's estimation of leaf damage, its association with yield or quality reductions, and the extent of damage incurred in a particular area. Assessments have varied from individual to individual depending on personal experience and expertise in identifying pollution injury. The lack of authenticated loss criteria for crops makes standardization of assessment impossible, and the accuracy and value of such surveys has been questioned.

Both chamber experiments and field observation assessments have certain advantages and problems inherent in their designs. Field observation assessments are adaptable to large agricultural areas but lack standardization and accuracy. Chamber experiments have much greater accuracy but are financially unfeasible for large geographical areas. Their results are, in most cases, not applicable to field conditions.

This project combines fumigation studies, field plots, and several statistical methods incorporated into an integrated program to develop the needed crop loss assessment methodology. Controlled fumigations were included to determine effects of oxidants and crop loss criteria for specific crops. Field studies throughout the South Coast Air Basin were established to insure that crop loss criteria developed from fumigations are applicable to field-grown crops. Reductions in yield or quality are correlated with ambient dosages during growth. Should these correlations be significant, further tests could be scheduled to determine the association of yield or quality reductions with other environmental influences.

This report summarizes results of the first phase of this study dealing with oxidant air pollutant effects on crop quality. It will be followed by phase 2 dealing with the effects of oxidant air pollutants on yield.

CHAPTER II - SUMMARY

Ozone and PAN did not affect the quality of produce from Golden Jubilee corn, H-11 tomato, Copenhagen cabbage, Emperator #58 carrots and Valencia oranges. A statistical correlation has linked ambient ozone levels to the incidence of irregular fruit produced by Tioga strawberries. Boston (dark green) leaf lettuce was found to be susceptible to quality reductions by both ozone and PAN.

Long-term fumigation studies under greenhouse conditions were observed to be accurate in forecasting the expression of oxidant effects on crops during the quality study. With the exception of leaf lettuce, no quality reductions were found to be caused by oxidant air pollutants during fumigations, and correlations between evaluated quality and ambient oxidant dosages during growth proved to be insignificant. The value of long-term fumigations will be magnified further should they prove as accurate in indicating yield effects.

Fumigation results indicated that ozone reduced the yield of every row-crop studied. The extent of reduction and the concentration threshold varied with the crop, but each was found to have a lower yield resulting from ozone exposures. The 1973 yield studies should determine whether ozone-induced yield reductions also occur on field-grown crops. The extent of reductions, should they occur, would be the basis for air pollution loss assessments.

Multi-harvest crops (tomato and strawberry) are characterized by a natural decline in plant vigor through an extended season. This effect should not be interpreted as an oxidant-induced effect. A few correlations of evaluated data and ambient oxidant dosages were statistically significant, when in reality they were a measurement of this natural decline. Care must be taken to avoid erroneous interpretation of these correlations.

PAN did not affect the quality or yield of Golden Jubilee sweet corn, H-11 tomato, Emperator #58 carrot, Copenhagen cabbage, and Tioga strawberry. Copenhagen cabbage and H-11 tomato were susceptible to leaf injury but this was not reflected in the harvest. Boston lettuce (dark green) was the only crop detrimentally affected by PAN. Fumigated plants incurred extensive leaf injury, rendering heads unacceptable for market.

Light oxidant dosages during the 1972 fall growing season prevented substantiation of fumigation results for leaf lettuce and cabbage. The oxidant levels were below injury thresholds and field-grown crops remained unaffected. Field plots established in the 1973 study will be closely scrutinized for quality effects as well as yield reductions.

The air monitoring biological indicator (AMBI) system proved successful in monitoring ambient oxidant levels. The injury evaluation - ozone dosage correlation was significant at a confidence level of 99.9%. The PAN injury evaluation - ambient dosage correlation at Riverside also proved to be significant, but a thorough field test of the South Coast Air Basin was not implemented due to lack of a PAN monitoring instrument.

The photo-reference system of plant injury evaluation was effective, providing the desired accuracy with excellent standardization. Duplicate evaluations of indicator plants by the Ventura County Agricultural Commissioner's personnel and State program personnel coincided well. We believe this type of system offers the best method of standardizing injury evaluations.

Employing controlled fumigations to isolate oxidant effects and field plots to substantiate the existence of the same effects in the field appeared to be effective. The quality phase of the program found that the field data essentially duplicated the fumigation results. Fumigations have established that the major effect of ozone was an overall reduction in yield. The 1973 yield phase should be critical in developing viable methodology.

CHAPTER III - DESIGN

This project incorporates several components integrated into a functional model to produce the desired methodology for economic assessment of air pollution damage to agriculture (Figure 1). The project's scope, in a geographical and physical sense, is outlined in the following discussion. Basic procedures used and systems developed are also described.

Study Area

The South Coast Air Basin, including Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties, was selected as the study area. County Air Pollution Control Districts of the respective counties have provided ambient oxidant data from a network of established instrument monitoring stations. A key to the stations used by this program is listed in Table 1. Actual geographical locations are presented in Map 2. A wide gradation of ambient oxidant levels exists within the South Coast Air Basin.

Two major production areas, the coastal plain and the inland valleys, provide a useful contrast in growing conditions.

Test Crops

Six table crops and a tree crop were selected for study. Varieties were selected on the basis of popularity and distribution throughout the air basin. The list of study crops includes:

1. Golden Jubilee sweet corn
2. H-11 pole tomatoes
3. Emperator #58 carrots
4. Copenhagen Market cabbage
5. Prizehead leaf lettuce
6. Tioga strawberries
7. Valencia oranges on Troyer rootstock

Test crops are seasonally grown and although some overlap exists between seasons for Tioga strawberries and Valencia oranges, both were arbitrarily defined as falling within one of the two selected growing seasons. Golden Jubilee corn, H-11 tomatoes, Emperator #58 carrots and Valencia oranges were designated as spring test crops and Copenhagen Market cabbage, Prizehead lettuce and Tioga strawberries as fall test crops.

Each field location within the study area was assigned an identification number (Table 2). Actual geographical locations for the spring test crops are given in Map 3 and fall test crops in Map 4.

Air Monitoring Biological Indicator System

Few regions within California are as well monitored for ambient air pollutants as the South Coast Air Basin. If the assessment methodology developed by this program was to be implemented without the tremendous expenditure of funds necessary to set up an intrument monitoring network, the development of an inexpensive mobile monitoring system was imperative. To this end an air monitoring biological indicator (AMBI) system, utilizing selected oxidant-sensitive indicator plants, was developed and tested. This system was correlated with actual ambient oxidant levels recorded by the instrument monitoring stations. A complete description and analysis of this system is presented in Chapter IV.

Field Studies

Field and test plots designed to determine possible quality reductions associated with oxidant air pollutants, were set up in the South Coast Air Basin. Two test plots, each growing the full complement of study table crops, were grown and maintained by project personnel and used as points of reference for the inland and coastal production areas.

Field plots, consisting of selected commercial grower fields, were sampled for quality analysis. Only growers recommended by the staff of the County Agricultural Commissioners' offices were considered. Selection of the field plots was based on variety of crop planted and location within the study area.

Statistical Evaluation and Analysis

All data from fumigations and from field plots were analyzed statistically to determine significance utilizing analysis of variance and Duncan's multiple range test. A statistical correlation was selected as the means of evaluating the association between ambient oxidants and crop quality reductions. If significant differences occurred between locations, a linear regression correlation was used.

The total ambient oxidant dosages affecting the growth of crops was correlated, via a linear regression, with the evaluated mean quality. The level of statistical significance given each correlation measures the probability of a significant association between the evaluated quality and the total oxidant dosage present during growth. Such correlations cannot confirm these associations as would controlled experiments, but do indicate the probability at given confidence levels.

The correlations are presented in graphic form with their respective correlation coefficients and T-slopes included. The following notations of significance are also presented if applicable: * = 95%
** = 99%

Figure 1. OUTLINE OF THE COMPONENT FUNCTIONS AND ASSOCIATIONS OF THE AIR POLLUTION METHODOLOGY PROGRAM

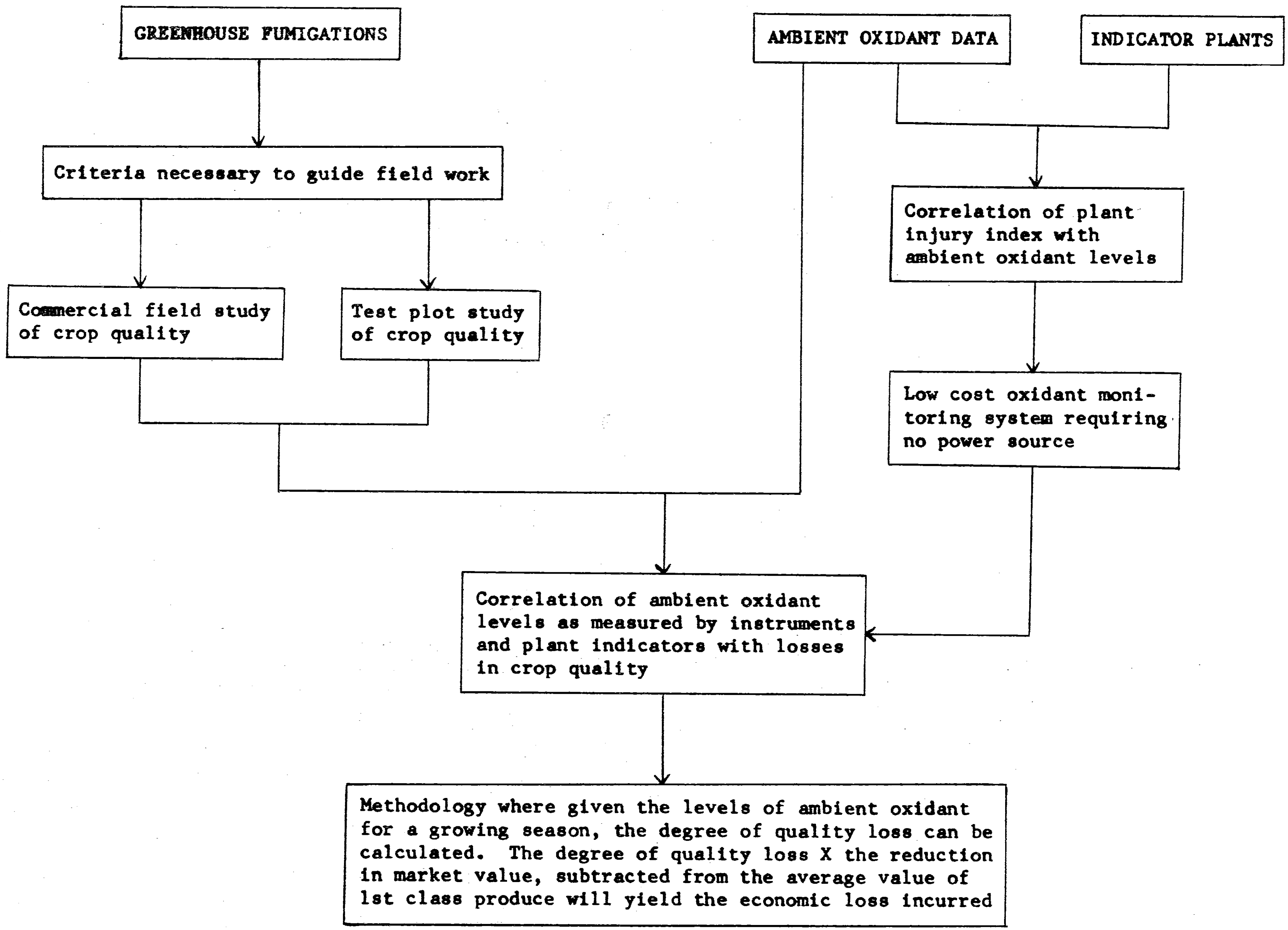


Table 1. Identification key to A.P.C.D. oxidant instrument monitoring stations utilized in the South Coast Air Basin.

Identification #	Monitoring Station
1	Azusa
3	Pomona
4	Anaheim
5	Costa Mesa
6	La Habra
7	Los Alamitos
8	Corona
9	Hemet
10	Riverside
11	U.C.R.1/
13	Redlands
14	San Bernardino
15	South Coast Field Station2/
16	Camarillo

1/ Instrument station run by the Statewide Air Pollution Research Center, University of California at Riverside

2/ Instrument station run by the Air Pollution Methodology Program

Table 2. Identification key to field and test plot locations and harvest data.

I. Golden Jubilee Corn

Identification #[1/]	Location
104	Orange Co.
107	" "
108	" "
130	San Bernardino Co.
131	" " "
132	" " "
142	Ventura Co.
501	U.C.R. Test Plot Set #1
502	" " " " #2
503	" " " " #3
504	" " " " #4
505	S.C.F. Test Plot Set #1
506	" " " " #2
507	" " " " #3
508	" " " " #4

II. H-11 Tomatoes

Identification #	Location
101, 201, 301	Orange Co.
102, 202	" "
103, 203, 303	" "
121, 221	Riverside Co.
122, 222, 322	" "
511-525	U.C.R. Test Plot
527-537	S.C.F. Test Plot

1/ Identification numbers consist of 3 digits. The 500 series refers to test plot harvests only. The 100-499 series refers to commercial field plots only. Within the commercial field plot series, the first integer identifies the harvest and the last two integers identifies the location.

Example:

111 = 1st harvest at field #11
211 = 2nd " " " "
311 = 3rd " " " "

Test plot identification numbers only identify specific harvests and not the location of the test plot.

Table 2 - continued

III. Emperator #58 Carrots

Identification #	Location
117	Riverside Co.
118	" "
119	" "
509	U.C.R. Test Plot
510	S.C.F. Test Plot

IV. Prizehead Lettuce

Identification #	Location
149	Orange Co.
150	" "
152	Riverside Co.
138	San Bernardino Co.
154	" " "
155	Ventura Co.
540	U.C.R. Test Plot
-	S.C.F. Test Plot

V. Copenhagen Market Cabbage

Identification #	Location
148	Orange Co.
151	" "
153	Riverside Co.
155	Ventura Co.
545	S.C.F. Test Plot
547	U.C.R. Test Plot

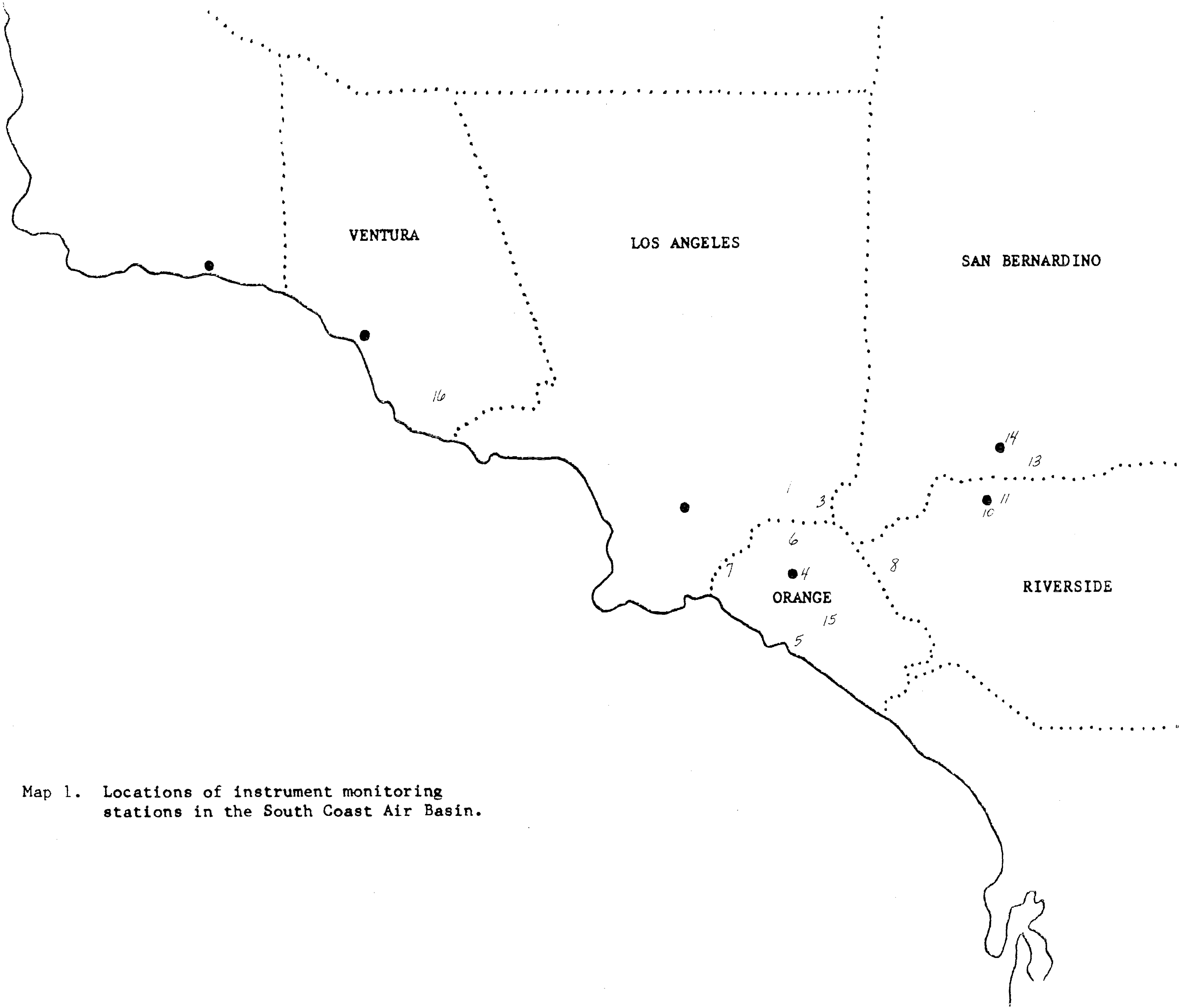
VI. Valencia Oranges on Troyer

Identification #	Location
105	Orange Co.
106	" "
109	" "
120	Riverside Co.
125	" "
133	San Bernardino Co.
134	" " "
139	Ventura Co.
140	" "
143	" "

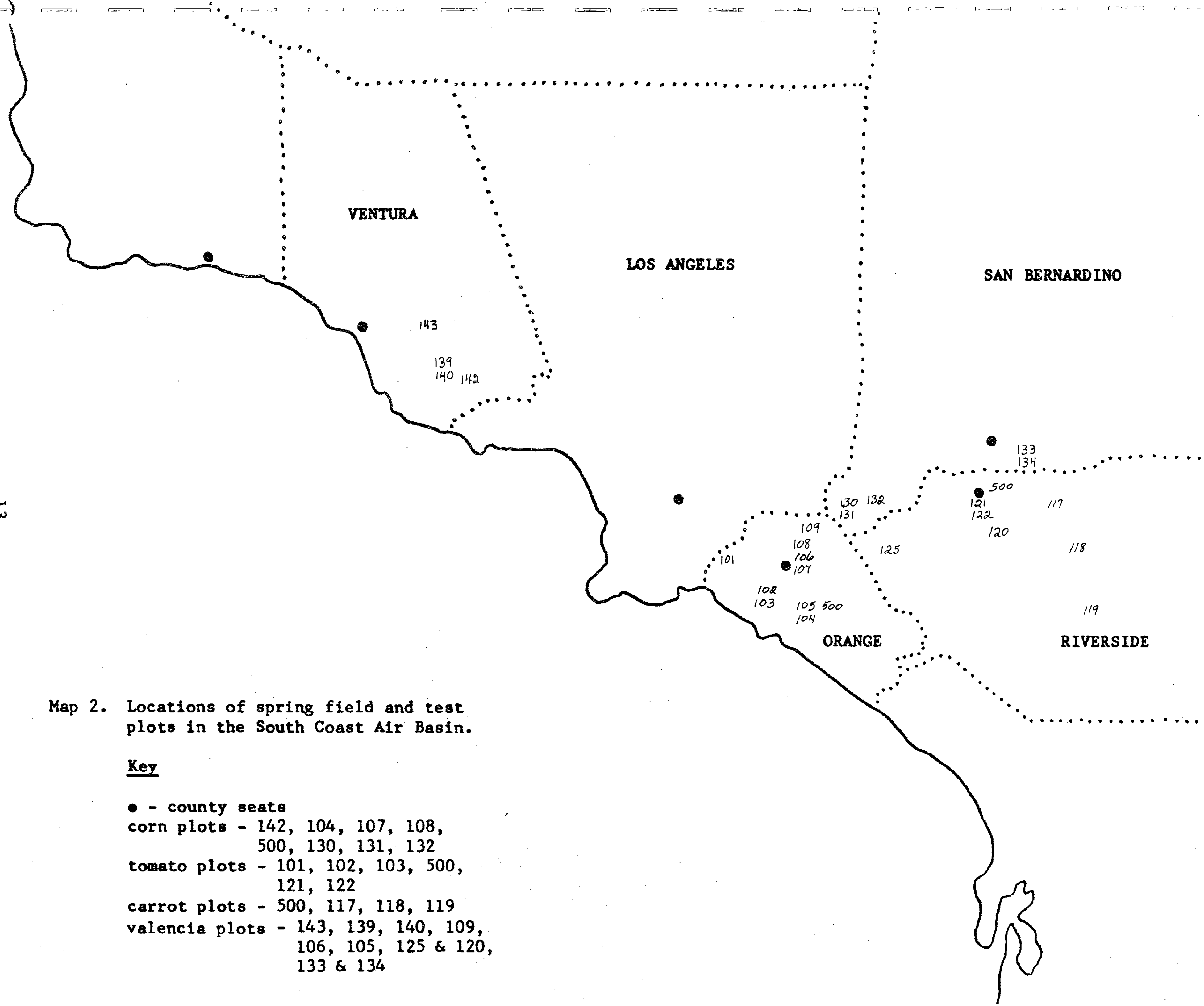
Table 2 - continued

VII. Tioga Strawberries

Identification #	Location
111, 211, 311	Orange Co.
112, 212, 312	" "
113, 213, 313	" "
114, 214, 314	Los Angeles Co.
115, 215, 315	" " "
126, 226, 326	Riverside Co.
127, 227, 327	" "
135, 235, 335	San Bernardino Co.
136, 236, 336	" " "
137, 237, 337	" " "
146, 246, 346	Ventura Co.
147, 247, 347	" "
550-577	U.C.R. Test Plot
580-607	S.C.F. Test Plot



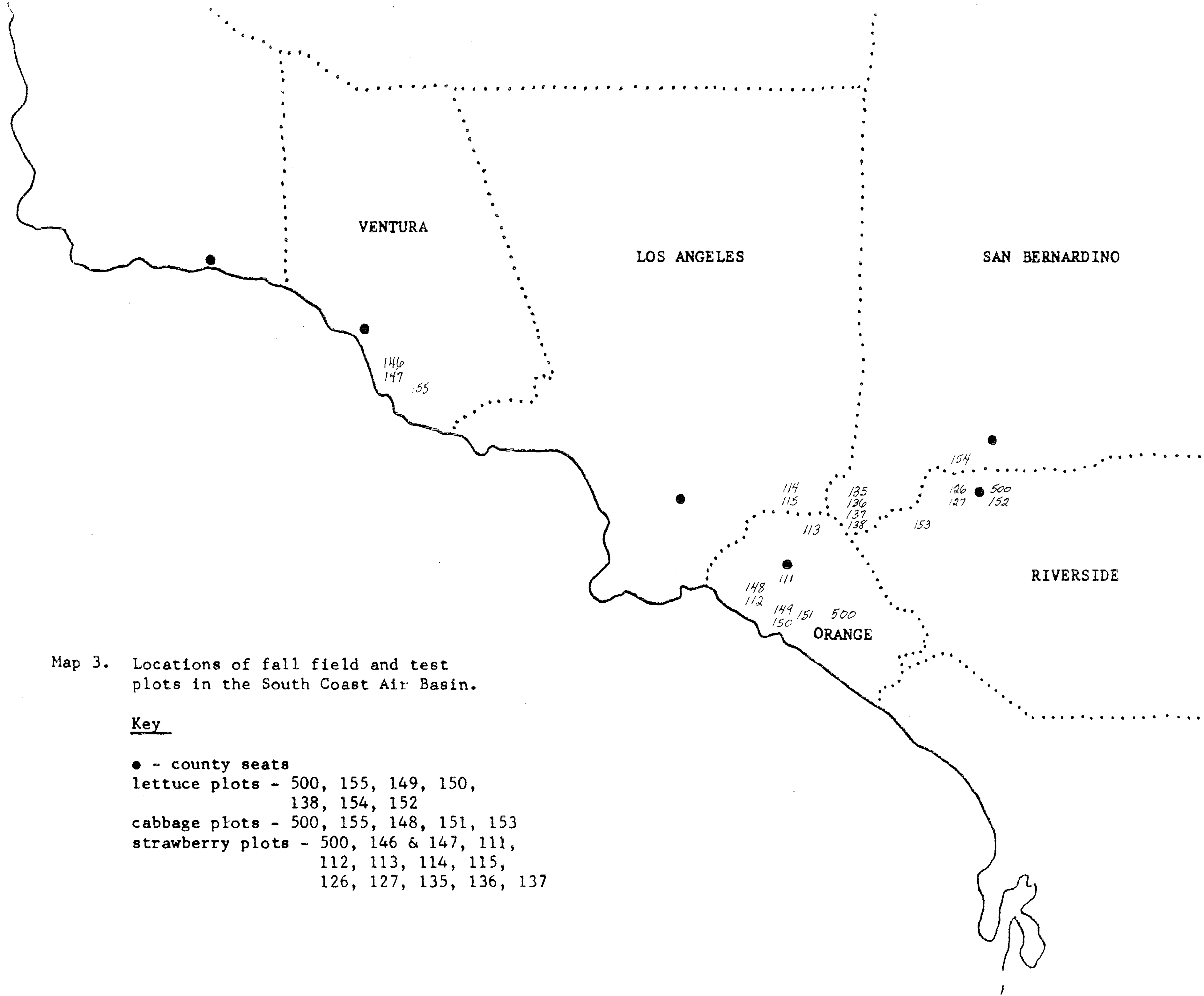
Map 1. Locations of instrument monitoring stations in the South Coast Air Basin.



Map 2. Locations of spring field and test plots in the South Coast Air Basin.

<u>Key</u>

● - county seats
corn plots - 142, 104, 107, 108, 500, 130, 131, 132
tomato plots - 101, 102, 103, 500, 121, 122
carrot plots - 500, 117, 118, 119
valencia plots - 143, 139, 140, 109, 106, 105, 125 & 120, 133 & 134



Map 3. Locations of fall field and test plots in the South Coast Air Basin.

Key

● - county seats
lettuce plots - 500, 155, 149, 150, 138, 154, 152
cabbage plots - 500, 155, 148, 151, 153
strawberry plots - 500, 146 & 147, 111, 112, 113, 114, 115, 126, 127, 135, 136, 137

Instrument Oxidant Data

Three general types of instruments are used to monitor ozone in the South Coast Air Basin: 1) colorimetric or coulimetric analyzers utilizing the oxidant reaction with a potassium iodide (KI) solution, 2) ethylene chemiluminescent ozone instruments, 3) ultra-violet absorption instruments. Instruments of the last two types are ozone-specific. Instruments using the colorimetric or coulimetric method monitor all oxidants which react with the KI solution.

Ozone normally comprises all but an extremely small increment of the total oxidants in the South Coast Air Basin during daylight hours. Nitrogen dioxide (NO_2) is dissipated during the synthesis of atmospheric ozone and generally does not exist in significant quantities when ozone is present. Some overlap exists in early morning or evening but the amount is usually negligible as NO_2 sensitivity is only 10% of the total oxidant scale when compared with ozone. The overlapping periods usually exhibit very low total oxidant levels.

Peroxyacetyl-nitrate (PAN) does exist in conjunction with ozone during daylight hours but only at extremely low levels, approximately 0.1% of the total oxidant scale when compared to ozone.

Variability among instruments of any one model and differences in efficiency of maintenance and operation by different agencies make the calculation of equilibrating factors impossible.

All data received, whether from ozone-specific intruments or total oxidant instruments, have therefore been used as measurements of ozone and compared against each other. Hourly averages above 10 pphm, the California standard for oxidant air pollutants, were used to calculate the average weekly dosage in pphm hours for the respective seasons. Only hourly averages for the daylight hours were used, as plant sensitivity to oxidants is reduced at night.

The hourly PAN levels at UCR were monitored by an Aerograph Panalyzer Model 681. Weekly average dosages calculated for the respective seasons were used in the plant injury-PAN dosage correlation for Snowstorm petunias.

Field locations within a five-mile radius of an instrument station were assigned the ozone dosages recorded by that station. Dosages for field locations outside the radius of an instrument station were computed through interpolation. The following formula was used:

$$I = \frac{\left(\frac{O_1}{d_1} + \frac{O_2}{d_2} + \frac{O_3}{d_3}\right)}{\left(\frac{1}{d_1} + \frac{1}{d_2} + \frac{1}{d_3}\right)}$$

where: I = interpolated dosage

O = oxidant dosage

d = distance from instrument

Instrument stations used in interpolations were selected for their proximity to the field location and their relative position in relation to the location.

Air Monitoring Biological Indicator (AMBI) System

The basic unit of this system consists of a hardware cloth enclosure, a five-gallon water reservoir, a siphon system watering mechanism which regulates the amount of water utilized and the intervals between waterings, and a tubing system to deliver water to the indicator plants (Plate 1). These units are easily transportable, inexpensive, and require no power source. Three of these AMBI units were used to monitor each field location to insure against malfunction and to obtain an adequate number of plant injury observations. Indicator plants were changed and evaluated at regular weekly intervals.

Each AMBI station was adjusted to maintain six indicator plants. After extensive testing the following plants were selected:

3 Pinto beans (Lot D415 Burpee Seed Company)
1 Snowstorm petunia (Burpee Seed Company)
2 California Mariot barley (UCR source)

The pinto beans were used as ozone indicators, the petunias as the PAN indicator, and barley as a check for both ozone and PAN injury.

Care was taken to preserve as much uniformity as possible in the growth and selection of each variety of indicator plant. Plants were potted in four-inch pots using a standard soil mix:

Ingredients/cubic yard of soil

1. 1/3 loam, peat moss, redwood
2. 4 oz. KNO_3
3. 4 oz. K_2SO_4
4. 2 lbs. single super phosphate
5. 4 lbs. $CaCO_3$
6. 5 lbs. Dolomark lime
7. 1 lb. 10 oz. Isobutylidene diurea (IBDU)

All plants were used at standard ages relative to their sensitivity. Pinto beans were set out 10-12 days old (2 primary leaves), petunias 20-25 days old (6-7 leaves), and barley 16-19 days old (3-leaf stage).

An air-conditioned 1973 1/2 ton G.M.C. van was modified and used as the transportation vehicle. The load area was insulated and fitted with an activated charcoal filter to remove oxidants. A regular weekly schedule for indicator plant replacement and AMBI station maintenance proved to be effective. A route servicing a different sector of the air basin was followed each day.

Several problems were encountered upon initiation of the AMBI system. The transportation vehicle was delivered four months late; therefore, an air-conditioned station wagon had to be used in its place. The replacement vehicle could not be fitted with a carbon filter and it was possible that oxidant contamination within the vehicle affected plant injury. The water quality in the inland areas was poor, leading to profusive blooms of algae in the units' tubing systems and heavy sedimentation of particulates. Both of these problems have since been remedied. Other relatively minor problems added to the major ones already discussed, and the project's late start in 1972, precluded using the plant-injury data for the spring-summer season of 1972.

The Photo-Reference Plant Evaluation System

The injury evaluation system for ozone on pinto beans was based on the visual comparison of injured plants with reference photographs of injury. This approach was selected over the various evaluation methods based on estimation of the percentage of leaf surface injured. The nature of ozone stipple, the usual form of ozone injury, makes an accurate estimation of leaf surface injured time-consuming and prone to individual bias. Moreover, it would be difficult to obtain uniform evaluations if several agencies were evaluating injury from their own programs. The photo-reference evaluation system eliminates both of these problems and has proven to be effective.

Five arbitrary but distinct classifications of injury were used for ozone injury on pinto beans. A zero rating refers to no injury. Ratings 1 to 4 were based on progressively greater injury to the primary leaves as listed:

Rating 1 - traces of ozone stipple (Plate 2);
Rating 2 - ozone stipple scattered over most of the primary leaf (Plate 3);
Rating 3 - dense ozone stipple extends over all or almost all of the primary leaf. The veins may be in sharp contrast with the surface of the leaf (Plate 4); and
Rating 4 - stipple present with severe bifacial injury occurring in patches or large areas of dead tissue (Plate 5).

When compared against each other, each rating could be easily identified (Plate 6). Only the most heavily injured leaf of any one plant was used for evaluation, and borderline ratings were automatically assigned the higher of the two in question.

The average weekly injury per pinto bean for a season was calculated from the following formulas:

$$1)\quad Aj = \frac{\sum_{i=i}^{nj} Iij}{nj} = \text{weekly average injury for week } j$$

$$2)\quad Am = \frac{\sum_{j=i}^{m} Aj}{m} = \text{average weekly injury for m weeks}$$

where: Iij = injury of ith plant during jth week
nj = number of plants during jth week
m = number of weeks

The evaluated ozone injury for each plant was averaged for each week of the season. The averages were then summed and divided by the number of weeks to yield the average weekly injury per plant, per season.

A photo-reference system for the PAN injury evaluation index on petunias was also developed. This system also utilized five arbitrary injury classifications which were photographed for reference. A zero rating denoted no injury. Ratings 1 to 4 were based on progressively greater leaf injury:

Rating 1 - light injury on 1-3 leaves (Plate 7);
Rating 2 - light injury or small areas of bifacial injury on 4-5 leaves (Plate 8);
Rating 3 - light and bifacial injury on 5-6 leaves with the most sensitive leaves showing severe bifacial injury (Plate 9); and
Rating 4 - all or nearly all of the leaves showing sever bifacial injury (Plate 10).

Weekly average PAN injury on petunias was calculated, utilizing the first of the two formulas given for pinto beans. These were plotted against the accompanying PAN dosages during the correlations. This abbreviated weekly average injury was used in order to plot against the single PAN monitoring instrument in use.

Correlation of Plant Injury with Ambient Ozone and PAN Dosages

The relationship between plant injury and oxidant level has been a matter of concern and controversy. Today, there is general agreement that plant injury is primarily dependent on the concentration of fumigant and time of exposure although environmental factors also influence this relationship. If dosage is defined in units of both concentration and time, a general curve can be drawn to illustrate the basic plant injury-oxidant dosage relationship (Figure 2). A low threshold dosage where visual injury begins and another higher threshold where a greater dosage produces no further injury are evident at both ends of the curve. If an injury index is employed, with initial damage rating at or above the minimal threshold dosage, axis 'A' and 'B' can be appropriately used and the lower end of the curve is not a factor. The curve's shape changes to that of a parabola with the upper threshold representing the apex. The slope and apex may vary with several environmental factors, but the same general shape should prevail.

After considering the injury-dose relationship discussed, a quadratic regression correlation of the average weekly ozone injury on pinto beans and the average weekly ambient dose greater than 10 pphm ozone was employed. Figure 3 presents this correlation for the following areas of the South Coast Air Basin during the fall of 1972:

1) Moorpark	6) Irvine	11) UCR
2) Hemet	7) Los Alamitos-Costa Mesa	12) Pomona
3) Camarillo	8) Redlands	13) UCR - Corona
4) Los Alamitos	9) Anaheim	14) Azusa
5) Corona1/	10) Anaheim-Corona-LaHabra	15) UCR - San Bernardino

Points represented by more than one area are interpolated locations. A positive correlation significant at the 99.9% confidence level was found.

The same quadratic regression correlation was applied to the injury-dosage relationship of PAN on Snowstorm petunias at UCR. No correlation could be undertaken for other areas in the South Coast Air Basin since no other PAN instrument monitoring stations exist. The weekly average injury per plant and the weekly average dose were plotted for each week of the season (Figure 4). Points 1-14 refer to successive weeks. The fit is not as good as the ozone dosage-pinto bean injury correlation, but a positive correlation significant at the 99.5% confidence level was found.

The AMBI monitoring system will be tested for an additional season to substantiate results. This type of biological system is designed to monitor air pollutants in areas devoid of instrumentation and power sources. It will provide a relative scale of ambient pollution levels for comparison. The AMBI system is not designed to replace or compete with instrument stations.

The major assets of this system are its low cost, mobility, and ease of operation. Such a system could be used to monitor agricultural areas within the State where no ozone monitoring system exists.

1/ Represents the period between 10-1-72 and 12-11-72

Figure 2. General curve associated with a fumigant dosage-plant injury relationship with superimposed axes representing the theoretical ordinate and abscissa established by this program's plant injury index.

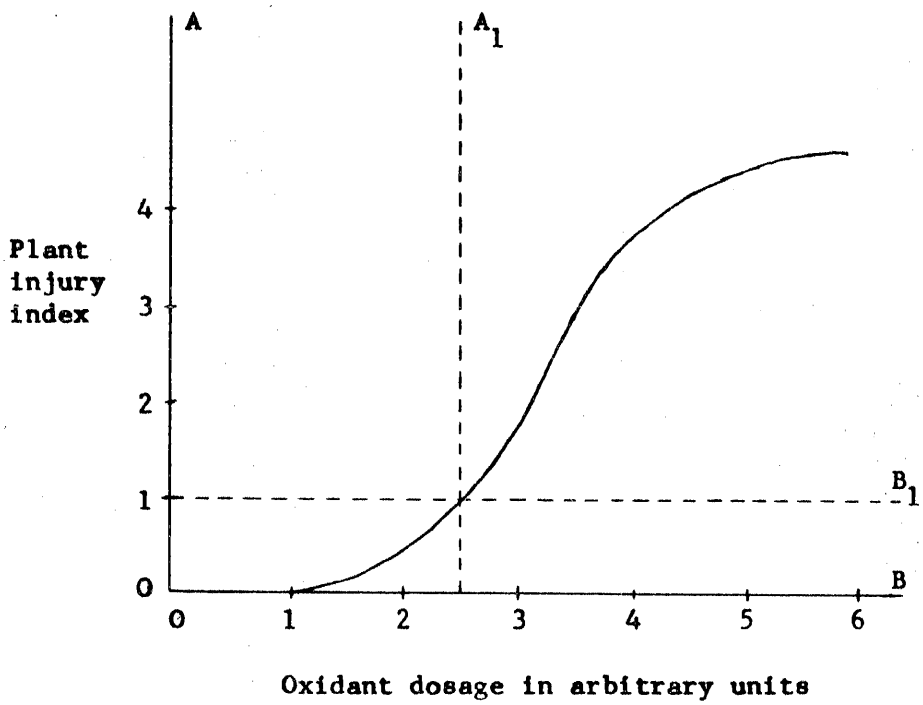


Figure 3. Correlation of average weekly oxidant doses for autumn 1972 with the average weekly pinto bean injury index at field locations in the South Coast Air Basin. A confidence level of 99.9% is associated with this correlation.

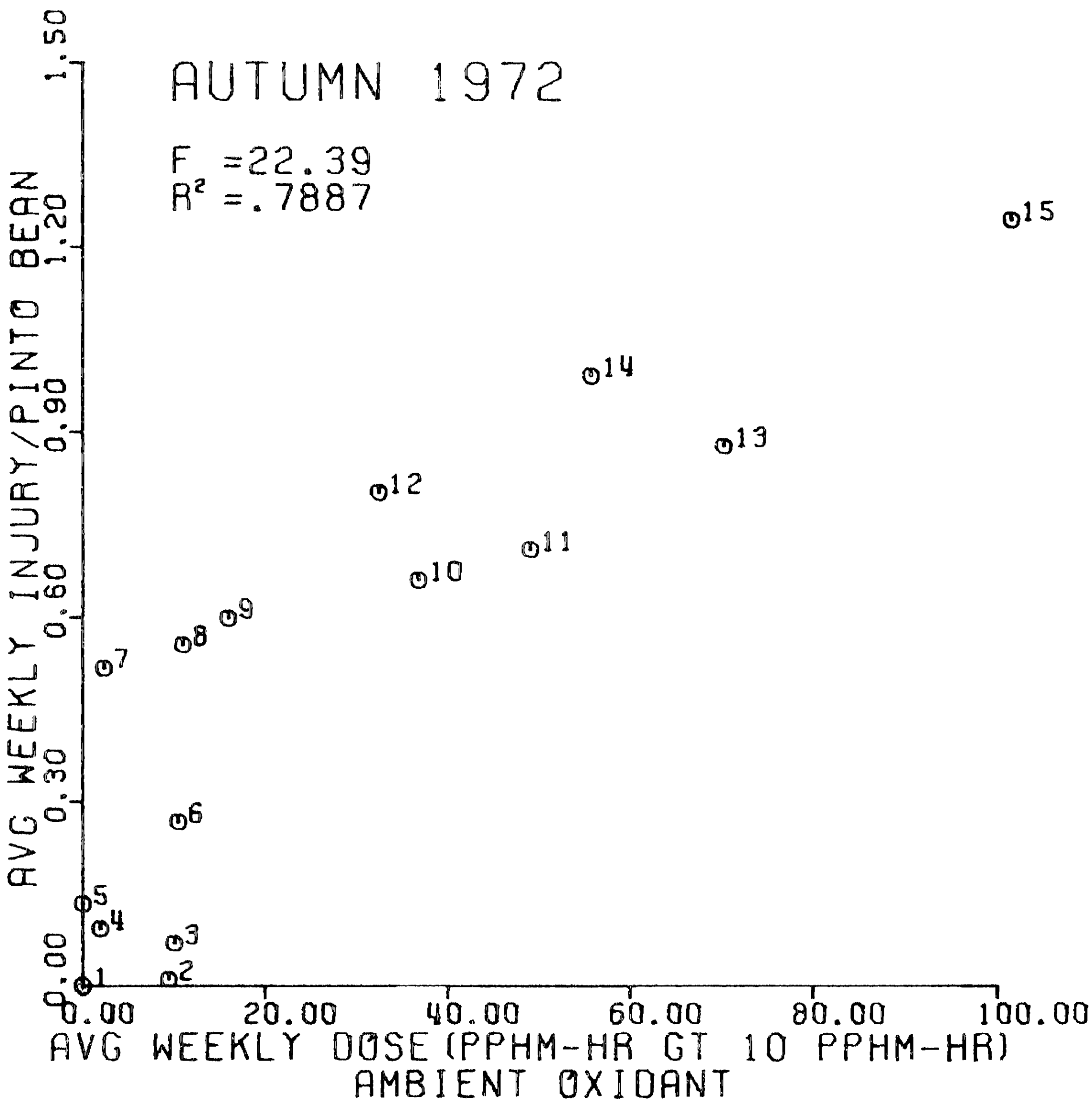


Figure 4. Correlation of weekly average Peroxyacetyl-nitrate (PAN) doses for autumn 1972 at U.C.R. with the weekly average petunia injury index. A confidence level of 99.5% is associated with this correlation.

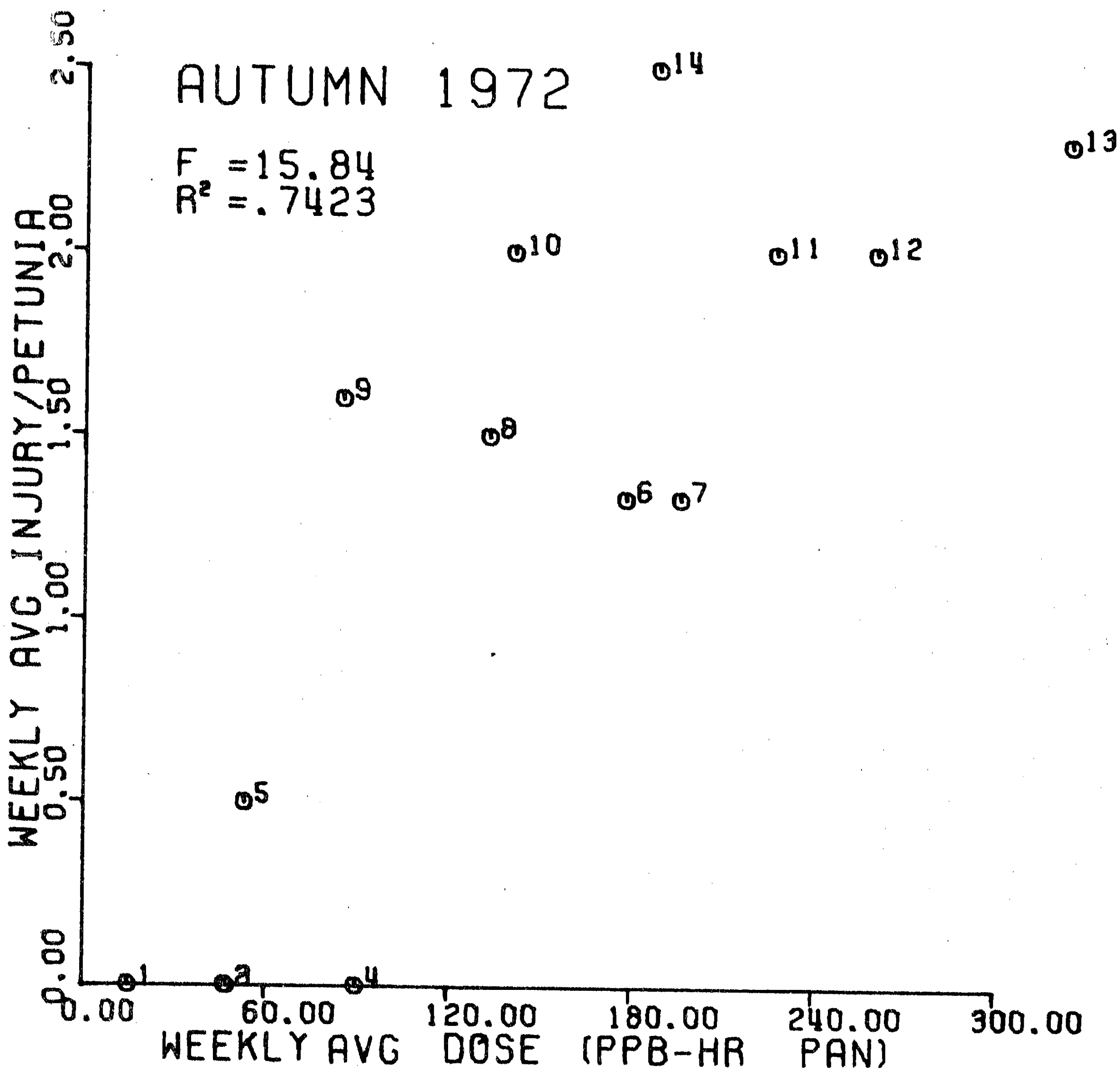


Plate 1. Air monitoring biological indicator (AMBI) station with indicator plants monitoring a carrot field in Riverside County.

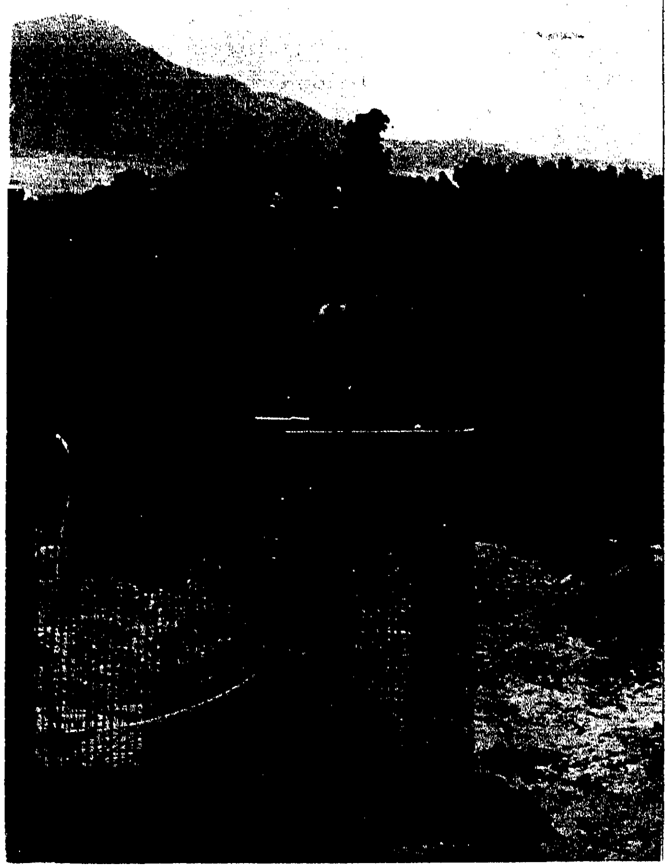


Plate 2. Ozone injured pinto bean rated as "1". Only traces of ozone stipple appear on the primary leaves.

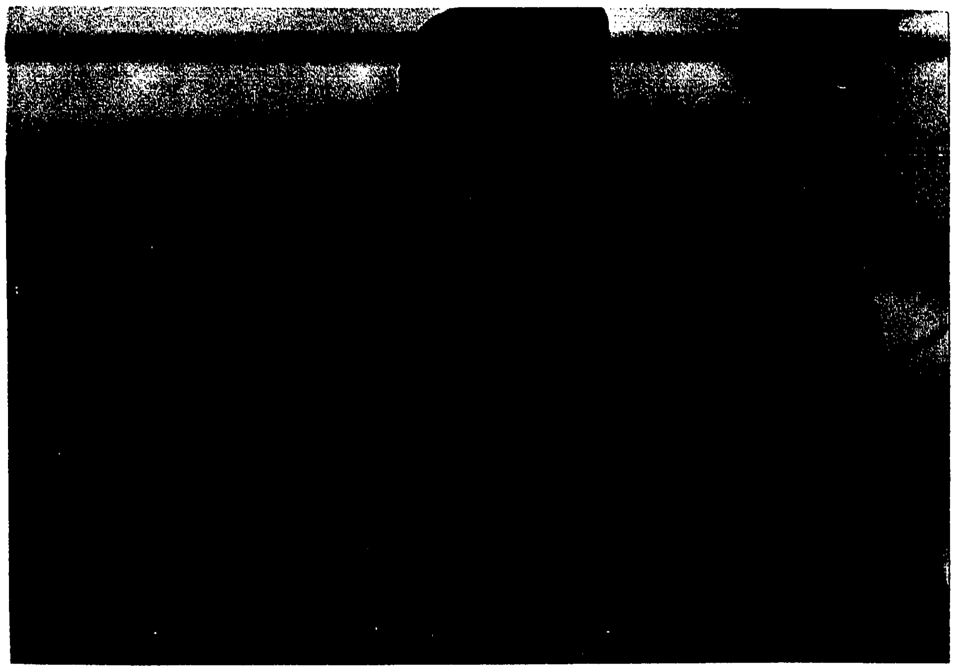


Plate 3. Ozone injured pinto bean rated as "2". Ozone stipple scattered over most of the primary leaves.

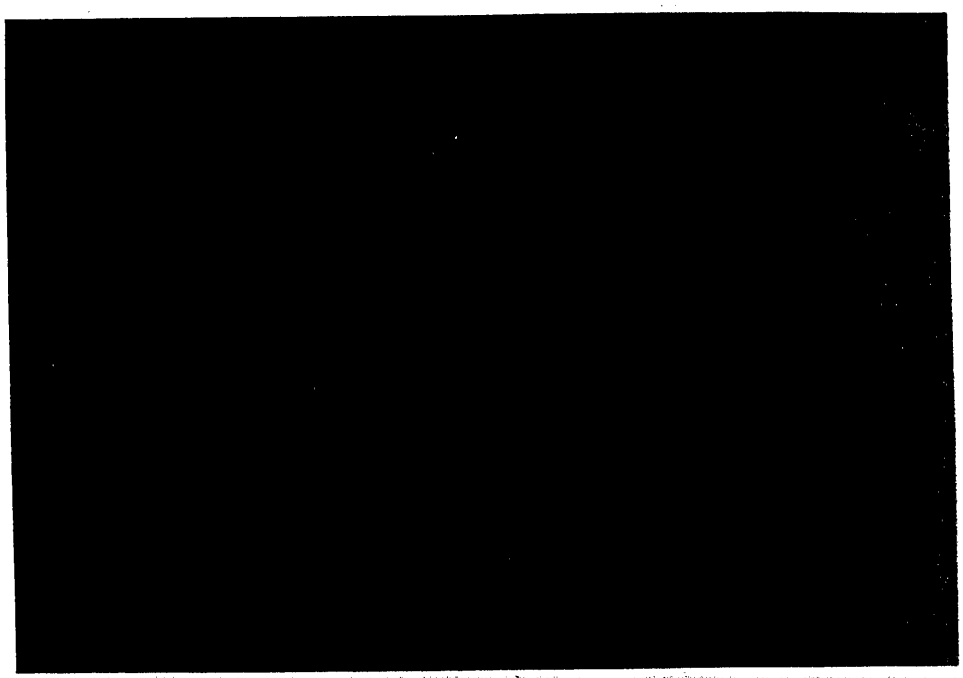


Plate 4. Ozone injured pinto bean rated as "3". Dense ozone stipple extends over all or nearly all of the primary leaf with the possible exception of leaf veins which may be in sharp contrast.

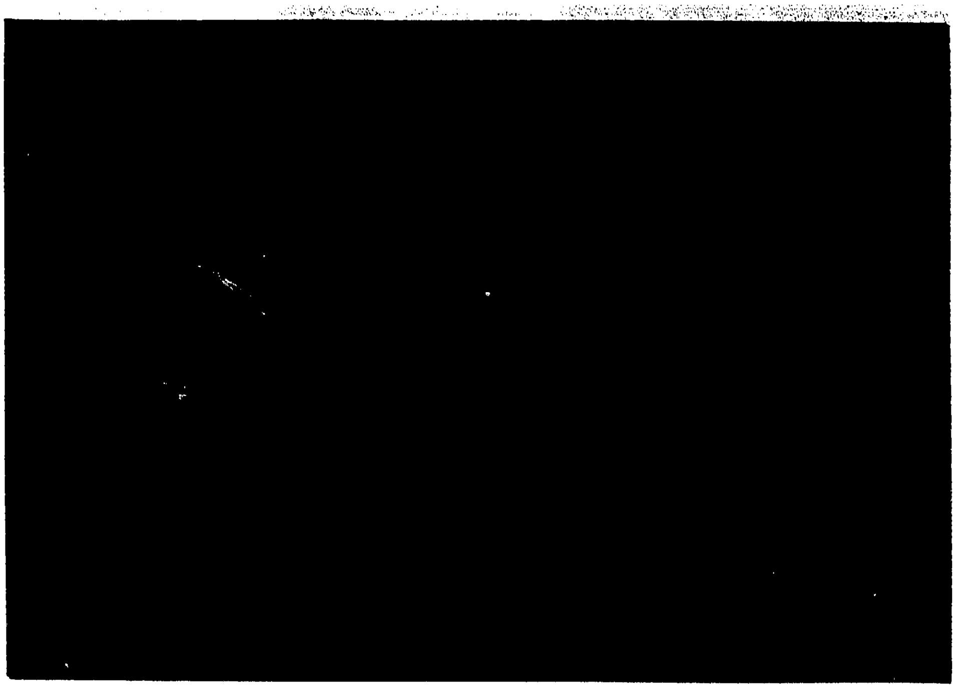


Plate 5. Ozone injured pinto bean rated as "4". Severe bifacial injury is present either in patches or large areas of dead tissue.

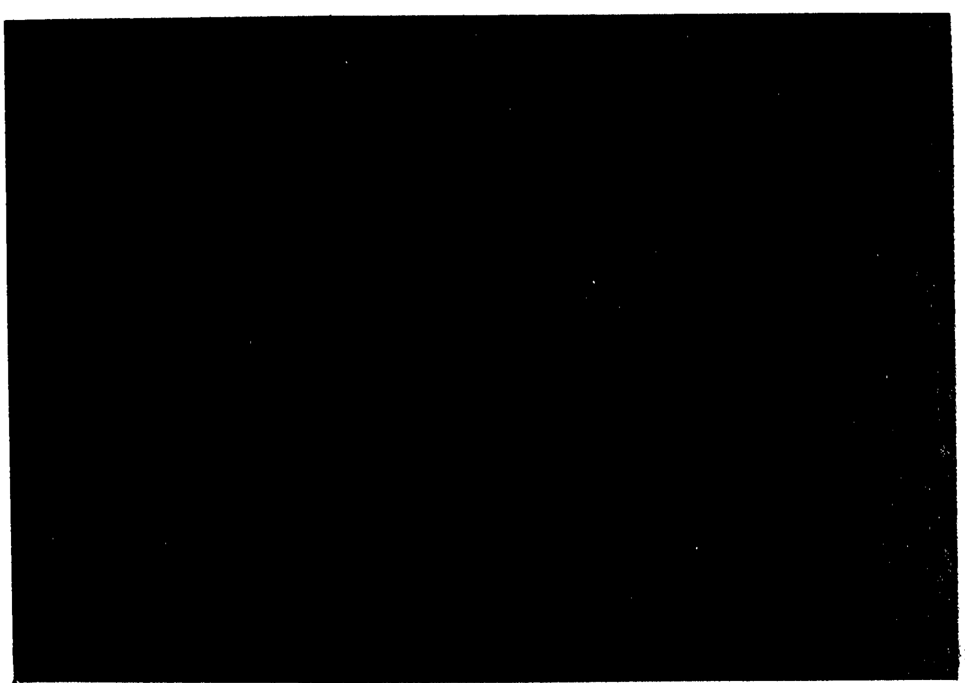


Plate 6. Comparison of the four ratings of ozone injury which comprises the criteria for the injury index.

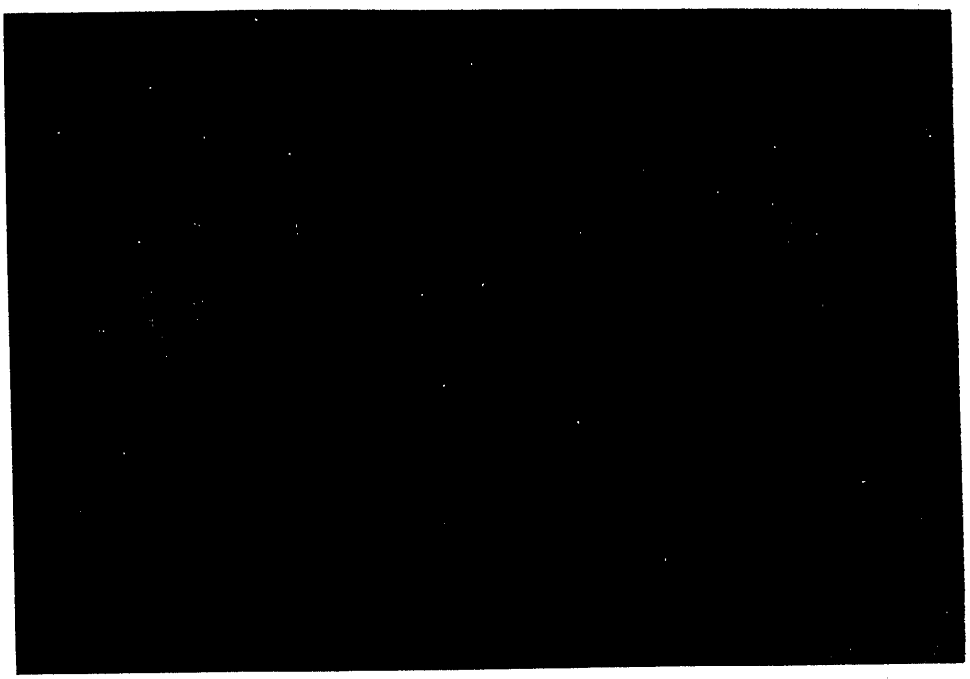


Plate 7. PAN injury on Snowstorm petunia rated as "1". Light injury is confined to 1-3 leaves.

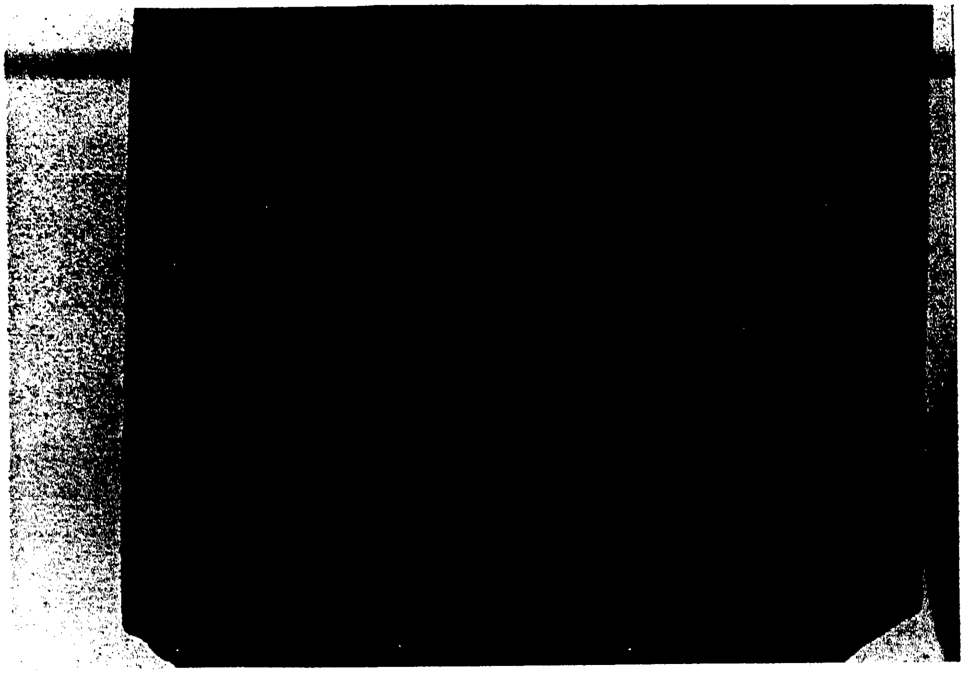


Plate 8. PAN injury on Snowstorm petunia rated as "2". Light injury or minor bifacial injury occurs on 4-5 leaves.

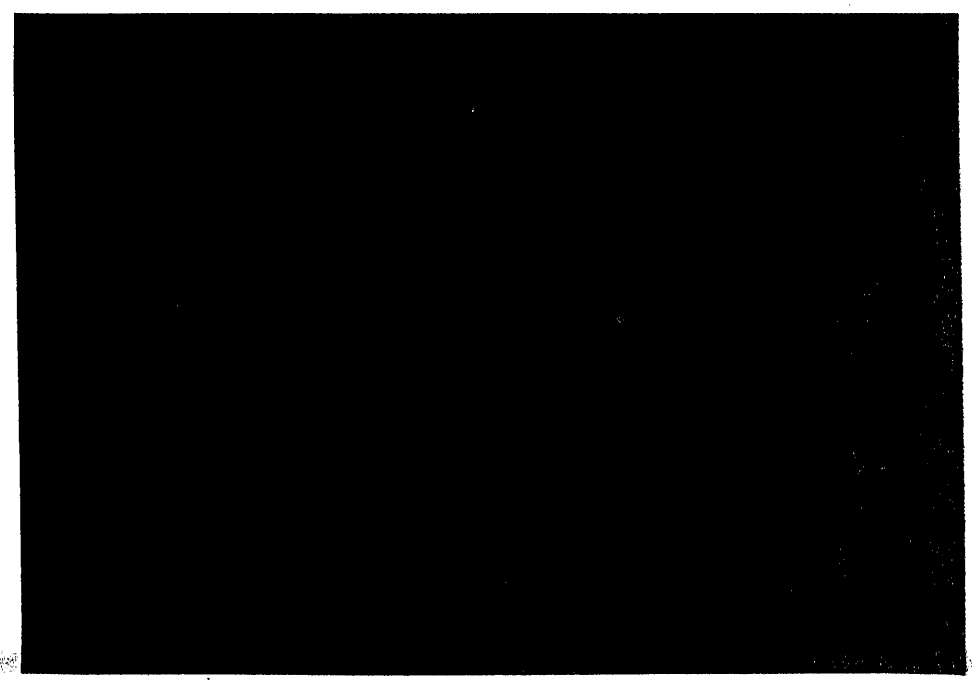


Plate 9. PAN injury on Snowstorm petunia rated as "3". Either light or bifacial injury occurs on 5-6 leaves with the most sensitive aged leaves showing severe injury.

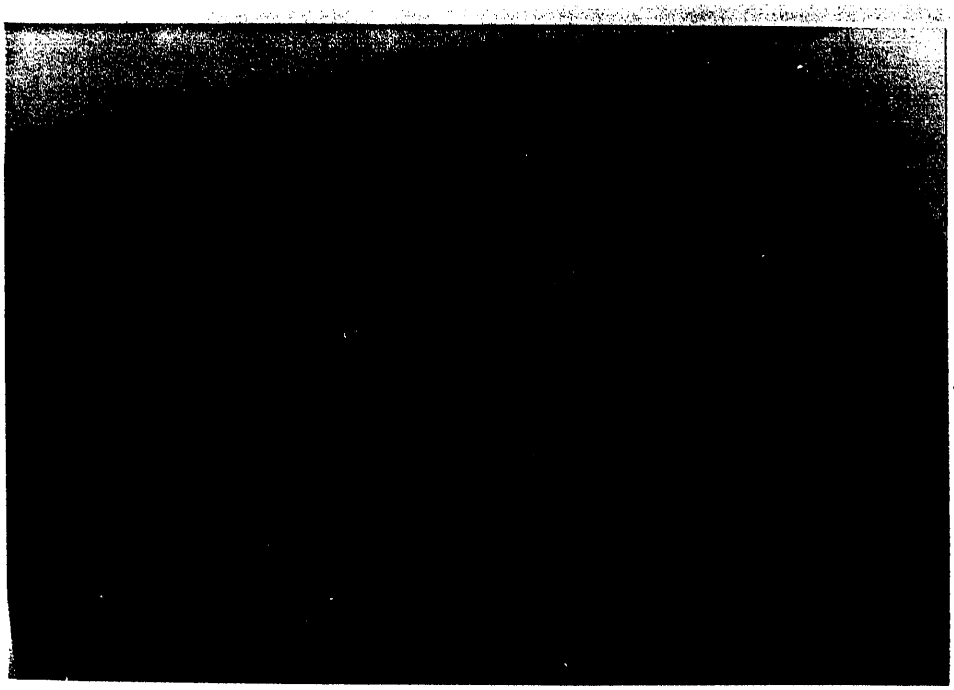


Plate 10. PAN injury on Snowstorm petunia rated as "4". All or nearly all of the leaves show severe bifacial injury.

CHAPTER V - CORN

Summary

Ozone does not seem to have a significant effect on the quality of harvested Golden Jubilee sweet corn. Fumigation studies demonstrated significant reductions in yield but little evidence to indicate that ear quality is affected. The association of kernel shrivel and ozone, noted during the long-term fumigation studies, did not materialize as a problem in the field. Stresses from confinement in 2-gallon pots may have significantly contributed to this effect during greenhouse fumigations.

Fumigation results appeared to accurately define the expression of ozone effects on Golden Jubilee corn. Most quality evaluations were not significant in fumigation results and this also held true for field work. Plant heights were significantly reduced during fumigations and also in test plot field work.

If fumigation results continue to accurately predict field results, the most significant effects of ozone should be observed in the 1973 yield studies.

Introduction

Golden Jubilee is a popular commercial variety of sweet corn used throughout the South Coast Air Basin. It is considered to be resistant to disease and air pollution injury.

A short-term fumigation study was undertaken to determine oxidant effects on young seedlings. A long-term fumigation study was used to determine effects on crop quality and yield and to develop criteria for field studies. Field work for the 1972 growing season focused on a quality study of field-grown ears correlated with oxidant levels present during growth.

Seedling Fumigation Study

Treatments: Control, .24 ppm ozone, 30 ppb PAN

Exposure: Treatments were exposed to respective concentrations of fumigant for 1.5% of the growing period. Fumigations were initiated upon emergence and discontinued after a 30-day period.

Effects of ozone on Golden Jubilee corn seedlings: Ozone injury was observed on the seedling corn leaves of the ozone treatment throughout the fumigations. At harvest, the fumigated plants were reduced in size and weight when compared to control plants (Table 3). All reductions were significant at the .01 level when tested by analysis of variance.

Effects of PAN on Golden Jubilee corn seedlings: PAN fumigated Golden Jubilee corn seedlings were not observed to have leaf injury and were not significantly reduced in size or weight.

Discussion: The growth and vigor of Golden Jubilee corn in the seedling stage was reduced by exposure to moderate levels of ozone. No growth reduction takes place after exposure to moderate levels of PAN.

Long-Term Ozone Fumigations of Golden Jubilee Corn

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Exposure: Treatments were exposed to the respective concentration of ozone for 47 out of 1,200 hours or about 4% of the growing period. The fumigations averaged about 3 hours in length and were staggered to provide time for plant recovery.

The effects of ozone on Golden Jubilee corn plants: Plants exposed to the .20 ppm and .35 ppm treatments were significantly reduced in size and weight as compared to the control plants at harvest (Table 4). The size reductions were easily apparent in a visual comparison (Plate 11). Plants in the .35 ppm treatment also produced fewer sucker shoots than plants in either the .20 ppm or the control treatments. Ozone injury was observed on leaves of plants in both fumigated treatments.

The effects of ozone on Golden Jubilee sweet corn ears: Criteria used to measure harvested ears are illustrated in Figure 5. Ears from the .35 ppm treatments weighed significantly less than ears from the .20 ppm or the control treatments (Table 5). Dry weight measurements showed them to be greatly reduced in solids. The .20 ppm treatment ears were also significantly reduced in solids, but did not display any reduction in weight in the husked fresh weight measurements. There were no significant differences in the size of the ears or in the incidence of kernel blanking among the three treatments. There was, however, a definite increase in the incidence and extent of kernel shrivel in the two fumigated treatments.

Discussion: Golden Jubilee corn was seriously affected by ozone in the .20-.35 ppm concentration range under greenhouse conditions. The general effect of the exposures was a reduction in the size and weight of the corn plants. These plants produced ears of comparable size but of significantly reduced weight due to low levels of solid materials. The degree of reductions correlated with the level of ozone to which the plants were exposed. A higher concentration of ozone (.35 ppm) reduced the dry weight of the ears by 22.3%, about double the 12.5% reduction found in the .20 ppm treatment. The dry weights of the plants showed a similar negative correlation to ozone concentration (Table 4).

The reduction in ear weight can be partially explained by increased incidence of kernel shrivel. The extent of the kernel shrivel, however, was not large enough to account for the total weight loss.

Long-Term PAN Fumigation of Golden Jubilee Corn

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Exposure: Treatments were exposed to the respective concentrations of PAN for 49 out of 1,200 hours or about 4% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effects of PAN on the Golden Jubilee corn plants: PAN injury symptoms were observed on the 40 ppb treatments, but no significant differences were found between any of the treatments.

Effects of PAN on Golden Jubilee corn ears: No significant differences were found among the ears of the three treatments.

Discussion: PAN does not seem to affect the growth of the Golden Jubilee corn plant or the quality and weight of its ears.

Field Study (Quality Effects)

Locations: Seven commercial field plots and two test plots of Golden Jubilee were set up in the South Coast Air Basin (Map 4). Each location was monitored for oxidant by three AMBI stations.

Sampling procedures: Each field plot was sampled prior to commercial harvest at a time specified by the owner. The resultant sample was therefore not comparable to other field plots in age but was acceptable for analysis of ear quality. Each sample comprised 150 randomly sampled ears harvested over the extent of each field. Only the primary ear from the main stalk of each plant was harvested.

Test plots contained 4 sets of Golden Jubilee corn planted at two-week intervals. Each set comprised two sample rows enclosed by two guard rows. Samples were harvested after the ear silks turned completely brown. No attempt was made to standardize age of harvest in order to randomize the sets with commercial field plots. A 100-plant sample was taken from the two sample rows. Height of each plant was measured and the primary ear analyzed.

Effects of ambient oxidants on field-grown Golden Jubilee corn: Data taken from the four sets of Golden Jubilee corn grown at each test plot are presented in two different ways. All test plot sets are compared against each other in one correlation and test plot sets were randomized with commercial field plots in a second correlation.

Significant correlations of plant height and extent of blemish with total oxidant dosage present during growth were observed in test plots (Figures 6, 21). Other correlations of the number of marketable secondary ears and ear length with ambient dosages proved to be statistically significant but realistically inapplicable due to the variation in harvest ages (Figures 19, 20). The extent of differences found in ear lengths would not make realistic reductions in marketability or quality.

The differences in the number of secondary ears present on harvested plants would also be economically unimportant. Correlations of ear diameter, ear weight, kernel blanking, number of banner leaves on the ear and kernel shrivel with total ambient dosage present during growth were insignificant (Figures 7, 8, 9, 10, 18).

Commercial field plots and test plots: The extent of blemishes occurring on harvested corn ears again proved to be significant when correlated with the total oxidant dosage present during growth (Figure 15). Test plot harvest data heavily biased this correlation, and effectiveness of earworm control may be a source of error.

Correlations of ear diameter and length with total oxidant dosage were significant but not applicable for determining crop losses due to the diversity of ear ages at harvest (Figures 12, 17). These correlations, while illustrating possible trends, are not true quality characteristics but measurements usually associated with yield studies.

No significant correlations with the total ambient oxidant dosage were found for ear weight, kernel blanking, kernel shrivel, and number of banner leaves (Figures 11, 13, 14, 16).

Discussion: Ozone does not appear to influence the quality of field-grown Golden Jubilee corn ears to any great extent. The only quality criterion possibly implicated in association with ambient oxidant dosages was the extent of blemishes on harvested ears. This may be an indication of ozone-lowered viability resulting in greater susceptibility to organic pests, but the relative efficacy of pest control programs may well be responsible for the significant correlation.

The significant correlations of ear length and diameter are not accurate indicators of these measurements, as all ears were not harvested at a uniform age or development.

Figure 5. Criteria for Measurements Taken on Golden Jubilee Corn Ears.

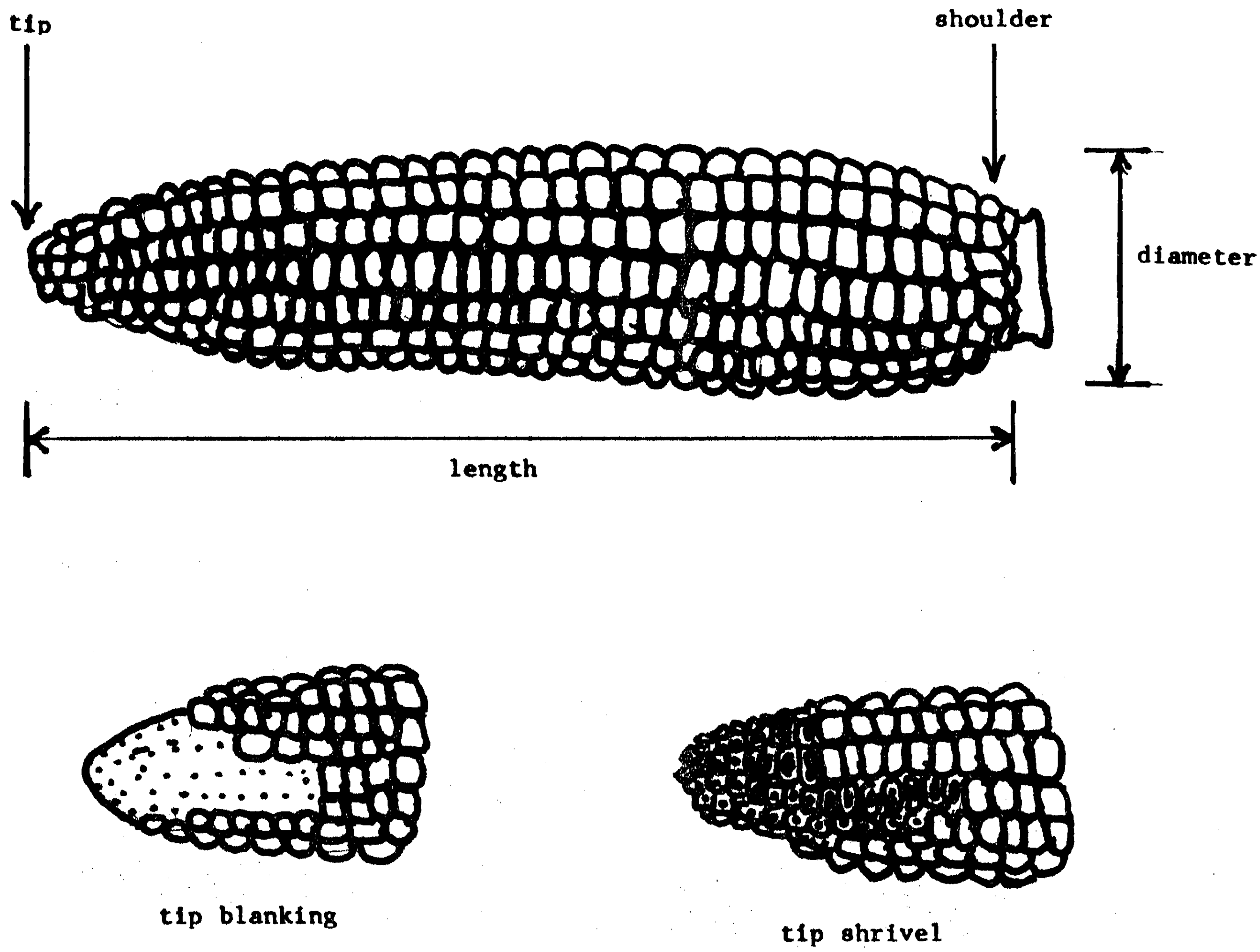


Figure 6. Correlation of the extent of tip blemish on test plot Golden Jubilee corn ears with the total ambient oxidant dosage present during growth.

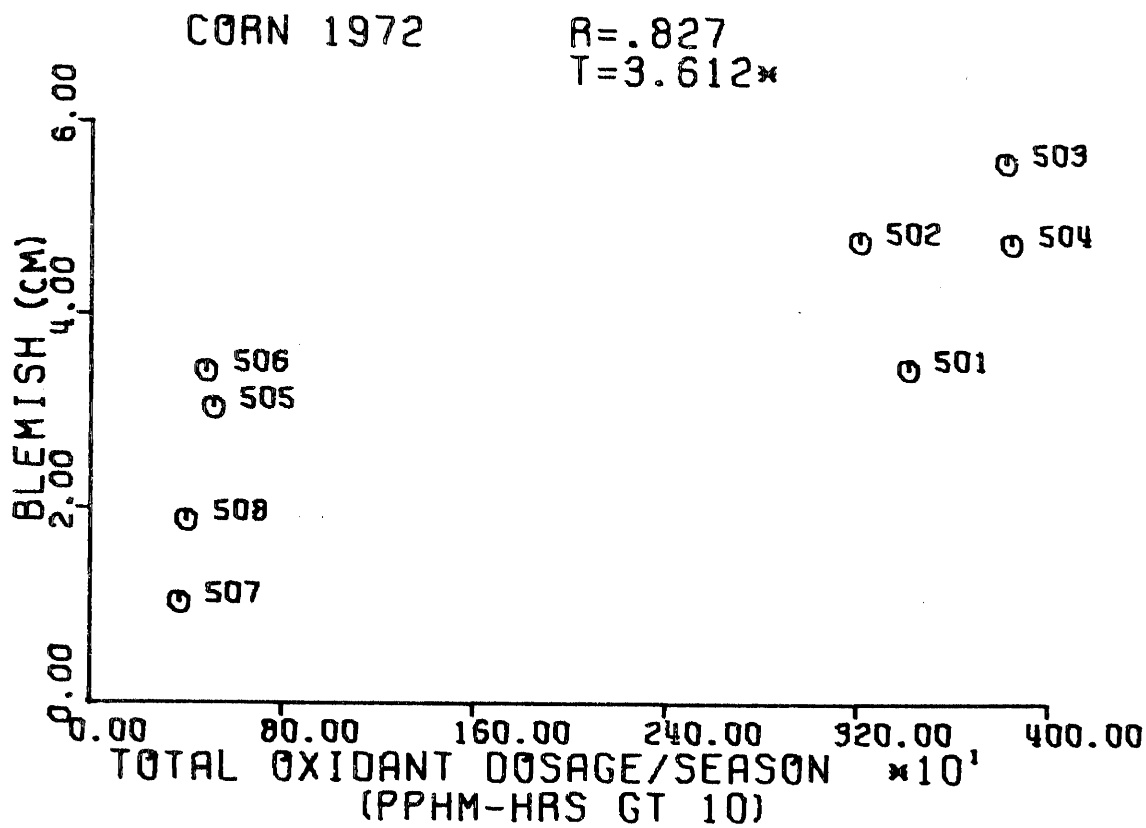


Figure 7. Correlation of the diameters of Golden Jubilee corn ears with the total ambient oxidant dosage present during growth.

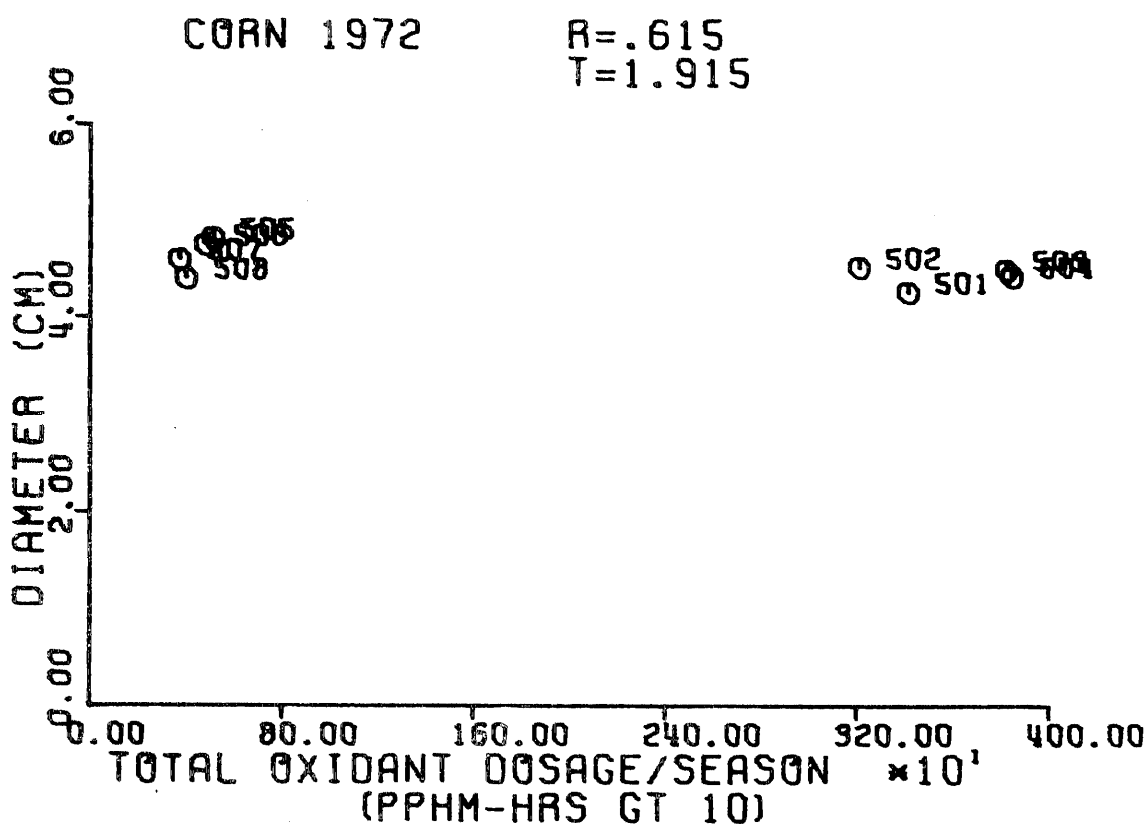


Figure 8. Correlation of the extent of kernel blanking on Golden Jubilee corn ears with the total ambient oxidant dosage present during growth.

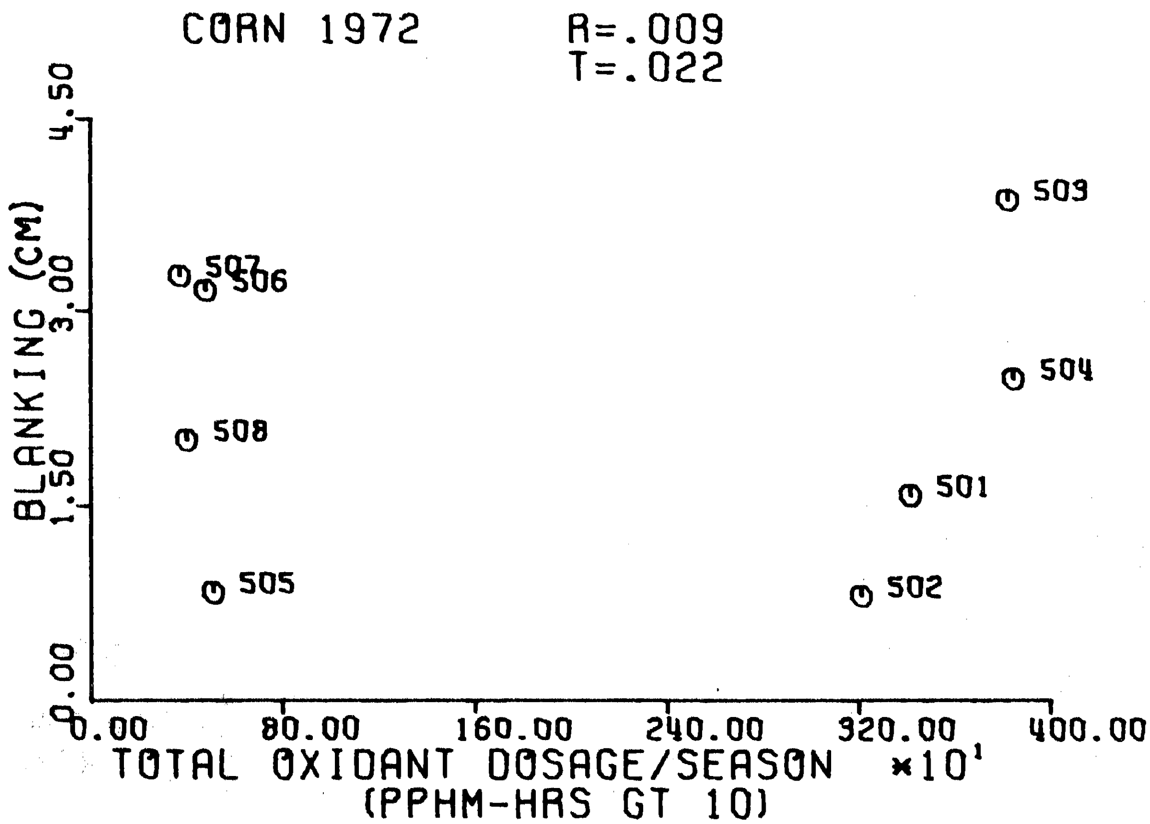


Figure 9. Correlation of the number of banner leaves on Golden Jubilee corn ears with the total ambient oxidant dosage present during growth.

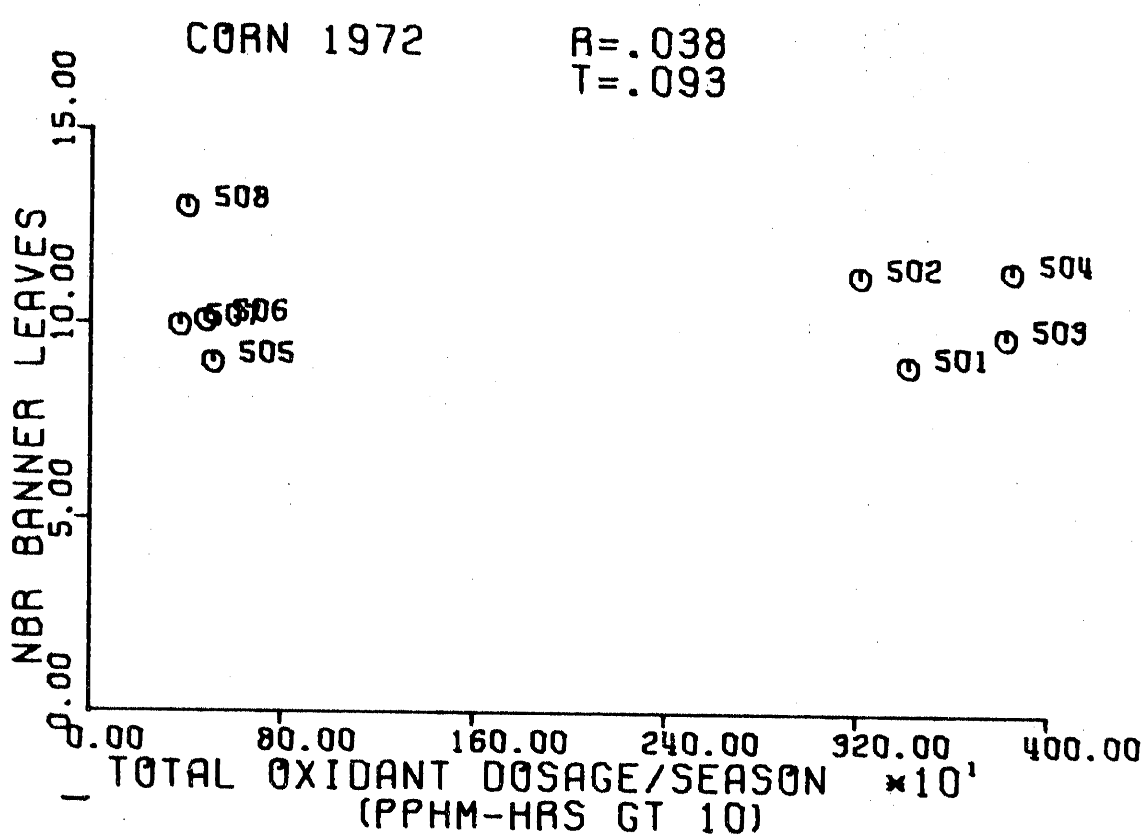


Figure 10. Correlation of the extent of kernel shrivel on Golden Jubilee corn ears with the total ambient oxidant dosage present during growth.

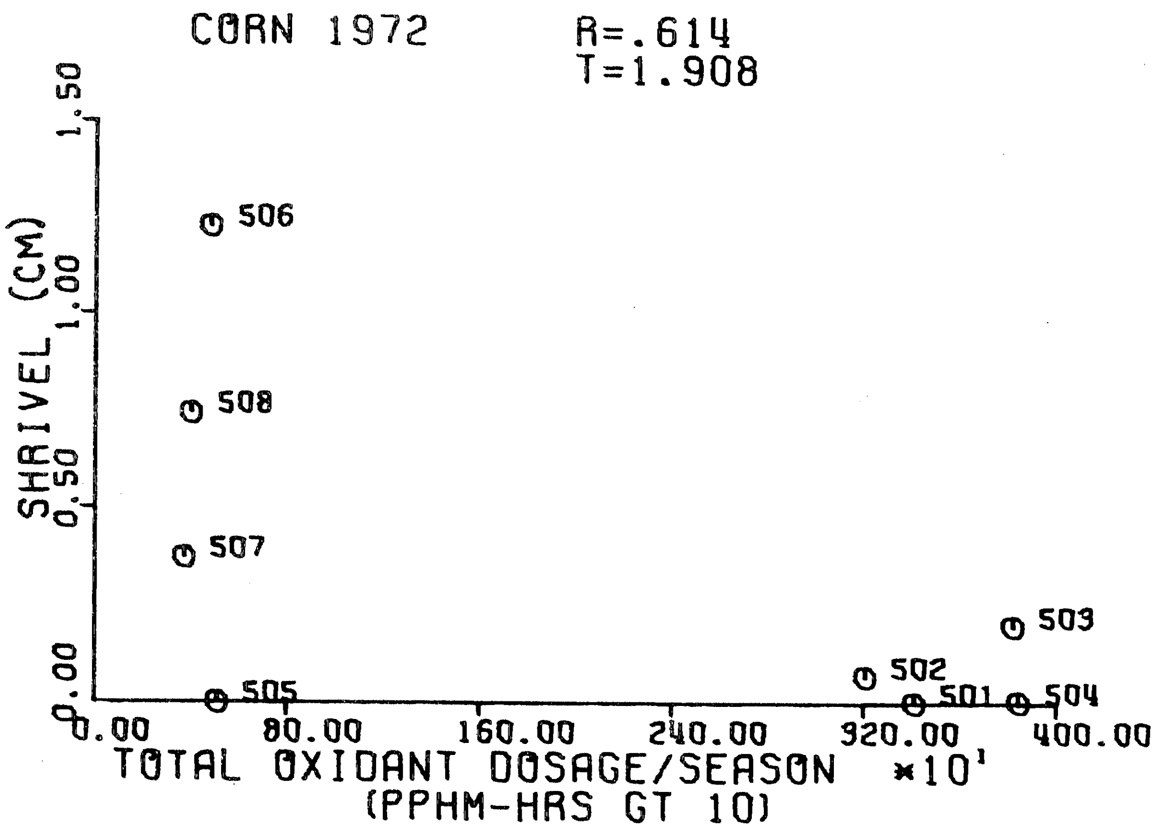


Figure 11. Correlation of weights of harvested Golden Jubilee corn ears from field and test plots with the total ambient oxidant dosage present during growth.

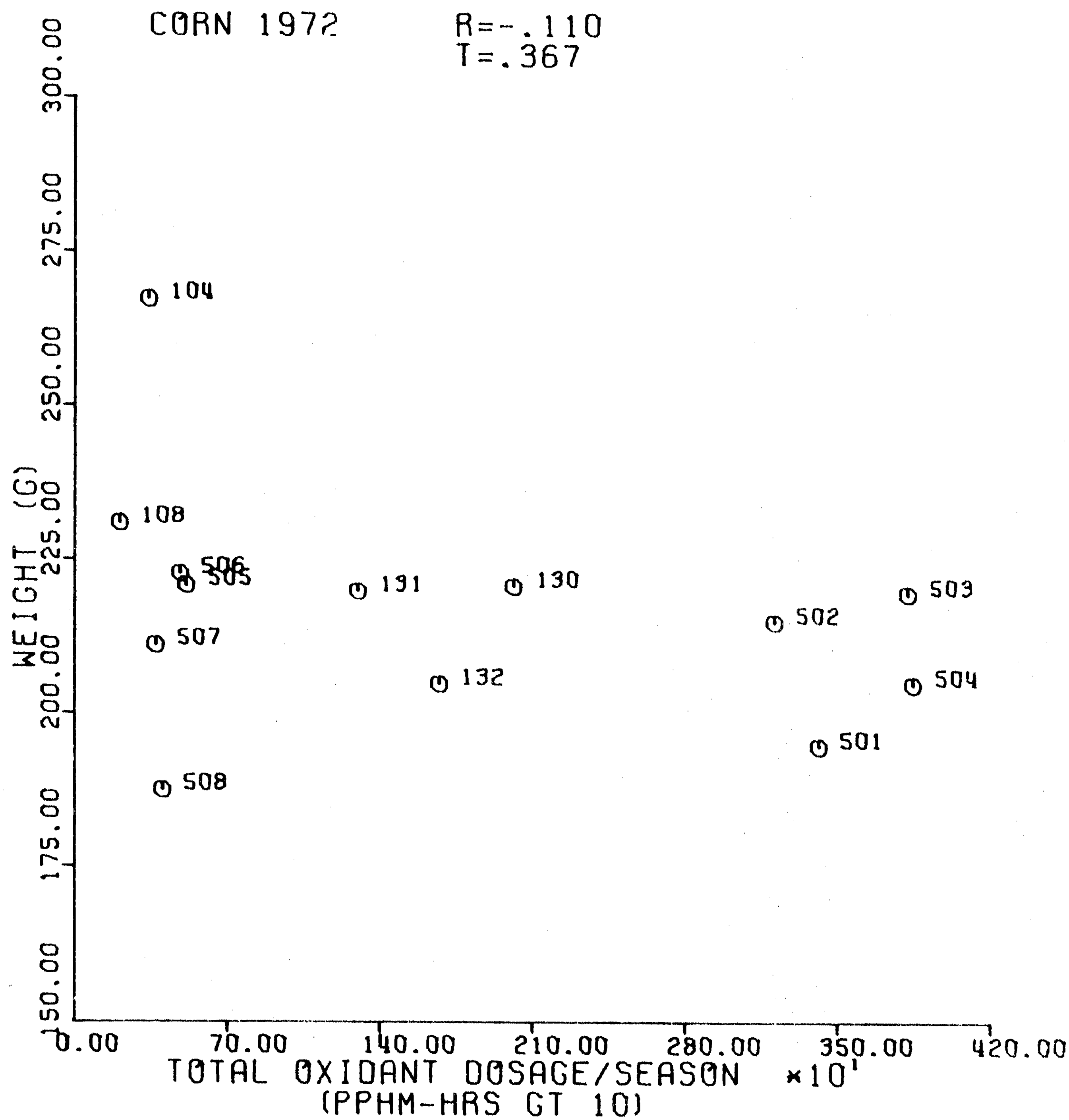


Figure 12. Correlation of lengths of harvested Golden Jubilee corn ears from field and test plots with the total ambient oxidant dosage present during growth.

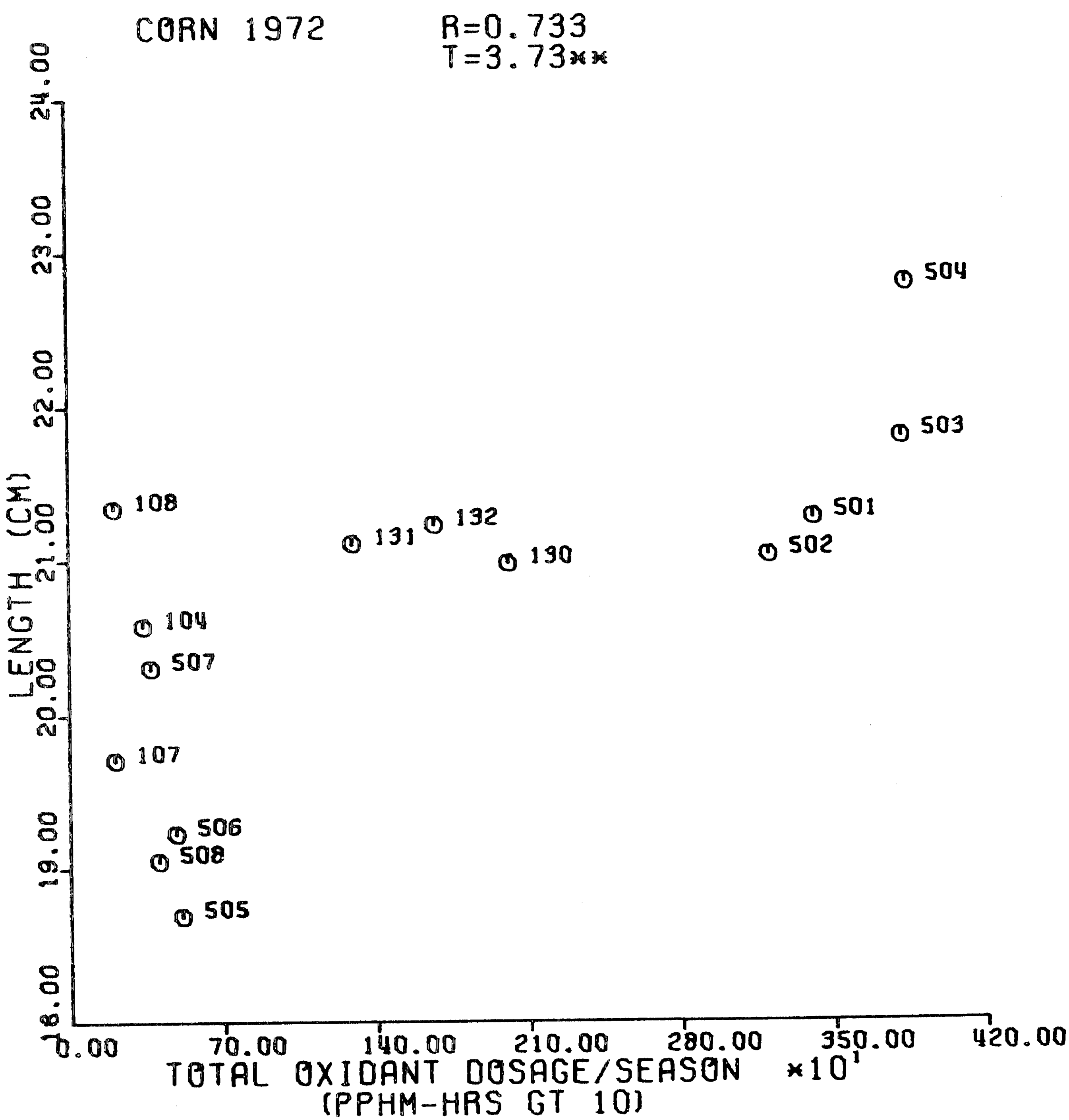


Figure 13. Correlation of the extent of kernel blanking on harvested Golden Jubilee corn ears from field and test plots with the total ambient oxidant dosage present during growth.

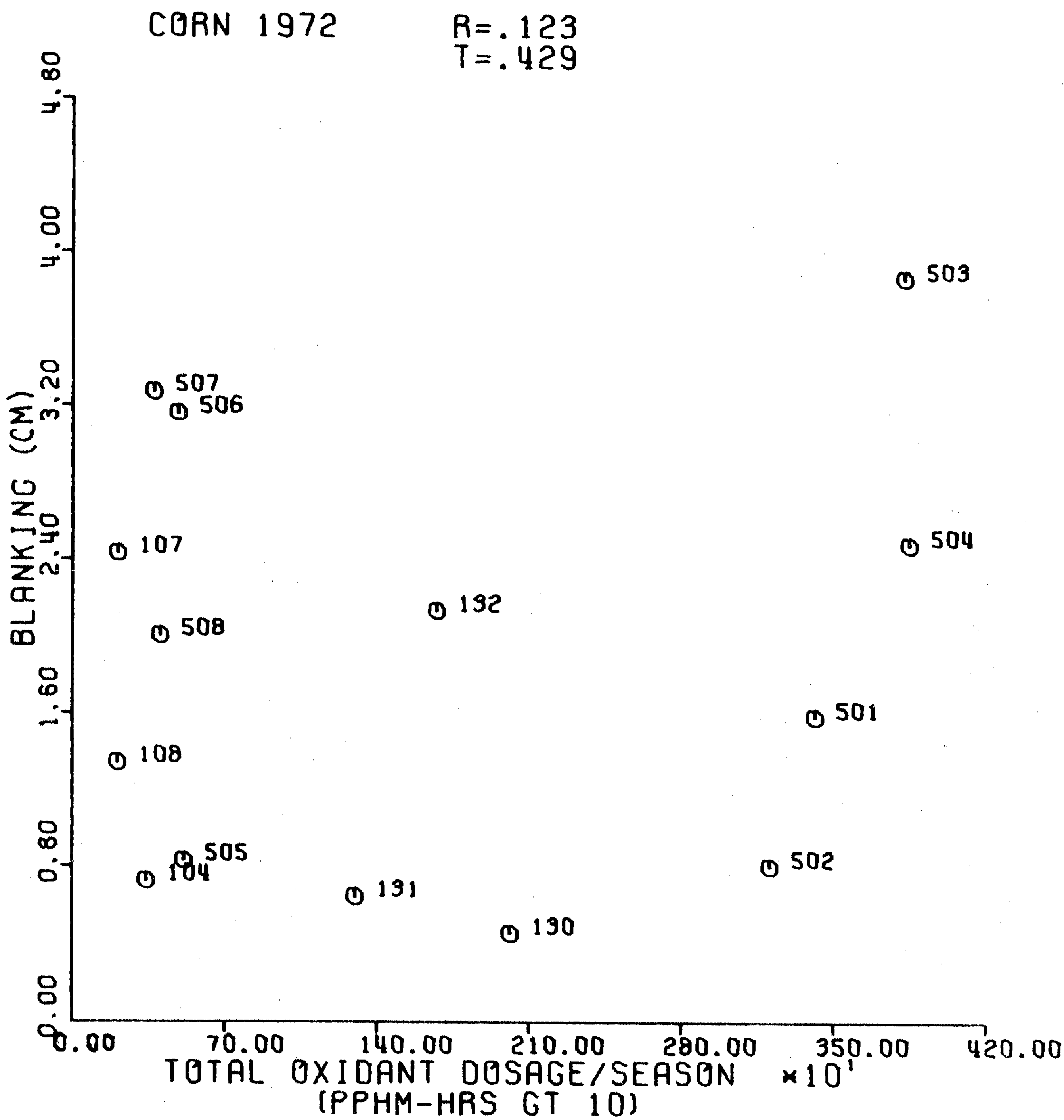


Figure 14. Correlation of the extent of kernel shrivel on harvested Golden Jubilee corn ears from field and test plots with the total ambient oxidant dosage present during growth.

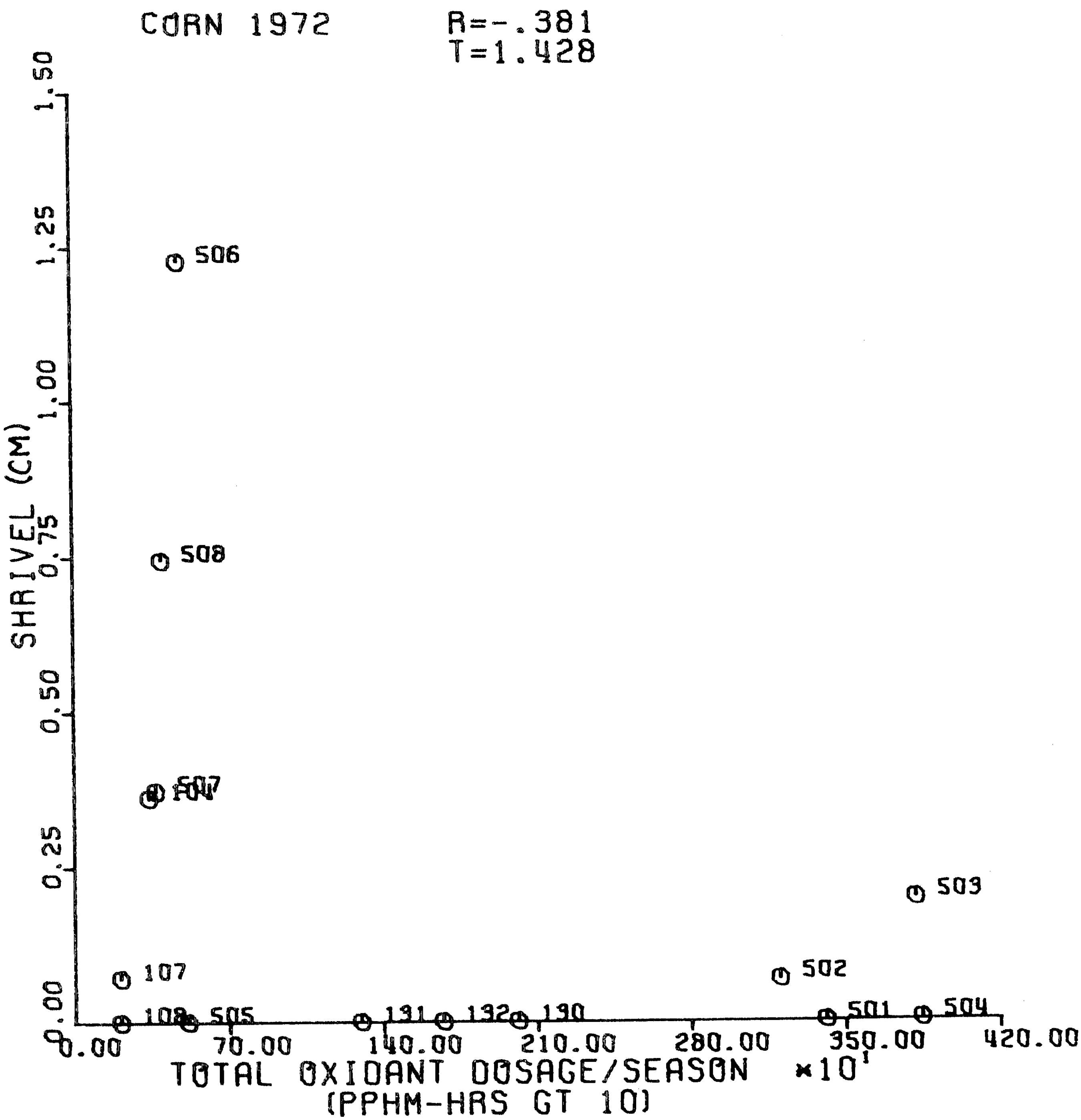


Figure 15. Correlation of the extent of blemish on harvested Golden Jubilee corn ears from field and test plots with the total ambient oxidant dosage present during growth.

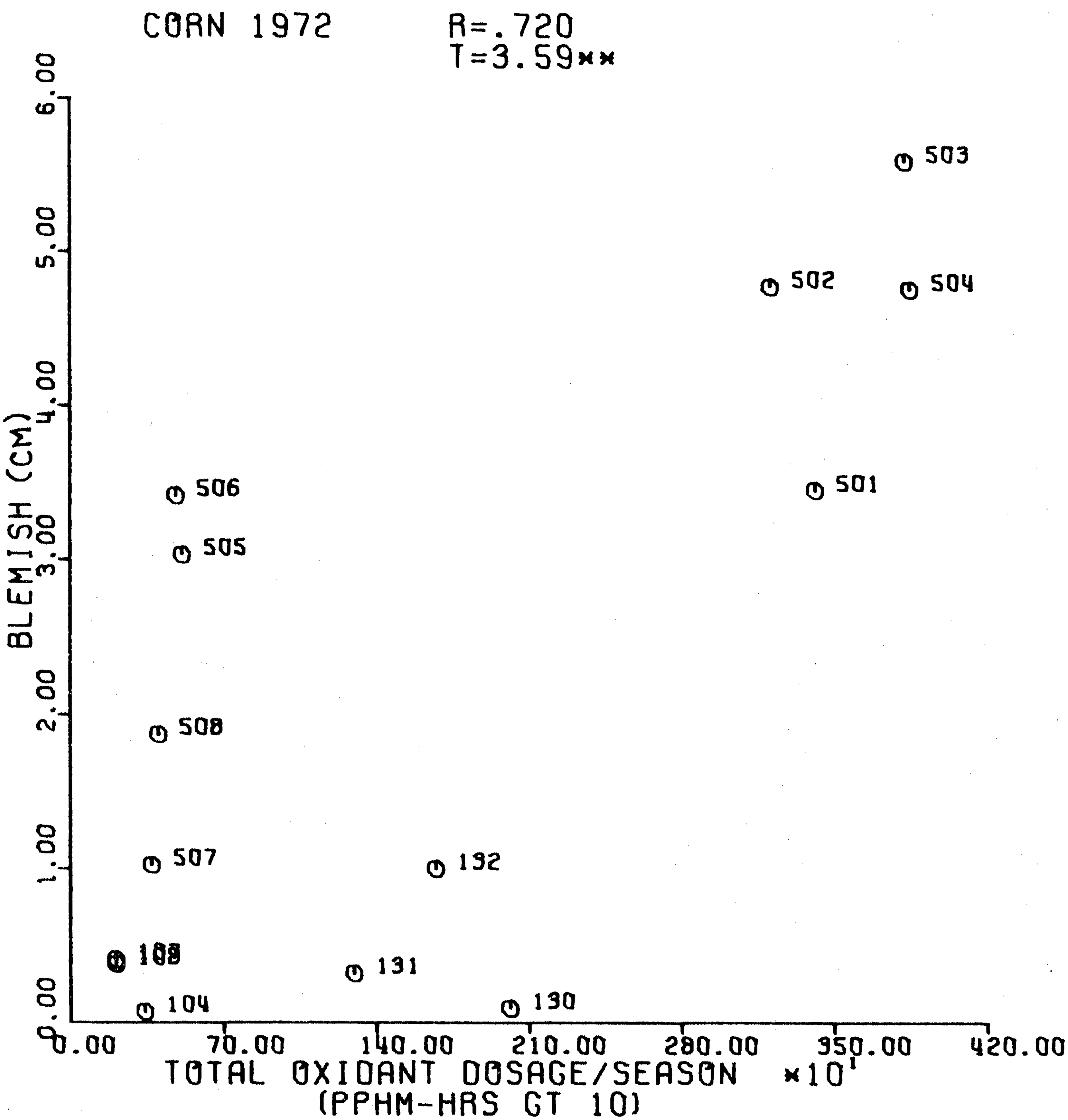


Figure 16. Correlation of the number of banner leaves on harvested Golden Jubilee corn ears from field and test plots with the total ambient oxidant dosage present during growth.

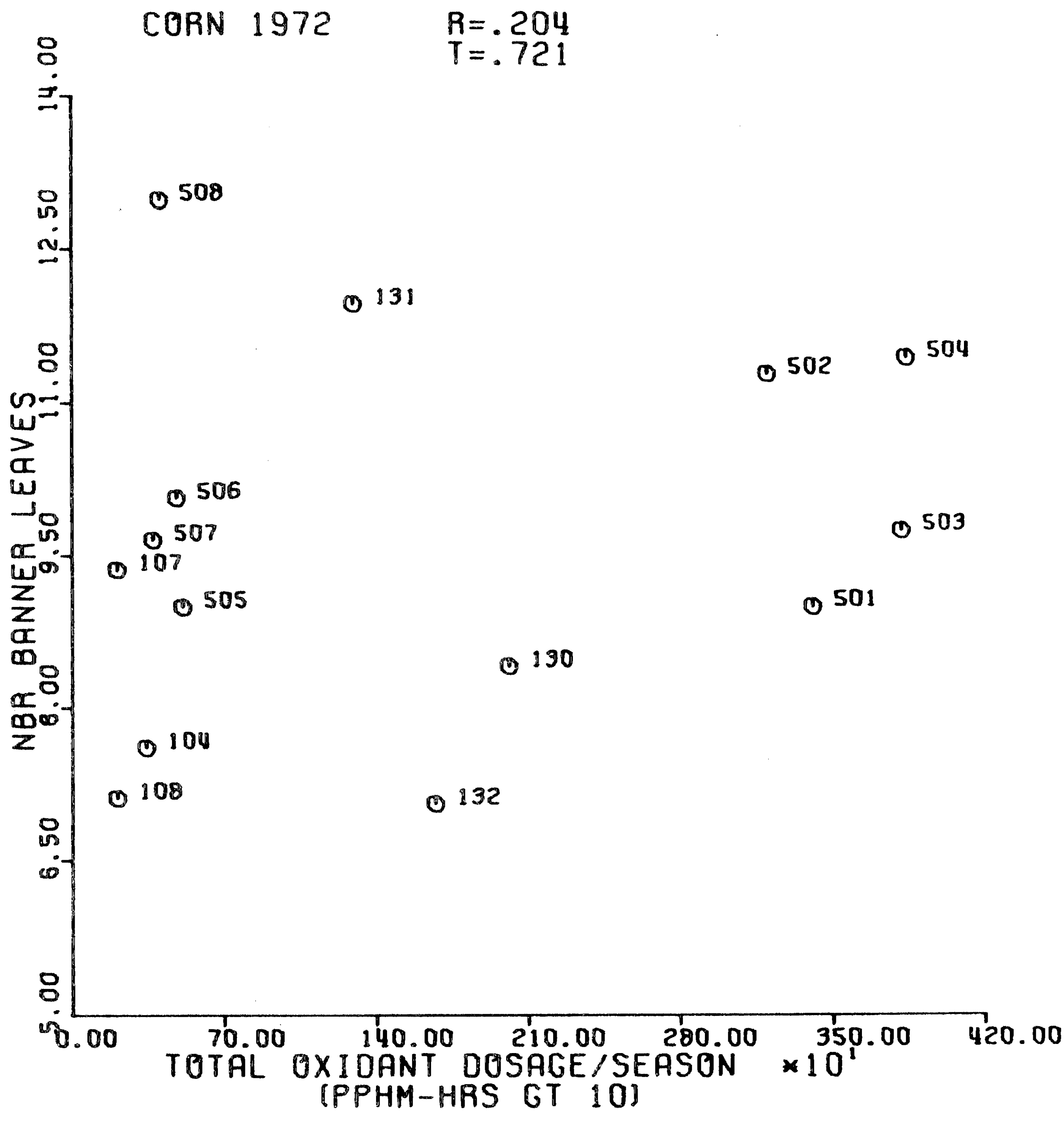


Figure 17. Correlation of diameters of harvested Golden Jubilee corn ears from field and test plots with the total ambient oxidant dosage present during growth.

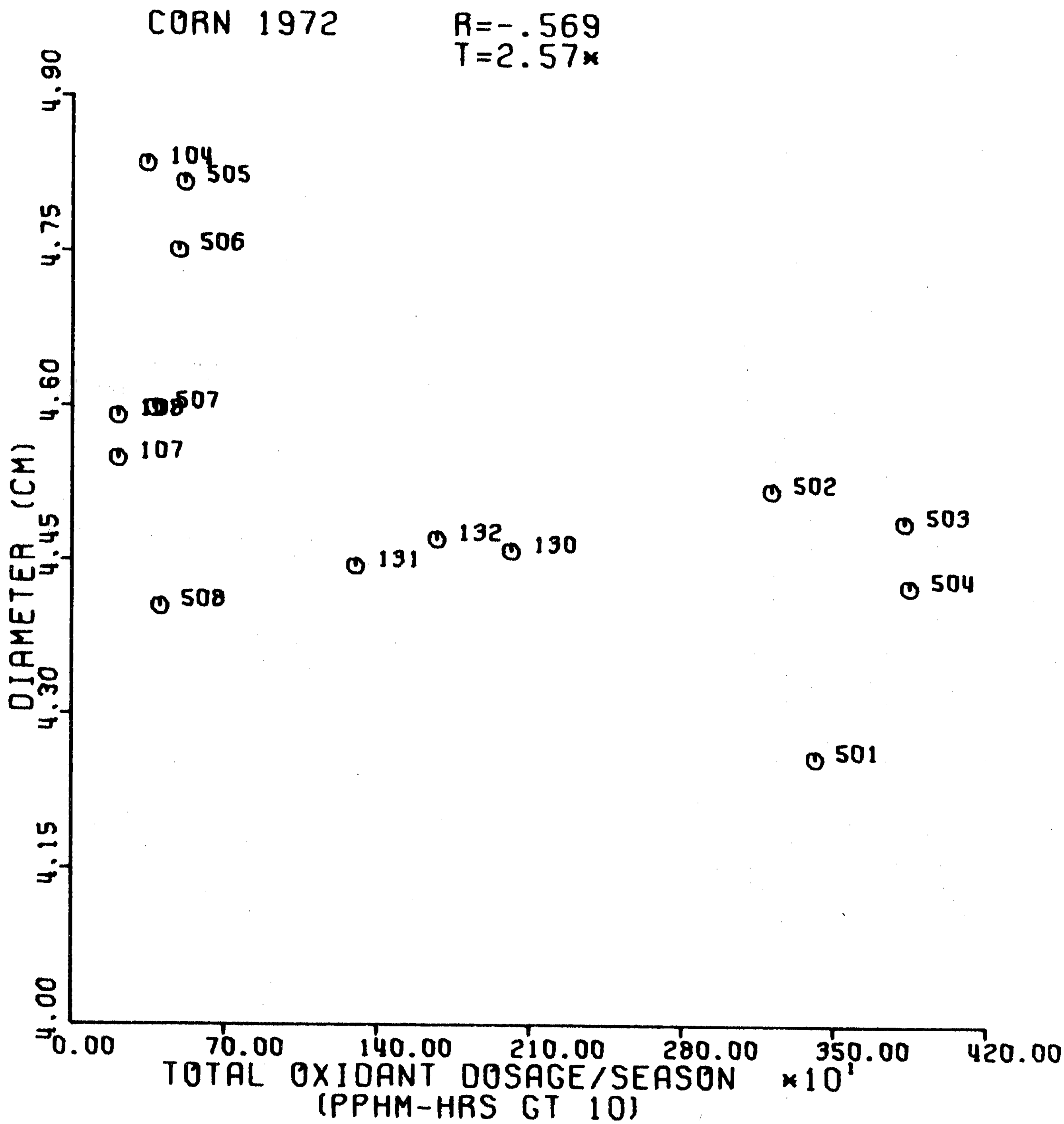


Figure 18. Correlation of weights of test plot Golden Jubilee corn ears with the total ambient oxidant dosage during growth.

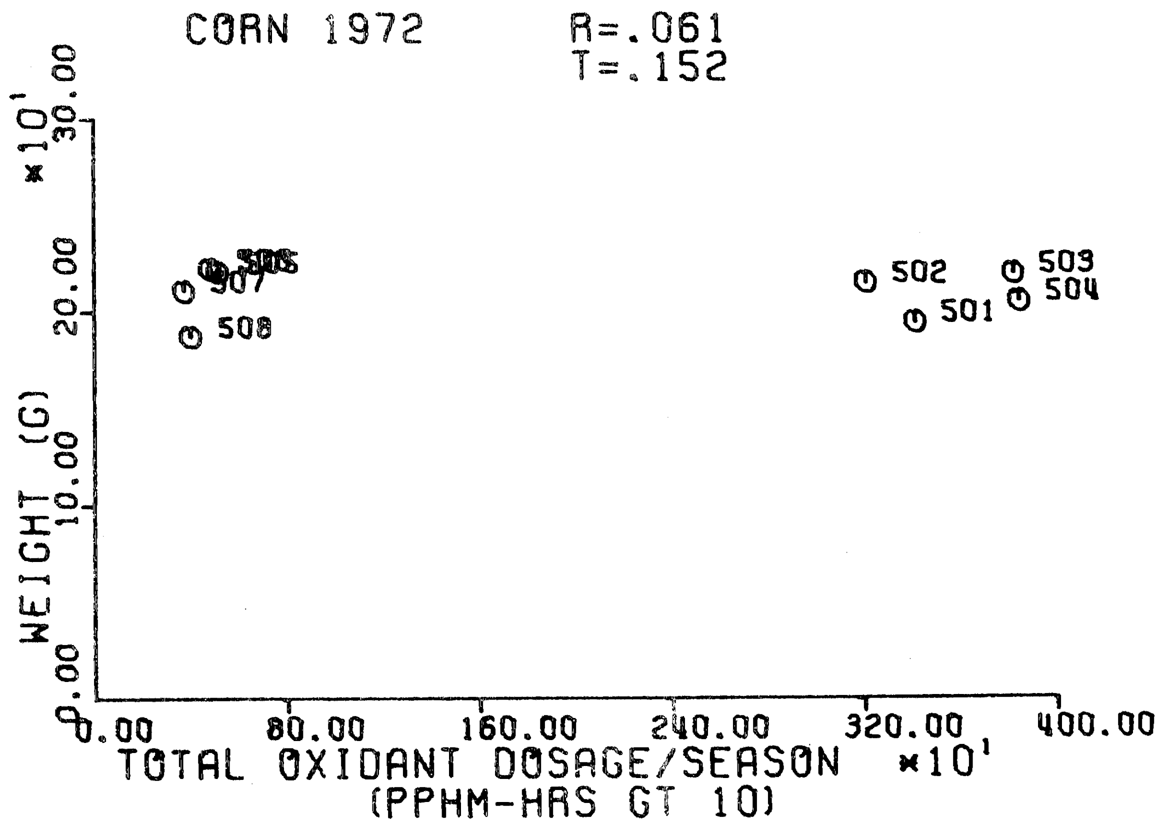


Figure 19. Correlation of lengths of test plot Golden Jubilee corn ears with the total ambient oxidant dosage during growth.

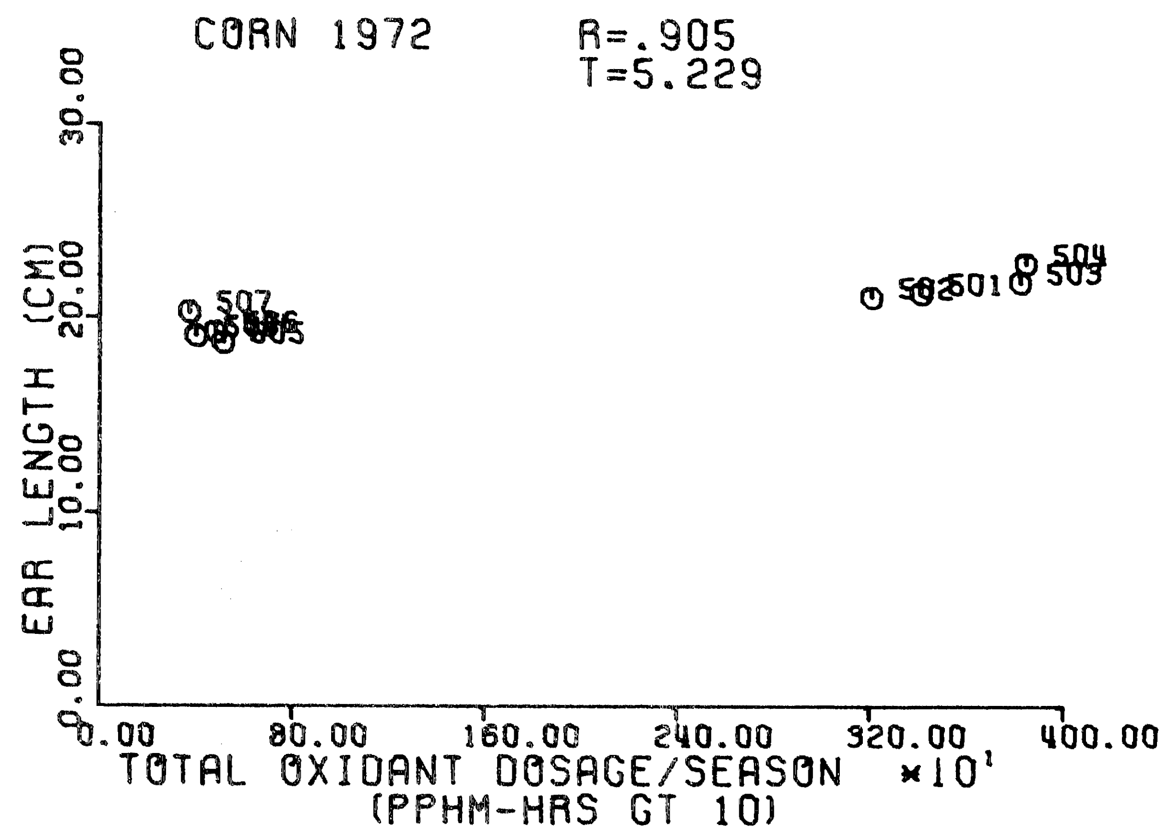


Figure 20. Correlation of the number of secondary ears from test plots of Golden Jubilee corn with the total ambient oxidant dosage during growth.

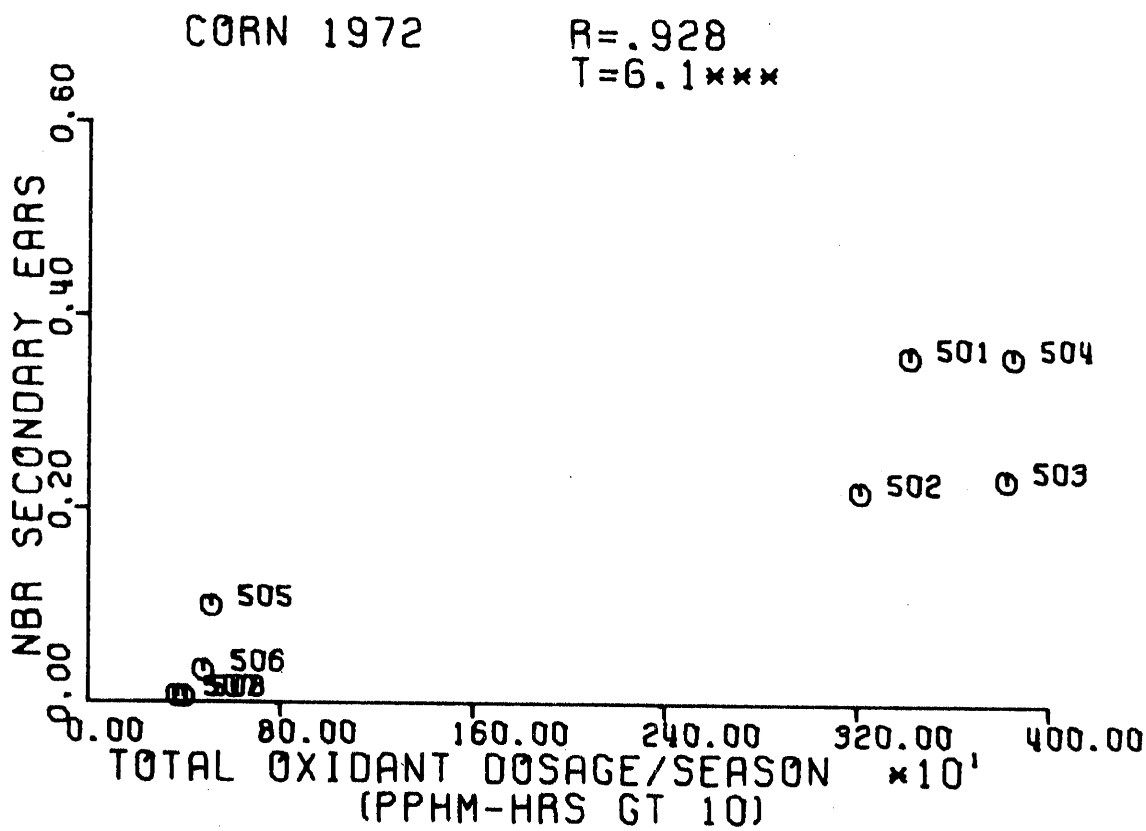


Figure 21. Correlation of the plant heights of test plot Golden Jubilee corn with the total ambient oxidant dosage during growth.

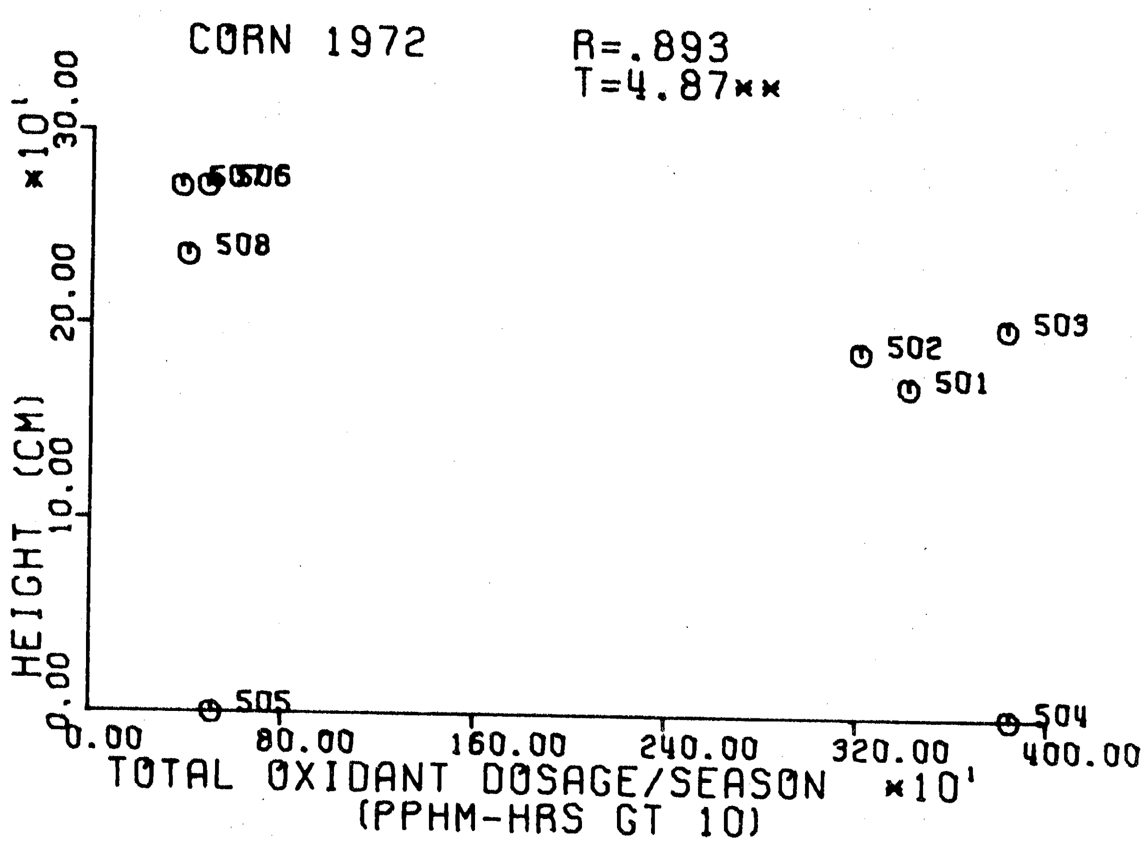


Table 3. Summary of ozone and PAN effects on Golden Jubilee sweet corn seedlings as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		# Leaves			Height			Fresh Wt.			Dry Wt.		
Control	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Ozone	.25 ppm	17.9	b	B	20.4	b	B	55.4	b	B	52.4	b	B
PAN	30 ppb	2.9	a	A	7.3	a	A	13.2	a	A	14.1	ab	A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

Table 4. Summary of significant ozone effects on Golden Jubilee sweet corn as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		Plant Ht.			Length Internodes			# Leaves			# Suckers			Plant Fresh Wt.			Plant Dry Wt.		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A	-	a	A	-	a	A
Treatments	.20	10.3	b	B	10.4	b	B	-	a	A	5.5	a	A	9.3	b	A	18.2	b	B
(ppm)	.35	14.5	c	B	18.2	c	C	-	a	A	33.3	b	A	29.3	c	B	43.4	c	C

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

Table 5. Summary of significant ozone effects on ears of Golden Jubilee sweet corn as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

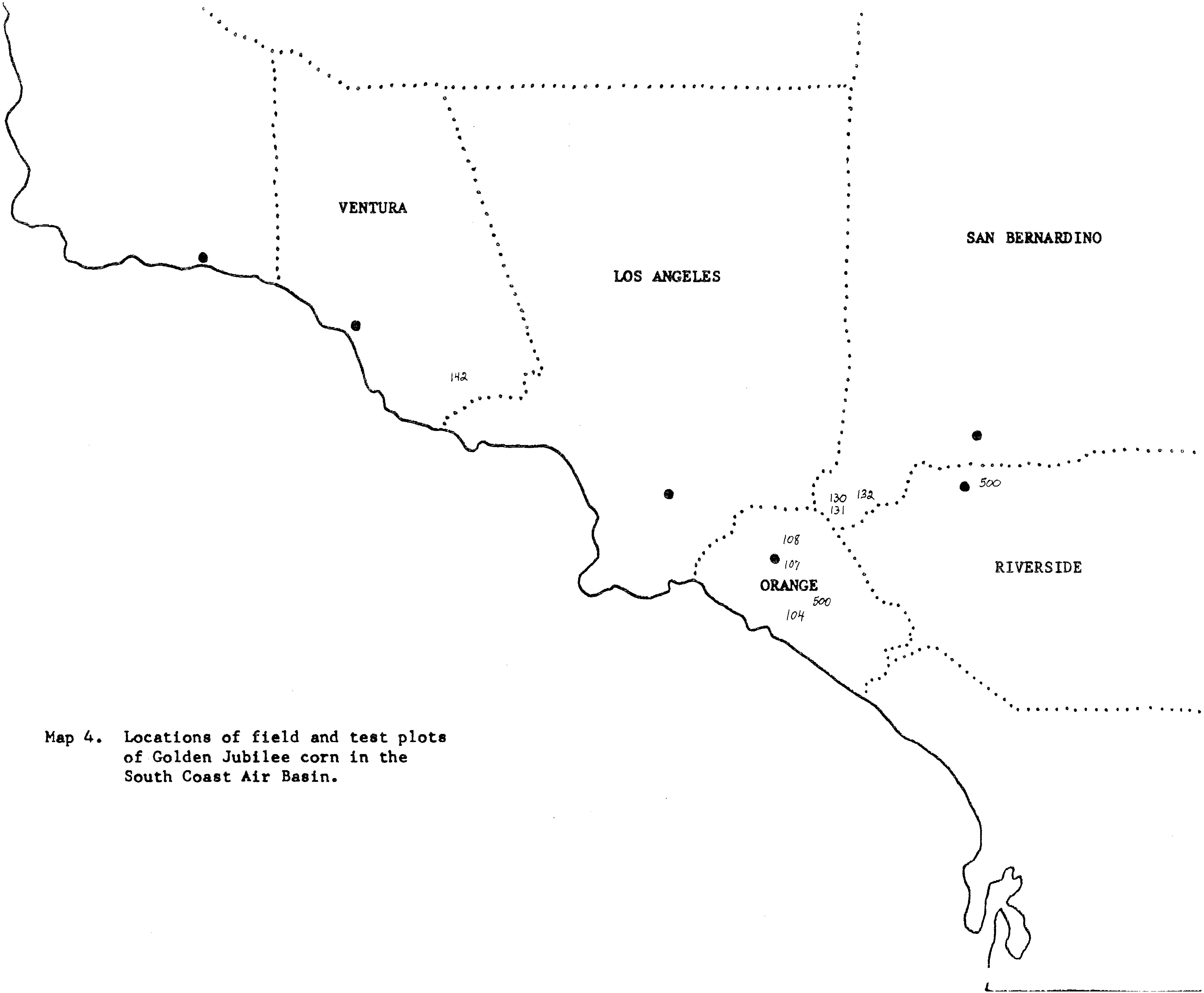
		Length Husked Ear			Diameter Husked Ear			Fresh Wt. Unhusked Ear			Fresh Wt. Husked Ear		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Treatments	.20	-	a	A	-	a	A	13.4	b	A	9.2	a	A
(ppm)	.35	-	a	A	-	a	A	31.8	c	B	26.1	b	B

		Dry Wt. Husked Ear			% Blanking Husked Ear			Max. Length of Shrivel[3] (cm)		
Ozone	0	-	a	A	-	a	A	0.2	a	A
Treatments	.20	12.5	b	B	-	a	A	6.2	b	B
(ppm)	.35	22.3	c	C	-	a	A	9.5	c	C

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

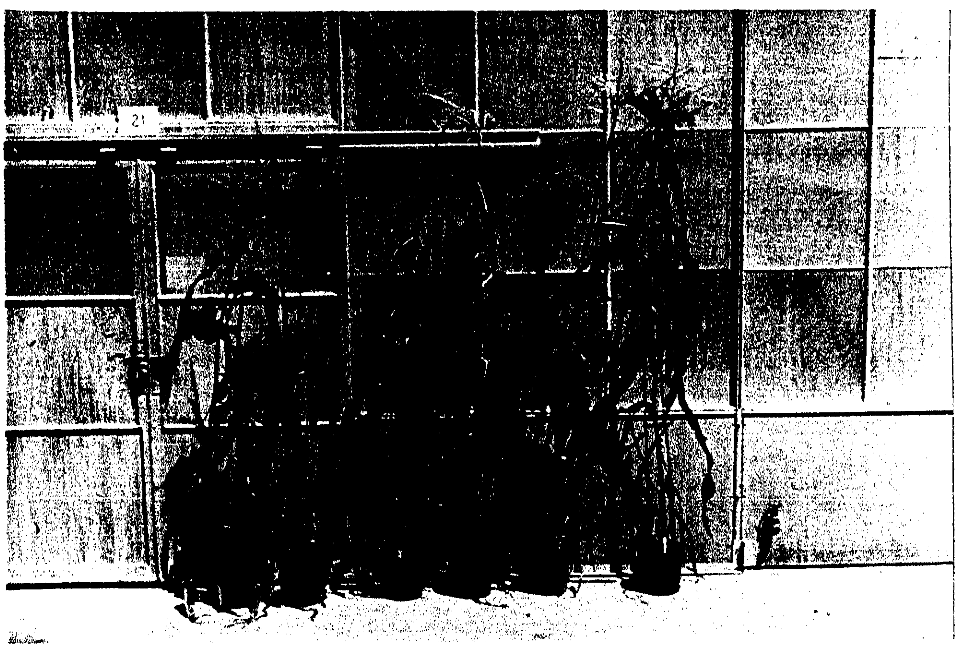
2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. These data are given in treatment means (cm).



Map 4. Locations of field and test plots of Golden Jubilee corn in the South Coast Air Basin.

Plate 11. The effect of ozone on the stature of Golden Jubilee corn. Pictured from right to left are: 2 control plants, 2 .20 ppm treatment plants, and 2 .35 ppm treatment plants.



CHAPTER VI - TOMATO

Summary

Tomato variety H-11 was found to be sensitive to ozone and PAN leaf injury under fumigation and field conditions, but significant fruit quality reductions were not observed.

PAN exposures did not significantly affect the yield or fruit quality of H-11 tomatoes. High levels of ozone, however, did produce a significant reduction in fruit yield during long-term fumigations but had no effect on fruit quality. Field work confirmed the fumigation quality observations, but yield results need to be tested in the field during the 1973 yield studies.

An absolute association between ozone leaf injury and yield reduction does not apply to this variety of tomato. Ozone fumigations at .20 ppm produced leaf injury but did not produce statistically different yield with control plants. An injury tolerance threshold may apply to other crops as well, and assessments of air pollution losses based on leaf injury alone should be re-evaluated.

Introduction

H-11 is a pole tomato variety used with success throughout the South Coast Air Basin.

A short-term fumigation study was undertaken to determine oxidant effects on young seedlings. A long-term fumigation study was used to determine effects on crop quality and yield and to develop criteria for field studies. Field work for the 1972 growing season focused on a quality study of field-grown fruit correlated with oxidant levels present during growth.

Seedling Fumigation Study

Treatments: Control, .24 ppm ozone, 30 ppb PAN

Exposure: Treatments were exposed to the respective concentrations of fumigant for 1.5% of the growing period. Fumigations were initiated upon emergence and discontinued after a 30-day period.

Effect of ozone on H-11 tomato seedlings: Obvious ozone injury was present on the leaves of the seedlings at harvest. Reductions in fresh and dry weights, size, and the number of leaves on harvested plants were also noted (Table 6).

Effects of PAN on H-11 tomato seedlings: Light PAN injury occurred on leaves of plants in the PAN fumigated treatment but no statistical differences in plant weights or sizes were found when compared to the control plants.

Discussion: Ozone exposures at a moderate level (.24 ppm) reduced the size and weight of H-11 tomato seedlings. Reductions in height of plant, weight, and number of leaves suggest that the fumigated seedlings were not as fully developed as control plants. This effect could delay the first harvest should it continue throughout growth.

Long-Term Ozone Fumigation of H-11 Tomato

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Exposure: Treatments were exposed to the respective concentrations of ozone for 97 out of 2,376 hours or about 4% of the growing period. The fumigations averaged about 3 hours in length and were staggered to provide time for plant recovery.

Effects of ozone on H-11 tomato plants: Ozone leaf injury was observed on plants in both fumigated treatments throughout the study (Plate 12). The .20 ppm and .35 ppm plants were reduced in both fresh and dry weights and were visibly less vigorous than the control plants. Weight losses were evenly distributed over all portions of the plants including roots (Table 7).

Effects of ozone on H-11 tomato fruit: Criteria used to measure harvested fruit are illustrated in Figure 22. A definite reduction in total yield, as measured by number and total weight of harvested fruit, occurred on plants exposed to the high fumigation level (.35 ppm) Table 8. The yields of the .20 ppm and the control treatments were not significantly different. The size and weight of individual fruit were not significantly different among treatments, but the plants in the .35 ppm treatment produced significantly less fruit per plant as measured by numbers produced and mean weight harvested.

Discussion: Greenhouse-grown H-11 tomato plants were found to be sensitive to ozone leaf injury at concentrations of .20 ppm and .35 ppm. This was reflected in reductions in fresh and dry weights of the plants at harvest. However, plants exposed to the .20 ppm exposures did not reflect this sensitivity in their fruit production and were comparable to control plants in yield. The number of immature fruit remaining on the plants at harvest suggests that the potential for continued production was not substantially different from the unfumigated treatments. Higher levels of ozone (.35 ppm) significantly affected fruit yield.

The size and quality of harvested fruit did not vary from treatment to treatment. Fruit harvested from the .35 ppm treatment were of comparable quality with control plants even though yields were reduced.

Reductions in plant growth, weight and number of fruit, and overall plant vigor were observed in this experiment.

Long-Term PAN Fumigation of H-11 Tomato

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Exposure: Treatments were exposed to the respective concentrations of PAN for 131 out of 2,600 hours or about 4% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effect of PAN on H-11 tomato plants: Although PAN leaf injury was observed on both fumigated treatments, no significant differences in fruit yield or quality were found between them.

Discussion: PAN concentrations of 20 ppb and 40 ppb did not affect the fruit production or quality of H-11 tomato plants.

Field Study (Quality Effects)

Locations: Five commercial field plots and two test plots of H-11 tomatoes were established in the South Coast Air Basin (Map 5). Each location was monitored for oxidant pollutants by three AMBI stations.

Sampling procedures: Commercial field plots were sampled three times during the harvest season at monthly intervals. Sampling was initiated with the first weeks of heavy production. Each sample consisted of 100 randomly selected fruit and care was taken to quarter each sampled plant to prevent a biased selection. Samples were stored in plastic bags and immediately transferred to the laboratory for analysis.

Test plots comprised two 100-foot rows of H-11 tomatoes. Each plant was trained on poles using methods standardized by commercial growers. One hundred plants were selected and harvested throughout the season. All harvested fruit were counted, weighed, and a 50-fruit sample from each harvest was carefully evaluated for quality.

Effects of ambient oxidants on field-grown H-11 tomatoes: The South Coast Field Station test plot was rendered unusable by a severe infestation of leaf miners. The vast majority of plants were defoliated.

Four random harvests from the UCR test plot were selected and correlated with their dates of harvest over the season. Evaluated quality data from harvested fruit were compared against each other to determine whether significant reductions in the size or quality of the fruit occurred as a result of their sequence in the seasonal harvest.

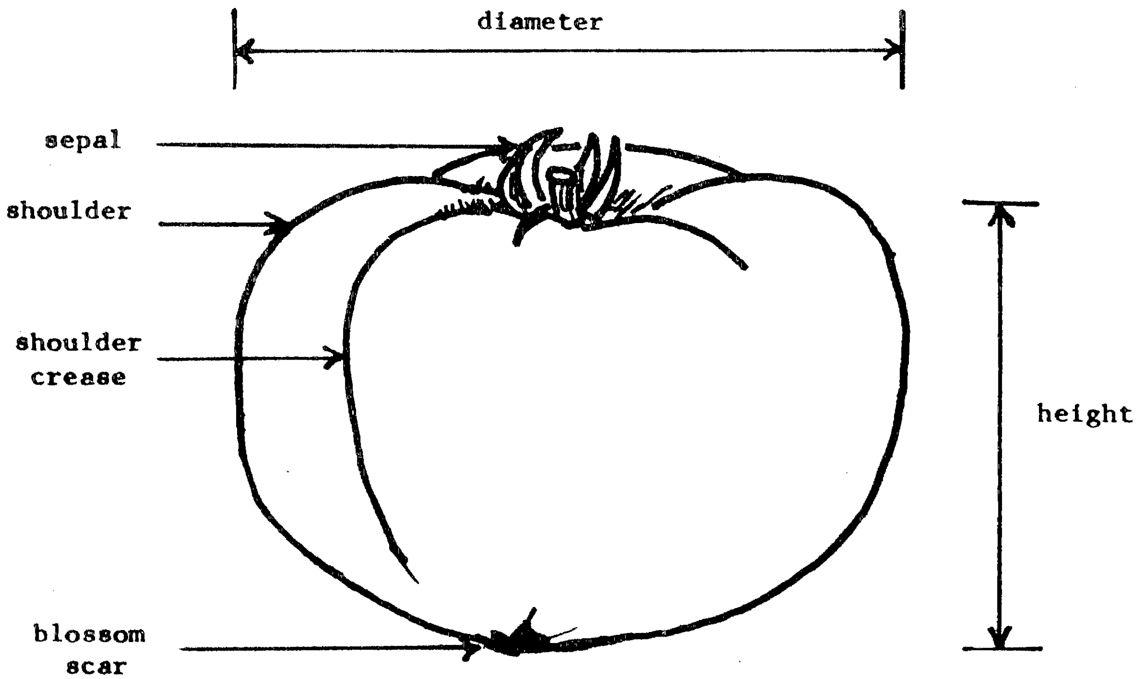
Significant correlations were found to be associated with the number of growth cracks, extent of blemishes and percentage of irregular fruit (Figures 30, 33, 34). All other evaluated criteria proved to have insignificant correlations with the times of harvest (Figures 23, 24, 25, 26, 27, 28, 29, 31, 32). The significant correlations may well be attributed to the normal decrease in vitality characteristic of multiple harvest crops as the harvest season progresses and not to ozone effects. It was interesting to note that no significant differences were determined in the mean size or weight of tomatoes as the season progressed.

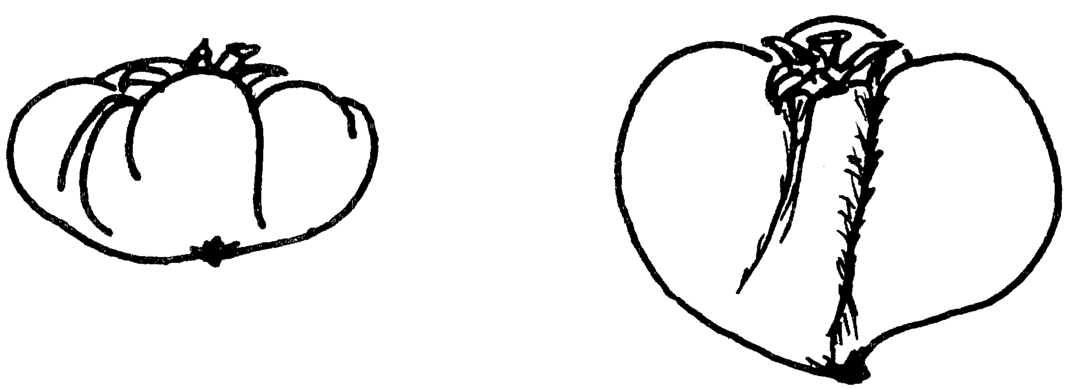
Fruit harvested from commercial field plots did not reveal any significant correlations with the oxidant dosages present during growth (Figures 35, 46). Evaluated quality varied irregularly between fields and harvests with no apparent association with oxidant dosages. Correlations of statistical significance found in UCR test plot data were not evident during commercial field evaluations.

Discussion: Fumigation results proved to be an accurate criteria for predicting field results. Although ozone injury was observed on field-grown tomato plants, no quality reductions attributed to ozone were detectable on harvested fruit.

Unfortunately, the failure of the South Coast Field Station test plot prevented a comparison of fruit quality between the inland and coastal areas in association with their oxidant dosages. The UCR test plot was exposed to much higher oxidant dosages than the South Coast Field Station. No losses in quality attributed to oxidant air pollutants were evident and it must be speculated that the lower seasonal dosages at the South Coast Field Station would not produce fruit quality reductions.

Figure 22. Criteria for Measurements taken on H-11 Tomato Fruit.





irregular-shaped fruit

Figure 23. Correlation of diameters of U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

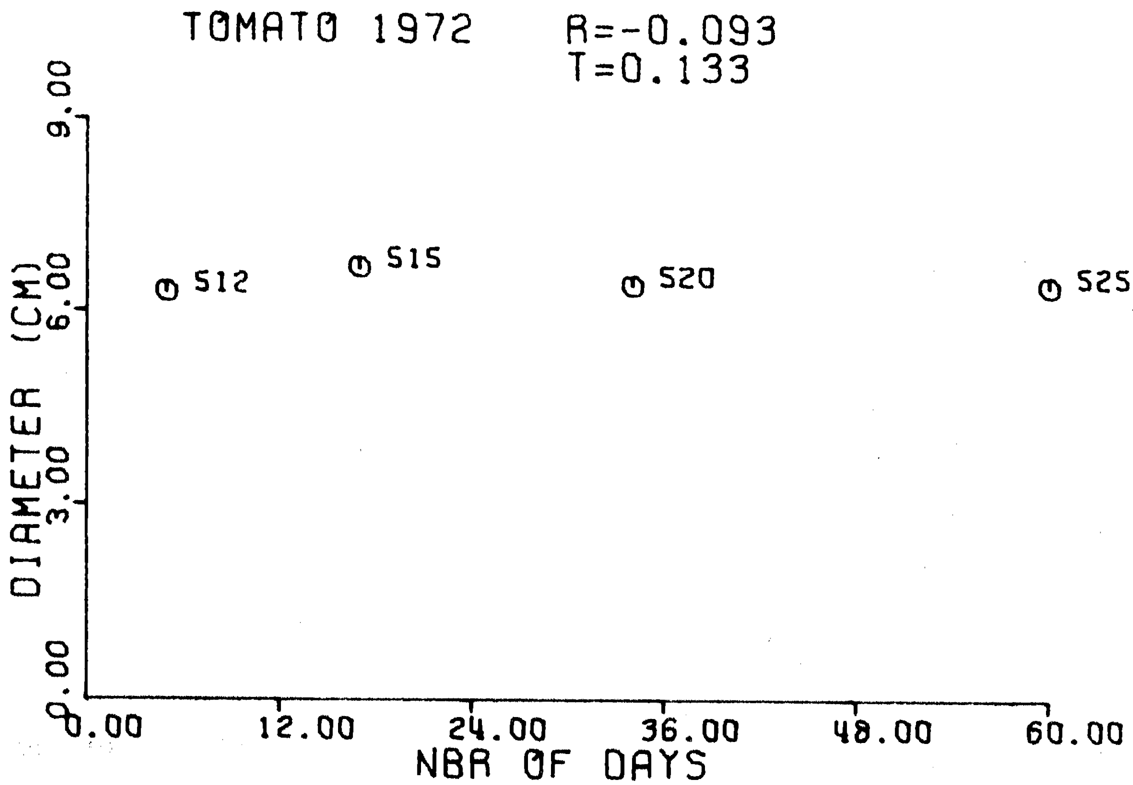


Figure 24. Correlation of heights of U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

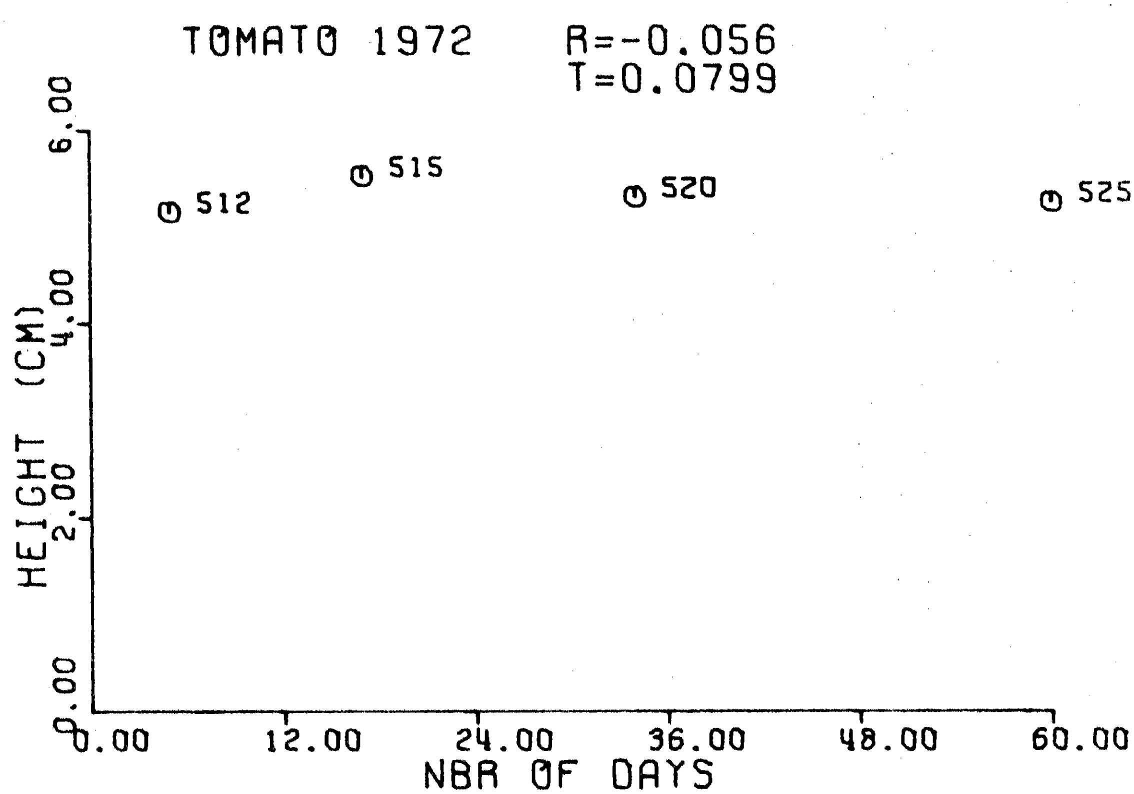


Figure 25. Correlation of weights of U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

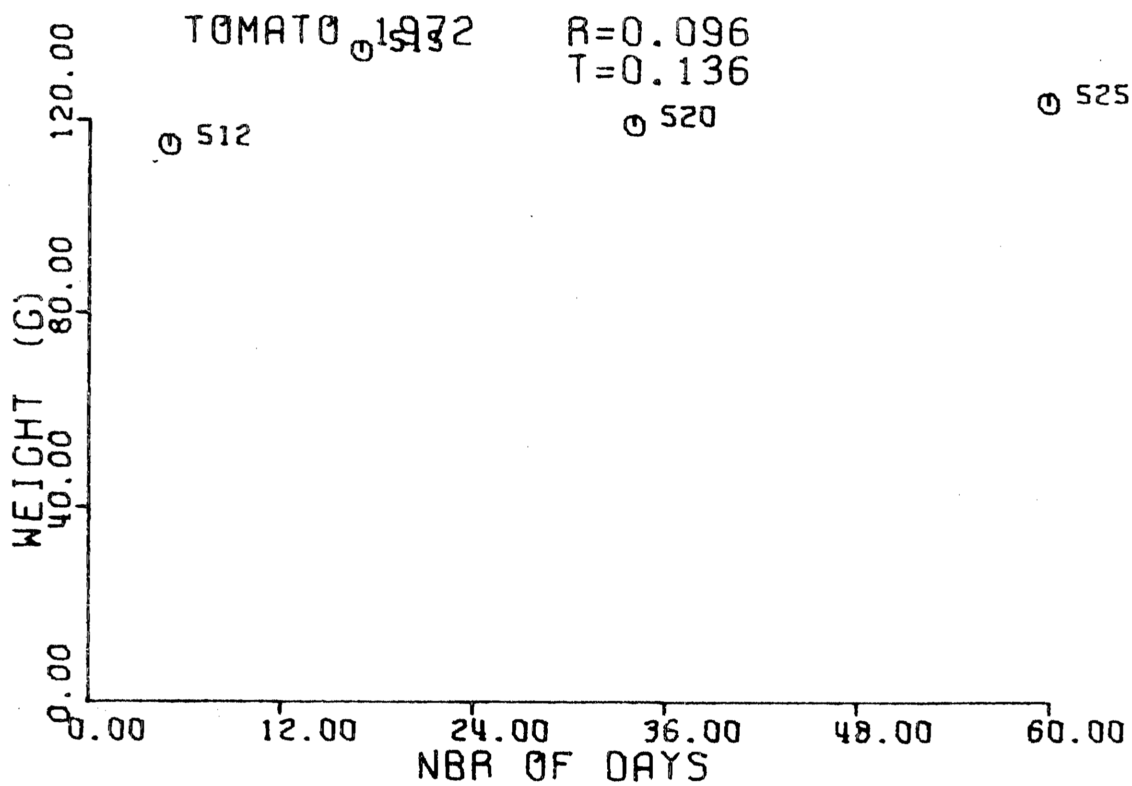


Figure 26. Correlation of the number of shoulder creases on U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

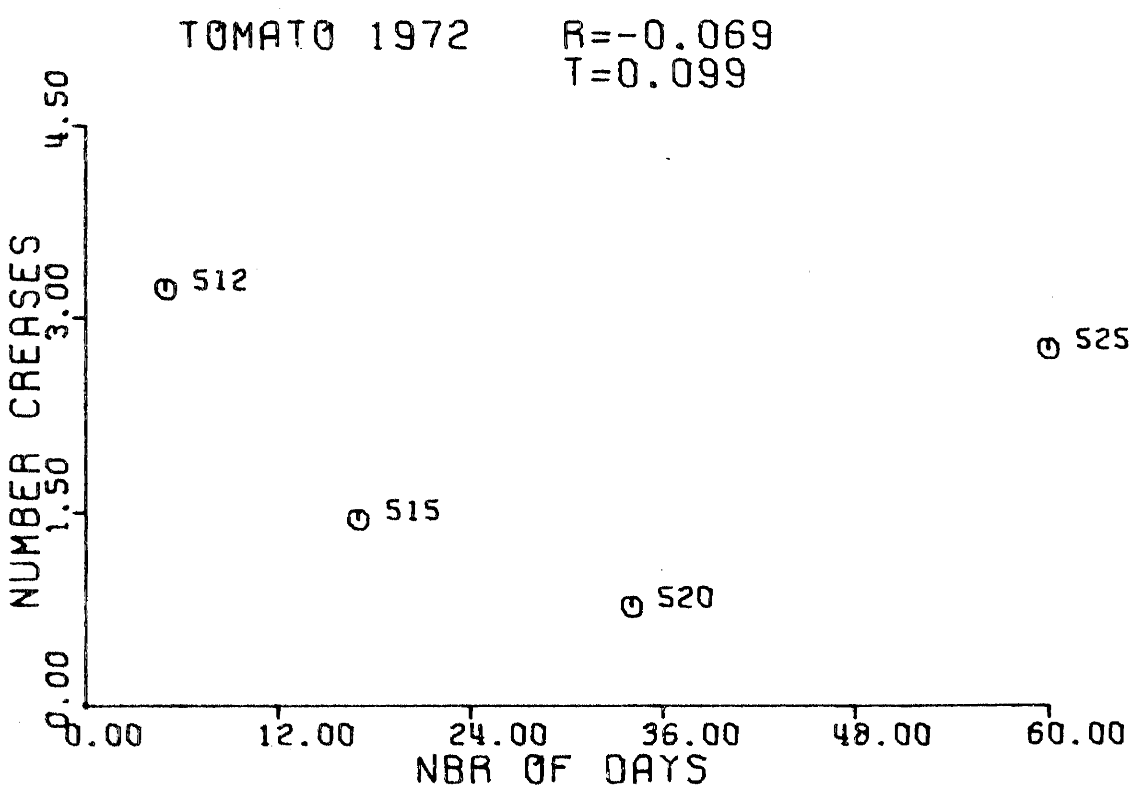


Figure 27. Correlation of the extent of shoulder creases on U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

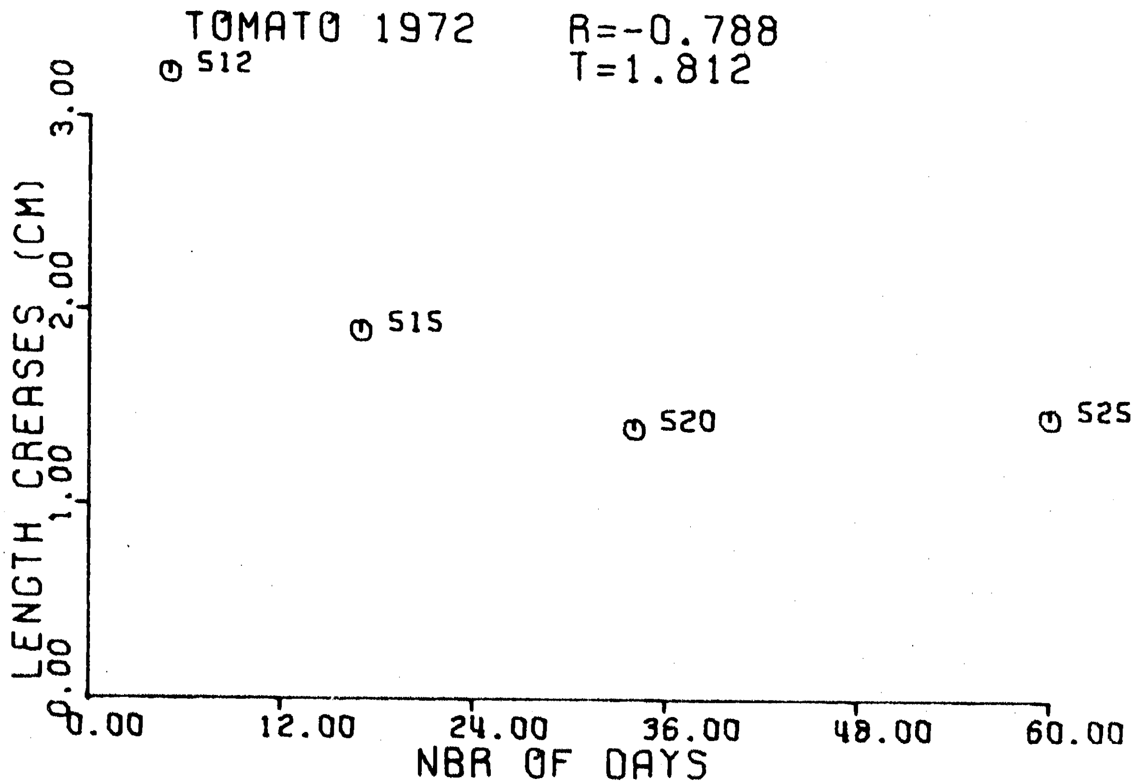


Figure 28. Correlation of the number of scars on U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

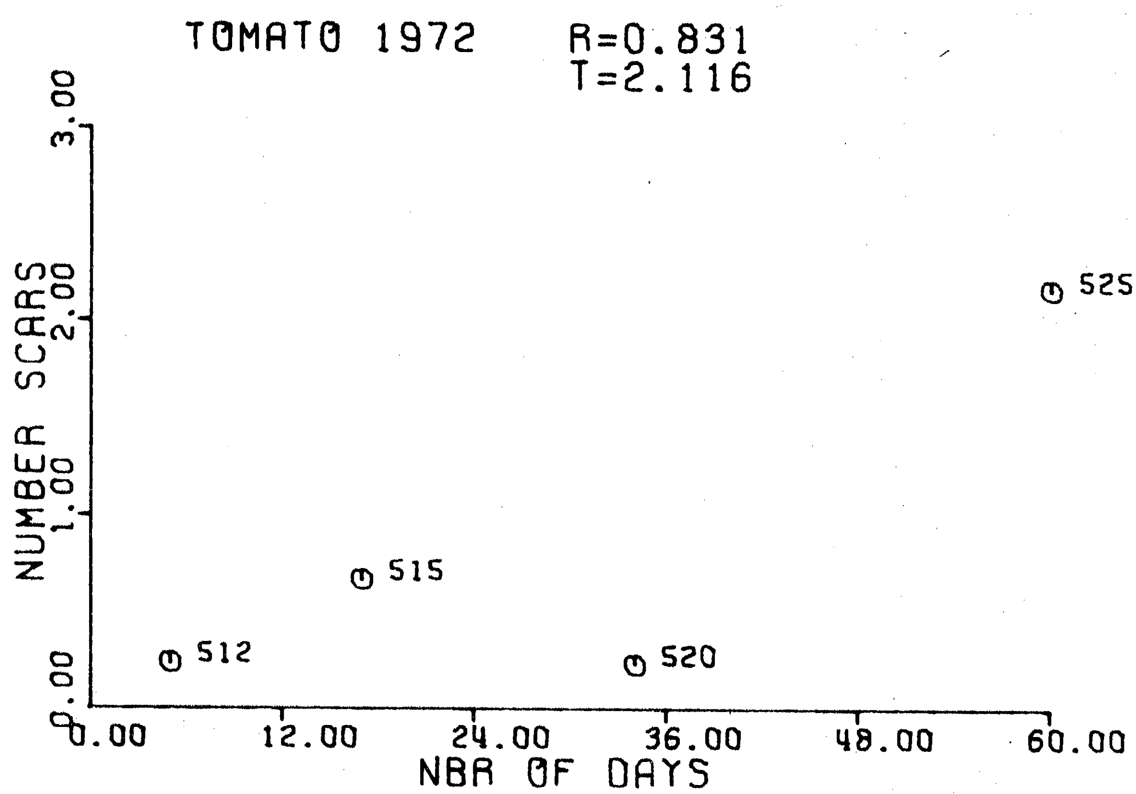


Figure 29. Correlation of the extent of scars on U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

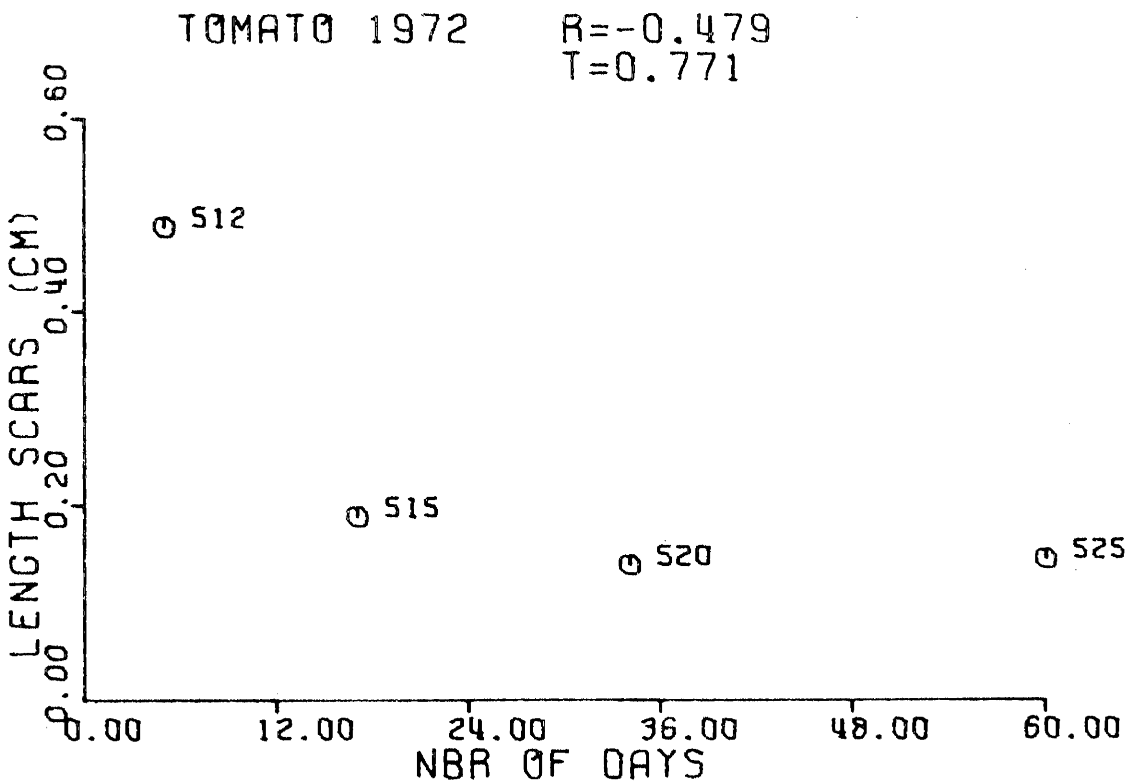


Figure 30. Correlation of the number of growth cracks on U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

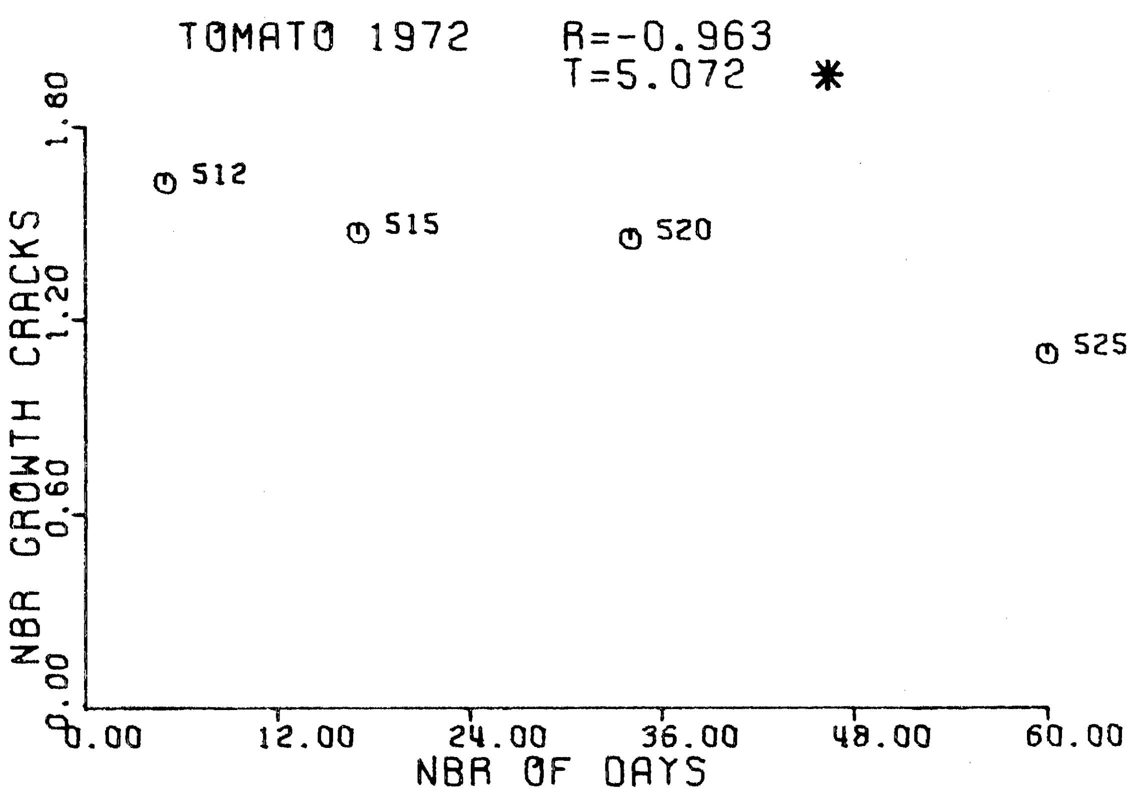


Figure 31. Correlation of the extent of growth cracks on U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

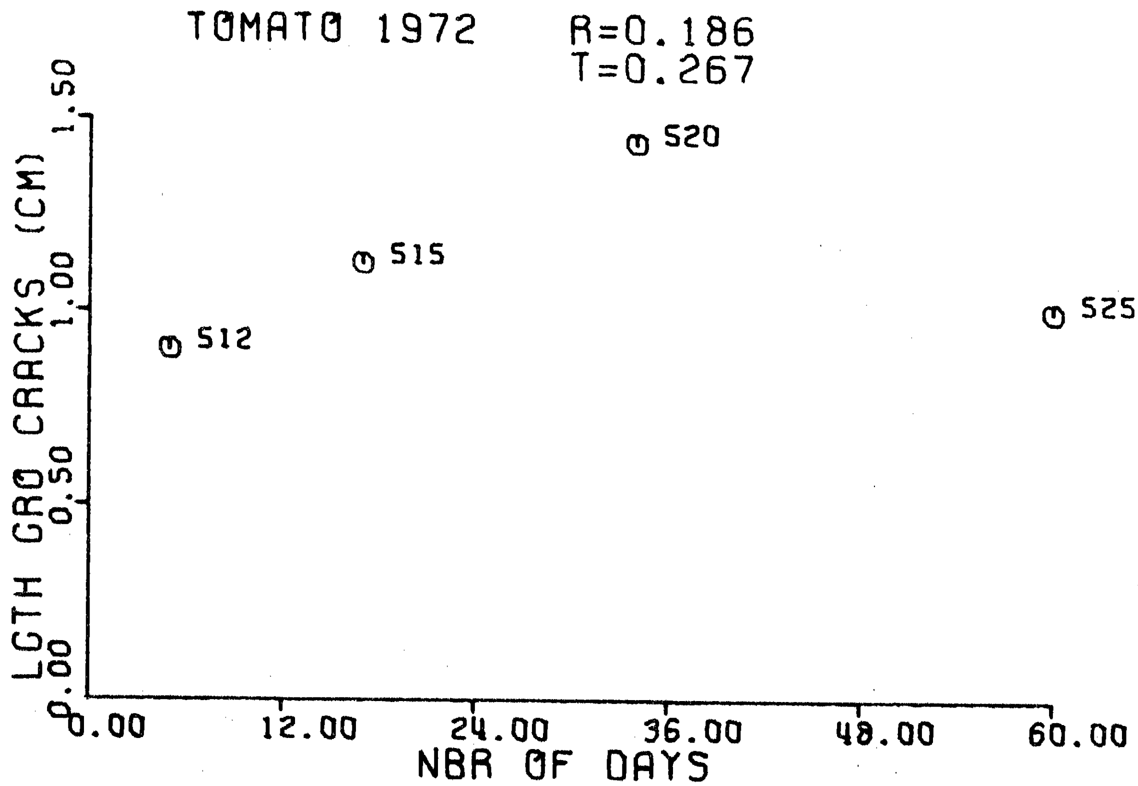


Figure 32. Correlation of the number of blemishes on U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

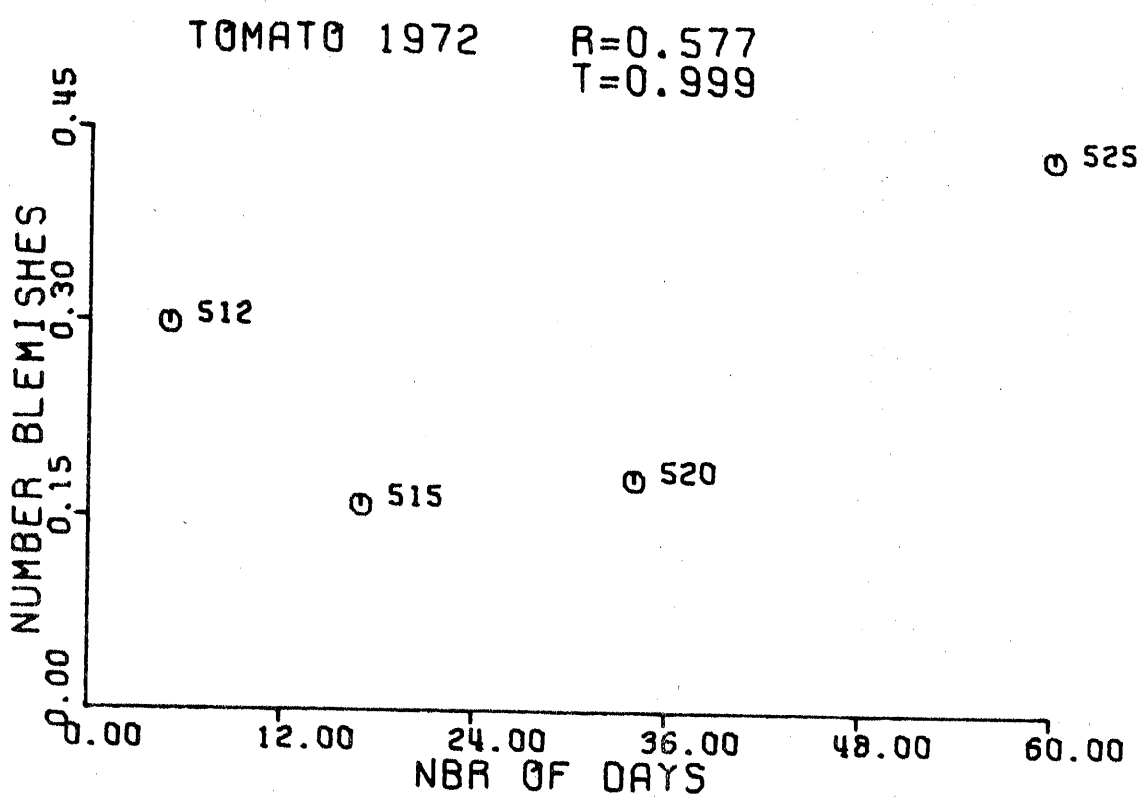


Figure 33. Correlation of the extent of blemishes on U.C.R. test plot H-11 tomato fruit with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

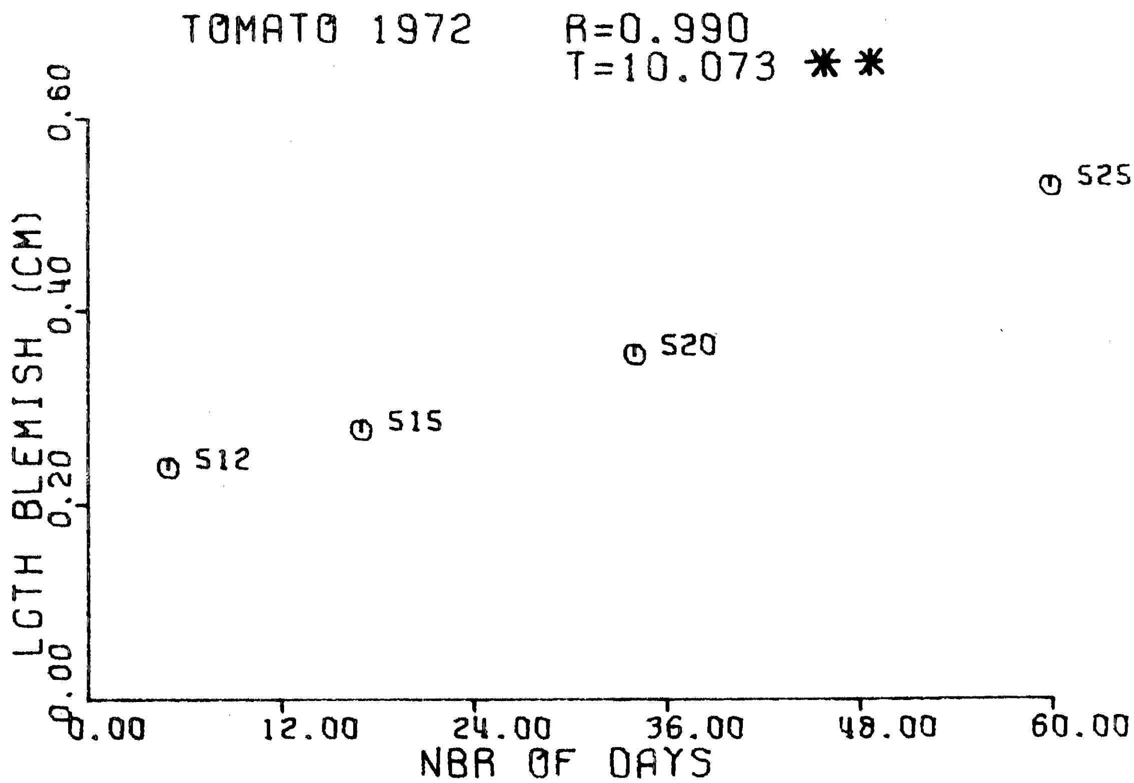


Figure 34. Correlation of the percentage of irregularly-shaped fruit from U.C.R test plot H-11 tomato harvests with time of harvest. The cumulative ozone dosage greater than 10 pphm was 5552 pphm hrs.

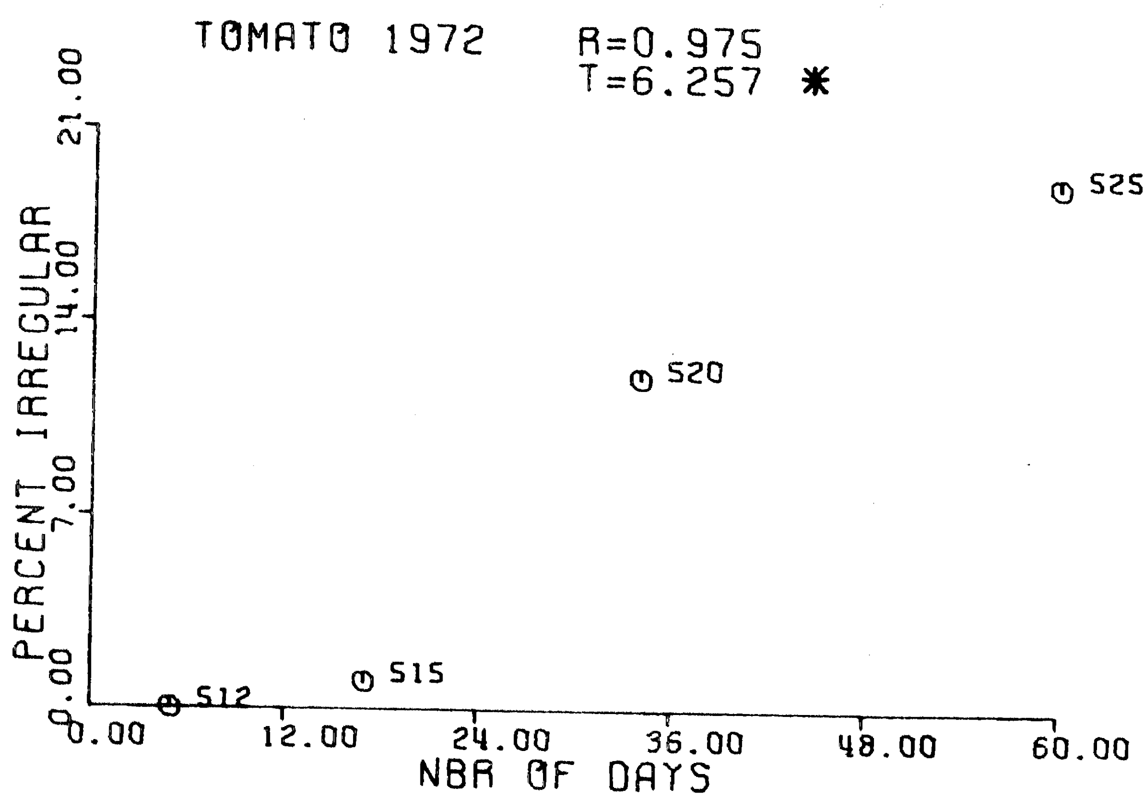


Figure 35. Correlation of diameters of harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

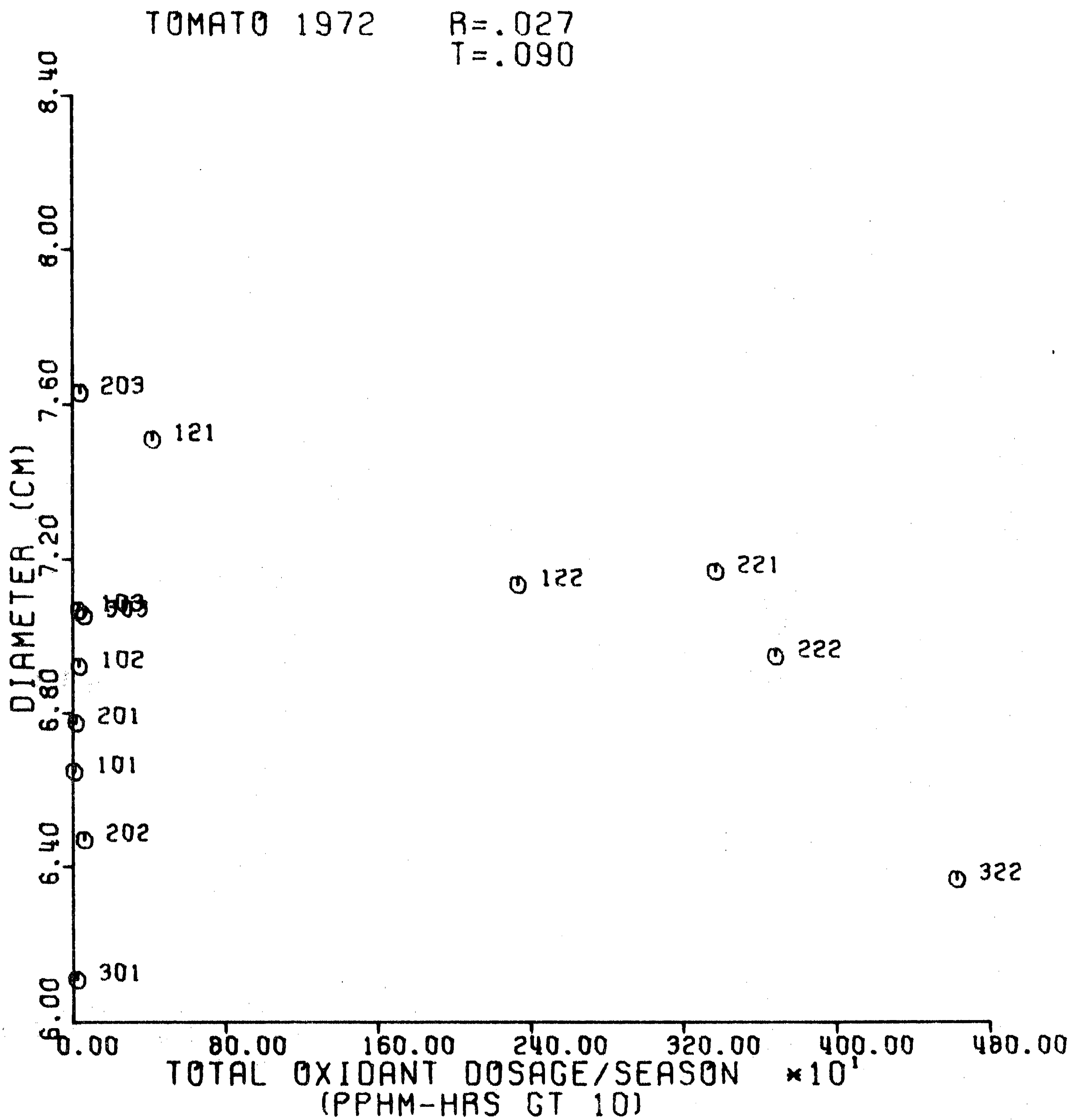


Figure 36. Correlation of heights of harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

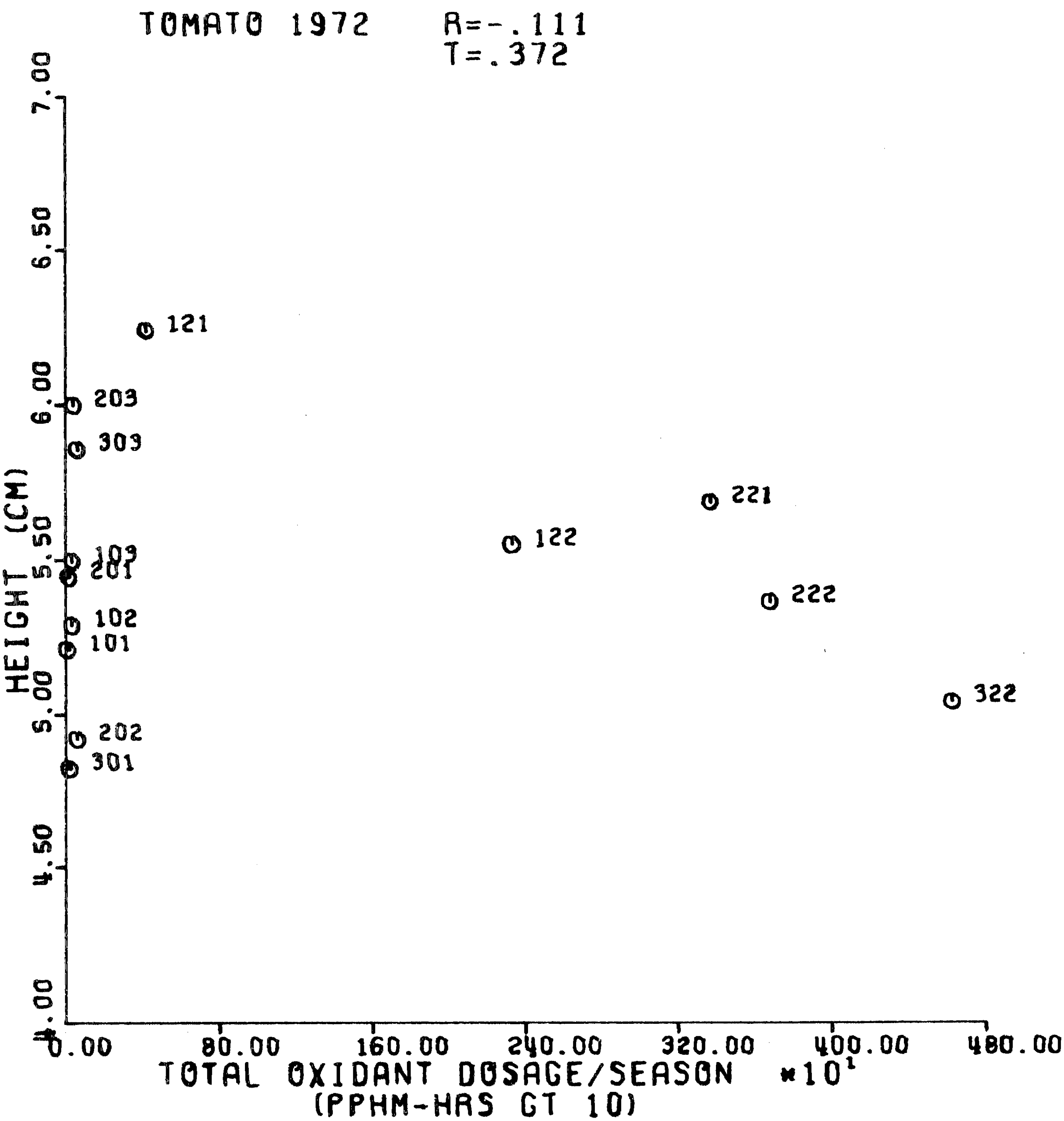


Figure 37. Correlation of weights of harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

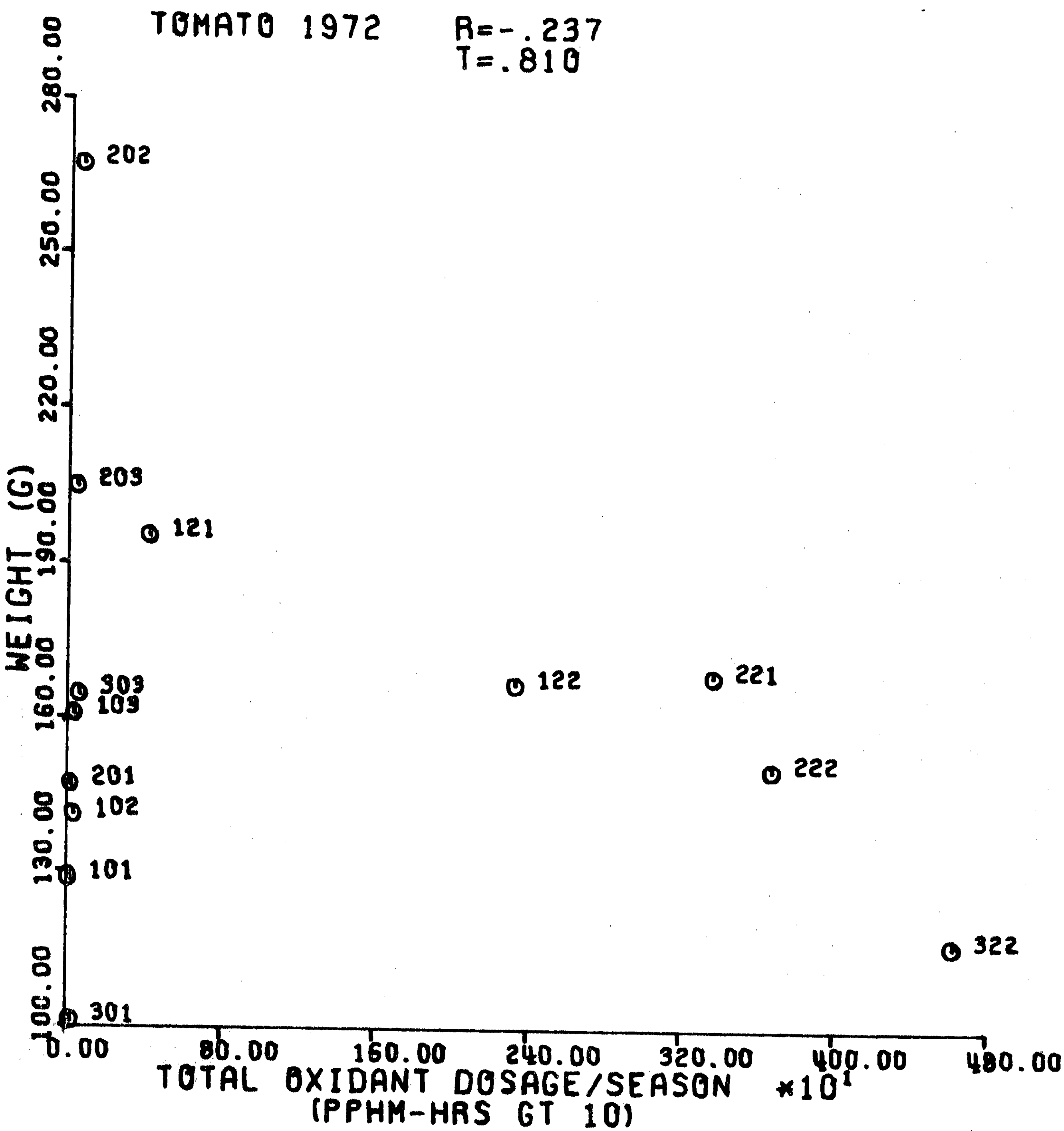


Figure 38. Correlation of the percentage of irregular H-11 tomato fruit harvested with the total ambient oxidant dosage present during growth.

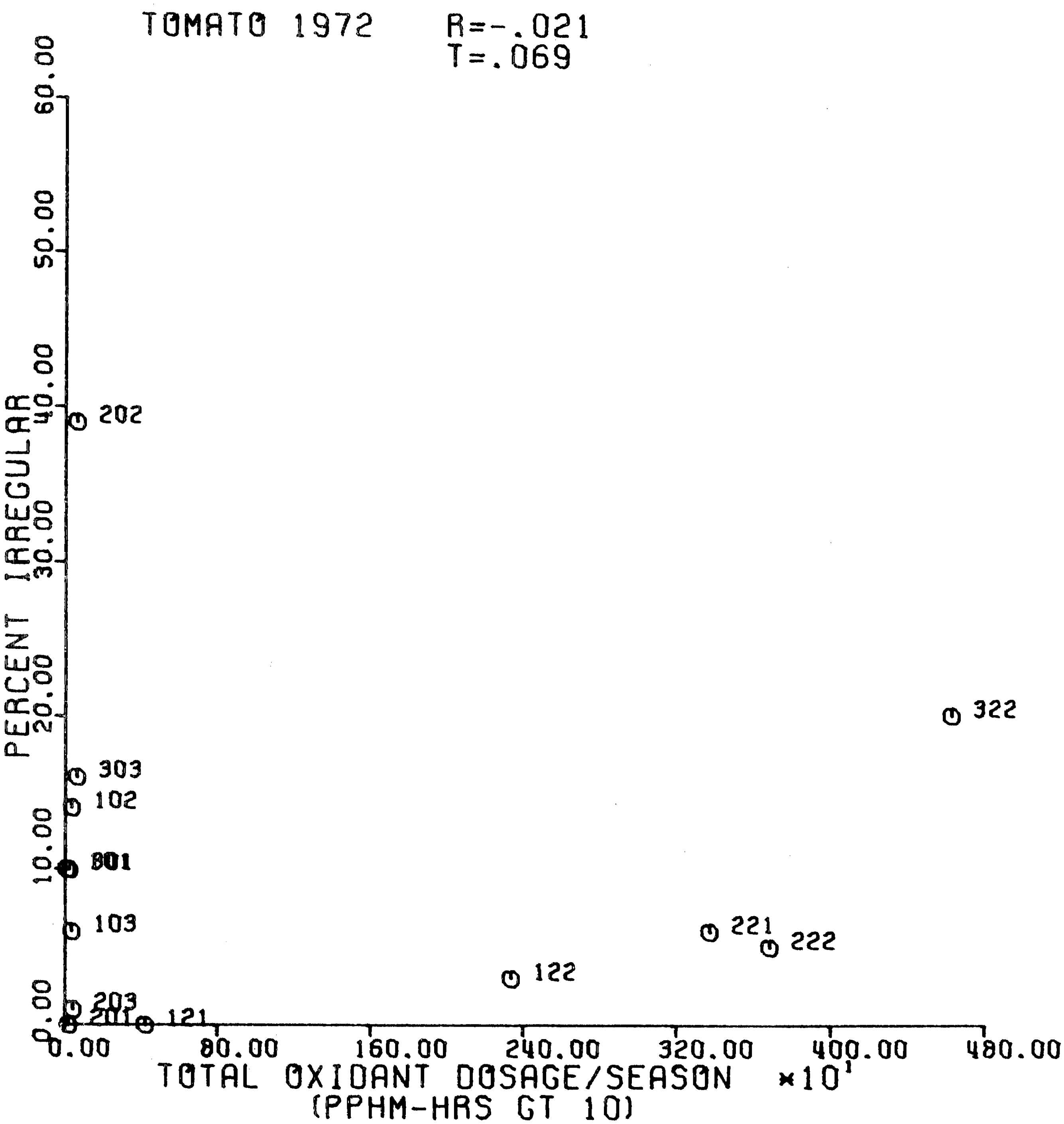


Figure 39. Correlation of the number of growth cracks on harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

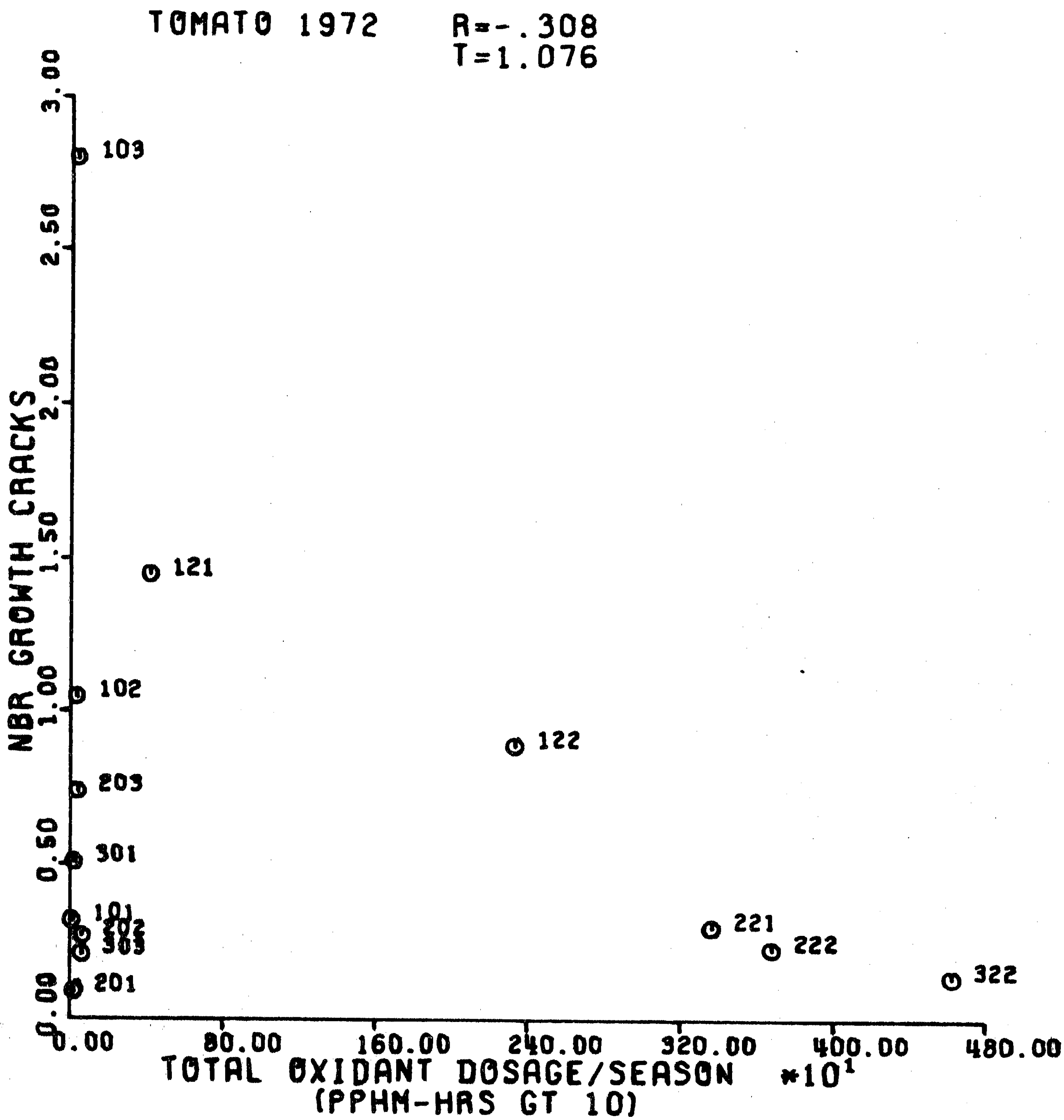


Figure 40. Correlation of the length of the longest growth cracks on harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

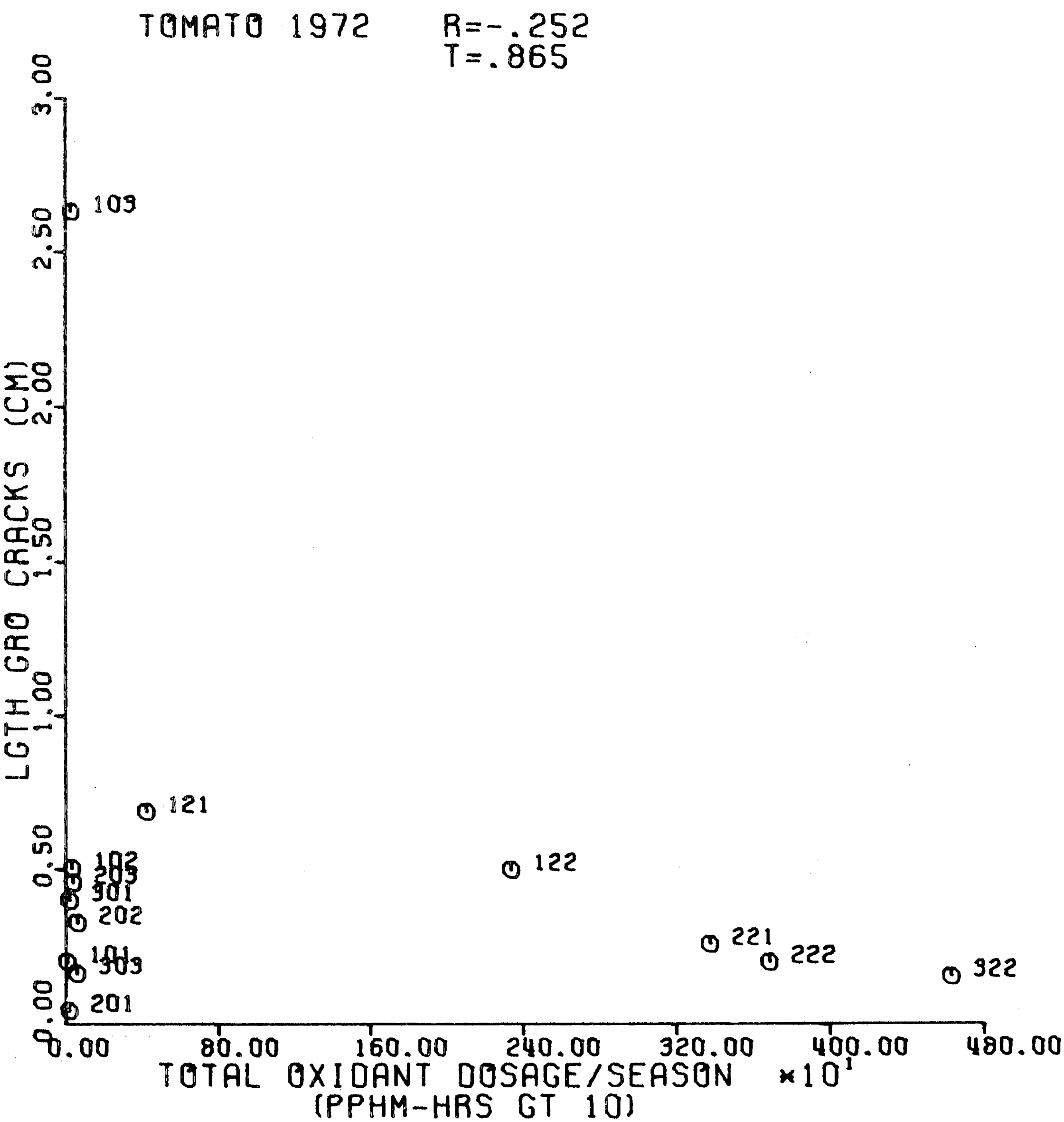


Figure 41. Correlation of the number of blemishes on harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

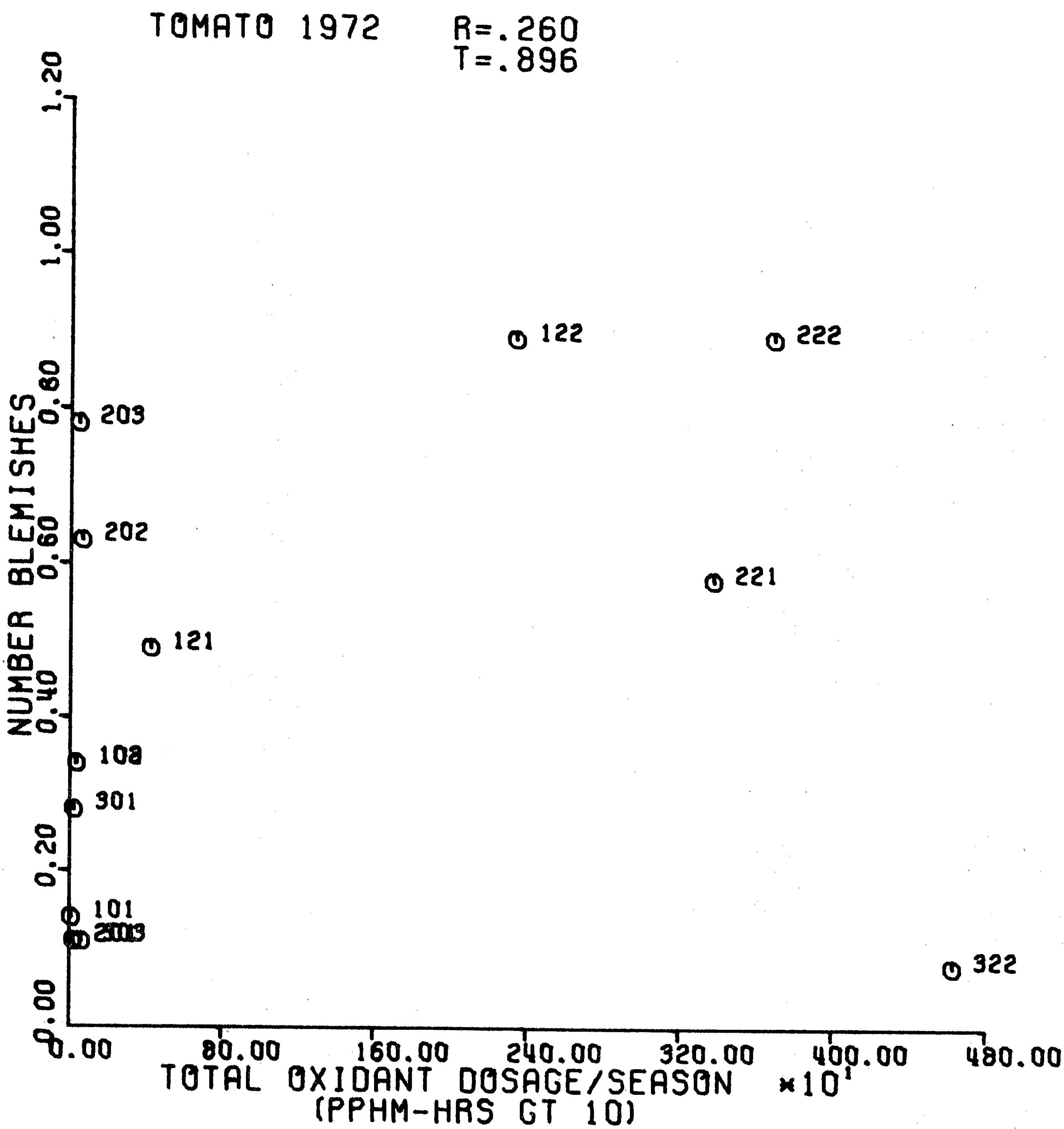


Figure 42. Correlation of the severity of blemishes on harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

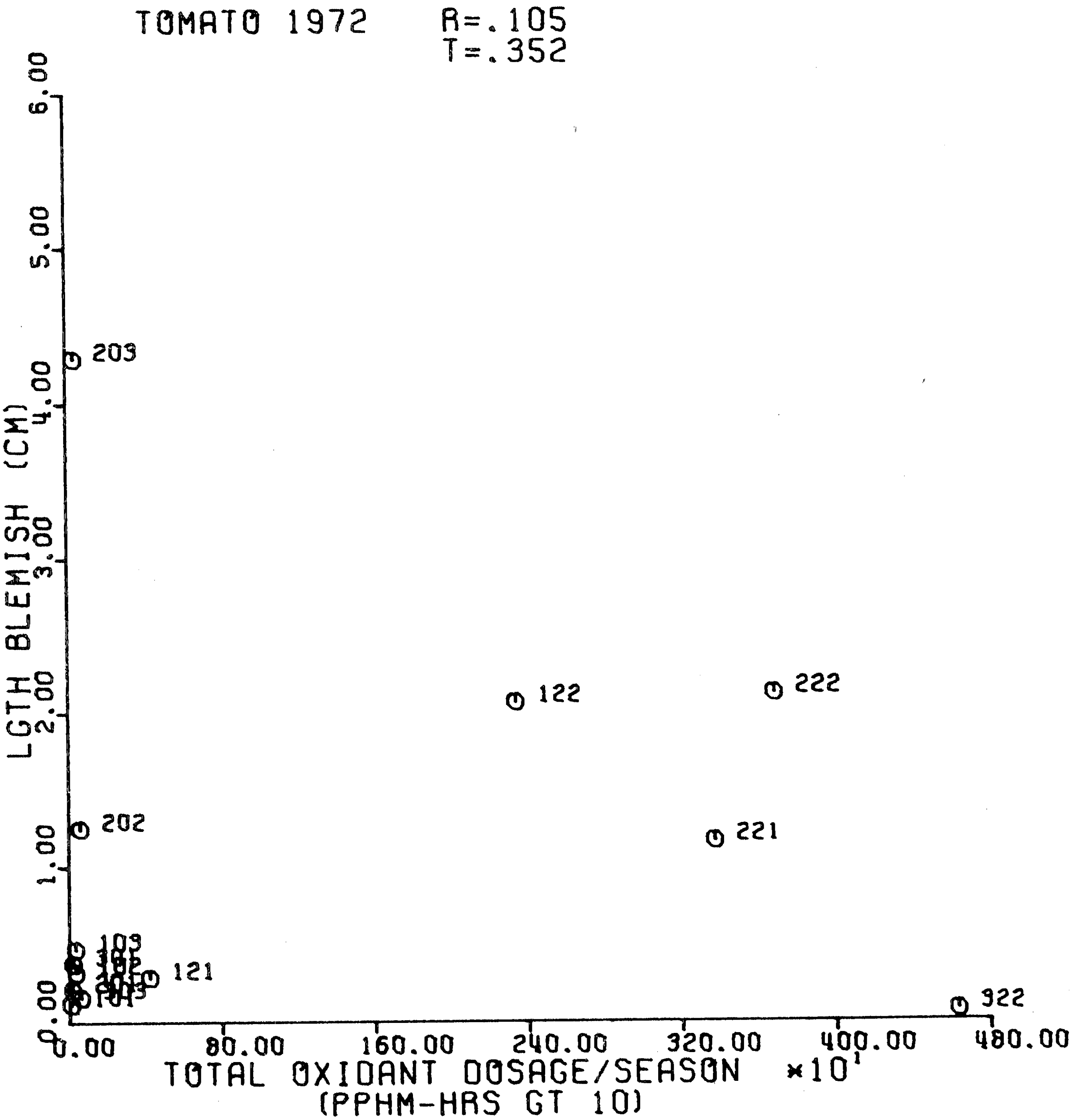


Figure 43. Correlation of the number of scars on harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

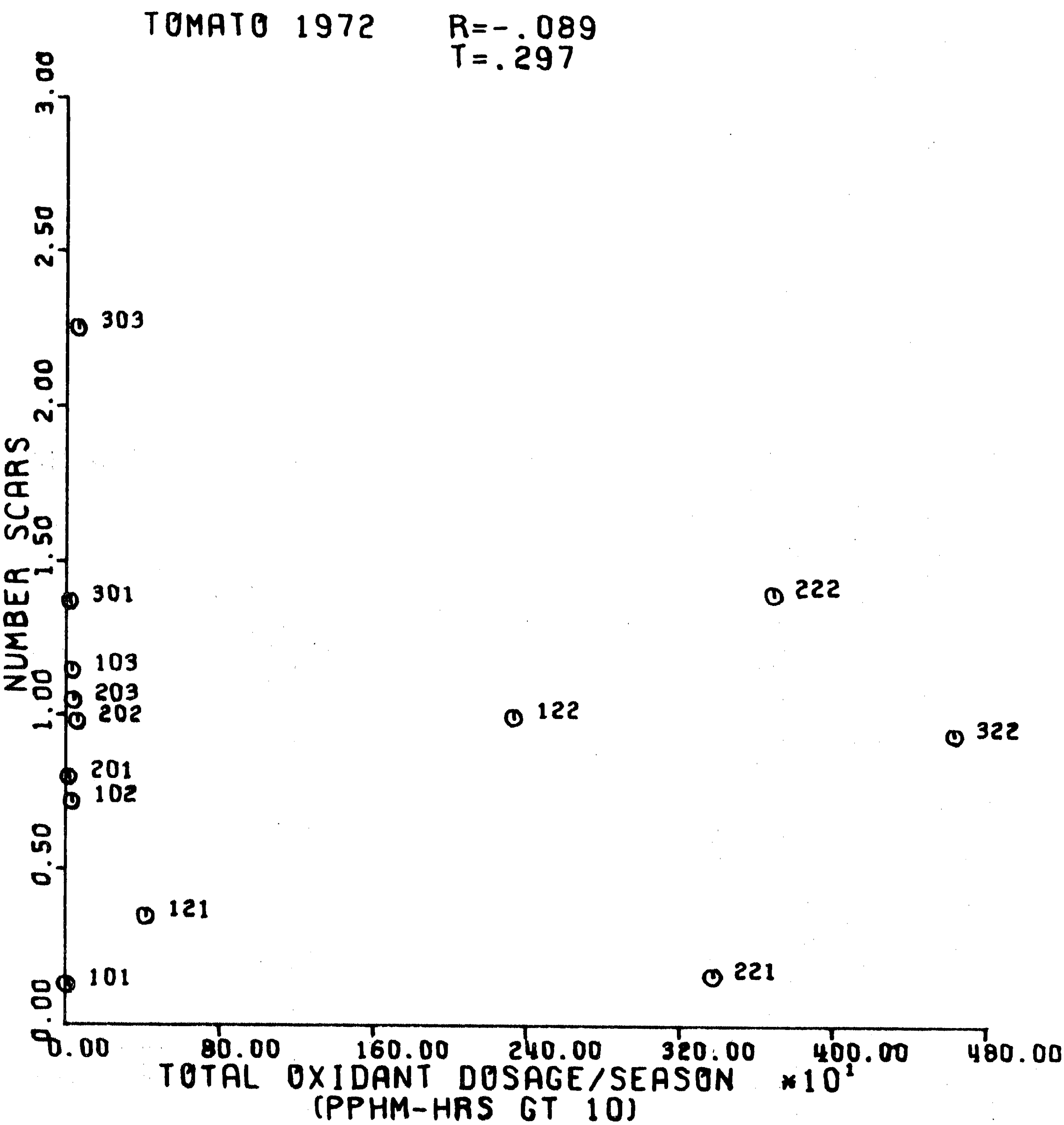


Figure 44. Correlation of length of scars on harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

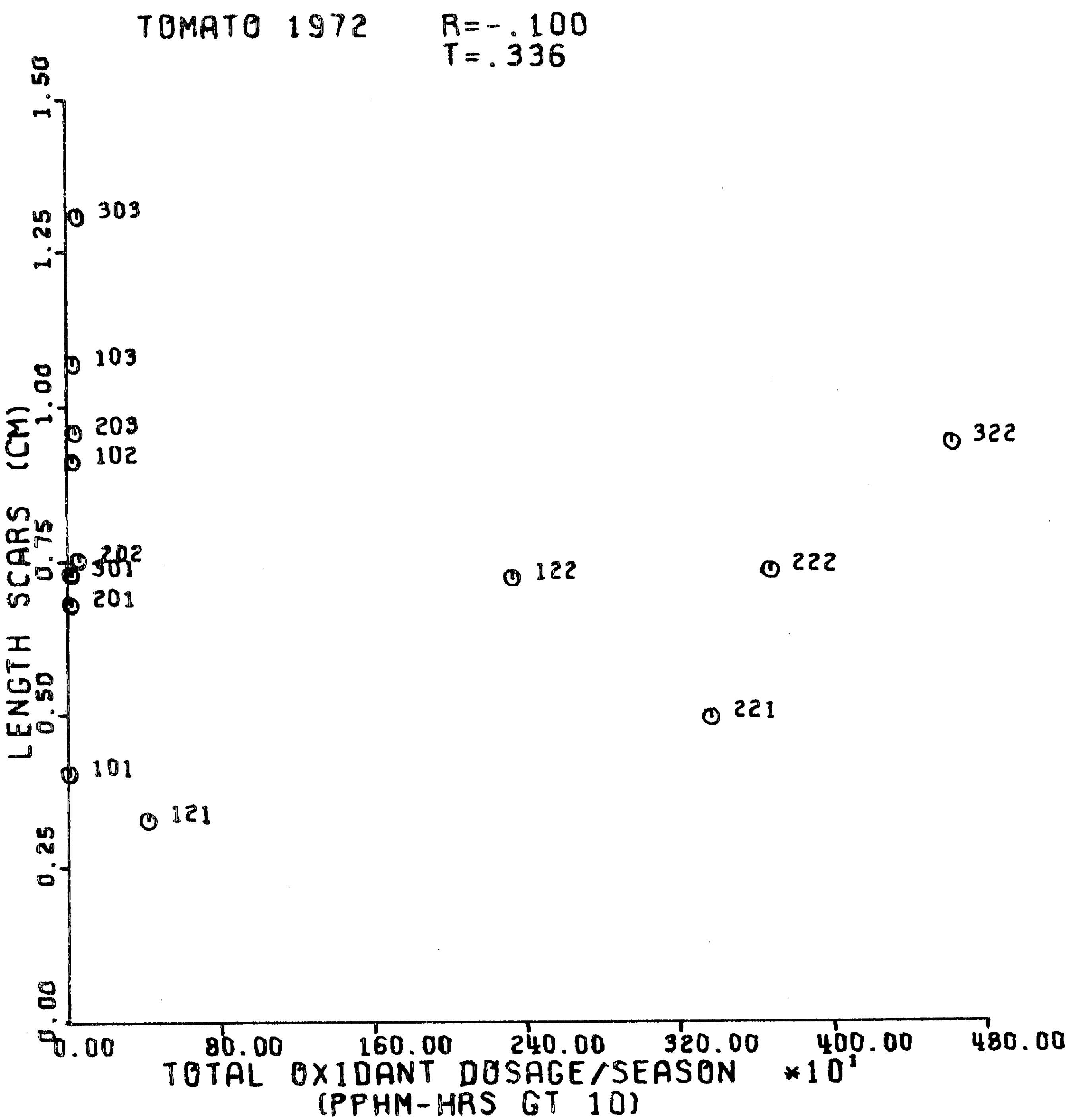


Figure 45. Correlation of the number of shoulder creases on harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

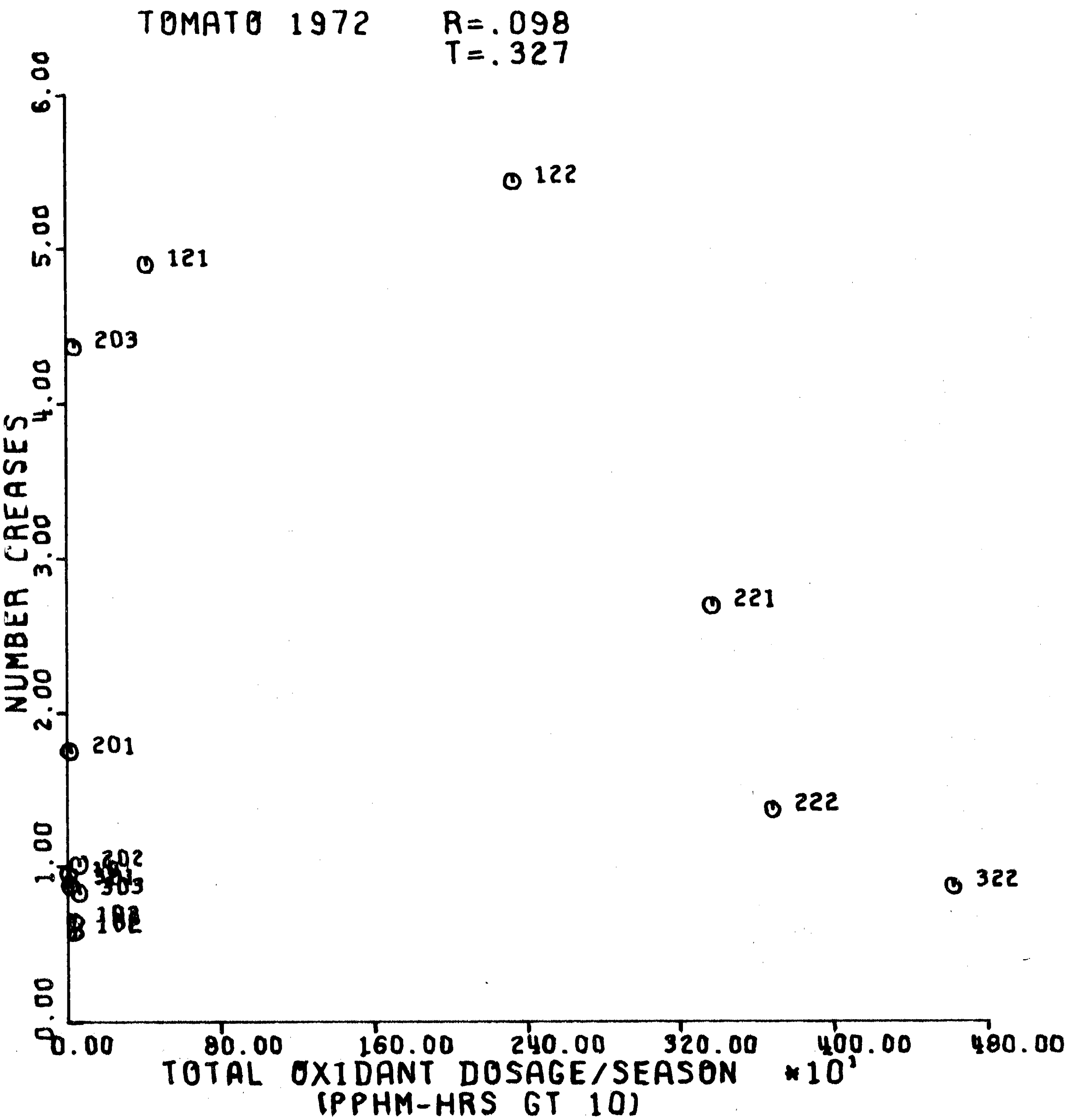


Figure 46. Correlation of the length of shoulder creases on harvested H-11 tomato fruit with the total ambient oxidant dosage present during growth.

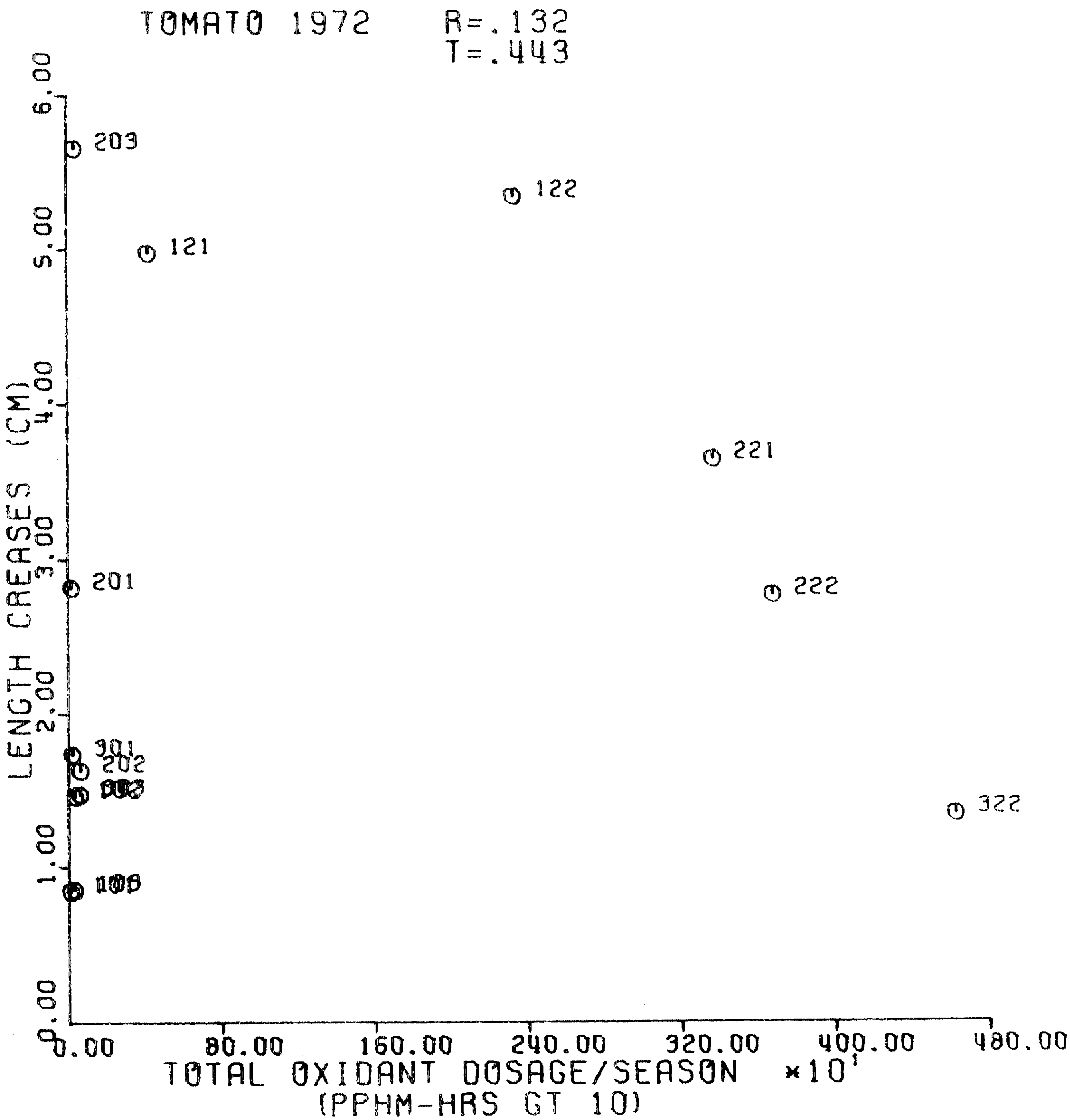


Table 6. Summary of ozone and PAN effects on H-11 tomato seedlings as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		# Leaves			Height			Fresh Wt.			Dry Wt.		
Control	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Ozone	.25 ppm	16.5	b	B	19.1	b	B	58.0	b	B	59.9	b	B
PAN	30 ppb	-	a	A	-2.3[3]	a	A	-10.6	a	A	-8.0	a	A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 7. Summary of significant ozone effects on H-11 tomatoes as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		# Suckers			# Immature Fruit			Fresh Wt. Plant			Dry Wt. Plant		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Treatments	.20	-	a	A	8.4	a	A	27.3	b	B	30.1	b	B
(ppm)	.35	-	a	A	69.5	b	B	62.2	c	C	65.6	c	C

		Dry Wt. Leaves & Stems			Dry Wt. Roots			Total Yield Wt.			Total Yield # of Fruit		
Ozone	0	-	a	A	-	a	A	-	a	A	-	a	A
Treatments	.20	31.7	b	B	11.4	a	A	-8.9[3]	a	A	12.6	a	A
(ppm)	.35	72.6	c	C	58.8	b	B	41.2	b	B	39.1	b	B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percentage increase over that of the control.

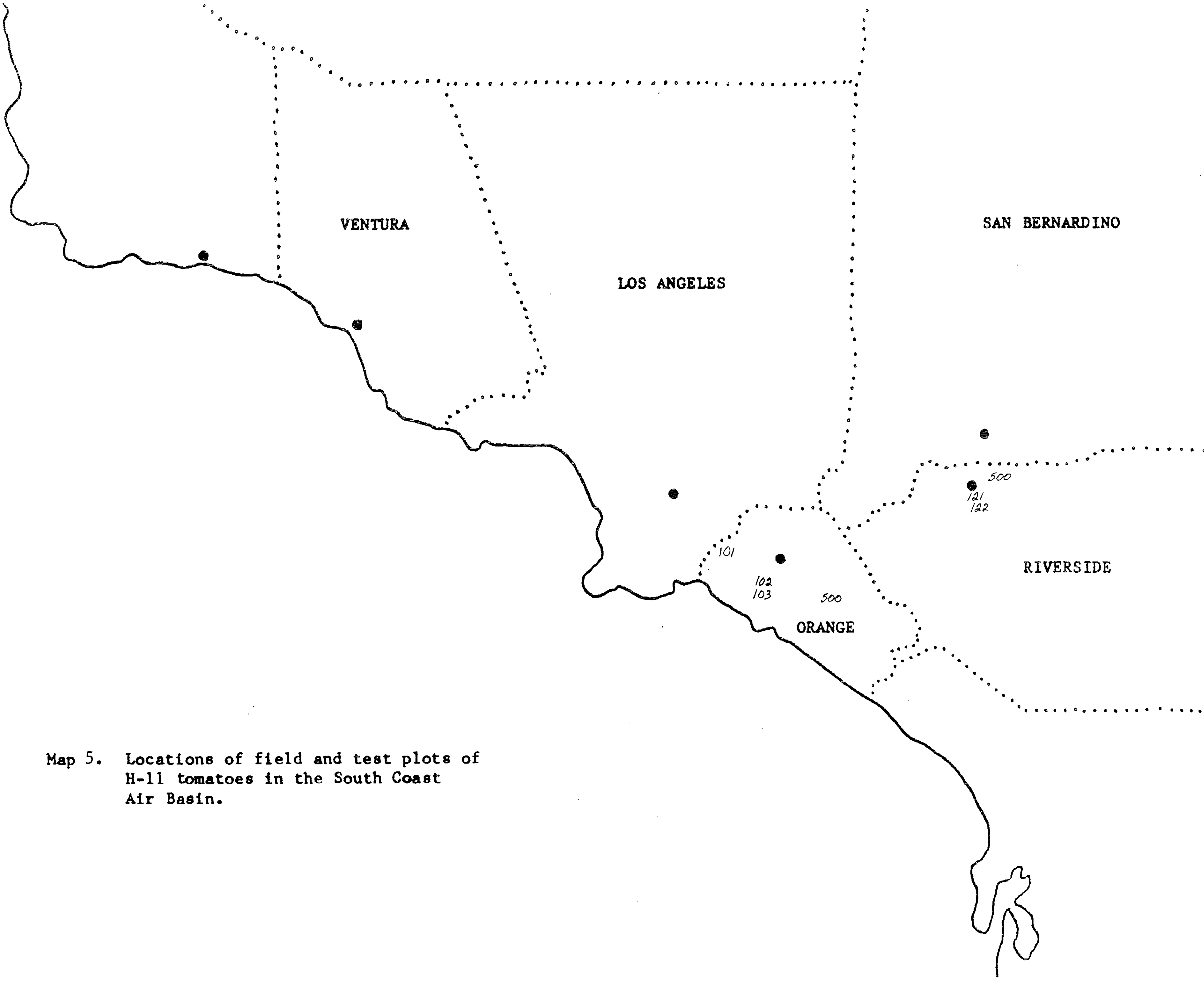
Table 8. Summary of ozone effects on the fruit of H-11 tomatoes as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		Height	Diameter	Weight	Mean # of Fruit Harvest/Plant	Mean Wt. of Fruit Harvested/per Plant
Ozone	0	- a[1] A[2]	- a A	- a A	- a A	- a A
Treatments	.20	- a A	- a A	- a A	12.6 a A	-8.0[3] a A
(ppm)	.35	- a A	- a A	- a A	39.1 b B	41.2 b B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

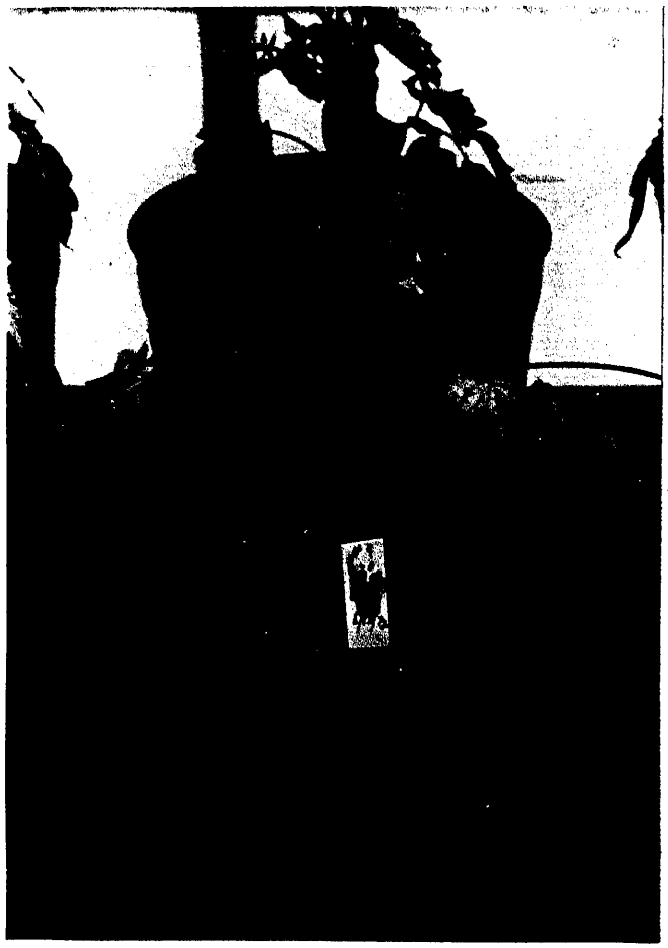
2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.



Map 5. Locations of field and test plots of H-11 tomatoes in the South Coast Air Basin.

Plate 12. Ozone injury on a young H-11 tomato plant from the .20 ppm treatment.



CHAPTER VII - CARROTS

Summary

Ozone does not appear to reduce the quality of Emperator #58 carrot roots. Although foliage of plants grown under greenhouse and field conditions were sensitive to ozone leaf injury, no quality effects were associated with the fumigant.

Long-term fumigation results indicated that ozone, in high concentrations (.35 ppm), caused a considerable reduction in yield. The yield phase field studies scheduled for 1973 will determine whether the same effect occurs in the field.

Quality data from field plots in the South Coast Air Basin seem to confirm long-term fumigation results. The correlations of various evaluated quality criteria with ambient oxidant dosages were not significant.

Introduction

Commercial carrot plantings in the South Coast Air Basin are restricted to the western section of Riverside County. The Emperator #58 variety has been used in this area successfully for several years.

A short-term fumigation study was undertaken to determine oxidant effects on seedlings. A long-term fumigation study was used to determine effects on crop quality and yield and to develop criteria for field studies. Field work for 1972 was focused on the quality study of field-grown carrots correlated with oxidant levels present during growth.

Seedling Fumigation Study

Treatments: Control, .24 ppm ozone, 30 ppb PAN

Exposure: Treatments were exposed to the respective concentrations of fumigant for 1.5% of the growth period. Fumigations were initiated upon emergence and discontinued after 30 days of growth.

Effects of ozone on Emperator #58 carrot seedlings: Ozone injury was observed on the compound leaves of the seedlings during the fumigations. The great variability of seedlings made statistical analysis difficult and no significant differences were found between the fumigated and control treatments (Table 9).

Effects of PAN on Emperator #58 carrot seedlings: The PAN fumigated plants did not display leaf injury or significant differences between the fumigated and control treatments.

Discussion: Emperator #58 carrot seedlings were susceptible to ozone leaf injury but no statement can be made as to the effects of ozone on the size or weight of affected plants due to extreme variability within treatments.

Long-Term Ozone Fumigation of Emperator #58 Carrots

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Exposure: Treatments were exposed to the respective concentration of ozone 68 out of 1,200 hours or about 5.5% of the growing period. The fumigations averaged about 3 hours in length and were staggered to provide time for plant recovery.

The effects of ozone on Emperator #58 carrots: Ozone injury was observed on the compound leaves of both fumigated treatments throughout the exposures. Significant responses to ozone occurred in the .35 ppm treatment in the form of definite reductions in fresh weights of both leaves and taproots (Table 10).

Criteria used to measure harvested roots are illustrated in Figure 47. The .35 ppm treatment plants showed a significant reduction in length of taproots, but not in diameter of the root stele or the root itself. Leaf lengths were also significantly reduced in the .35 ppm treatment.

Effects of ozone on Emperator #58 carrot roots: Fresh weights of the .35 ppm treatment roots were significantly less than in the .20 ppm or the control treatments. No differences were found between taproots of the .20 ppm and control treatment. Control treatment and size differences were obvious (Plate 13).

Discussion: All treatments were found to have irregularly-shaped taproots at harvest due to the limited depth of pots. Measurements of taproots and the lateral root counts cannot therefore be taken as representative of greenhouse-grown Emperator #58 carrots. These roots were, however, functional in their storage ability and any differences in size and weight are highly indicative of differences in yield.

Ozone at the .35 ppm level caused an overall reduction in plant size. The taproots and leaves were significantly reduced in size and weight compared to the control and the .20 ppm treatments. Plants in the .20 ppm and the control treatments were not significantly different from each other.

Long-Term PAN Fumigation of Emperator #58 Carrots

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Exposure: Treatments were exposed to the respective concentrations of PAN for 48 out of 1,040 hours or about 4.5% of the growth period. Fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effects of PAN on the Emperator #58 carrot plants: No significant differences were found between treatments.

Effects of PAN on the Emperator #58 carrot roots: No significant differences were found between treatments.

Discussion: Irregularly-shaped taproots with a proliferation of lateral roots were found in all treatments. These characteristics were duplicated in the ozone fumigated treatments and, for reasons previously stated, are not representative of PAN effects.

Field Study (Quality Effects)

Locations: Three commercial field plots and two test plots of Emperator #58 carrots were set up in the South Coast Air Basin (Map 6). Each location was monitored by three AMBI stations.

Sampling procedures: Test plots at UCR and South Coast Field Station comprised two 150-foot rows. Each field plot was sampled prior to commercial harvest at a time specified by the grower. One hundred fifty individual plants were harvested randomly over the extent of the field and evaluated. All sampled produce were at a mature, harvestable stage but not at a uniform age. Weights and gross measurements were therefore not applicable as a measure of yield but the produce was acceptable for quality evaluation.

Effect of oxidants on field-grown Emperator #58 carrots: Some of the data taken from harvested carrots does not pertain to quality evaluation. Root diameter, length and weight would normally be used in yield studies, but in this case, are not indicative of yield differences. Harvests were not initiated at a uniform age and these characteristics are therefore not comparable. Measurements are presented to illustrate the range of weights and sizes of the harvested carrots and to complete the overall comparison of harvested plants (Figures 48, 49, 50).

Those measurements which reflect the overall appearance of carrots and thus have a direct bearing on their marketability are presented in Figures 51, 52, 53, 54, and 55. In each case, the correlation between evaluated quality data and total oxidant dosage proved to be insignificant.

The category "number yellow leaves" refers to a count of injured or chlorotic leaves and does not segregate ozone injury from any other. Other categories are self-explanatory.

Discussion: The field study found no quality criteria to be associated with ambient ozone levels. All correlations proved to be insignificant, essentially confirming the fumigation results. The 1973 yield study will determine possible yield reductions implicated by fumigation results.

Figure 47. Criteria for Measurements Taken on Emperator #58 Carrot Roots.

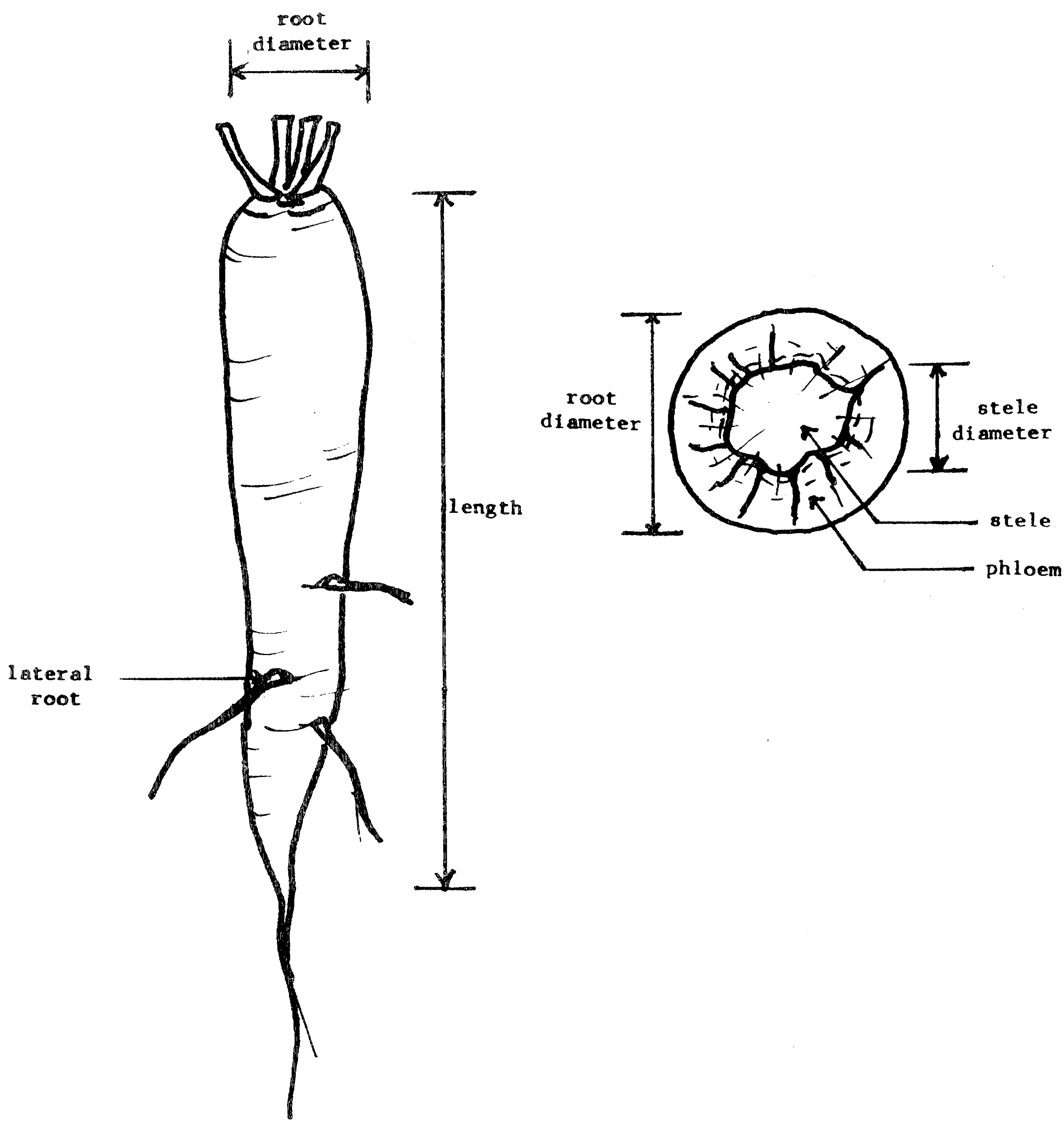


Figure 48. Correlation of diameters of harvested Emperator #58 carrot roots with the total ambient oxidant dosage present during growth.

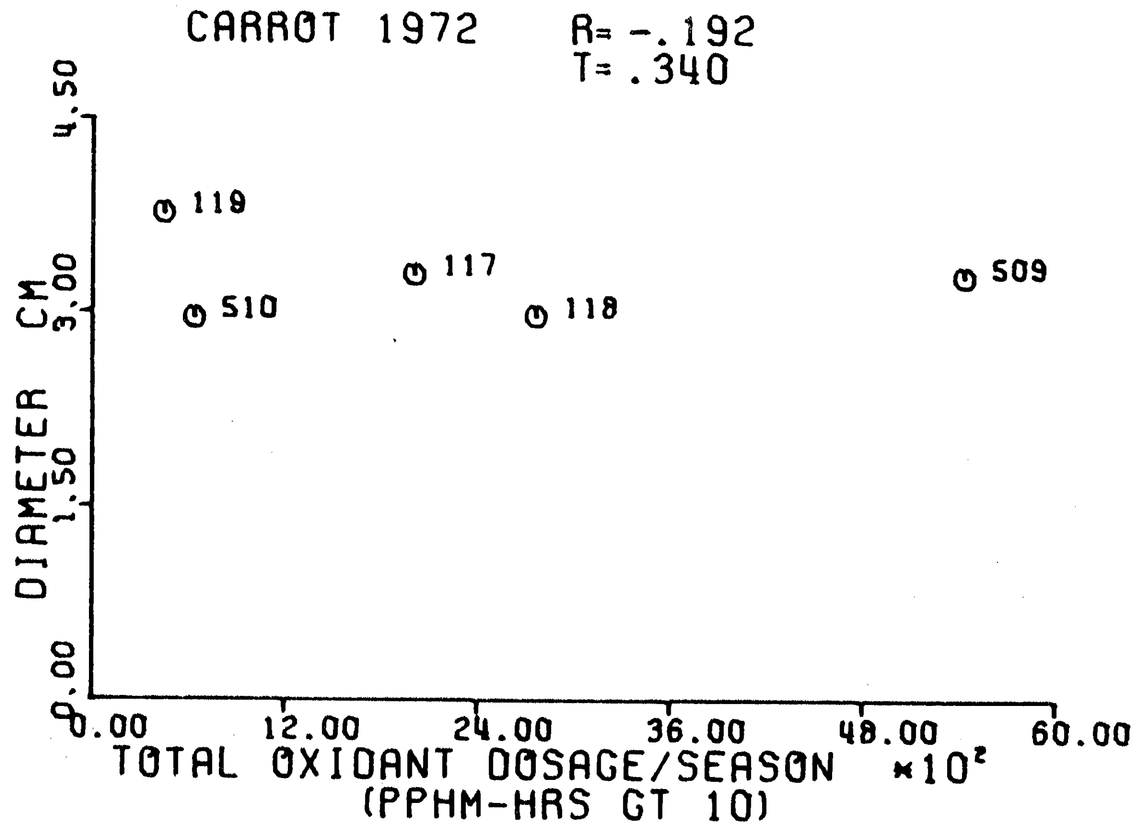


Figure 49. Correlation of lengths of harvested Emperator #58 carrot roots with the total ambient oxidant dosage present during growth.

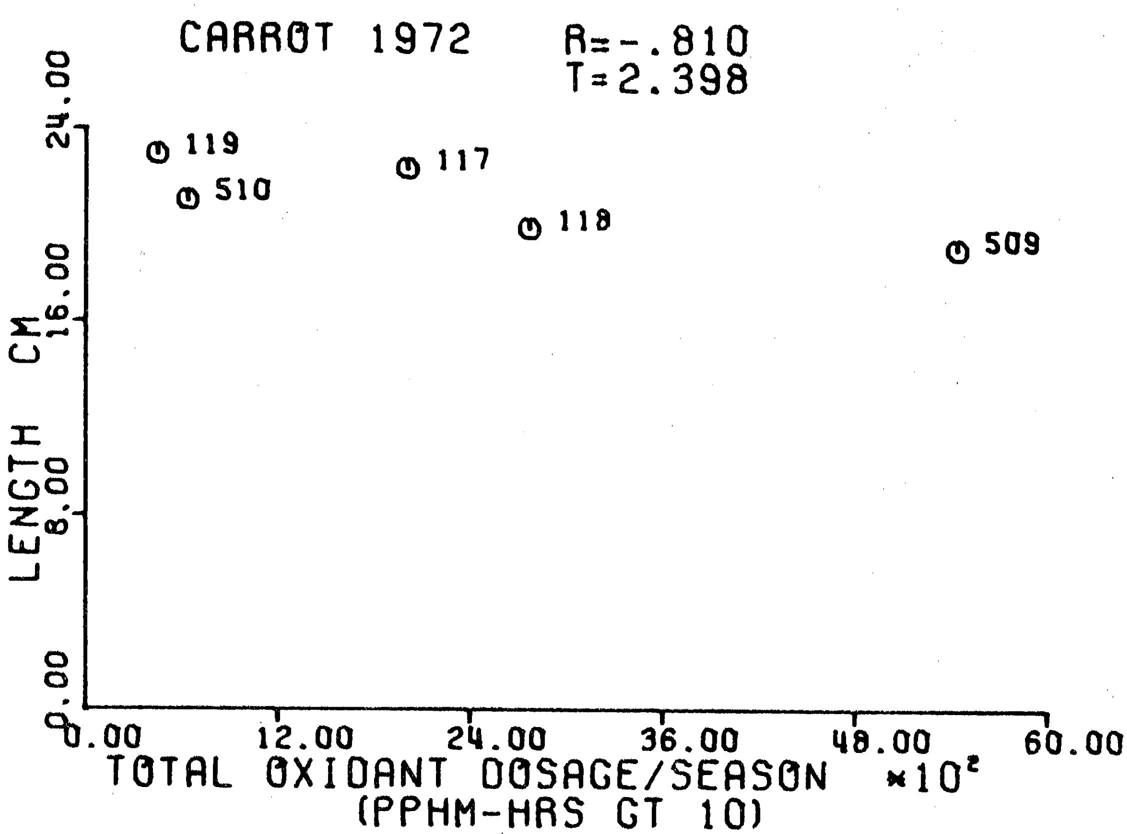


Figure 50. Correlation of weights of harvested Emperator #58 carrot roots with the total ambient oxidant dosage present during growth.

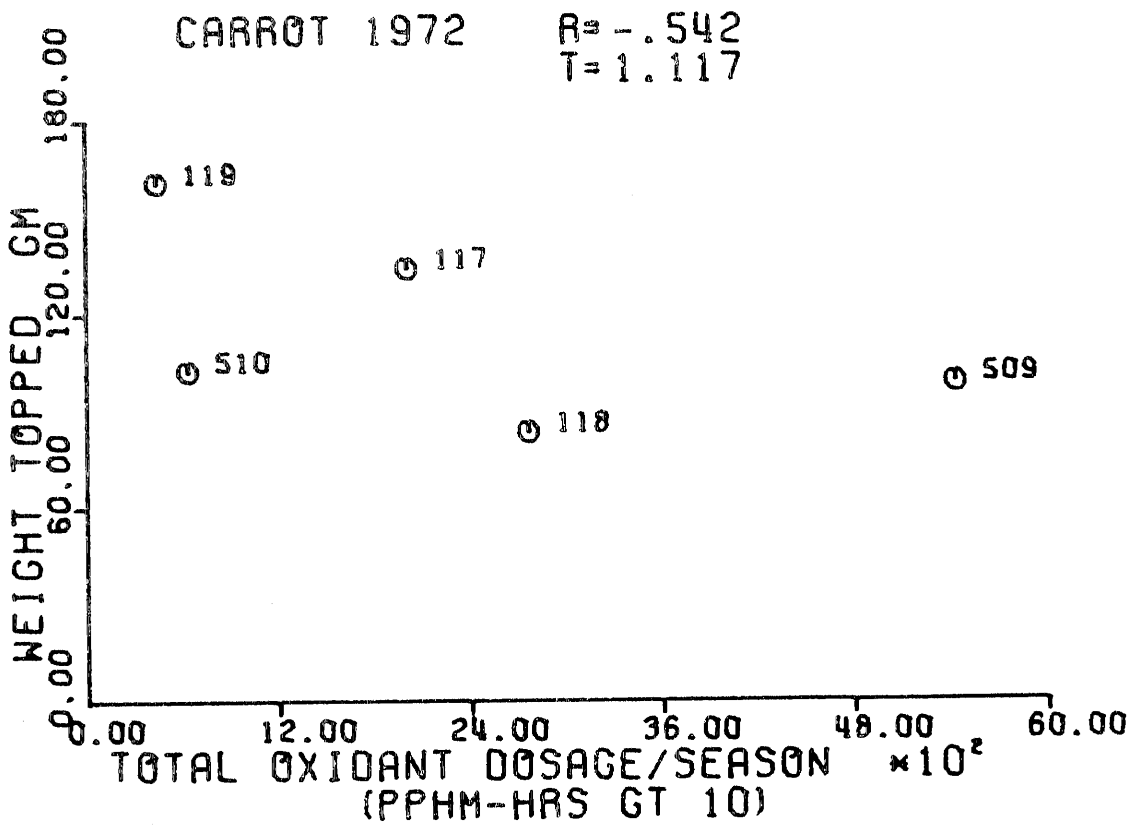


Figure 51. Correlation of the total number of leaves of harvested Emperator #58 carrot roots with the total ambient oxidant dosage present during growth.

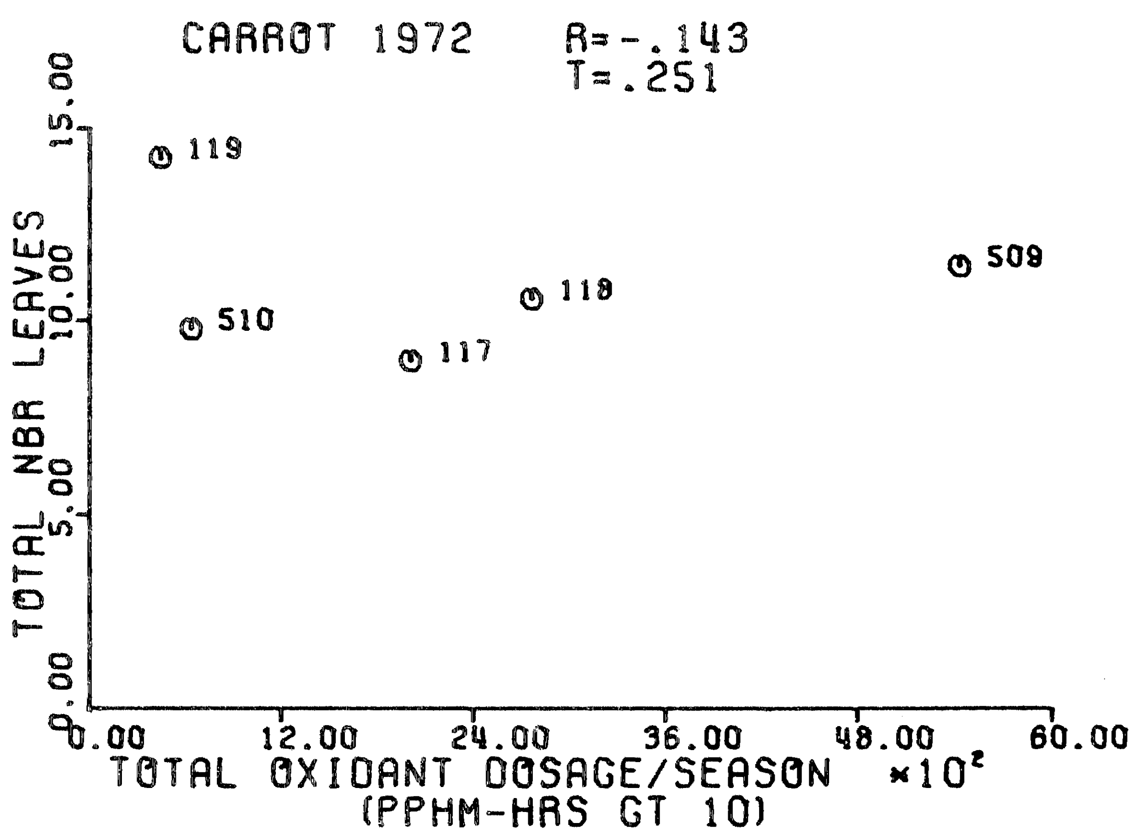


Figure 52. Correlation of the percentage of deformed roots of harvested Emperator #58 carrot roots with the total ambient oxidant dosage present during growth.

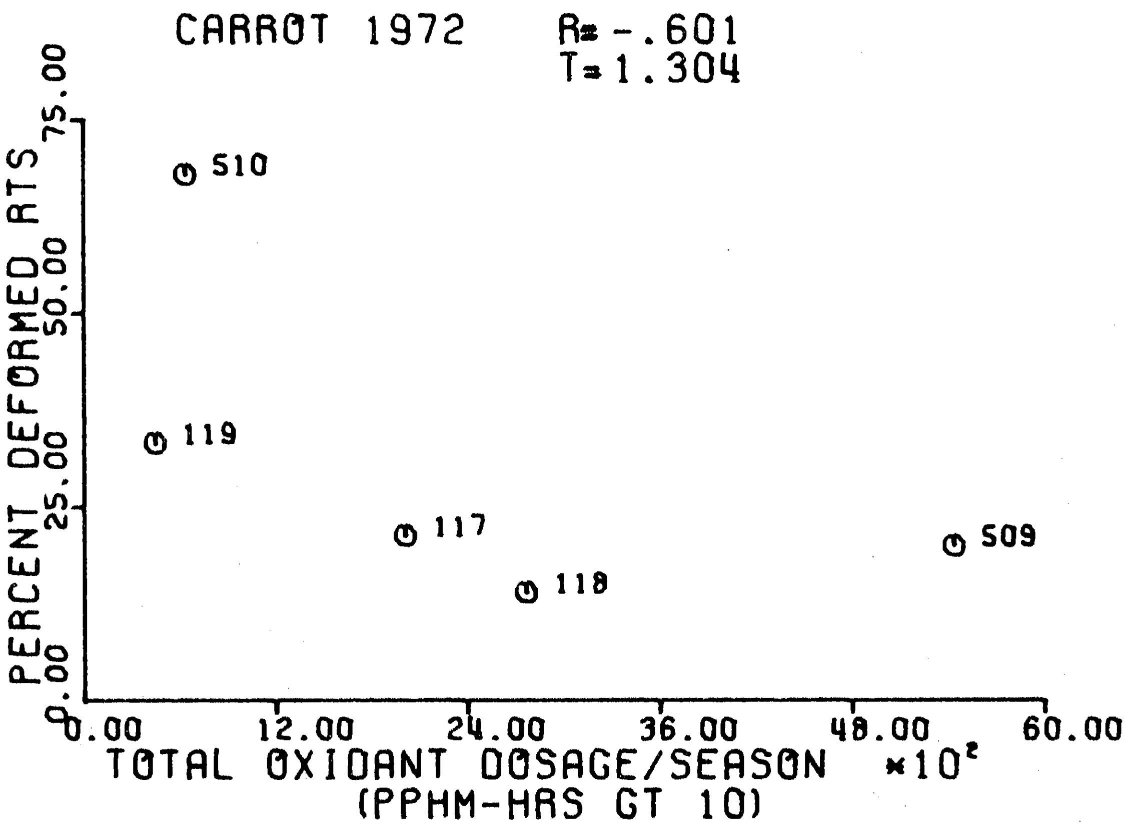


Figure 53. Correlation of stele diameters of harvested Emperator #58 carrot roots with the total ambient oxidant dosage present during growth.

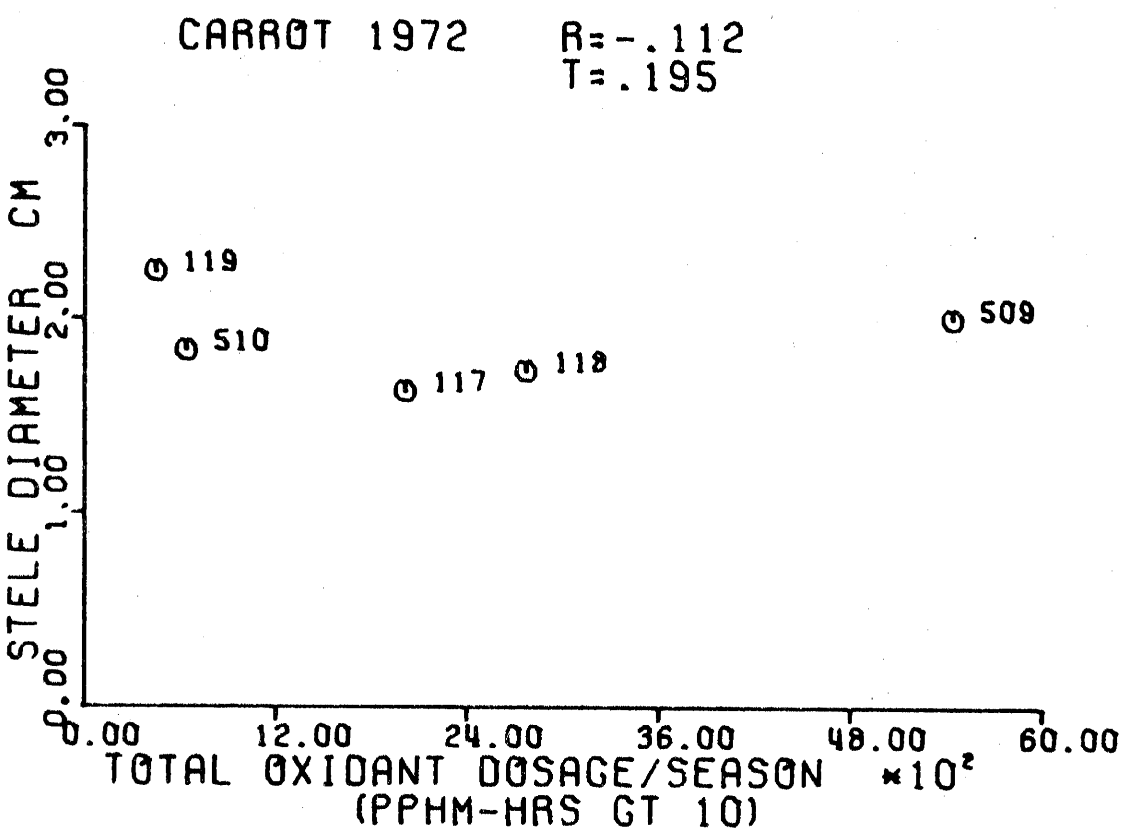


Figure 54. Correlation of the number of yellowed leaves of harvested Emperator #58 carrot roots with the total ambient oxidant dosage present during growth.

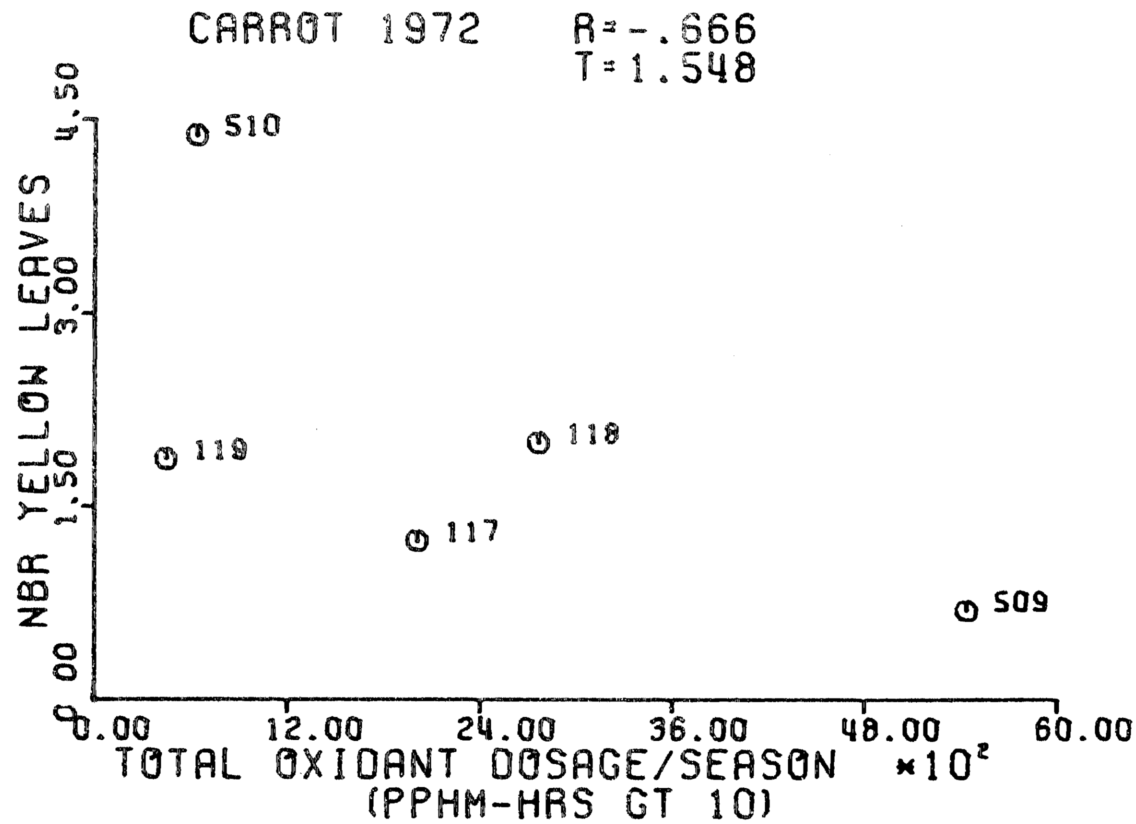


Figure 55. Correlation of the number of lateral roots of harvested Emperator #58 carrot roots with the total ambient oxidant dosage present during growth.

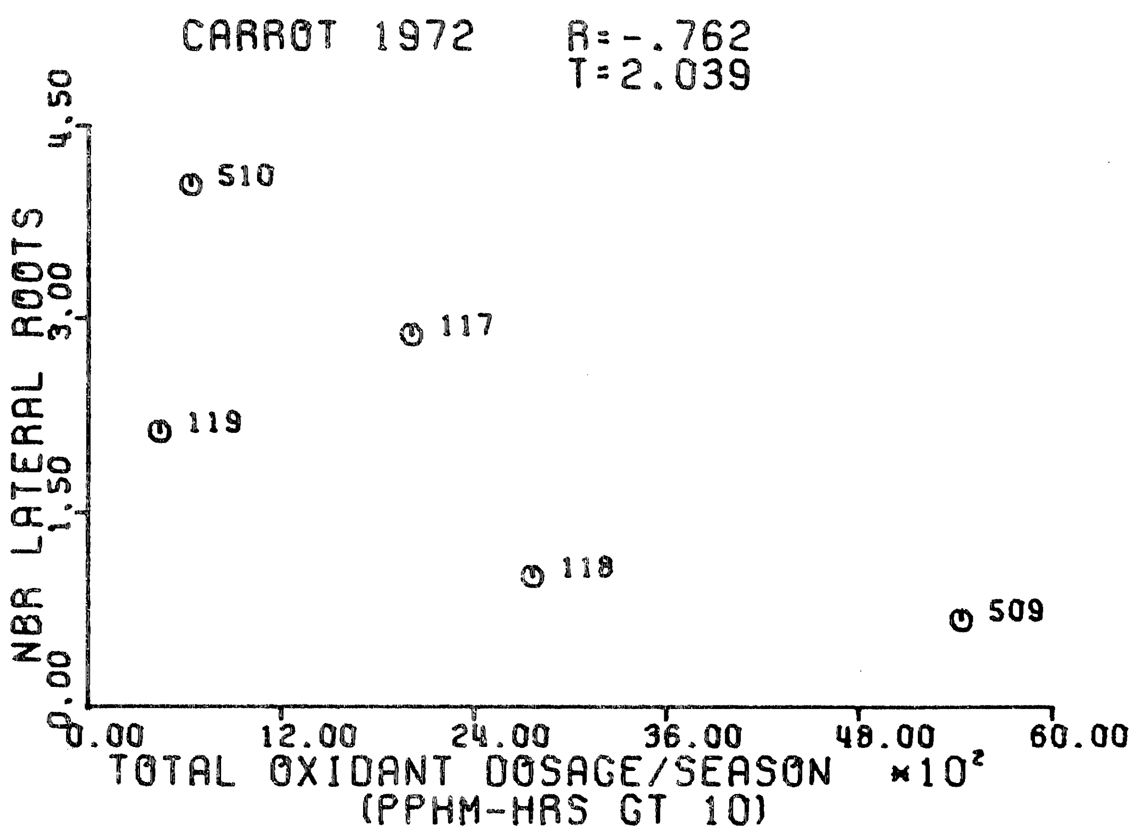


Table 9. Summary of ozone and PAN effects on Emperator #58 carrot seedlings as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		# Leaves			Height			Fresh Wt.		
Control	0	-	a[1]	A[2]	-	ab	A	-	a	A
Ozone	.25 ppm	-	a	A	20.0	a	A	-	a	A
PAN	30 ppb	-	a	A	-8.2[3]	b	A	-	a	A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 10. Summary of significant ozone effects on Emperator #58 carrots as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

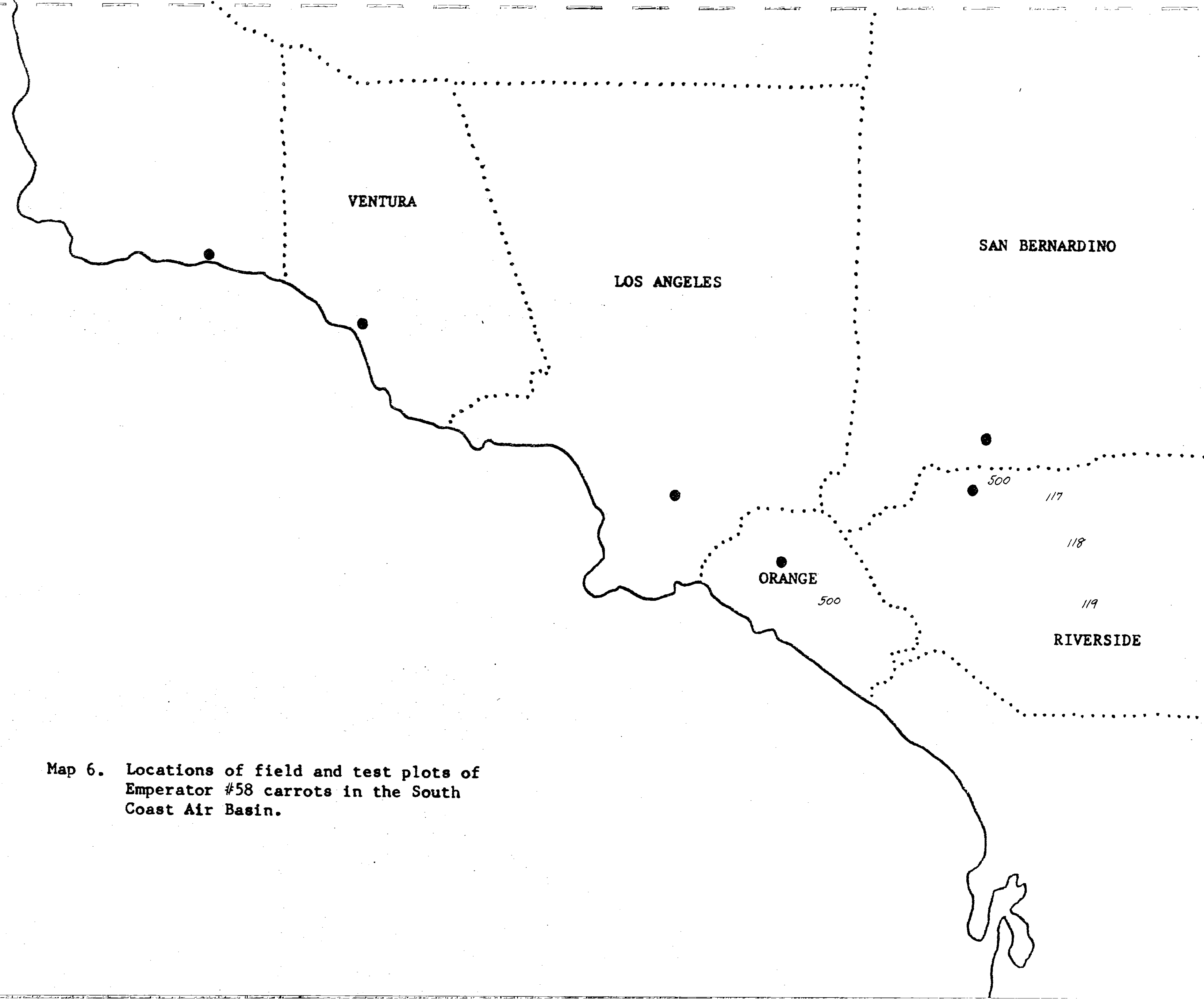
Ozone Treatments (ppm)		Length Leaves			# Leaves			Length Root			Diameter Root			Diameter Stele		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A	-	a	A
Treatments	.20	-5.1[3]	a	A	-	a	A	15.8	a	A	-	a	A	-	a	A
(ppm)	.35	13.7	b	B	-	a	A	51.5	b	B	-	a	A	-	a	A

Ozone Treatments (ppm)		Fresh Wt. Roots			Fresh Wt. Leaves			Dry Wt. Leaves			# Lateral Roots		
Ozone	0	-	a	A	-	a	A	-	a	A	-	a	A
Treatments	.20	11.1	a	A	-3.4	a	A	6.0	a	A	18.2	a b	A B
(ppm)	.35	75.0	b	B	64.7	b	B	67.5	b	B	43.1	b	B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percentage increase over that of control.



Map 6. Locations of field and test plots of Emperator #58 carrots in the South Coast Air Basin.

Plate 13. Effect of ozone on Emperator #58 carrots. Pictured right to left are: 2 control treatment plants and 2 .35 ppm ozone treatment plants.

CHAPTER VIII - LETTUCE

Summary

Prizehead lettuce was found to be resistant to both ozone and PAN at all stages of growth. Ozone-fumigated seedlings were reduced in solid materials from control plants, but only the high concentration (.35 ppm) of ozone over a period of time produced detrimental effects on the mature stages of growth.

No reductions in size or weight of plants were found to be associated with either fumigated or ambient PAN levels. Prizehead lettuce did not exhibit PAN leaf damage at any stage of growth.

High levels of ambient oxidants do not usually occur during the fall growing season. The 1972 fall season was exceptionally free from high dosages and accordingly, the field study produced no oxidant effects on field-grown Prizehead lettuce.

Dark green Boston lettuce was selected for long-term fumigation studies as a comparison to Prizehead. This variety proved to be far more susceptible to both ozone and PAN than the Prizehead variety. The number of leaves affected by both oxidants would easily make these plants unacceptable for market. Only the low PAN fumigation level (20 ppb) did not produce significant injury. Ozone also produced a reduction in the overall size of plants in both fumigated treatments.

The marked sensitivity to oxidant pollutants displayed by Boston (dark green) leaf lettuce illustrated the high risk of leafy crops. Sensitivity to the pollutant, expressed as leaf injury, directly affects the marketability of the crop. Bearing crops may suffer a period of injury but usually continue to bear fruit and may well grow out of the pollution effects. Once injured, leafy crops immediately lose value, and if this injury covers a significant number of leaves on the majority of plants, the loss is 100 percent.

Introduction

Prizehead is a bronze variety of leaf lettuce which is popular throughout the South Coast Air Basin. It is considered to be resistant to air pollution damage. This variety was the original study crop listed in the proposal.

Boston (dark green) leaf lettuce is a green variety which is also well liked by commercial growers. It is considered to be susceptible to damage from both ozone and PAN and was added to the long-term fumigation study as a comparison to Prizehead. No field work was initiated with this variety.

A short-term fumigation study was undertaken to determine oxidant effects on seedlings. A long-term fumigation study was used to determine effects on crop quality and yield and to develop criteria for field studies. Field work for 1972 focused on the quality study of field-grown lettuce correlated with oxidant levels present during growth.

Seedling Fumigation Study (Prizehead Lettuce)

Treatments: Control, .24 ppm ozone, 30 ppb PAN

Exposure: Plants were exposed to the respective concentrations of fumigant for 1.5% of the growth period. Fumigations were initiated upon emergence and discontinued after 30 days of growth.

Effects of ozone on Prizehead lettuce seedlings: Ozone injury was observed on the older leaves of plants in the fumigated treatment. This injury was extremely light and barely noticeable due to the bronze pigmentation of the leaves. Control and fumigated treatment plants were of comparable size but differed in weights. Fresh and dry weights revealed reductions in solid material in the ozone fumigated plants (Table 11).

Effects of PAN on Prizehead lettuce seedlings: The PAN fumigated seedlings were of greater size and weight than the control plants at harvest. These increases were statistically significant at the .01 level in every case (Table 11). No evidence of PAN leaf injury was observed during the fumigations or at harvest.

Discussion: Ozone exposure at .24 ppm reduced the solids content of seedling Prizehead lettuce and would presumably affect the growth at a later stage. Light leaf injury was observed but this variety seems to be resistant to the obvious ozone stipple and chlorosis found on other varieties of leaf lettuce.

Plants fumigated with 30 ppb of PAN were larger and weighed more than control plants. No explanation of this effect will be presented until further investigations are completed and the chance of experimental error is eliminated.

Long-Term Ozone Fumigation of Prizehead Lettuce

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Exposure: Plants were exposed to the respective concentrations of ozone for 45 out of 792 hours or about 6.0% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

The effects of ozone on Prizehead lettuce: Criteria used to measure harvested plants are illustrated in Figure 56. This variety proved to be very resistant to ozone as only the .35 ppm treatment displayed significant effects (Table 12). The .20 ppm treatment did not show any significant reduction from the control and no visible leaf injury was observed. No dry weights are presented as samples were frozen and sent out for nutritional analysis.

Discussion: Lettuce is regarded as a cool weather crop and is generally grown in the spring or fall. As such, it is not subjected to the high exposures of ozone which affect summer-grown crops. The high ozone exposures given the .35 ppm treatment are not representative of actual field dosages nor are they a realistic measure of this variety's sensitivity. At the more realistic .20 ppm fumigation, no significant effects were found.

Long-Term PAN Fumigation of Prizehead Lettuce

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Exposure: Plants were exposed to the respective concentrations of PAN for 30 out of 685 hours or about 4.6% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

The effects of PAN on Prizehead lettuce: No significant effects were found between treatments.

Discussion: PAN does not seem to affect the growth or quality of Prizehead lettuce.

Long-Term Ozone Fumigation Study of Boston Leaf Lettuce (Dark Green)

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Exposure: Plants were exposed to the respective concentrations of ozone for 44 out of 624 hours or about 7% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

The effects of ozone on Boston lettuce: Both ozone fumigated treatments were found to be comparable to the control treatment in number of leaves produced and in fresh and dry weights of heads. The only major reduction in weights occurred in dry weights of roots (Table 14). The .20 ppm and .35 ppm treatment plants were found to be smaller than the control plants. Ozone leaf injury was observed on plants in both the fumigated treatments (Plate 15). Leaf injury was widespread and easily detectable on affected leaves.

Discussion: This variety of leaf lettuce is susceptible to ozone at moderate and high levels. Greenhouse-grown plants were totally unmarketable due to the extensive injury on leaves of plants in both fumigated treatments. The fumigated plants were also significantly reduced in size from the control plants.

Long-Term PAN Fumigation of Boston Leaf Lettuce (Dark Green)

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Exposure: Plants were exposed to the respective concentrations of PAN for 44 out of 624 hours or about 7% of the growing period. Actual concentrations averaged 22 ppb and 44 ppb PAN. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effect of PAN on Boston leaf lettuce: PAN exposures at 40 ppb proved to be injurious to leaves of this variety of lettuce (Plate 14). The lower (20 ppb) treatment exhibited some leaf damage but the number of leaves affected was not significant to the overall appearance of the plant. Slight reductions in the relative plant diameters, fresh weight, and number of leaves were observed (Table 13). A comparison of dry weights between treatments showed no differences, except in the dry weight of roots.

Discussion: Leaf injury rendered plants in the 40 ppb fumigation treatment unacceptable for market. Ambient levels may reach high concentrations occasionally during the fall and cause considerable damage to commercial-grower fields.

Reductions in size and fresh weight proved to be relatively minor and probably would not influence the marketability of the heads at the investigated fumigation levels.

The erratic dry weights of roots may have been due to the incomplete washing of soil from roots.

Field Study (Quality Effects) of Prizehead Lettuce

Locations: Six commercial field plots and two test plots of Prizehead lettuce were set up in the South Coast Air Basin (Map 7). Each location was monitored by three AMBI stations.

Sampling procedures: Each field plot was harvested prior to the commercial harvest at a time specified by the grower. Fifty individual plants were harvested randomly over the extent of the field and evaluated for quality. The variation in harvest ages made samples unacceptable for yield study but acceptable for evaluation of quality criteria.

Test plots at UCR and South Coast Field Station comprised two 150-foot rows of Prizehead lettuce. Fifty individual plants were sampled from the rows and evaluated. No attempt was made to standardize a uniform harvest age in order to randomize the test plots with commercial field plots.

Effect of oxidants on field-grown Prizehead lettuce: Some of the data taken from harvested lettuce does not directly pertain to quality evaluation. Plant diameter, height, and weight are measurements normally associated with yield studies but, in this case, are not indicative of yield differences. Harvests were not initiated at a uniform age and these measurements are therefore not comparable. They are presented to illustrate the range of sizes and weights of the harvested plants (Figures 57, 58, 59).

The one measurement that has a direct bearing on the quality of lettuce is the number of injured leaves per plant (Figure 60). The correlation between this measurement and the oxidant dosage proved to be insignificant.

Discussion: Ambient levels of oxidant pollutants were very low during the fall growing season for 1972 in comparison to other years. This occurrence coupled with the remarkable resistance of Prizehead lettuce to ozone and PAN resulted in a lack of damage to this crop in the South Coast Air Basin.

Assessment Methodology

Unfortunately, the lack of significant levels of oxidants in the fall of 1972 and the resistance of Prizehead lettuce precluded the economic assessment of damage on field-grown plants. Ambient dosages never reached injury threshold levels and resulted in injury-free crops at all field locations.

However, the fumigation data from the Boston (dark green) variety indicate that any range of assessment would be extremely narrow for a sensitive variety. In most cases, if leaf injury occurs over a significant number of leaves and if a majority of the field exhibits such damage, the loss will be 100 percent. It is usually economically unfeasible to select the few uninjured plants for market as only a fraction of the yield will be realized and labor costs prohibitive.

Figure 56. Criteria for Measurements Taken on Prizehead and Dark Green Boston Lettuce.

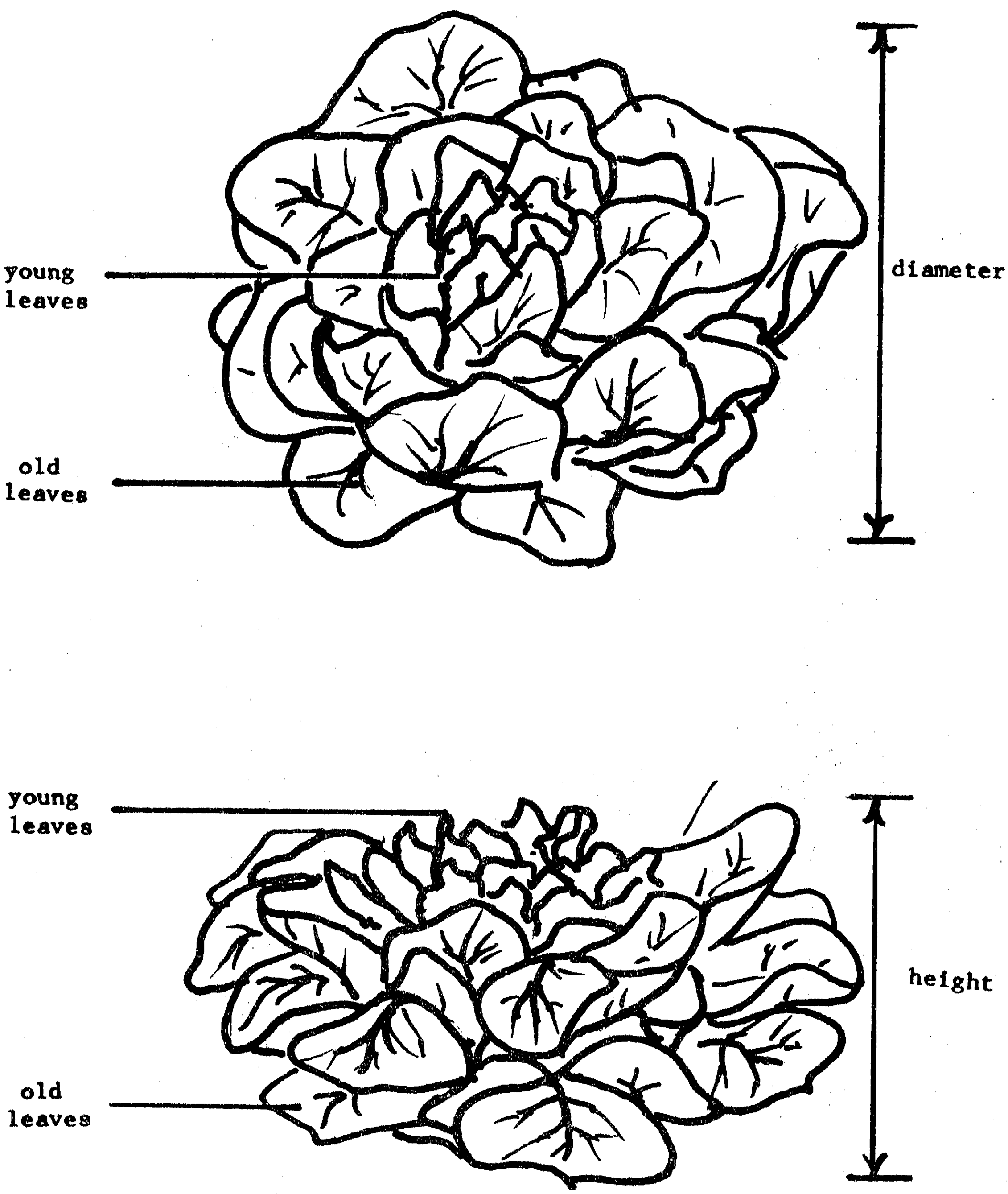


Figure 57. Correlation of weights of harvested Prizehead lettuce heads with the total ambient oxidant dosage present during growth.

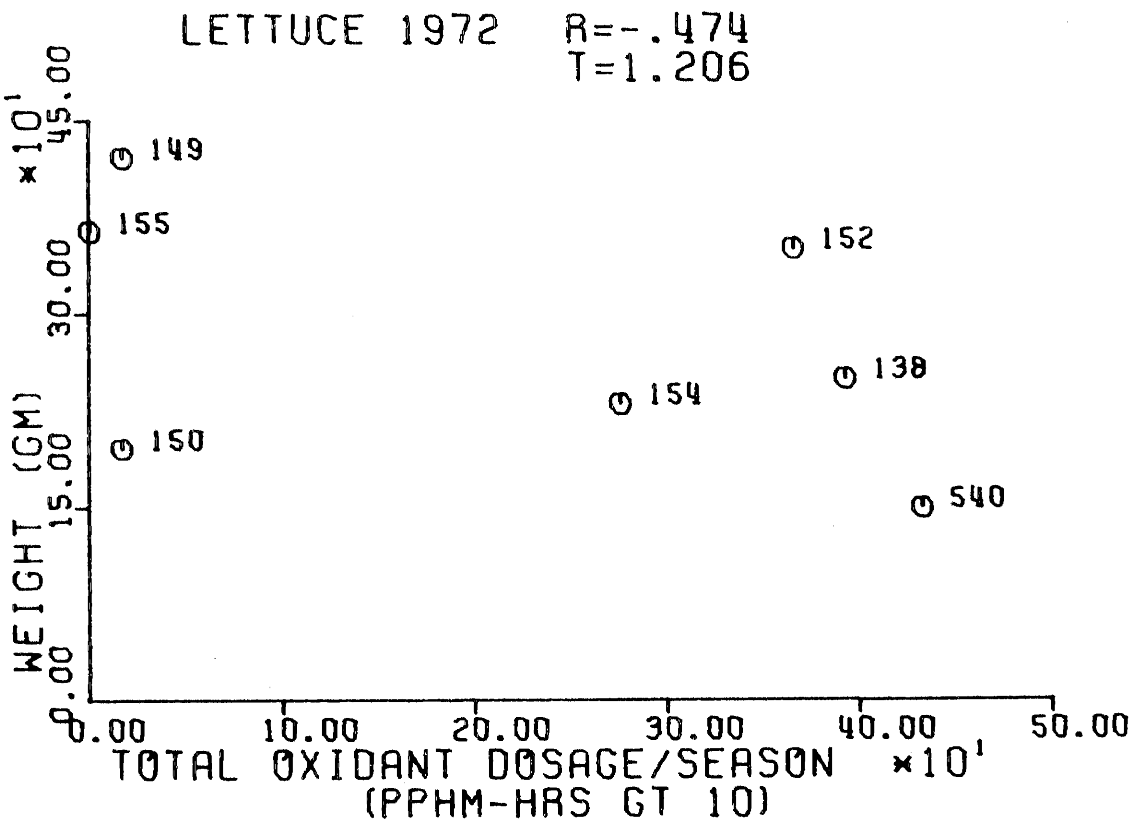


Figure 58. Correlation of diameters of harvested Prizehead lettuce heads with the total ambient oxidant dosage present during growth.

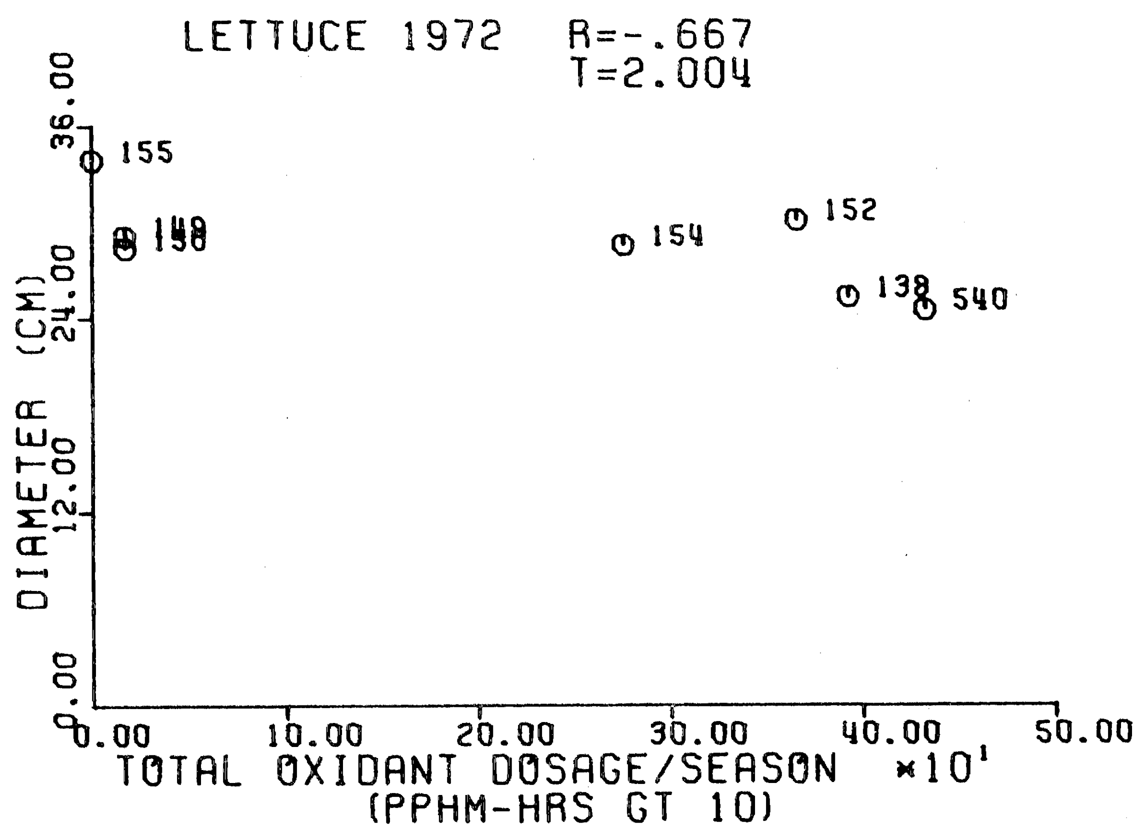


Figure 59. Correlation of heights of harvested Prizehead lettuce heads with the total ambient oxidant dosage present during growth.

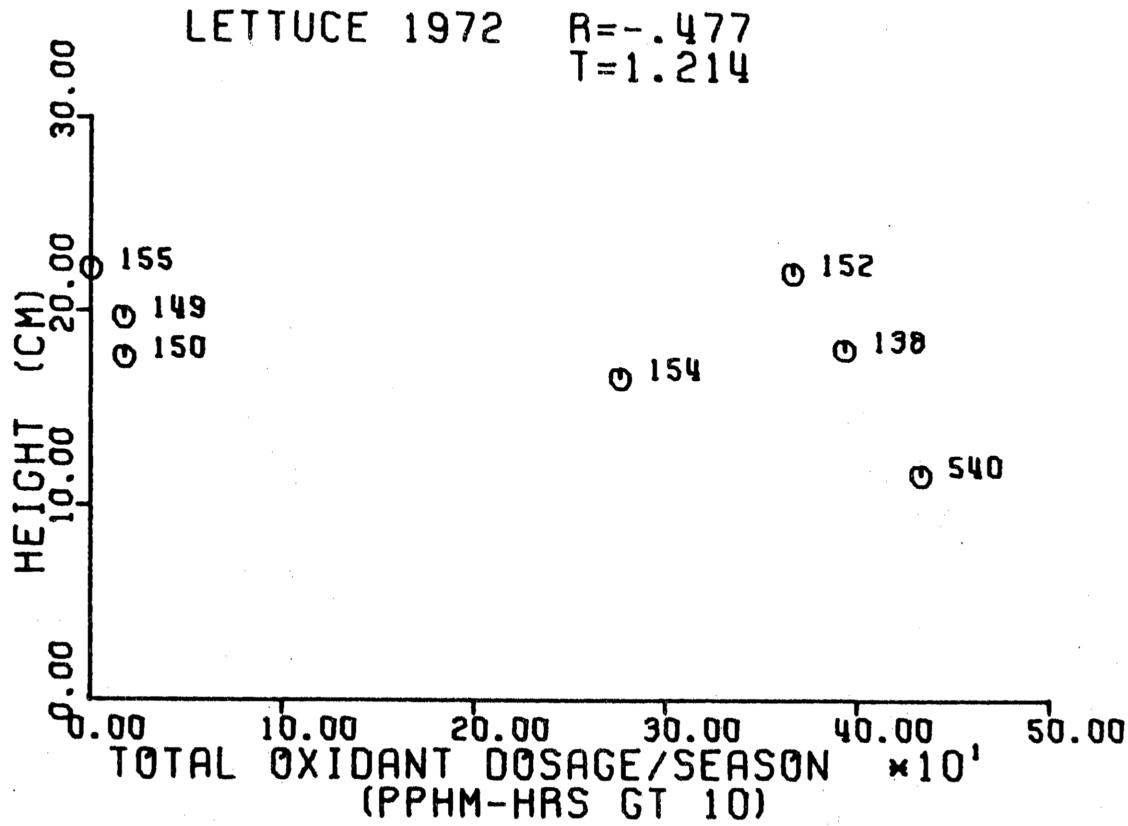


Figure 60. Correlation of the number of injured leaves on harvested Prizehead lettuce heads with the total ambient oxidant dosage present during growth.

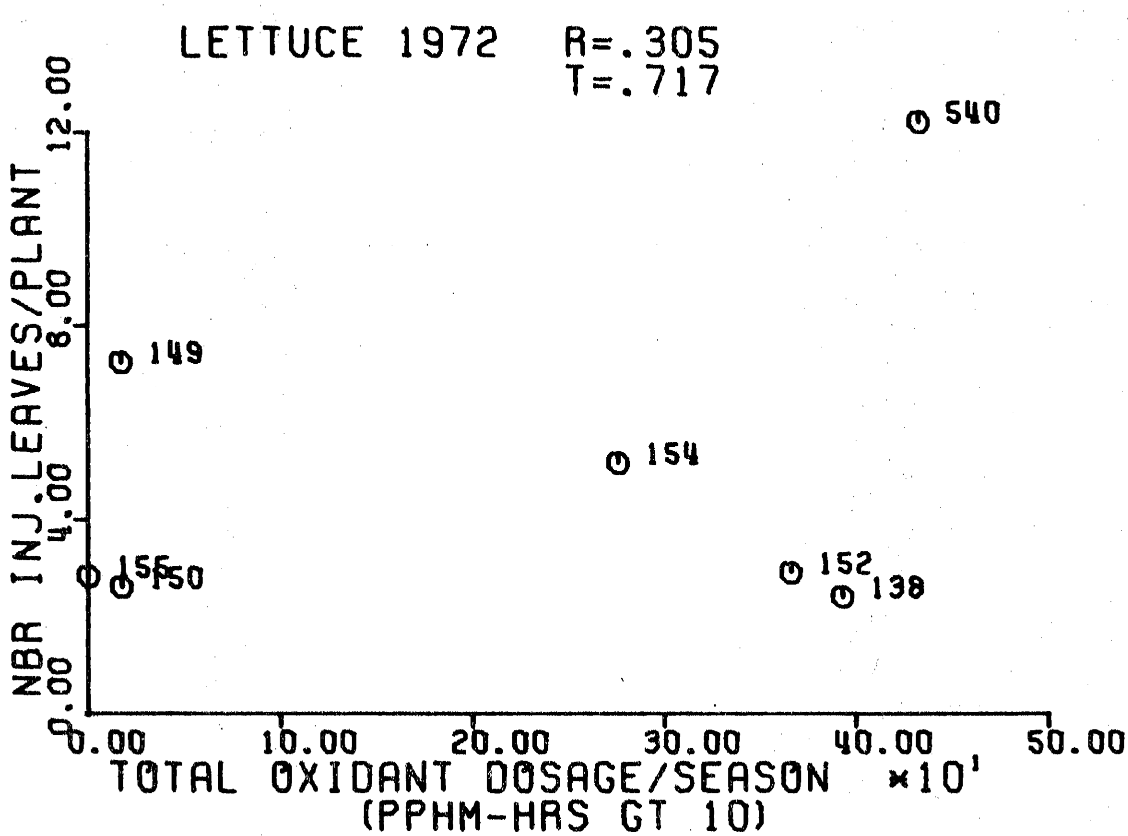


Table 11. Summary of ozone and PAN effects on Prizehead lettuce seedlings as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		# Leaves	Height	Fresh Wt.	Dry Wt.
Control	0	- a[1] A[2]	- a A	- a A	- a A
Ozone	.25 ppm	- a A	4.8 a A	44.1 b B	42 b A
PAN	30 ppb	- a A	-37.7[3] b B	-46.0 c C	-64 c B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 12. Summary of significant ozone effects on Prizehead lettuce as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		Height	Plant Diameter	No. Leaves	No. Injured Leaves[1]	Fresh Wt.
Ozone	0	- a[2] A[3]	- a A	- a A	0 a A	- a A
Treatments	.20	3.8 a A	6.0 a A	- a A	0 a A	5.7 a A
(ppm)	.35	18.6 b B	30.3 b B	- a A	15.6 b B	54.6 b B

1. Figures given in this category represent the treatment means and not calculated percent reductions from the control treatment.

2. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

3. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

Table 13. Summary of significant PAN effects on Boston lettuce as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		Height	Diameter	Fresh Wt. Leaves	# Leaves
PAN	0	- a[1] A[2]	- a A	- a A	- a A
Treatments	20	- a A	3.28 ab A	0.297 a A	14.06 b B
(ppb)	40	- a A	8.35 b A	6.83 b B	9.96 b AB

		# Injured Leaves[3]	Dry Wt. Leaves	Dry Wt. Roots	Total Dry Wt.
PAN	0	0 a A	- a A	- a A	- a A
Treatments	20	0.5 a A	- a A	-53.998[4] b B	- a A
(ppb)	40	23.67 b B	- a A	13.35 a A	- a A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. Number of injured leaves is given in treatment averages.

4. A minus percent reduction signifies a percent increase over that of the control treatment.

Table 14. Summary of significant ozone effects on Boston lettuce as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

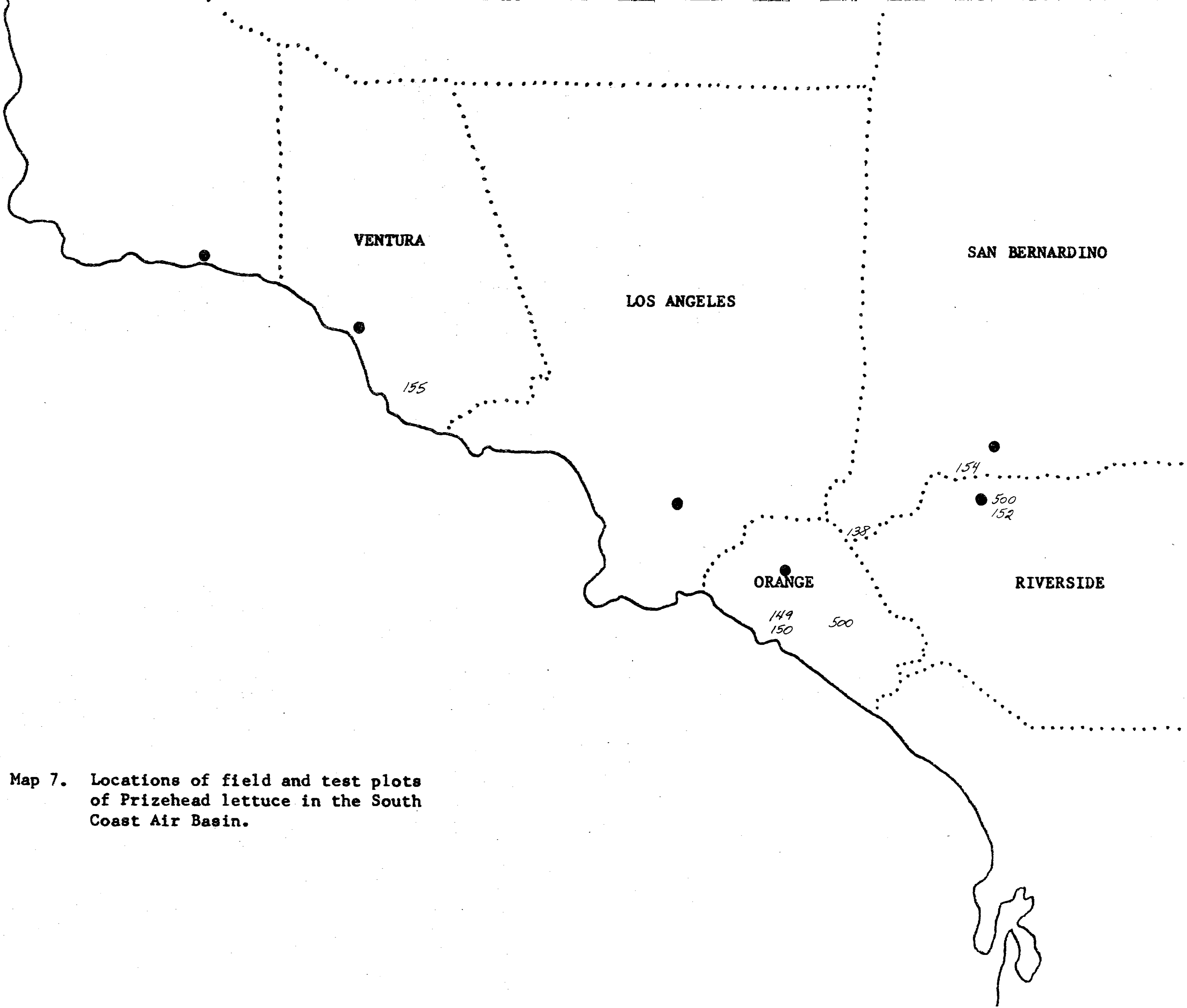
		Height			Diameter			Fresh Wt. Leaves			# Leaves		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Treatments	.20	8.66	b	A	9.85	b	B	-	a	A	-	a	A
(ppm)	.35	7.79	b	A	12.41	b	B	-	a	A	-	a	A

		# Injured Leaves[3]			Dry Wt. Leaves			Dry Wt. Roots			Total Dry Wt.		
Ozone	0	0	a	A	-	a	A	-	a	A	-	a	A
Treatments	.20	25.1	b	B	-	a	A	21.12	b	B	-	a	A
(ppm)	.35	34.6	c	C	-	a	A	45.57	c	C	-	a	A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. Number of injured leaves is given in treatment averages.



Map 7. Locations of field and test plots of Prizehead lettuce in the South Coast Air Basin.

Plate 14. PAN damage on the dark green variety of Boston lettuce.

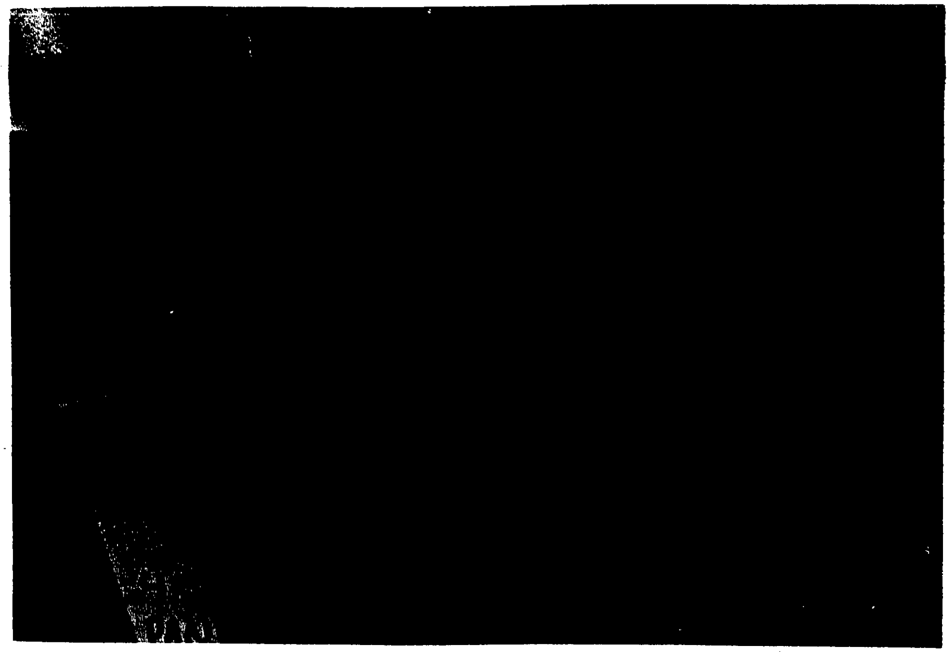
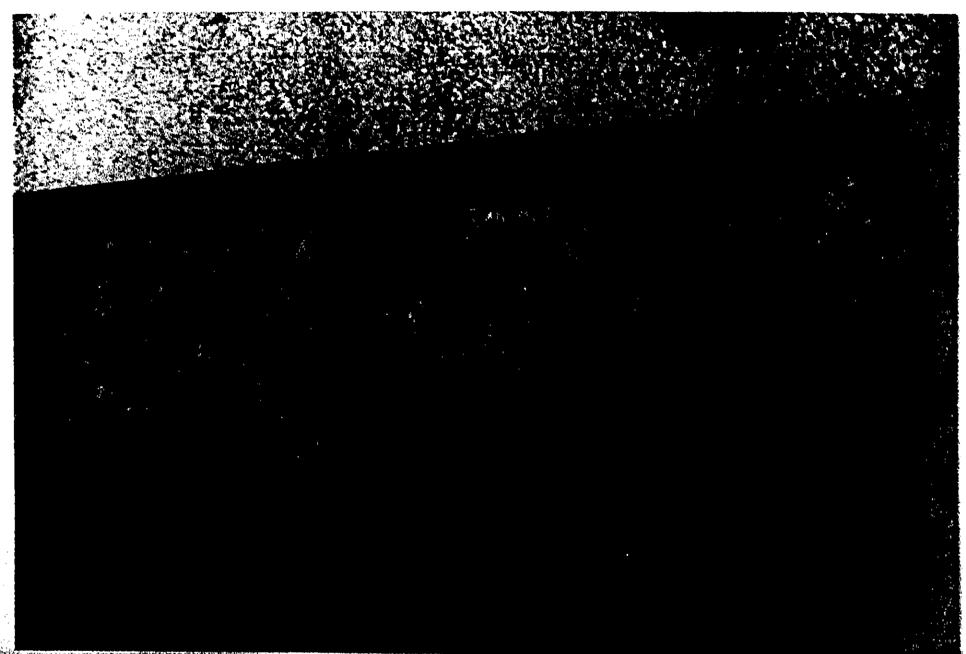


Plate 15. Effect of ozone on the dark green variety of Boston lettuce. Pictured from right to left are: a control treatment plant, a .20 ppm treatment plant, and a .35 ppm treatment plant.



CHAPTER IX - CABBAGE

Summary

Long-term fumigations indicated that ozone and PAN do not affect the quality of Copenhagen Market cabbage heads. This was not substantiated by field work because of exceptionally low oxidant levels during the 1972 fall growing season.

Greenhouse-grown Copenhagen Market cabbage was found to be sensitive to PAN and ozone leaf injury at all stages of growth. However, injury to wrapper leaves did not always reflect reduced yields or quality. Plants exposed to the lower level of ozone (.20 ppm) displayed considerable leaf injury but the size or weight of harvested heads were not reduced. Plants in the .35 ppm treatment were also observed to have ozone leaf injury and did show significant reductions in yield. This cabbage variety apparently tolerates a degree of ozone leaf injury without any effect on size or weight of the head. PAN exposures did not produce significant reductions in yield or quality on the harvested Copenhagen Market heads. Ambient oxidant levels were below injury threshold dosages and resulted in a lack of leaf injury or measureable effects.

Jet Pack cabbage, a commercial hybrid, was included in long-term fumigation studies as a comparison with Copenhagen Market. Ozone effects were essentially the same as Copenhagen Market but PAN appeared to stimulate plant growth. This effect did not produce heads of significantly different size or weight. Other fumigations would have to be initiated to determine whether the PAN effect was real or due to experimental error.

Introduction

Copenhagen Market cabbage has been a favorite cabbage variety in the South Coast Air Basin for many years. It is considered to be a good yielding variety with excellent flavor; growers favor it because of past successes. This was the original variety listed in the proposal.

Jet Pack cabbage is one of a number of hybrid varieties bred to increase yields. It has not been as well received as many standard varieties and relatively few commercial growers use it. No field work was initiated with this variety.

A short-term fumigation study was undertaken to determine oxidant effects on seedlings. A long-term fumigation study was used to determine oxidant effects on crop quality and yield and to develop criteria for field studies. Field work in 1972 focused on the quality study of field-grown cabbage correlated with oxidant levels present during growth.

Seedling Fumigation Study

Treatments: Control, .24 ppm ozone, 30 ppb PAN

Exposure: Plants were exposed to the respective concentrations of fumigant for 1.5% of the growth period. Fumigations were initiated upon emergence and discontinued after 30 days of growth.

Effects of ozone on Copenhagen Market cabbage seedlings: Ozone injury was observed on older leaves of many seedlings throughout the fumigations. No reductions in the plant height or the number of leaves of seedlings were noted when compared to plants in the control treatment. Significant reductions in fresh and dry weights of seedlings were observed (Table 15).

Effects of PAN on Copenhagen Market cabbage seedlings: PAN injury was observed on plants in the fumigated treatment throughout the fumigations. A reduction in the fresh and dry weights of fumigated plants was found when compared to control plants. The extent of these weight reductions closely approximated the ozone treatment plants. No significant differences were found in height or number of leaves.

Discussion: Copenhagen Market seedlings were found to be sensitive to both ozone and PAN at the specified dosages. Significant reductions were observed in fresh and dry weights of fumigated seedlings. This loss of solids may result in less vigorous growth or in reduced yield at harvest. At this stage, plants from the fumigated and control treatments were of comparable size.

Long-Term Ozone Fumigation of Copenhagen Market Cabbage

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Exposure: Plants were exposed to the respective concentrations of PAN for 72 out of 1,656 hours or about 4% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effect of ozone on Copenhagen cabbage: Criteria used to measure harvested plants and heads are illustrated in Figure 61. Although injury was observed on plants in both the .20 ppm and .35 ppm treatments, the only size measurement reflecting a reduction from the control plants was the diameter of plants in the .35 ppm ozone treatment (Table 16). Definite differences between treatments were observed visually (Plate 16) and in weight measurements. The greatest differences were observed in the .35 ppm treatment.

Effect of ozone on Copenhagen cabbage heads: Only the .35 ppm treatment heads were significantly reduced in size (Table 17). Significant differences in the fresh weights of .20 ppm treatment heads were observed at the .05 level. The heads harvested from the .35 ppm treatment of significantly lower weight and also of reduced size.

Discussion: The Copenhagen variety of cabbage appears to be ozone resistant as only the high level of ozone effected significant reductions in yield. It is highly unlikely that ambient ozone levels would reach concentrations causing a marked reduction in yield in the fall. The fresh weight of heads and total fresh weight of plants show significant differences in the .20 ppm treatment compared to the control. Only the high fumigation (.35 ppm) treatment plants showed reductions in head weight.

Long-Term PAN Fumigation of Copenhagen Cabbage

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Exposure: Plants were exposed to the respective concentrations of PAN for 57 out of 1,704 hours or about 3.5% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

The effect of PAN on Copenhagen cabbage: PAN injury was observed on the wrapper leaves of both the 20 ppb and 40 ppb treatment plants but no significant differences were found in measurements of the three treatments.

The effect of PAN on Copenhagen cabbage heads: No significant differences were found among harvested heads of the three treatments.

Discussion: The fumigation levels used were sufficiently high to produce wrapper leaf injury on the fumigated treatments but produced no effects on the marketable heads. PAN does not appear to produce yield or quality reductions on Copenhagen cabbage.

Long-Term Ozone Fumigation of Jet Pack Cabbage

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Exposure: Plants were exposed to the respective concentrations of PAN for 56.5 out of 1,503 hours or about 4% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effects of ozone on Jet Pack cabbage: Criteria used to measure harvested plants and heads are illustrated in Figure 61. Plants exposed to the .20 ppm and .35 ppm treatments were found to be significantly affected. As might be expected, the higher fumigation level produced the greatest reductions in fresh and dry weights (Table 18) even though ozone injury was evident on an almost equal number of wrapper leaves in both treatments.

Effects of ozone on Jet Pack cabbage heads: The greatest differences between treatments occurred in the harvested heads. The .35 ppm treatment heads were significantly reduced in size and weight (Table 19) when compared to both the .20 ppm treatment and the control. No significant differences were found between the .20 ppm treatment and the control.

Discussion: Ozone at the .20 ppm fumigation level was phytotoxic enough to inflict leaf injury and reduce fresh weights in the leaves and stems, but did not produce significant reductions in the size or weight of the heads. The .35 ppm fumigation level did produce reduced head weights in addition to an overall reduction in the size and weight of the total plant. Fumigation levels are not representative of ambient levels during the normal cabbage season and the probability of such reductions in harvested head weight occurring in the field is slight.

Long-Term PAN Fumigation of Jet Pack Cabbage

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Exposure: Plants were exposed to the respective concentrations of PAN for 41.5 out of 1,278 hours or about 3% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effect of PAN on Jet Pack cabbage: Exposure to the two fumigation levels of PAN produced no significant differences between treatments in most of the size and weight measurements. Two exceptions to this were 10% increase in height and a 28% increase in total dry weight in the 40 ppb treatment over the control and 20 ppb treatments. The increase in height was significant at the .05 level and the increase in dry weight at the .01 level.

Effect of PAN on Jet Pack cabbage heads: No significant differences were found between treatments.

Discussion: The significant differences in the 40 ppb treatment are difficult to explain. Normally, PAN sensitive plants are hardest hit by the higher concentration levels. In this case, the 40 ppb level appeared to stimulate growth in height and production of solids in the plant as measured by dry weight. Experimental error may have been responsible for these increases.

Field Study (Quality Effects) of Copenhagen Market Cabbage

Locations: Four commercial field plots and two test plots of Copenhagen Market cabbage were set up in the South Coast Air Basin (Map 8). Each location was monitored by three AMBI stations.

Sampling procedures: Field plots were harvested prior to the commercial harvest at a time specified by the grower. Fifty individual plants were harvested randomly over the extent of the field and evaluated for quality. The variation in harvest ages were not acceptable for yield comparisons but were acceptable for evaluation of quality criteria.

Two field plots were plowed under by growers before samples could be taken because of low market price. Locations 148 and 153 thus were lost to the study.

Test plots at UCR and South Coast Field Station comprised two 150-foot rows of Copenhagen Market cabbage. Fifty individual plants were sampled from the rows and evaluated. No attempt was made to standardize a uniform harvest age in order to randomize the test plots with commercial field plots.

Effects of oxidant air pollutants on field-grown Copenhagen Market cabbage: Some of the data taken from the harvested cabbage do not directly pertain to quality evaluation. Measurements of size and weight are normally associated with yield studies, but in this case are not indicative of yield. Harvests were not taken at a uniform age and yields are therefore not comparable. These data are presented only to illustrate the range of weights and sizes of the harvested cabbage (Figures 62, 63, 67, 68).

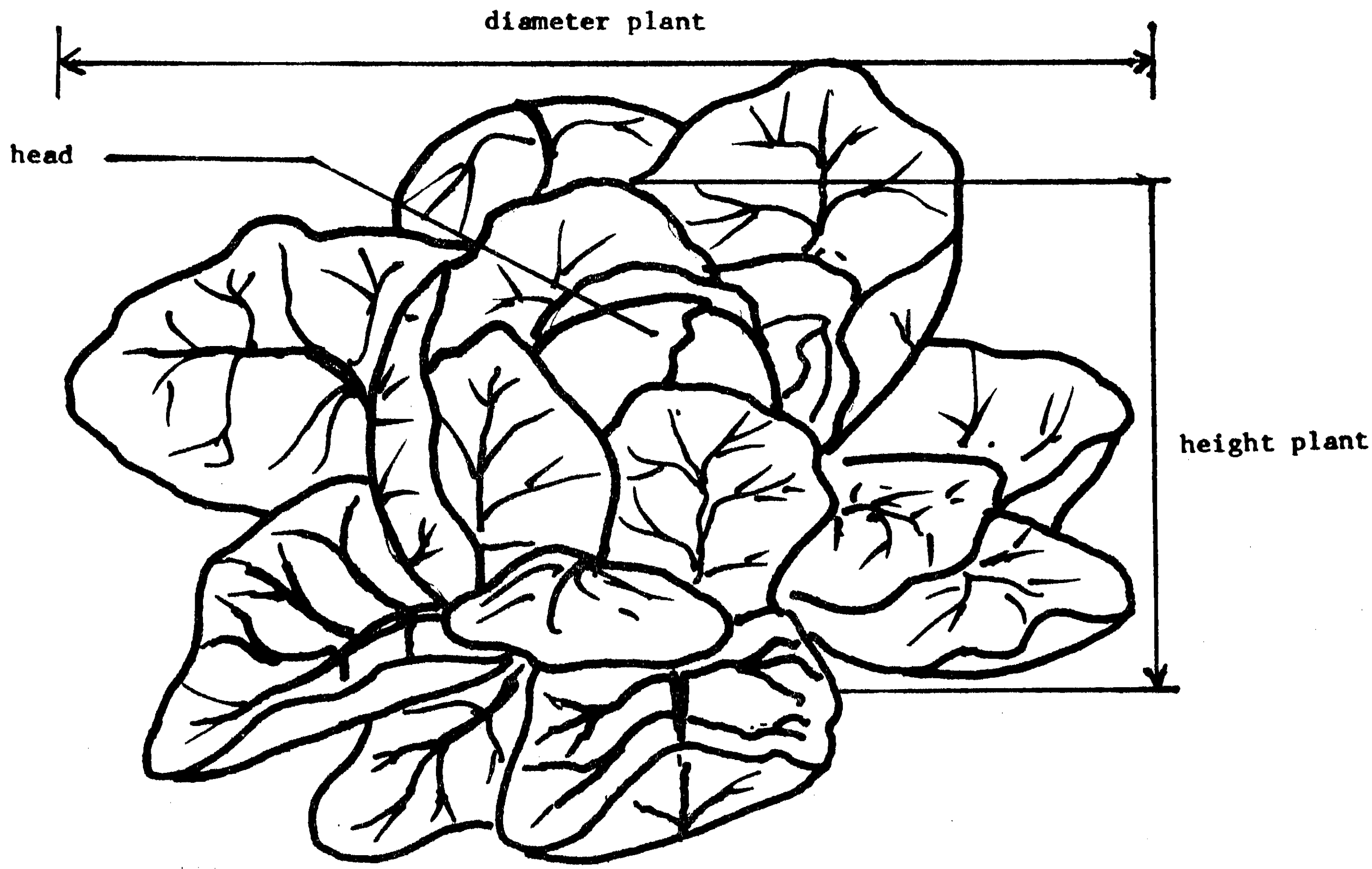
Data taken from the quality evaluation of the plant and harvested head are also presented in the same format (Figures 64, 65, 66). All correlations of quality data, weight, and size with total oxidant dosage proved to be insignificant.

Discussion: The 1972 fall growing season had unusually low levels of oxidant pollutants. Dosages in the heaviest areas of pollution barely exceeded 50 pphm hours[1/]. The resultant field work reflects the lack of oxidant injury as all correlations proved to be insignificant.

While the long-term fumigation study produced both PAN and ozone injury on the wrapper leaves of Copenhagen Market cabbage, no evidence of this type of injury was observed in the field.

1/ Calculated as pphm hours greater than 10 pphm.

Figure 61. Criteria for Measurements Taken on Copenhagen Market and Jet Pack Cabbage.



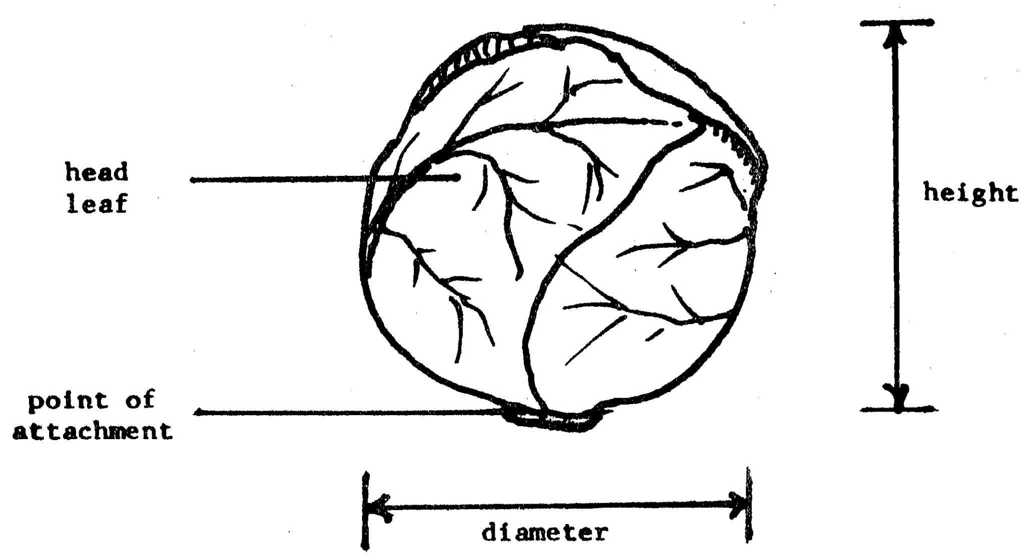


Figure 62. Correlation of weights of harvested Copenhagen Market cabbage plants with the total ambient oxidant dosage present during growth.

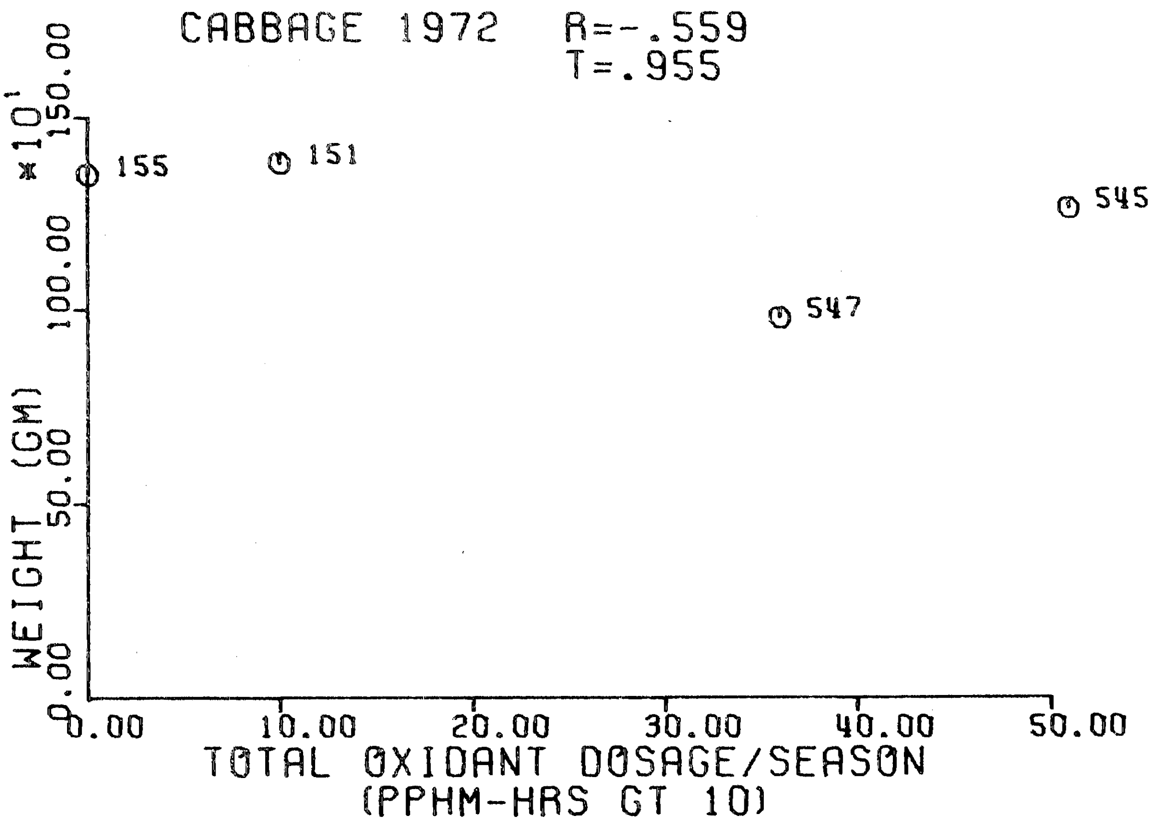


Figure 63. Correlation of weights of harvested Copenhagen Market cabbage heads with the total ambient oxidant dosage present during growth.

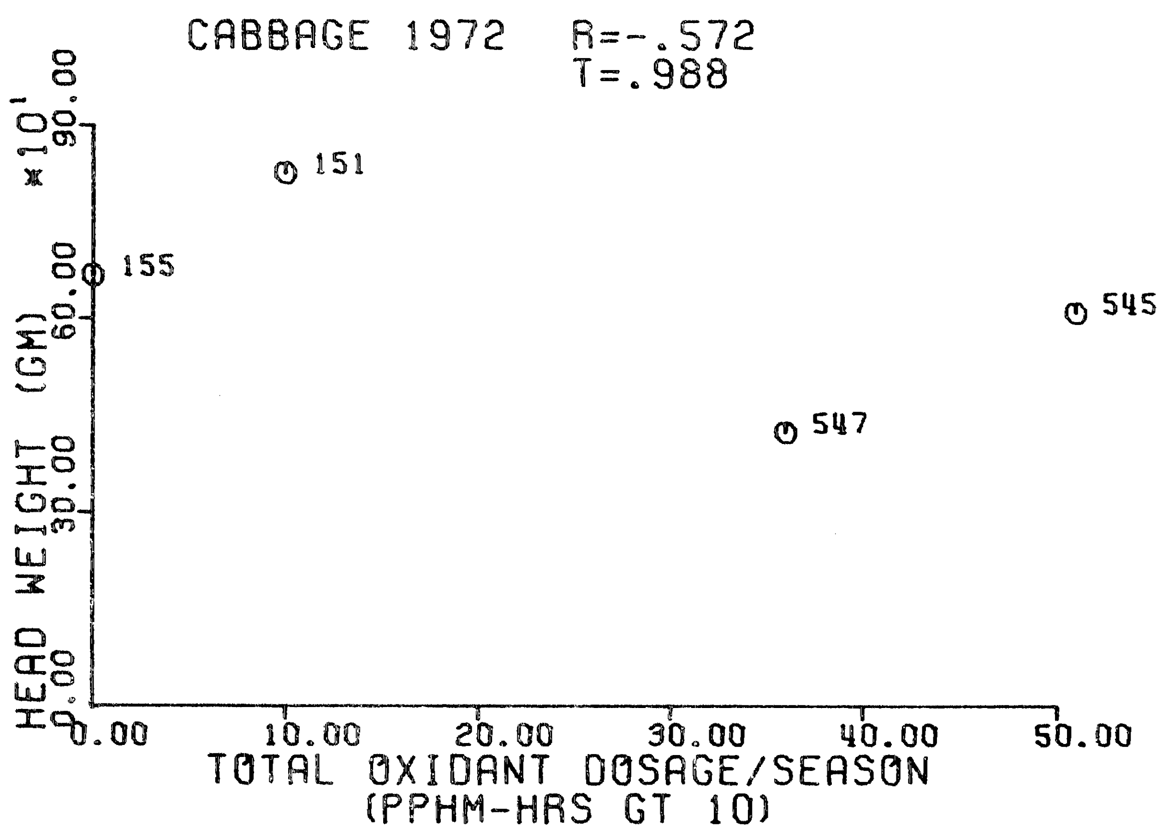


Figure 64. Correlation of the number of wrapper leaves on harvested Copenhagen Market cabbage with the total ambient oxidant dosage present during growth.

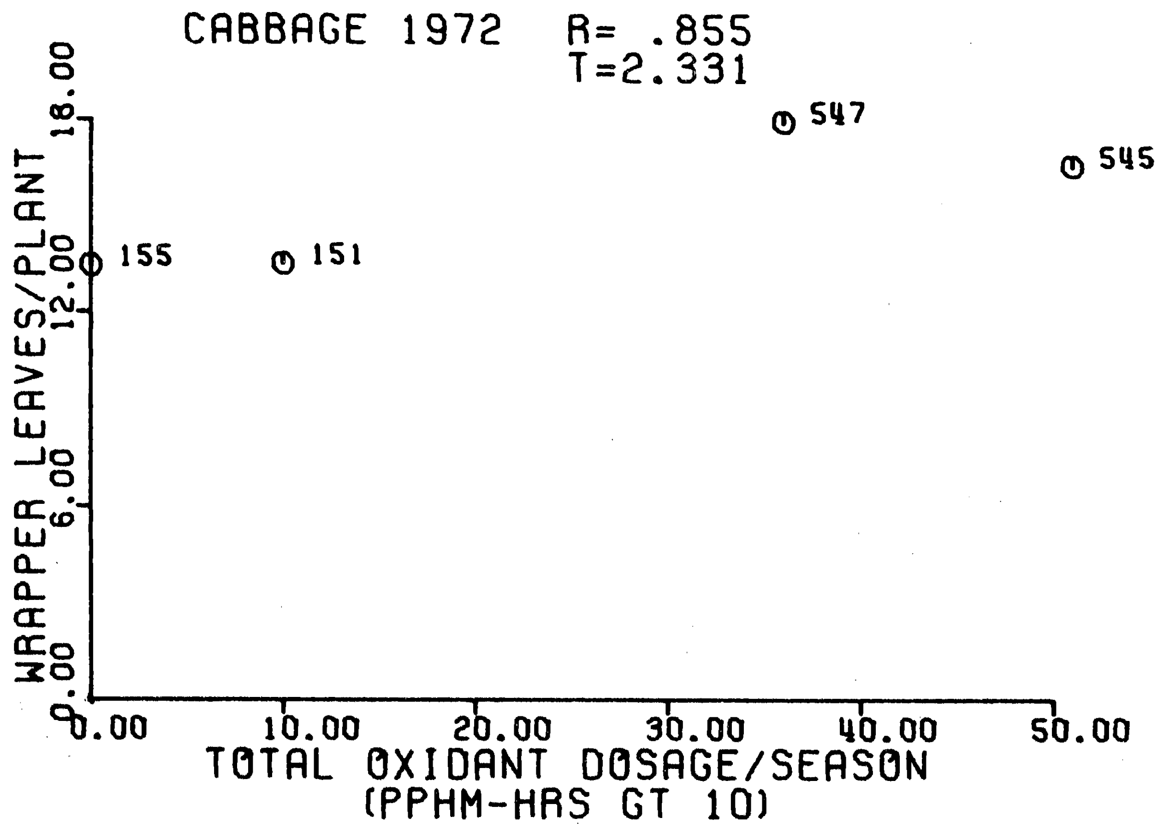


Figure 65. Correlation of the number of injured wrapper leaves on harvested Copenhagen Market cabbage with the total ambient oxidant dosage during growth.

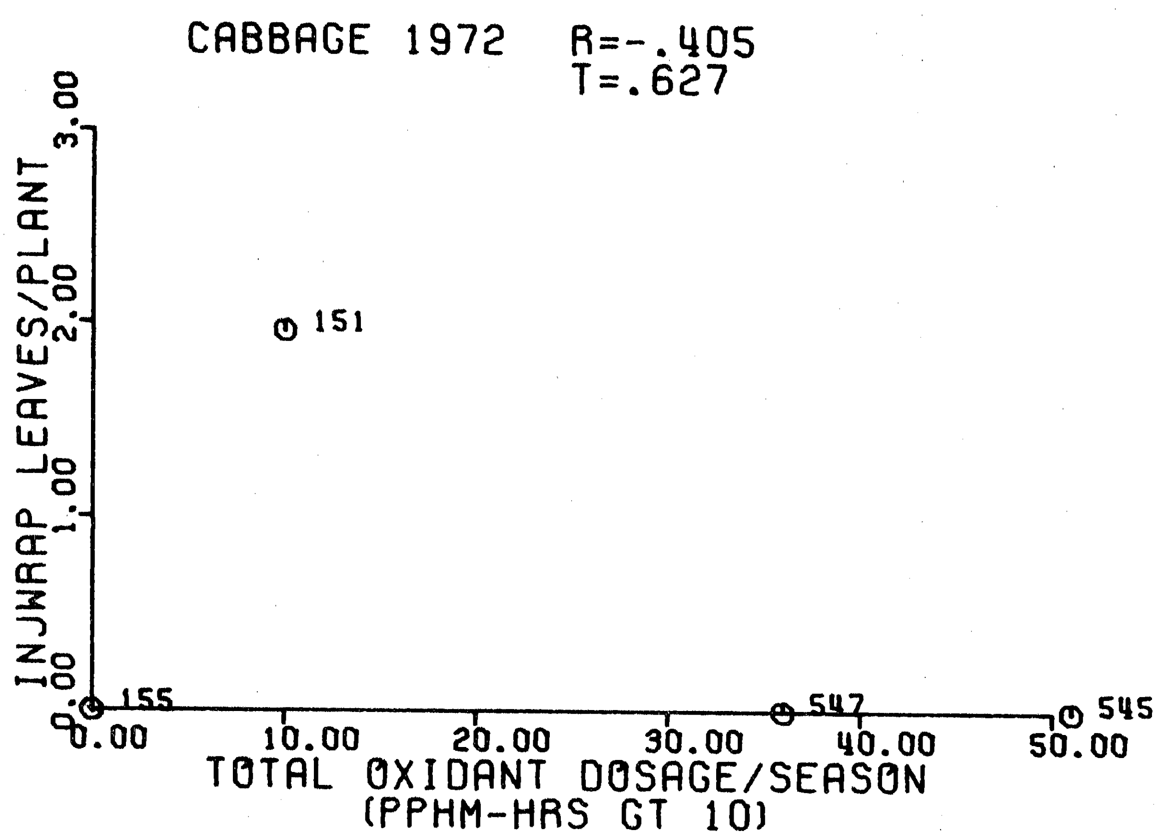


Figure 66. Correlation of the number of injured head leaves on harvested Copenhagen Market cabbage with the total ambient oxidant dosage present during growth.

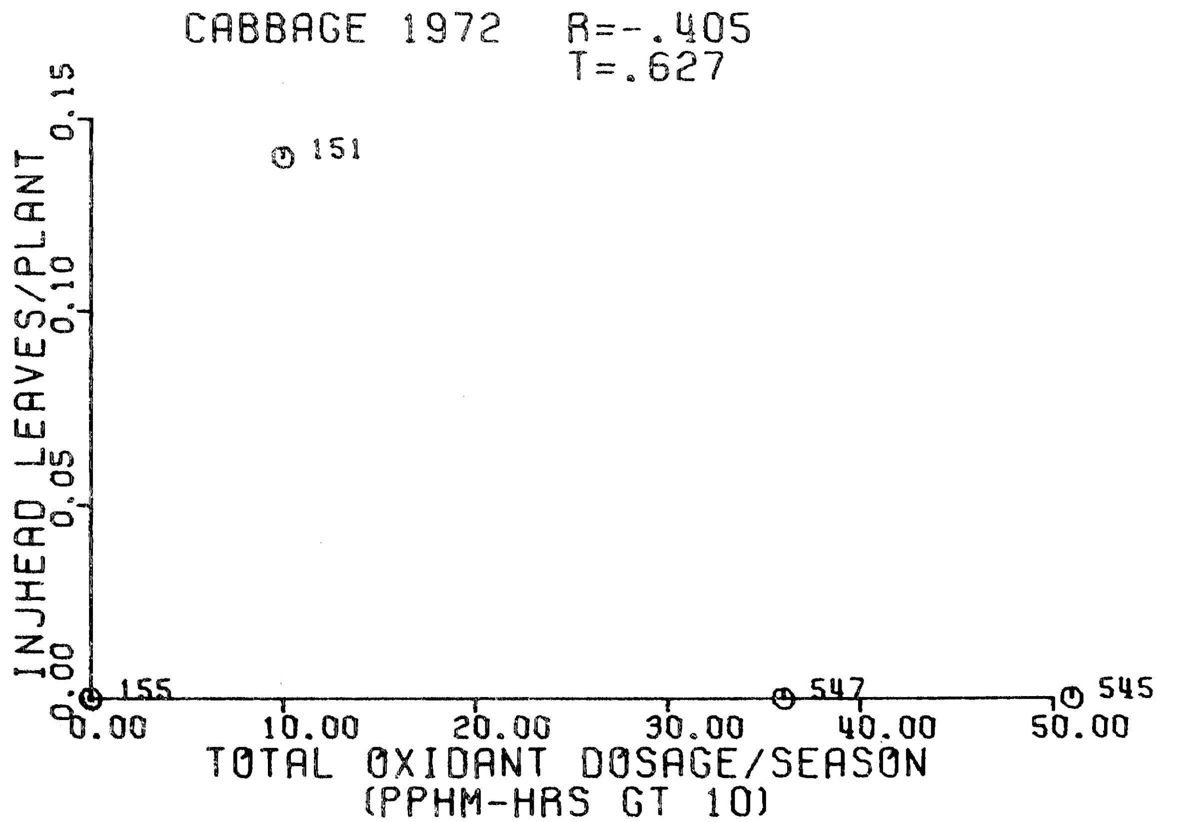


Figure 67. Correlation of diameters of harvested Copenhagen Market cabbage heads with the total ambient oxidant dosage present during growth.

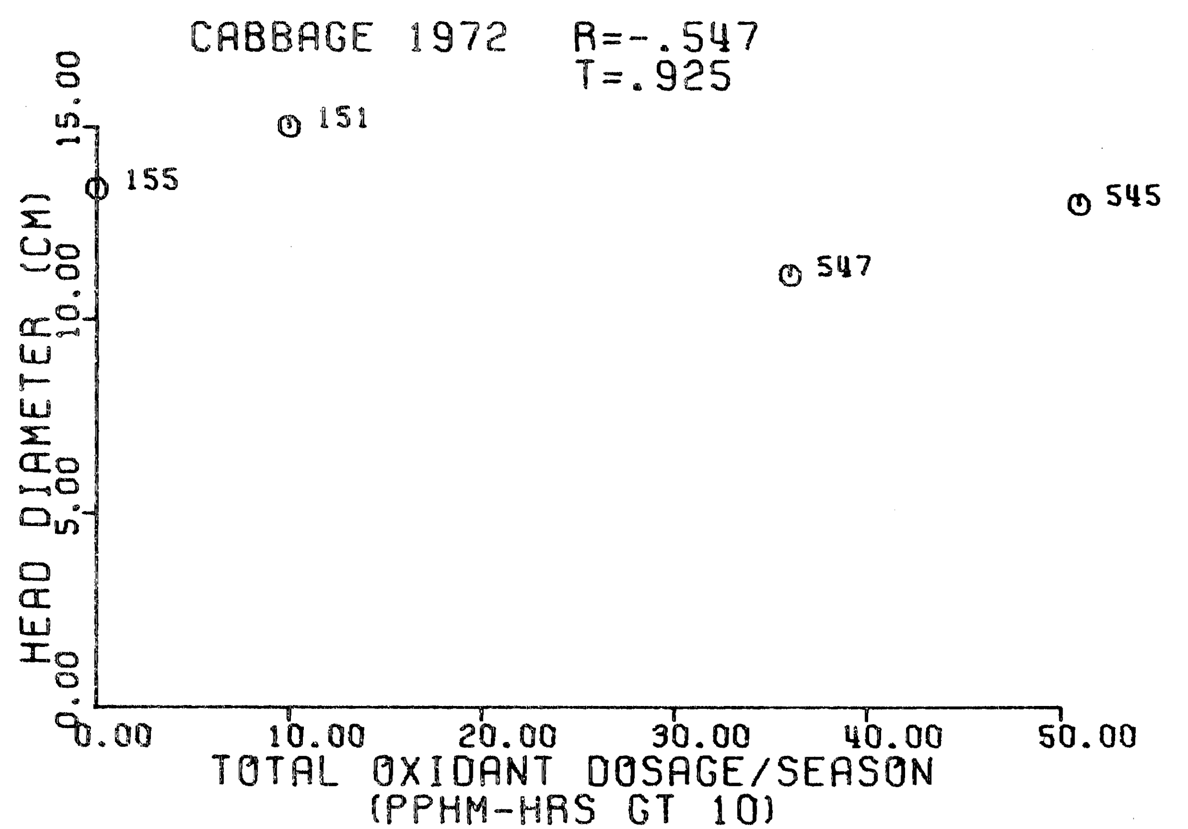


Figure 68. Correlation of heights of harvested Copenhagen Market cabbage plants with the total ambient oxidant dosage present during growth.

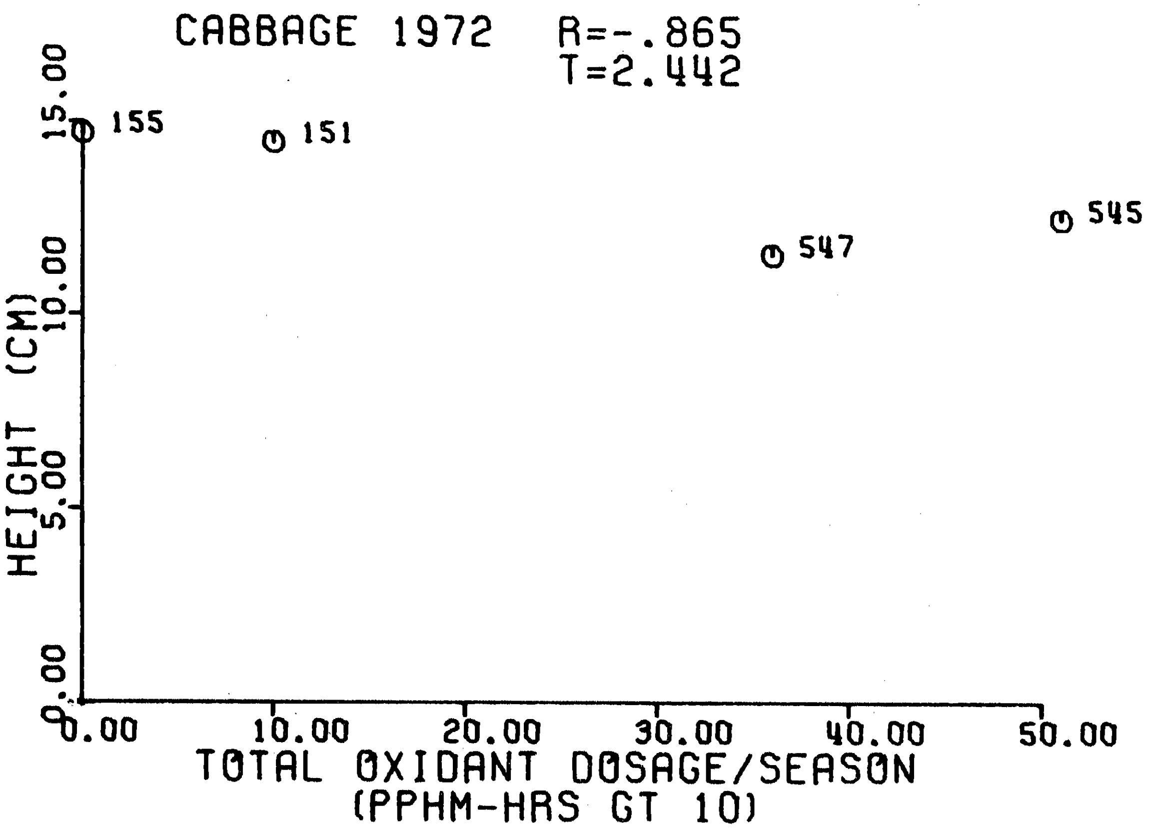


Table 15. Summary of ozone and PAN effects on Copenhagen Market cabbage seedlings as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		# Leaves			Height			Fresh Wt.			Dry Wt.		
Control	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Ozone	.25 ppm	-	a	A	-	a	A	37.1	b	A	40.5	b	B
PAN	30 ppb	-	a	A	-	a	A	33.3	b	A	43.4	b	B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

Table 16. Summary of significant ozone effects on Copenhagen cabbage as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

Ozone Treatments (ppm)	Plant Ht.			Plant Diameter			No. Wrapper Leaves		
0	-	a[1]	A[2]	-	a	A	-	a	A
.20	-	a	A	5.2	a	A	-	a	A
.35	-	a	A	17.9	b	B	-	a	A

Ozone Treatments (ppm)	No. Injured Leaves[3]			Fresh Wt. Stems & Leaves			Total Fresh Wt.		
0	0	a	A	-	a	A	-	a	A
.20	4.3	b	B	11.7	b	A	11.7	b	A
.35	5.9	b	B	53.0	c	B	53.0	c	B

Ozone Treatments (ppm)	Dry Wt. Roots			Dry Wt. Leaves & Stems			Total Dry Wt.		
0	-	a	A	-	a	A	-	a	A
.20	-6.7[4]	a	A	-0.2	a	A	0	a	A
.35	35.1	b	B	25.9	b	B	28.2	b	B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. Figures given in this category represent the treatment means and not calculated percent reductions from the control treatment.

4. A minus percent reduction represents a percent increase over the control treatment.

Table 17. Summary of significant ozone effects on Copenhagen cabbage heads as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		Head Diameter			Head Ht.			No. Injured Head Leaves			Fresh Wt. Head		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Treatments	.20	-0.1[3]	a	AB	6.1	a	A	-	a	A	20.2	b	A
(ppm)	.35	25.0	b	B	27.0	b	B	-	a	A	68.6	c	B

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

3. A minus percent reduction represents a percent increase over the control treatment.

Table 18. Summary of significant ozone effects on Jet Pack cabbage as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

Ozone Treatments (ppm)	Plant Ht.	Plant Diameter	No Wrapper Leaves
0	- a[1] A[2]	- a A	- a A
.20	- a A	10.1 b B	- a A
.35	- a A	17.1 c B	- a A

Ozone Treatments (ppm)	No. Injured Leaves[3]	Total Fresh Wt.	Fresh Wt. Leaves & Stems
0	0 a A	- a A	- a A
.20	4.5 b B	8.2 a A	22.5 b B
.35	3.6 b B	46.9 b B	26.6 b B

Ozone Treatments (ppm)	Total Dry Wt.	Dry Wt. Leaves & Stems	Dry Wt. Roots
0	- a A	- a A	- a A
.20	12.7 a A	17.0 b AB	- a A
.35	40.0 b B	23.1 b B	- a A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

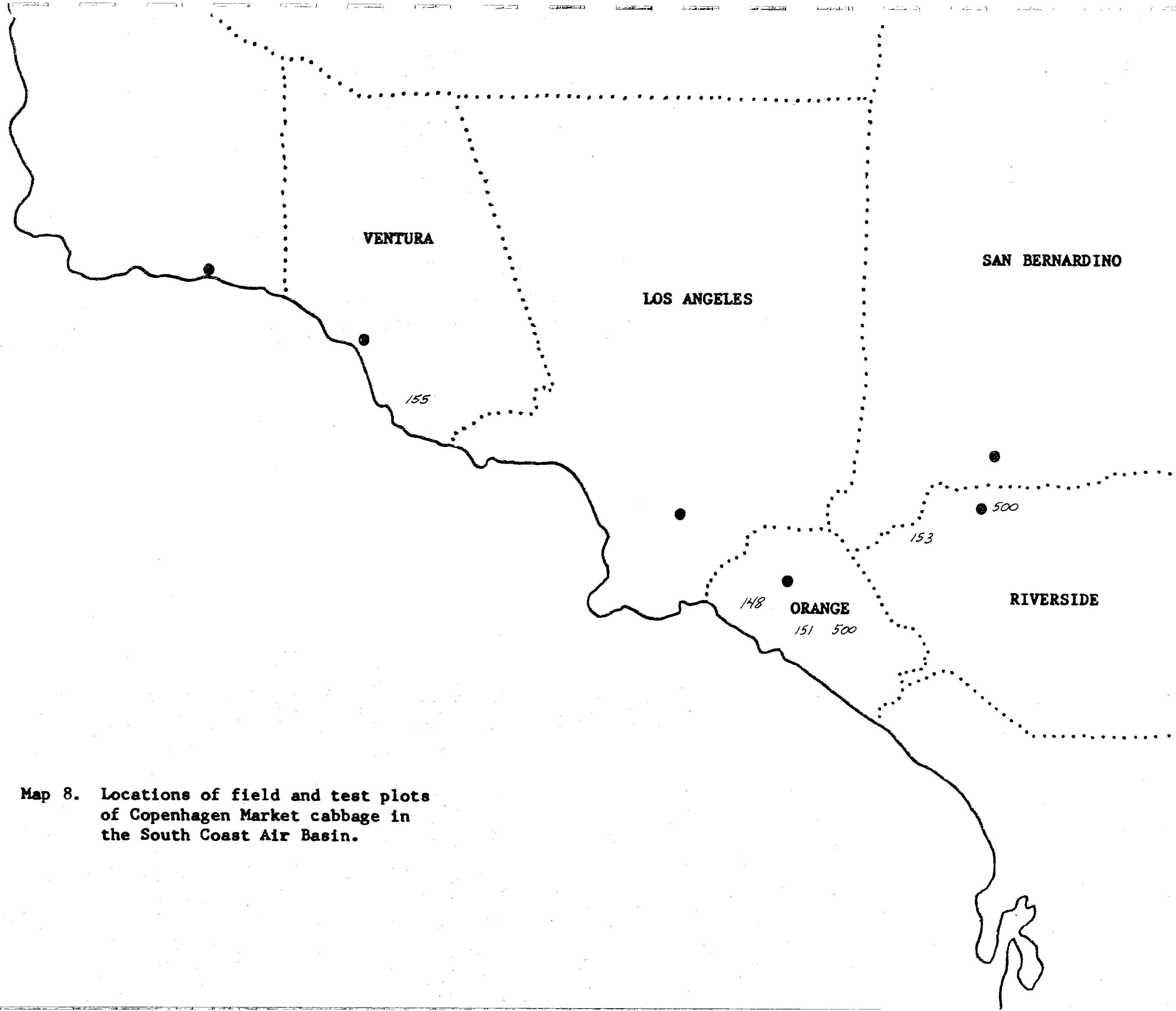
3. Figures given in this category represent the treatment means and not calculated percent reductions from the control treatment.

Table 19. Summary of significant ozone effects on Jet Pack cabbage heads as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		Diameter Head			Ht. Head			Fresh Wt. Head			Dry Wt. Head		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Treatments	.20	2.8	a	A	1.6	a	A	3.4	a	A	9.5	a	A
(ppm)	.35	33.3	b	B	30.6	b	B	69.7	b	B	63.0	b	B

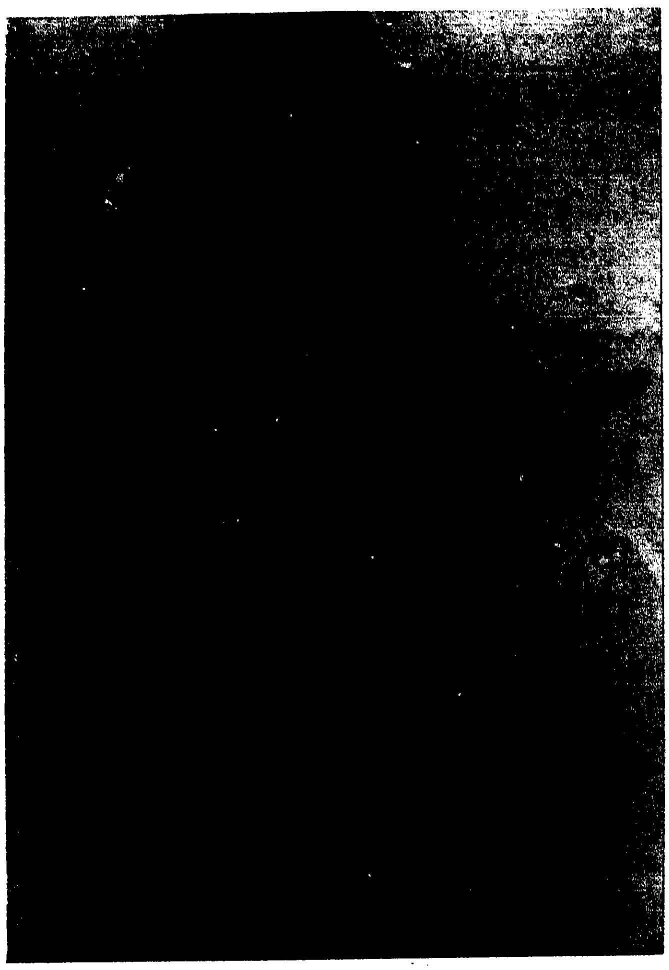
1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.



Map 8. Locations of field and test plots of Copenhagen Market cabbage in the South Coast Air Basin.

Plate 16. Effect of ozone on Copenhagen Market cabbage pictured from bottom to top are: a control treatment plant, a .20 ppm treatment plant, and a .35 ppm treatment plant.



CHAPTER X - STRAWBERRIES

Summary

Field studies have implicated ozone as a possible factor influencing the production of irregular fruit. Unfortunately, a definitive statement cannot be made due to a lack of experimental evidence to this effect in long-term fumigations. Spraying for mite control introduced a possibility of error in evaluations of irregular fruit. Fumigation studies in the 1973 yield study should clear up this uncertainty.

Definite yield reduction associated with ozone exposures was found at high fumigation levels (.35 ppm). Total number of berries harvested and total weight of harvest were both reduced significantly.

Ozone also caused leaf injury to greenhouse-grown strawberry plants.

PAN did not appear to be phytotoxic to Tioga strawberries.

Introduction

Tioga strawberry is the most popular variety currently in production in the South Coast Air Basin. It is exceptionally high yielding and produces firm fruit later into the summer than most other varieties. Two separate plantings are commonly made each year: 1) a summer planting which starts bearing in late spring and produces the greatest yield, and 2) a winter planting which bears early in the spring and produces large berries but lesser total yield. The summer planting was selected for field study.

A long-term fumigation study was undertaken to determine oxidant effects on crop quality and yield and to develop criteria for field studies. Field work for the 1972 growing season focused on a quality study of field-grown berries correlated with oxidant levels present during growth.

Long-Term Ozone Fumigations of Tioga Strawberries

Treatments: 0 ppm ozone, .20 ppm ozone, .35 ppm ozone

Exposure: Plants were exposed to the respective concentrations of fumigant for 78 out of 2,600 hours or about 3% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effects of ozone on Tioga strawberry plants: Plants in both fumigation treatments were observed to have extensive leaf injury (Plate 17). The injured strawberry leaves were characterized by interveinal chlorosis with small islands of green tissue (Plate 18). Older leaves were most sensitive and often developed a red pigmentation about one week after injury. The association of mature physiological age and sensitivity was characteristic of ozone injury, but the injury itself was not typical of ozone. Stipple was absent and the overall appearance of the injured leaves was difficult to distinguish from mineral difficiency symptoms or normal senescence.

The .35 ppm treatment plants were generally shorter-growing but other measurements were not significantly different.

The three treatments were infested with mites during the fumigations and a regular program of spraying with diazinon and malathion was necessary for control. Although precautions were taken to protect flowers, the production of irregular fruit may have been partially caused by the insecticides rather than ozone.

Effect of ozone on Tioga strawberry fruit: Plants fumigated with .35 ppm ozone were found to yield significantly less over the harvest season in terms of both weight and number of berries harvested (Table 20). An arbitrary index of shape (Figure 69) was used in evaluating the harvested berries. Both fumigated treatments appeared to have fewer irregular berries than the control plants, although this may have been due to the frequent spraying for mite control. The average berry weight for all harvested fruit was not significantly different between treatments.

Discussion: An arbitrary rating of berries as to shape proved to be confusing as the control plants appeared to have a significantly higher incidence of irregularly-shaped fruit. This data must be questioned as frequent sprayings were applied to control mites.

Long-Term PAN Fumigation of Tioga Strawberries

Treatments: 0 ppb PAN, 20 ppb PAN, 40 ppb PAN

Exposure: Treatments were exposed to the respective concentrations of PAN for 155 out of 4,950 hours or about 3.2% of the growing period. The fumigations averaged about 6 hours in length and were staggered to provide time for plant recovery.

Effects of PAN on Tioga strawberry: No PAN leaf injury was observed on fumigated plants and no significant differences were found between treatments.

Effects of PAN on Tioga strawberry fruit: No significant differences were found among the fruit of the three treatments.

Discussion: PAN does not seem to affect the growth of strawberry plants or the yield or quality of the berries.

Field Study (Quality Effects) of Tioga Strawberries

Locations: Twelve oommercial field plots and two test plots of the summer planting of Tioga strawberries were established in the South Coast Air Basin (Map 9). Each location was monitored by three AMBI stations.

Sampling procedures: Each field plot was harvested monthly for a period of three months, beginning in April. Each sample consisted of 100 randomly-selected fruit taken over the extent of the field. Care was taken to quarter each sampled plant to prevent a biased selection.

Test plots comprised two 100-foot rows of Tioga plants at UCR and three 100-foot rows at South Coast Field Station. One hundred plants were selected and harvested throughout the season. All harvested fruit were counted and weighed, and a 50-fruit sample from each harvest was carefully evaluated for quality.

Effects of ambient oxidants on field-grown Tioga strawberries: The test plot harvest produced typical seasonal berry weight curves (Figures 70, 72). These curves should not be interpreted to be the result of ozone effects.

Correlations were run to determine the possibility of statistical error should a linear regression correlation be applied to the curves. The .05 level of significance given the South Coast berry weight reduction curve illustrated the unfeasibility of applying the linear regression correlation to a single location.

The percentages of irregularly-shaped berries at the test plots (Figures 71, 73) were correlated with the ambient ozone dosages present during growth and proved to be insignificant.

Normally, strawberries produce prime berries early in the season and fruit quality and size gradually decrease as the season progresses. Warming temperatures and the ripening of secondary, tertiary, and later berries on Tioga flowering stalks, are responsible for this quality reduction. Monthly correlations of commercial harvests implicate ozone as a possible factor in the decrease in fruit quality.

Low ozone levels during April did not produce a significant correlation with the percentage of irregular berries (Figure 75). However, as the season progressed and ozone dosages increased, correlations of increasingly greater significance were observed (Figures 77, 79). The last month of production produced the greatest percentage of irregular berries and also had the largest ozone dosages.

Correlations of berry weight and ambient ozone dosages were run as a matter of course, but test plots have illustrated that the normal reduction of berry weight through a season could be incorrectly interpreted by the linear regression correlation (Figures 74, 76, 78).

Discussion: Ambient ozone levels appear to be a factor influencing the percentage of irregular fruit produced by Tioga strawberries although there are undoubtedly other factors which interact with or directly influence the production of irregular berries. This association will be further explored during the 1973 yield study.

The normal berry weight reduction curve for a season excludes the use of a linear regression correlation as a measure of a significant association between ozone and berry weight reduction.

Figure 69. Criteria for Measurements Taken on Tioga Strawberry Fruit.

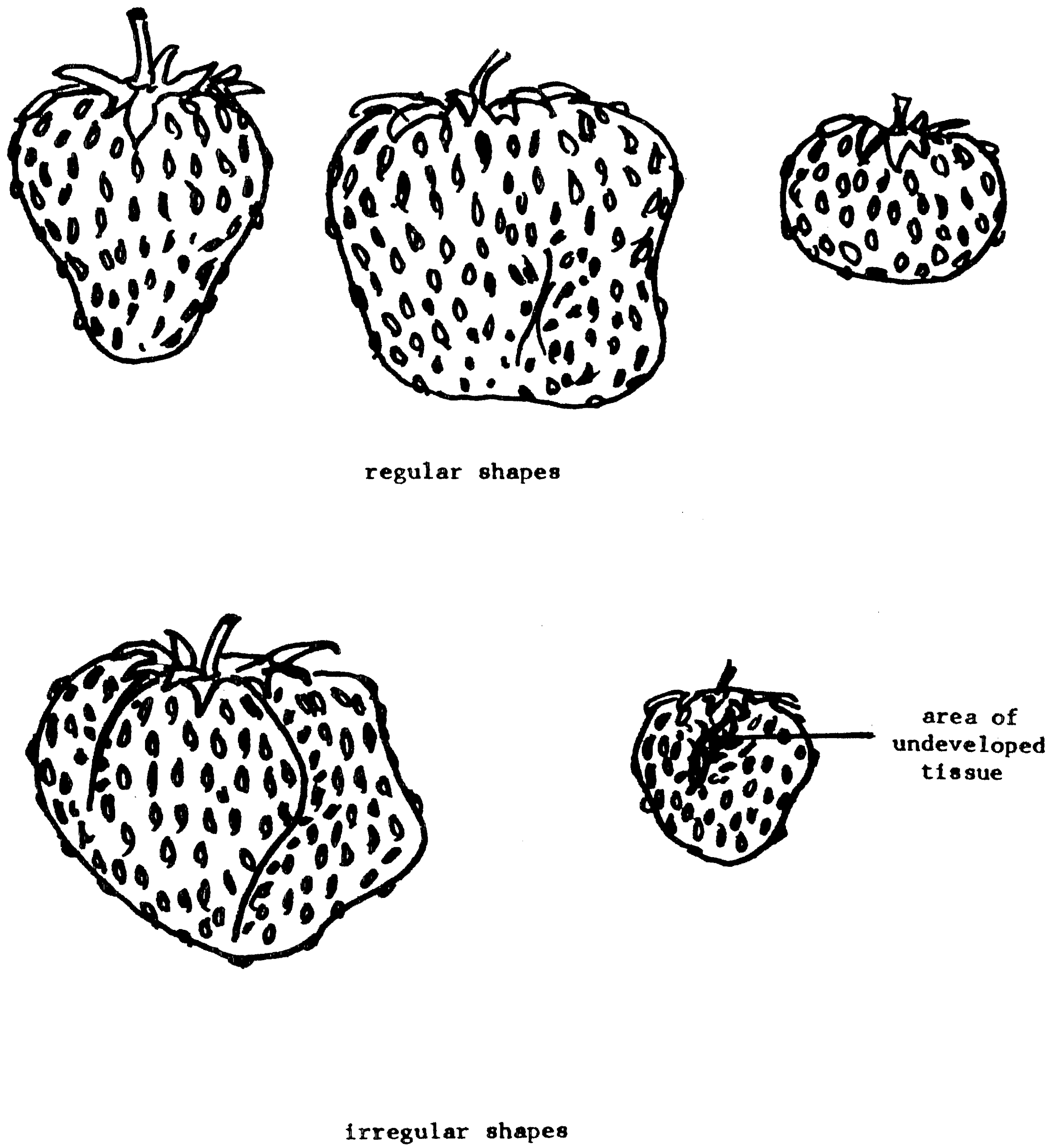


Figure 70. Correlation of mean weight of fruit from U.C.R. test plot harvests with the total ambient oxidant dosage present during growth.

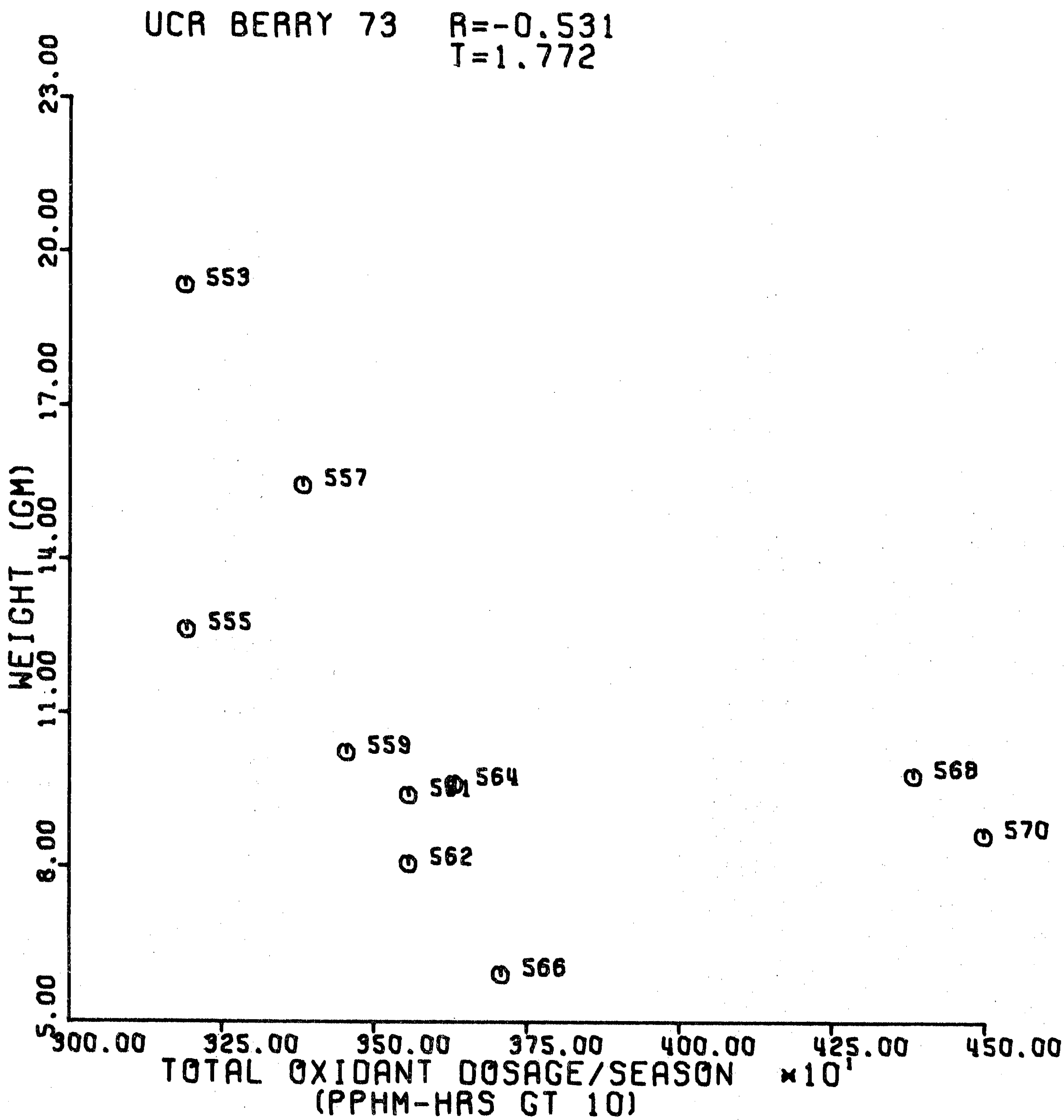


Figure 71. Correlation of percentage of irregular-shaped fruit from U.C.R. test plot harvests with the total ambient oxidant dosage present during growth.

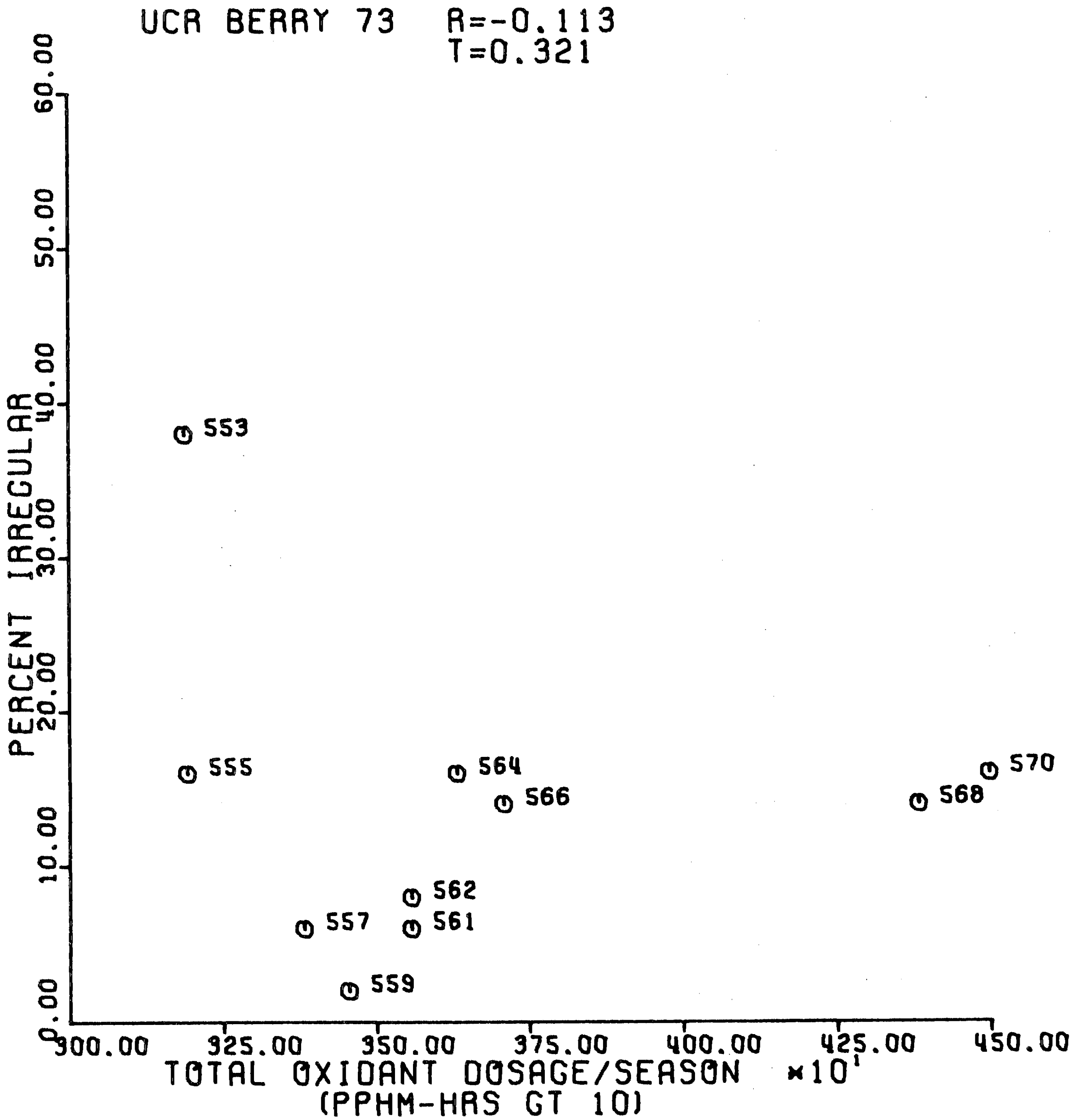


Figure 72. Correlation of mean weight of fruit from South Coast Field Station test plot harvests with the total ambient oxidant dosage present during growth.

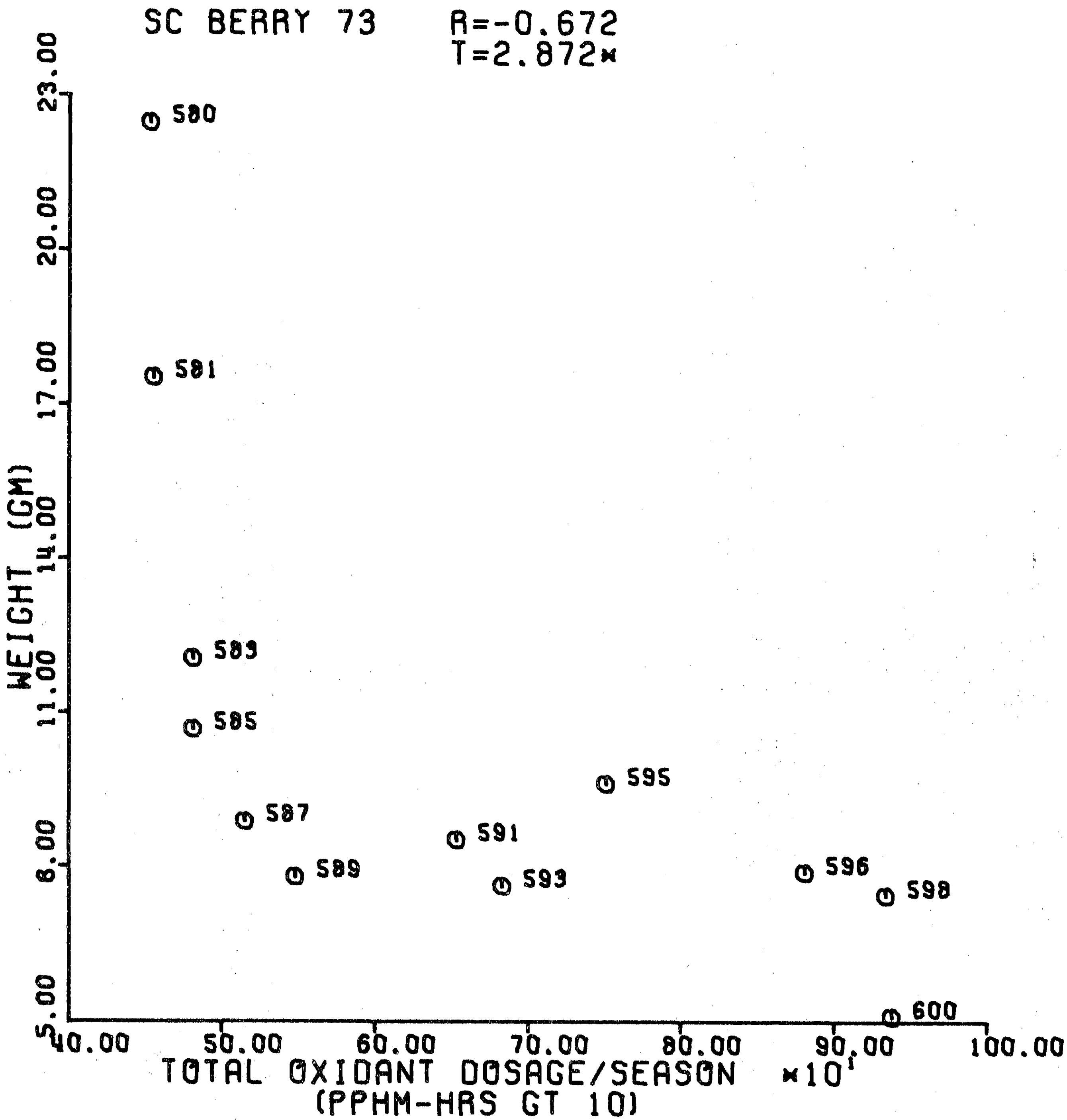


Figure 73. Correlation of percentage of irregular-shaped fruit from South Coast Field Station test plot harvests with the total ambient oxidant dosage present during growth.

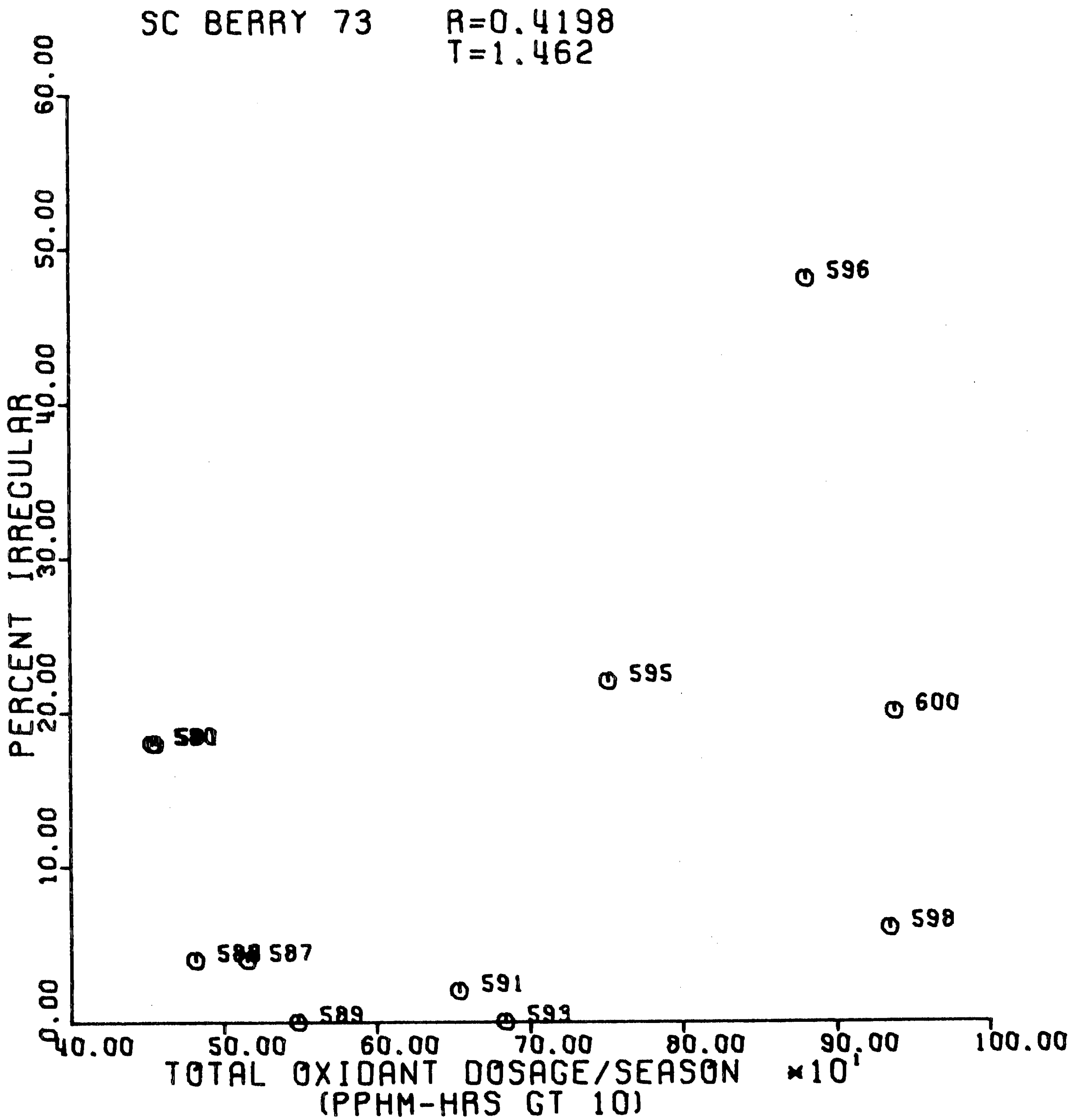


Figure 74. Correlation of mean weight of fruit from harvested commercial field plots in April 1973 with the total ambient oxidant dosage present during growth.

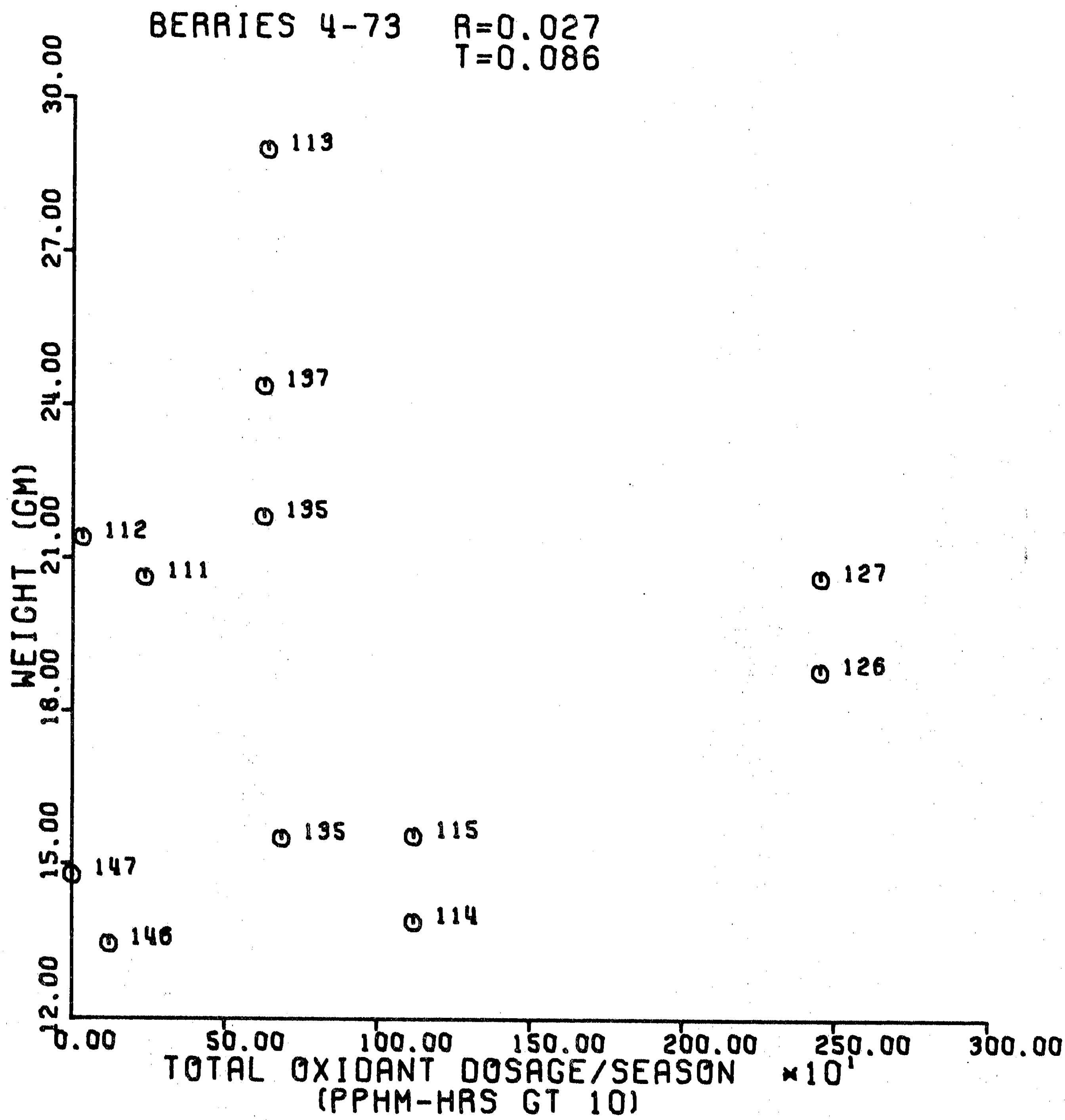


Figure 75. Correlation of percentage of irregular fruit from harvested commercial field plots in April 1973 with the total ambient oxidant dosage present during growth.

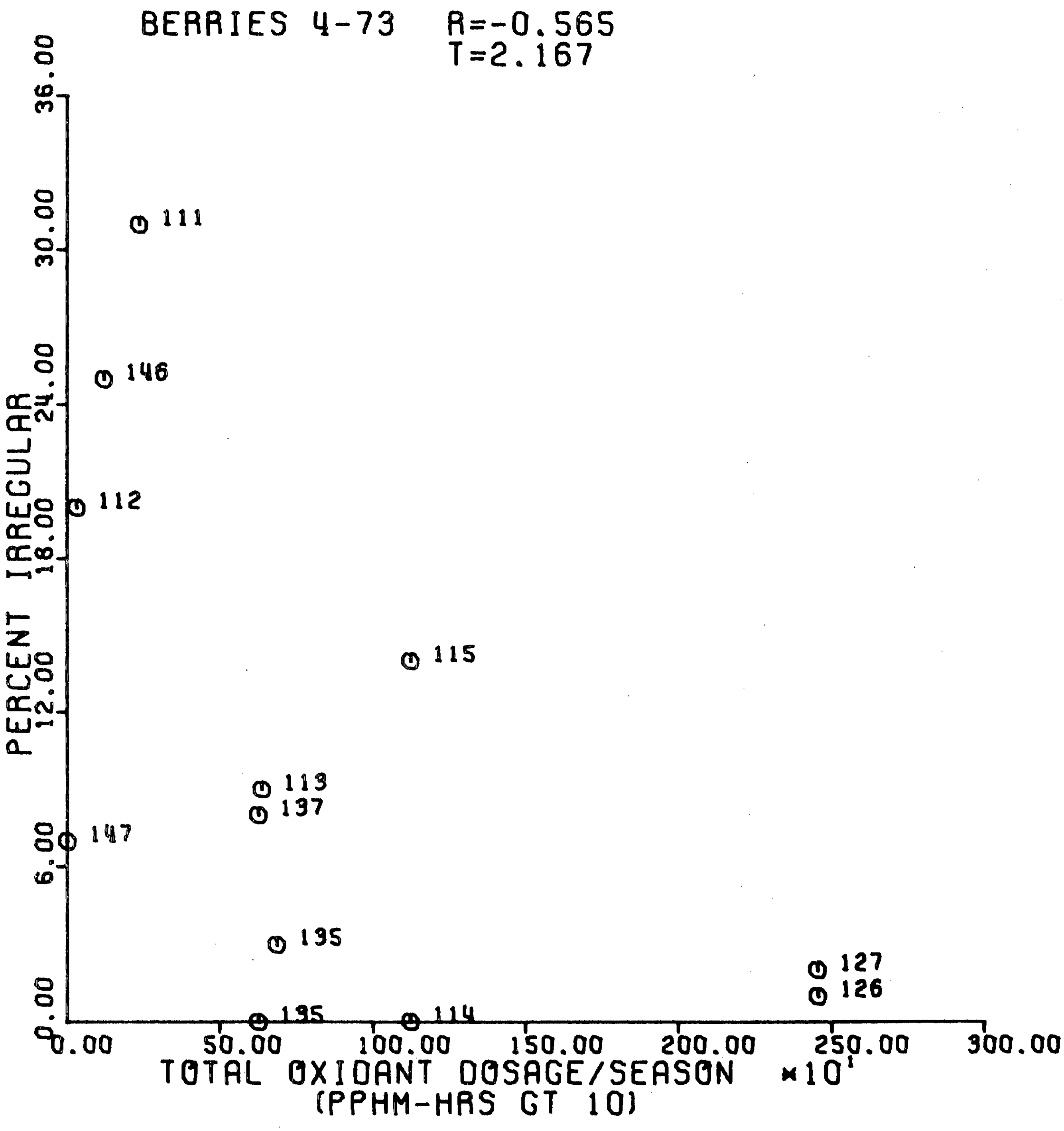


Figure 76. Correlation of mean weight of fruit from harvested commercial field plots in May 1973 with the total ambient oxidant dosage present during growth.

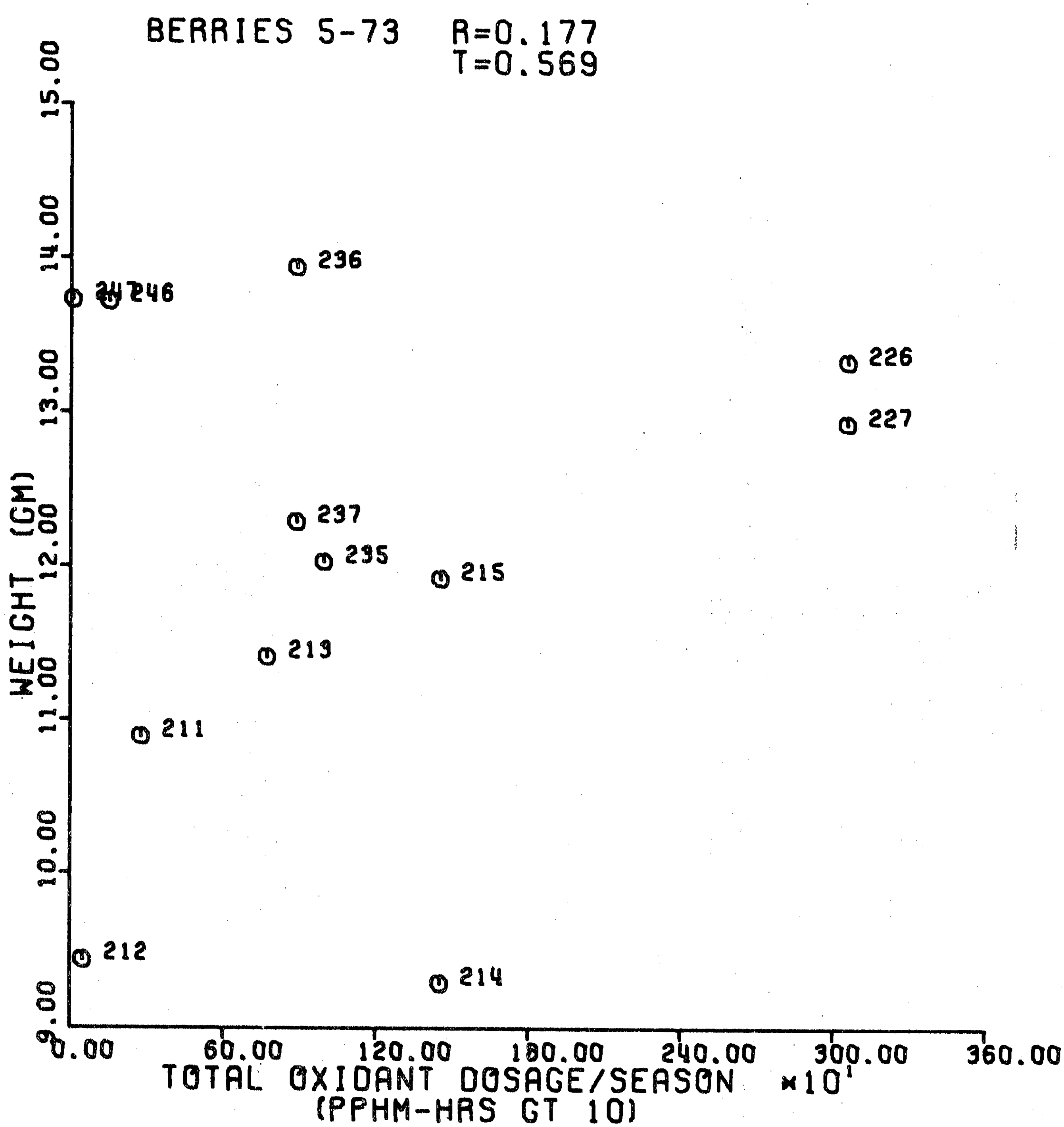


Figure 77. Correlation of percentage of irregular fruit from harvested commercial field plots in May 1973 with the total ambient oxidant dosage present during growth.

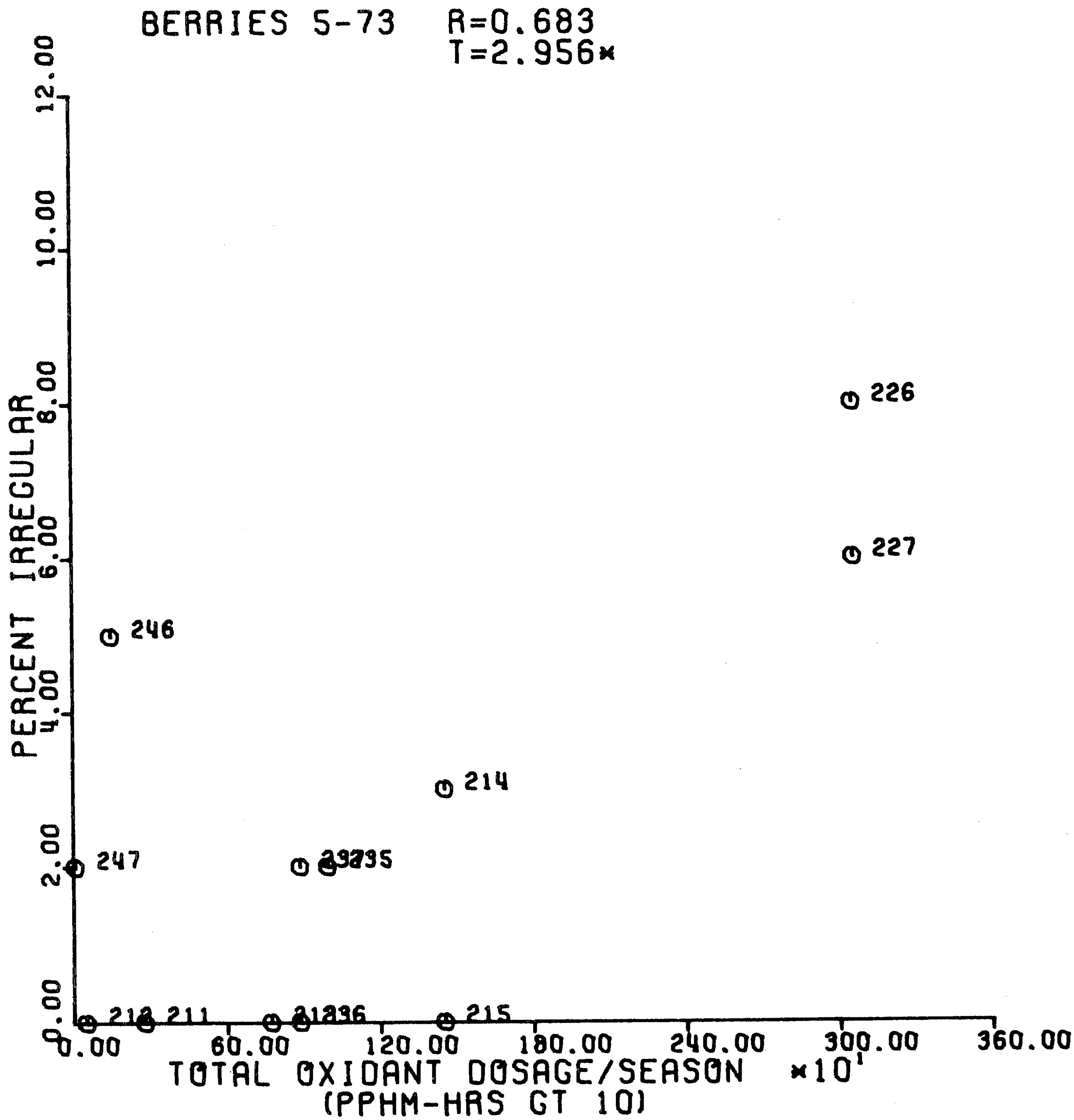


Figure 78. Correlation of mean weight of fruit from harvested commercial field plots in June 1973 with the total ambient oxidant dosage present during growth.

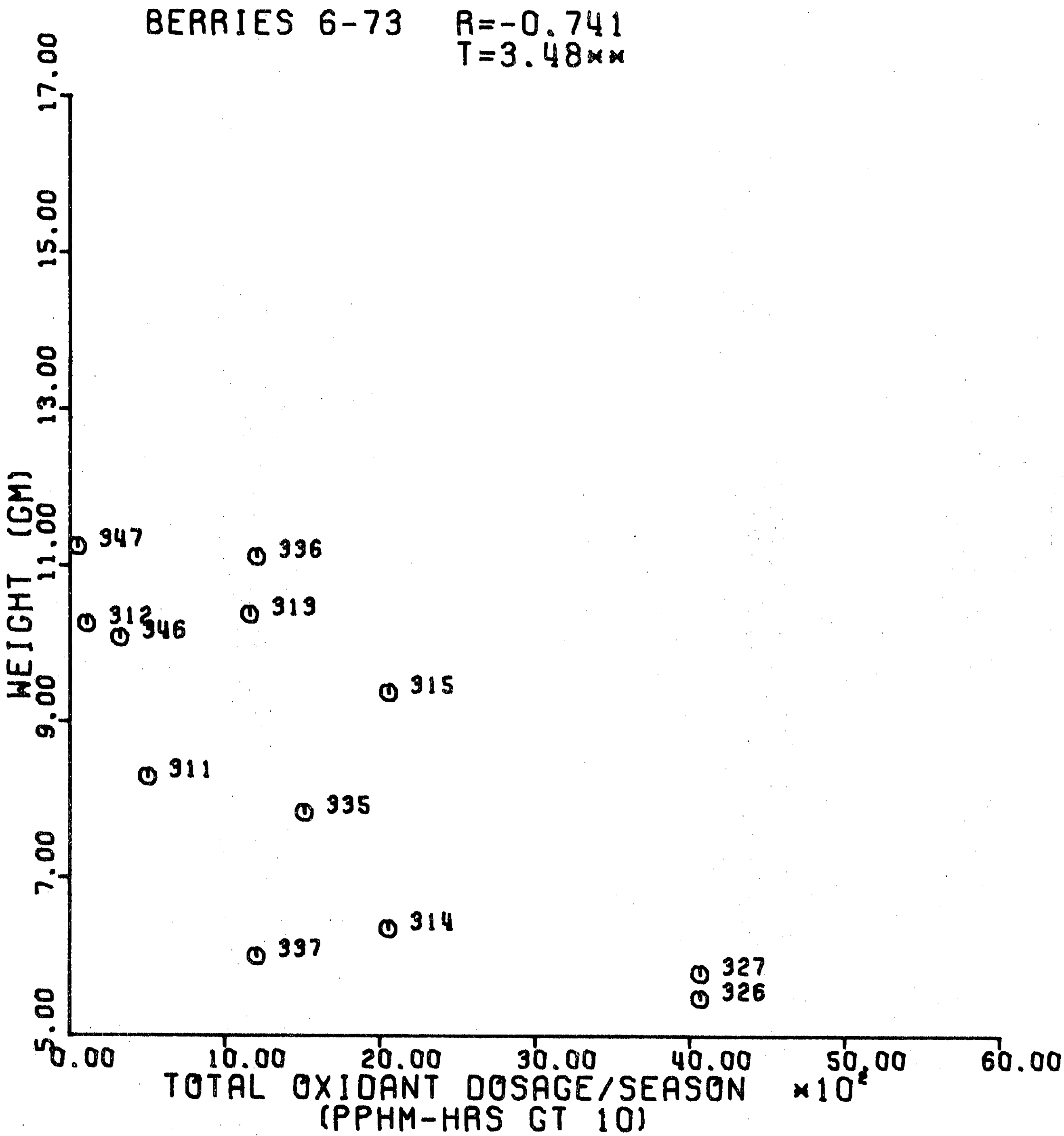


Figure 79. Correlation of percentage of irregular-shaped fruit from harvested commercial field plots in June 1973 with the total ambient oxidant dosage present during growth.

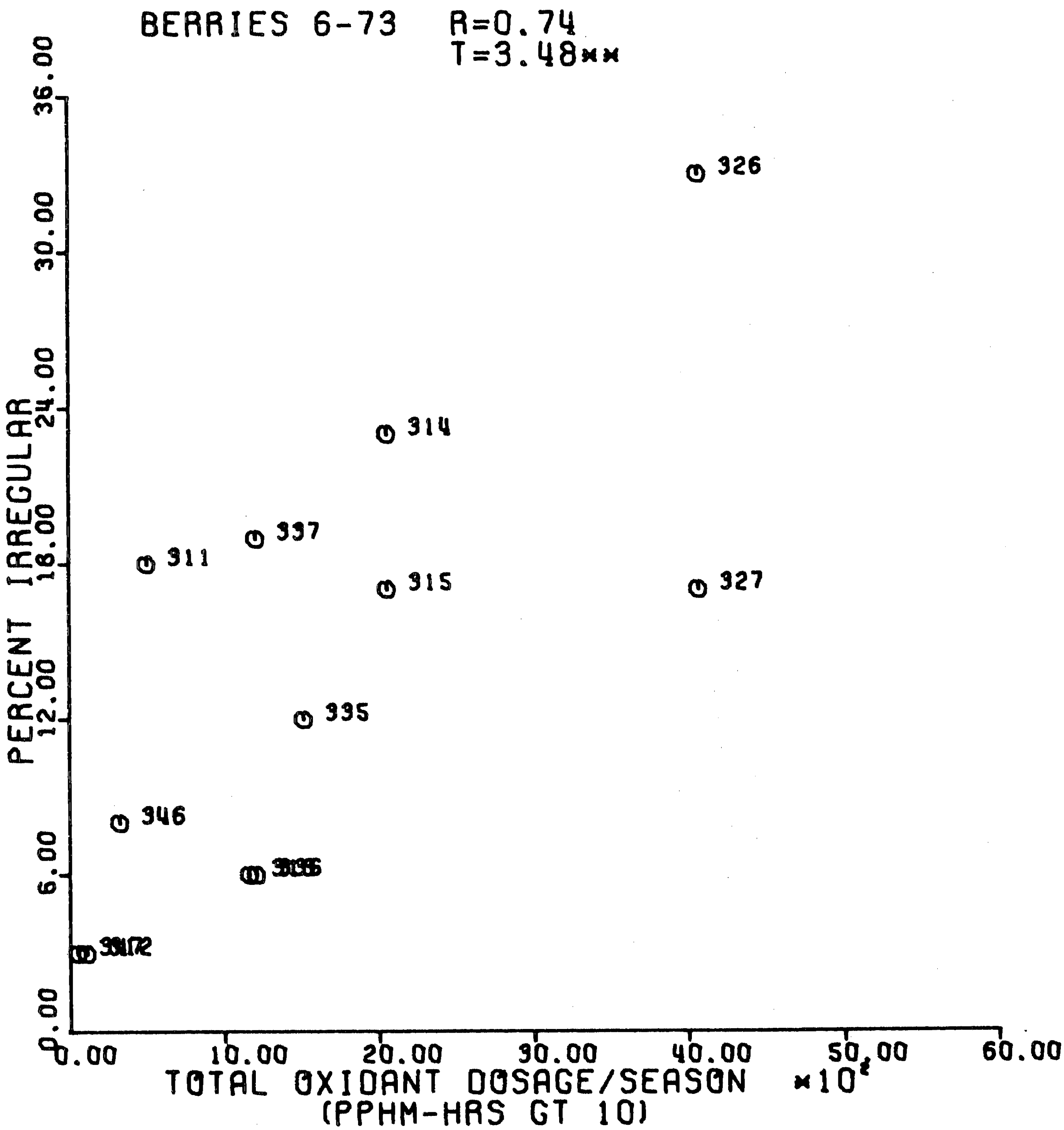


Table 20. Summary of ozone effects on Tioga strawberries as shown by percent reduction from the control treatment and the analyses of variance coupled with Duncan's multiple range test.

		Height			Diameter			Wet Weight			Dry Weight		
Ozone	0	-	a[1]	A[2]	-	a	A	-	a	A	-	a	A
Treatments	.20	1.14	a	A	-	a	A	-	a	A	-	a	A
(ppm)	.35	16	b	A	-	a	A	-	a	A	-	a	A

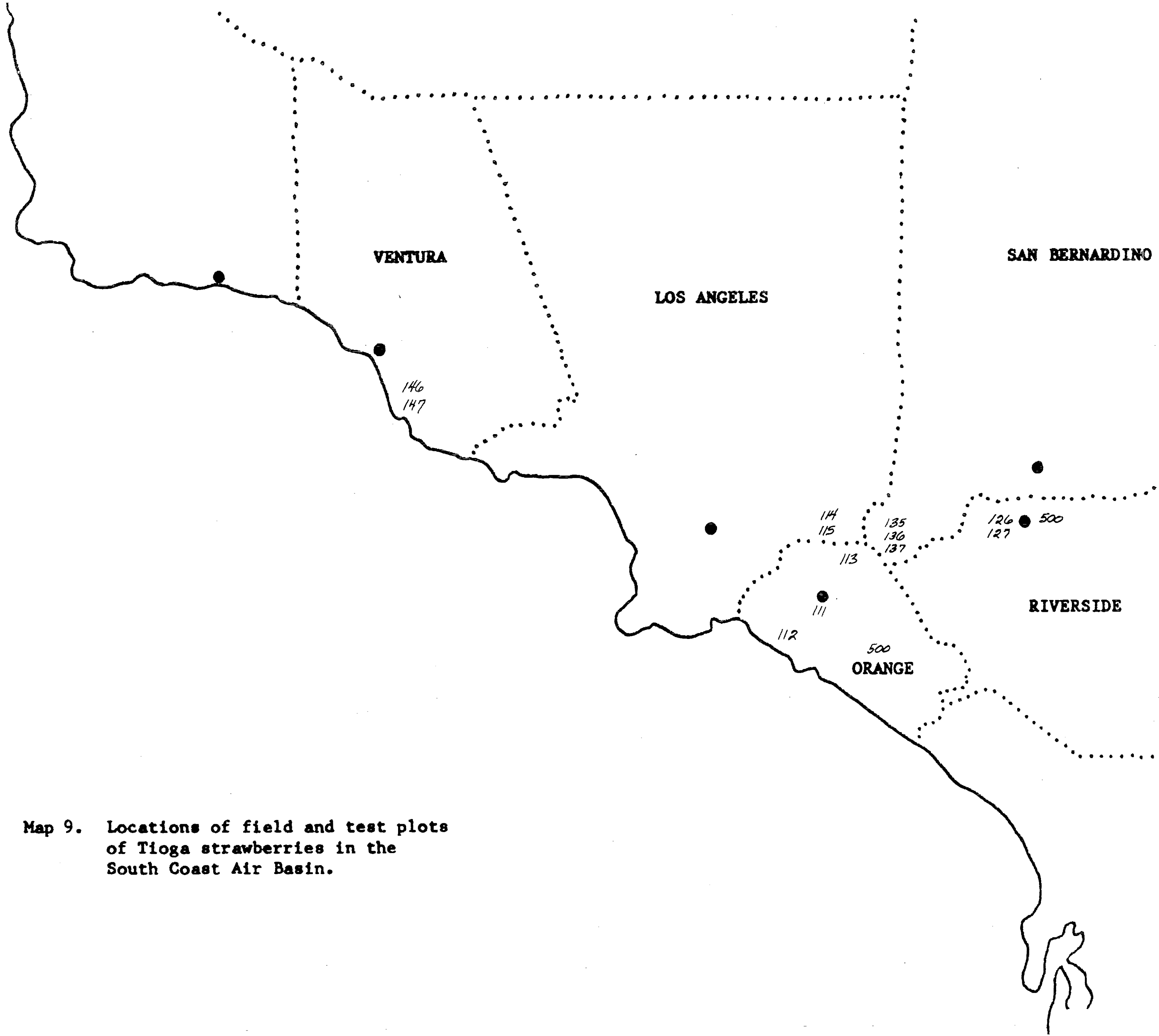
		# Leaves			# Berries (Left on Plant)			# Flowers			Total Berries Harvested		
Ozone	0	-	a	A	-	a	A	-	a	A	-	a	A
Treatments	.20	-	a	A	70	b	A	-	a	A	9.72	a	AB
(ppm)	.35	-	a	A	77.5	b	A	-	a	A	33.05	b	B

		Total Weight			Percent Irregular Berries			Average Berry Weight		
Ozone	0	-	a	AB	-	a	A	-	a	A
Treatments	.20	-5.8[3]	a	A	18.2	b	B	-	a	A
(ppm)	.35	26.97	b	B	14.15	b	AB	-	a	A

1. Percent reductions calculated from the treatment means followed by the same lower case letter are not significantly different at the .05 level.

2. Percent reductions calculated from the treatment means followed by the same capital letter are not significantly different at the .01 level.

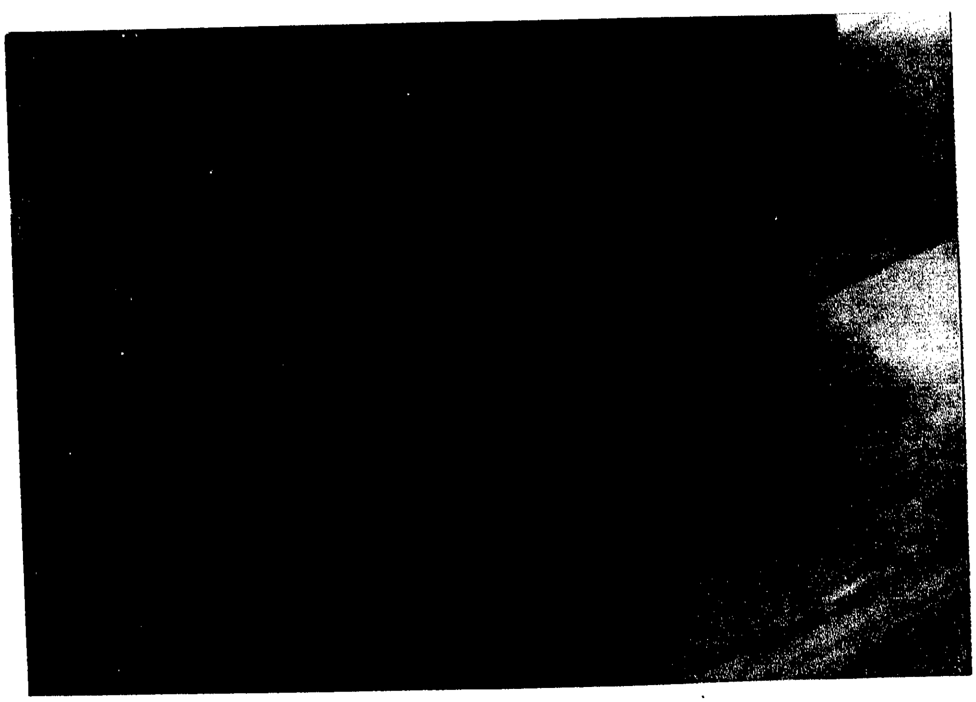
3. A minus percent reduction signifies a percent increase over that of the control treatment.



Map 9. Locations of field and test plots of Tioga strawberries in the South Coast Air Basin.

Plate 17. Effect of ozone on Tioga strawberry plants fumigated at .35 ppm.

Plate 18. Typical ozone injury on Tioga strawberry leaves.



CHAPTER XI – VALENCIAS

Summary

Field work was designed as a survey to determine whether ozone influences fruit quality of Valencia oranges. Apparently, effects are relatively minor or undetectable by this type of study as no significant correlations were detected between evaluated quality of Valencia oranges and total ambient oxidant dosages present during growth.

Introduction

Valencia oranges are commonly grown throughout the South Coast Air Basin and make up a major portion of the total citrus industry. This study had been concentrated on Valencias on Troyer rootstock, a popular disease-resistant rootstock commonly found in the study area. Groves of young trees between 9 and 13 years of age were selected to insure sampling the ascending slope of production curves.

No fumigations were initiated due to the expense of building fumigation facilities large enough to include a statistically acceptable number of bearing trees. Also, past field chamber studies on citrus provided information necessary to set up field studies (Thompson 1969, 1970).

Field studies for 1972 focused on the quality of field-grown fruit. Quality evaluations were then correlated with oxidant levels present during growth.

Field Study (Quality Effects) of Valencia Oranges

Locations: Ten commercial field plots of 9-13 year old Valencia oranges on Troyer rootstock were set up in the South Coast Air Basin (Map 10). Each location was monitored by three AMBI stations.

Sampling procedures: Each field plot was sampled prior to the commercial harvest at a time specified by the grower. One hundred fruits were harvested from 50 individual trees selected at random throughout the grove. The sampled fruits were taken at shoulder height from opposite sides of each tree, using a north-south directional bias whenever possible.

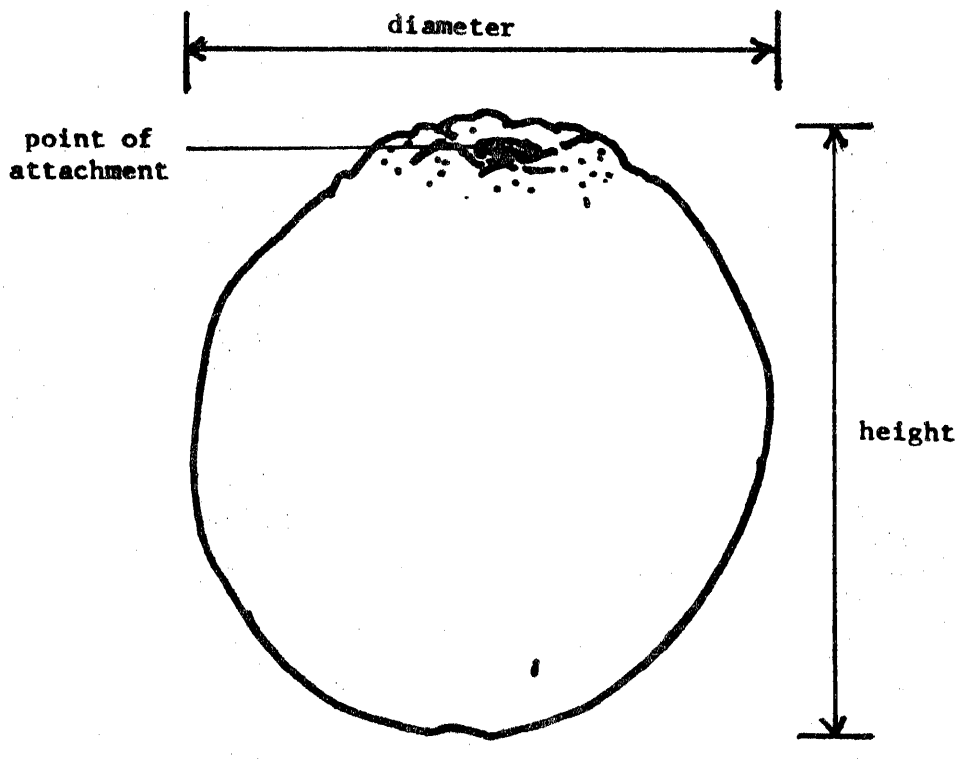
The fruits were evaluated for quality using arbitrary standards for blemishes, rind texture, and "smog damage." Weights and size measurements were also taken (Figure 80). The term "smog damage" was given to a peculiar type of injury not identifiable as common organic blemishes or insect wounds. Areas of rind tissue would die leaving the oil glands protruding. This area would be devoid of a margin of "off-color" or obviously dying tissue. This type of injury has not actually been associated with the presence of air pollution, but was labelled "smog injury" for lack of a better description.

Effect of oxidants on field-grown Valencia oranges: Some of the data taken from harvested oranges does not directly pertain to quality evaluation. Fruit height, diameter, and weight are measurements normally associated with yield studies, but, in this case are not indicative of yield differences. Harvests were not initiated at a uniform age or sugar content and these measurements are therefore not comparable. They are presented to illustrate the range of sizes and weights of the harvested fruit (Figures 81, 82, 83).

The correlations between fruit blemishes, rind texture and "smog damage" with the total ambient oxidant dosage present during growth proved to be insignificant (Figures 84, 85, 86).

Discussion: Previous chamber work with citrus (Thompson 1969, 1970) revealed that ozone may have a major role in reducing yields of citrus in areas of high pollution. Significant increase in leaf drop and CO uptake were also cited as effects of ozone and may reduce the vigor of affected trees and render them more susceptible to organic pests or ozone injury of fruit. This field survey grouped most types of organic injury into the major category of blemishes and evaluated the aesthetic consideration of rind appearance. Correlations of oxidant dosages were attempted to determine whether trends would appear to implicate ozone as being a factor in fruit quality. No final determination of these efforts was possible due to the lack of controlled conditions, but it may be speculated that if ozone were a major influence in determining quality, some indication should be detectable in such a survey. This was not the case, as all correlations were inconclusive.

Figure 80. Criteria for Measurements Taken on Valencia Oranges.



regular shape

Figure 81. Correlation of heights of harvested Valencia oranges with the total ambient oxidant dosage present during growth.

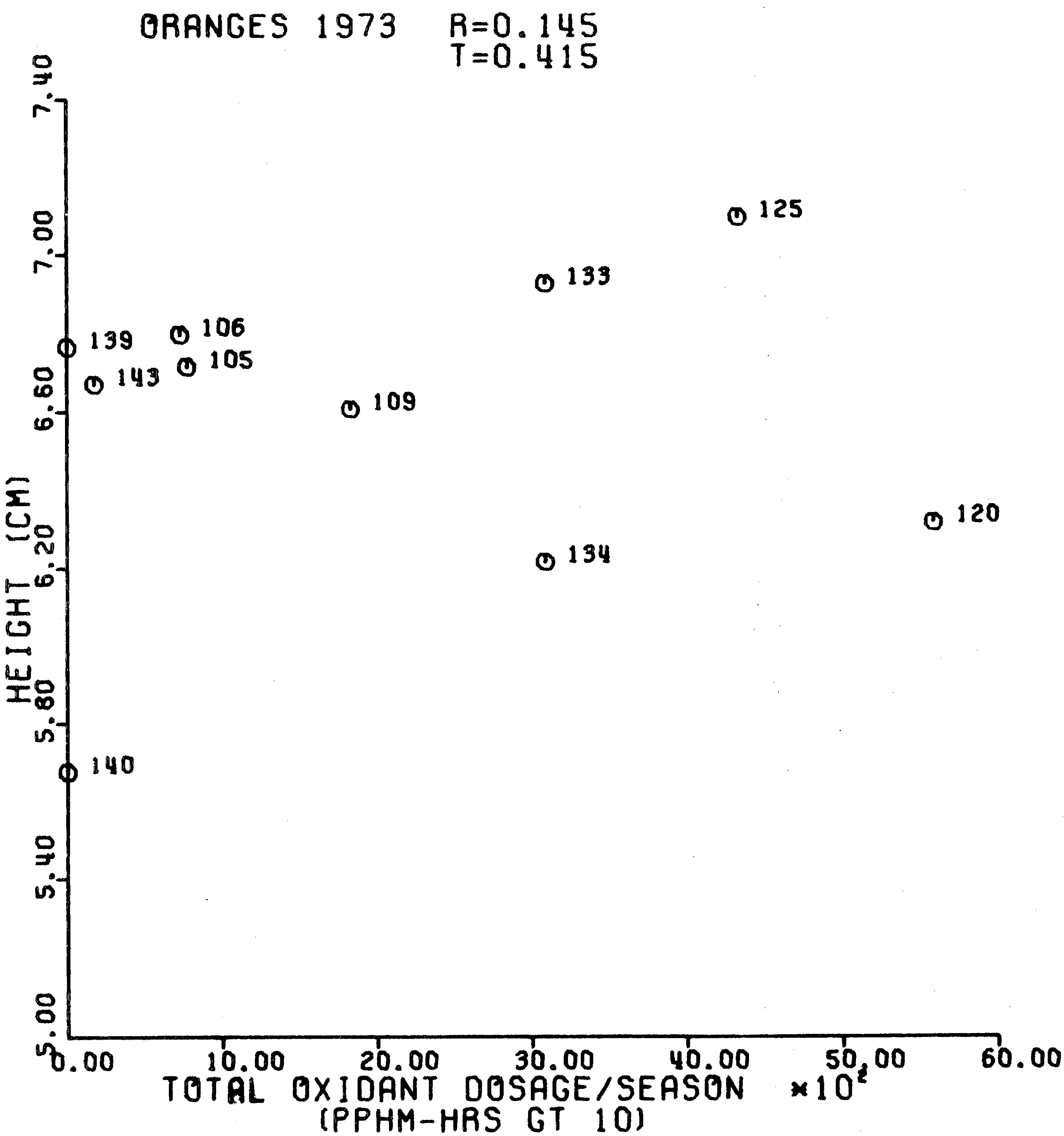


Figure 82. Correlation of diameters of harvested Valencia oranges with the total ambient oxidant dosage present during growth.

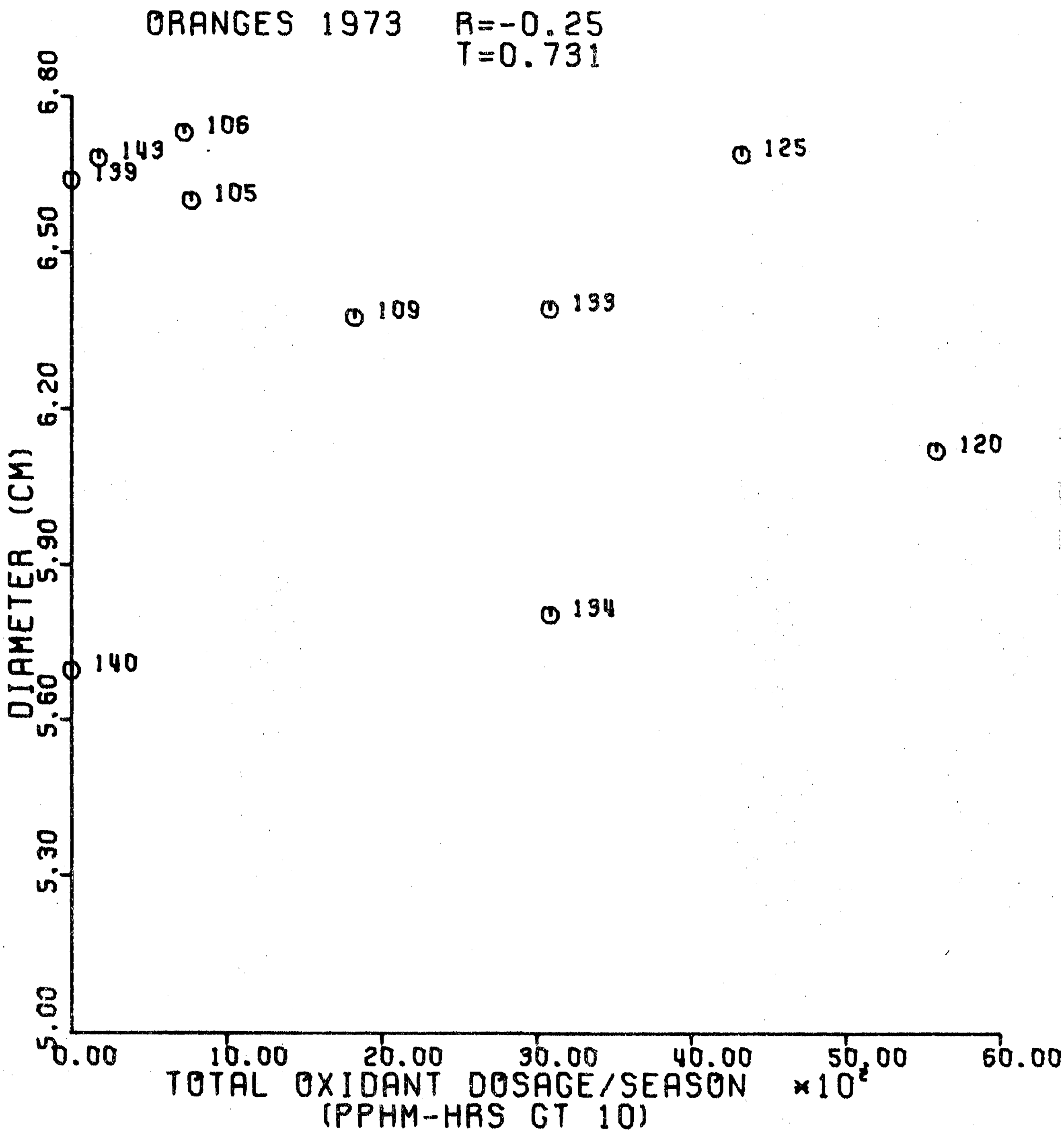


Figure 83. Correlation of weights of harvested Valencia oranges with the total ambient oxidant dosage present during growth.

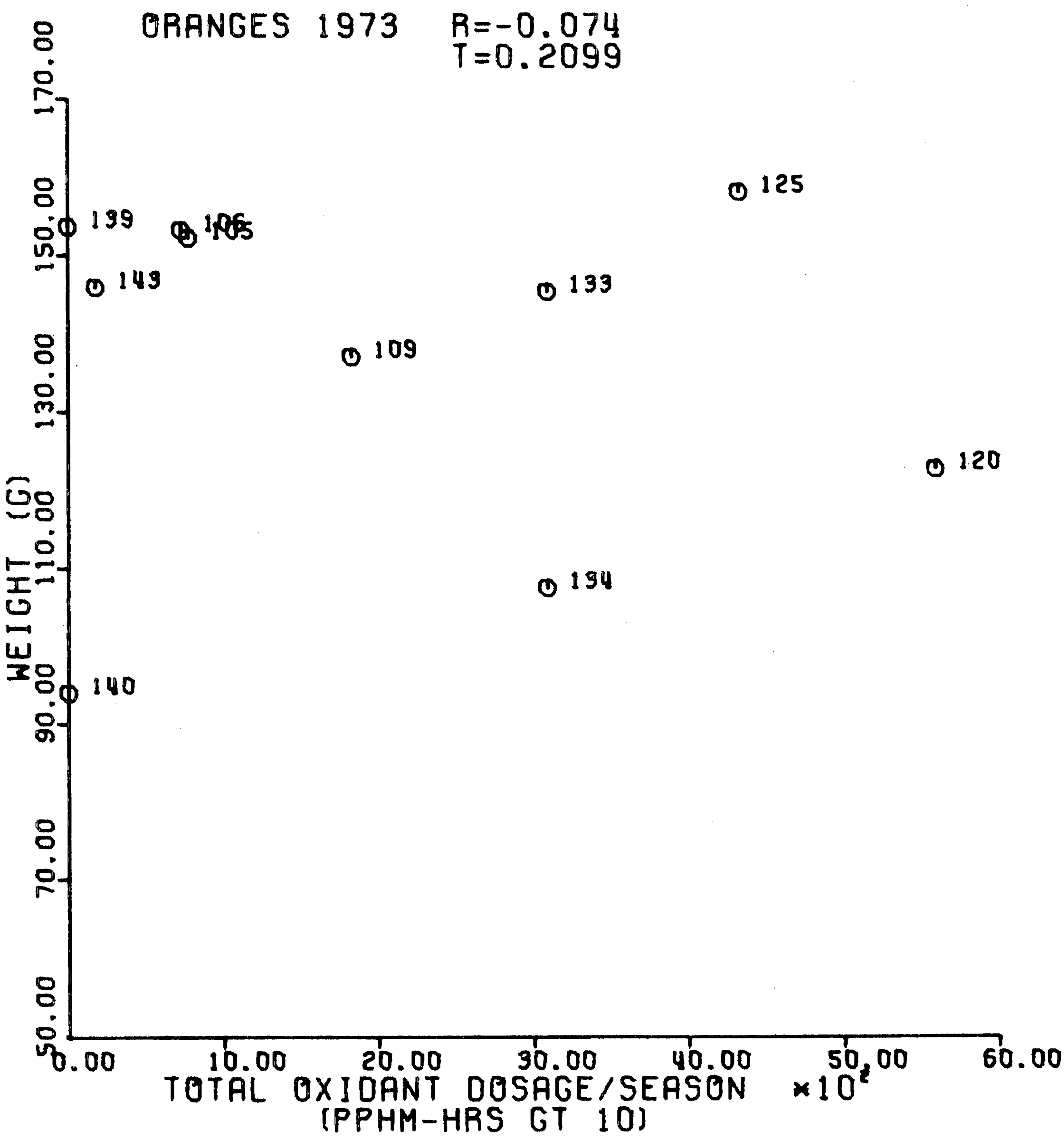


Figure 84. Correlation of the percent of harvested Valencia oranges displaying blemishes with the total ambient oxidant dosage present during growth.

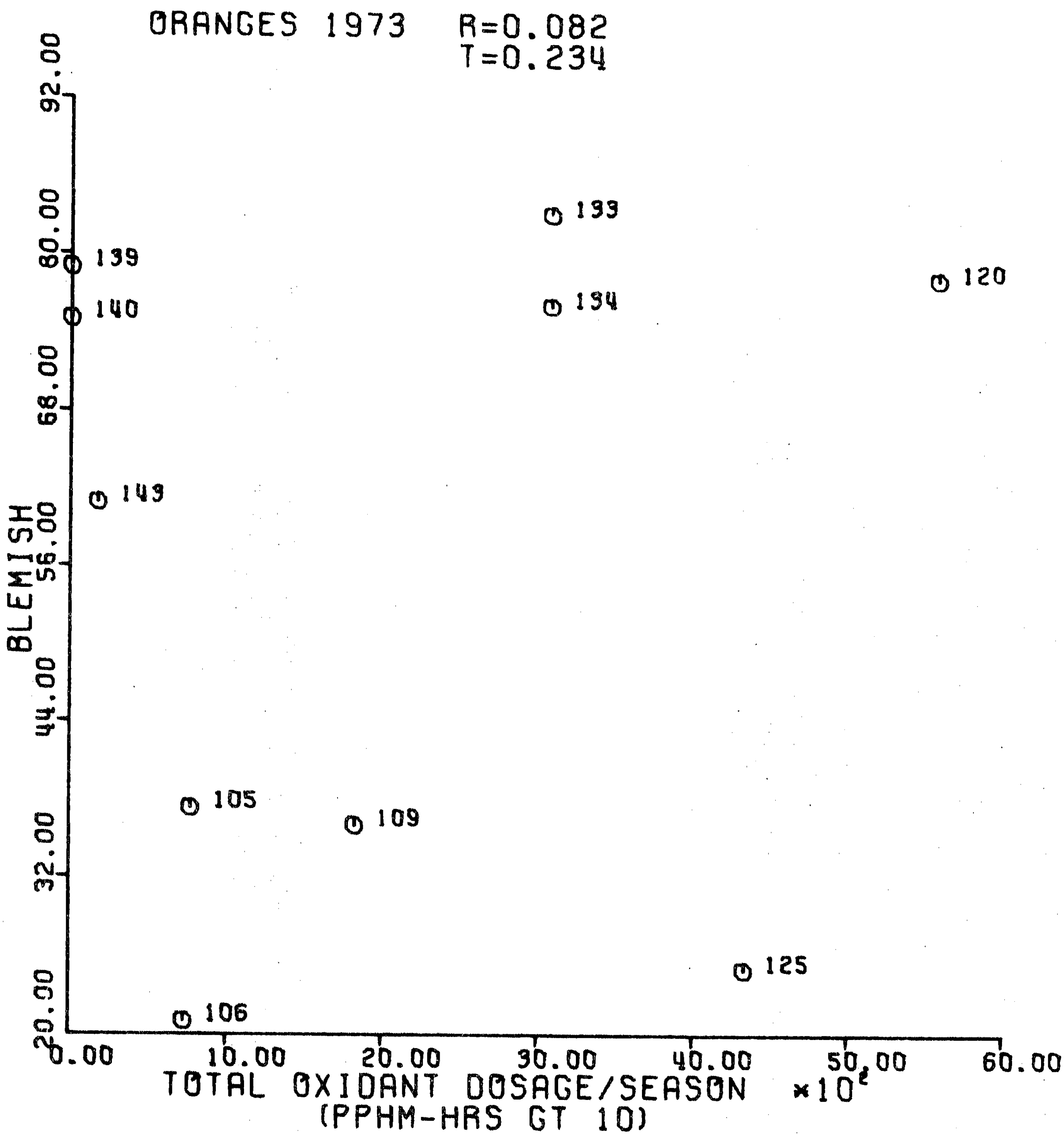


Figure 85. **Correlation of the percent of harvested Valencia oranges displaying rough rind texture with the total ambient oxidant dosage present during growth.**

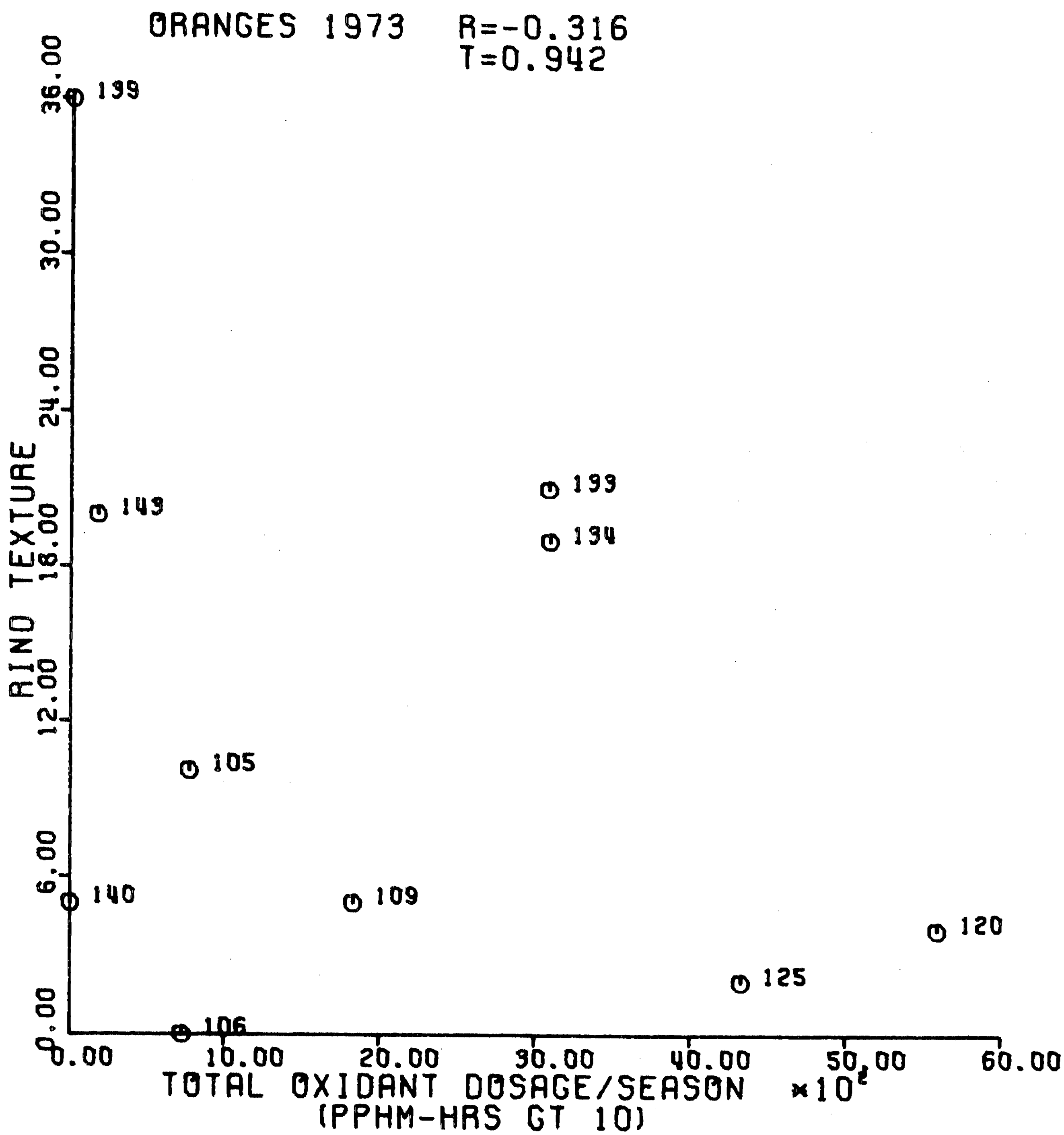
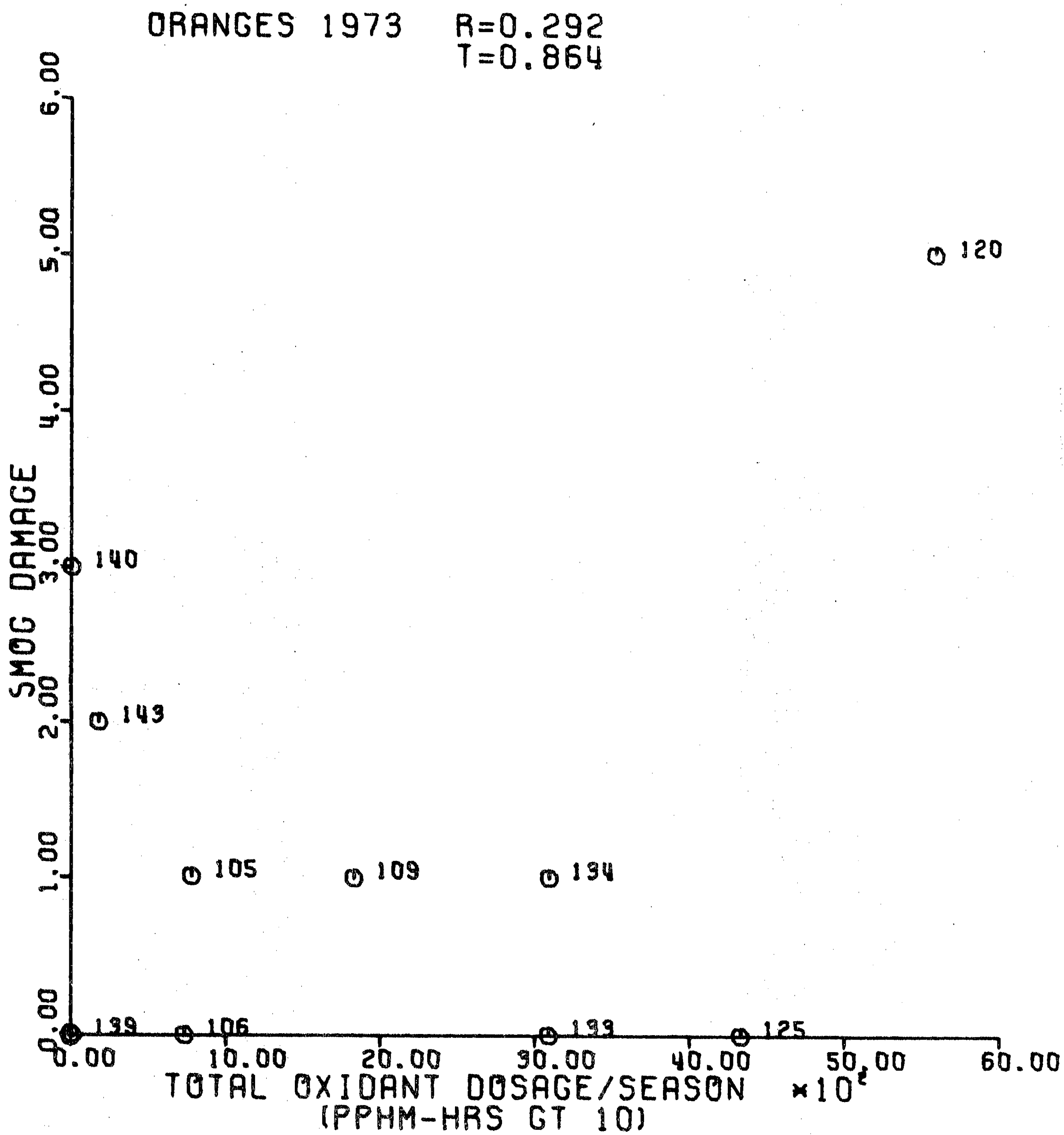
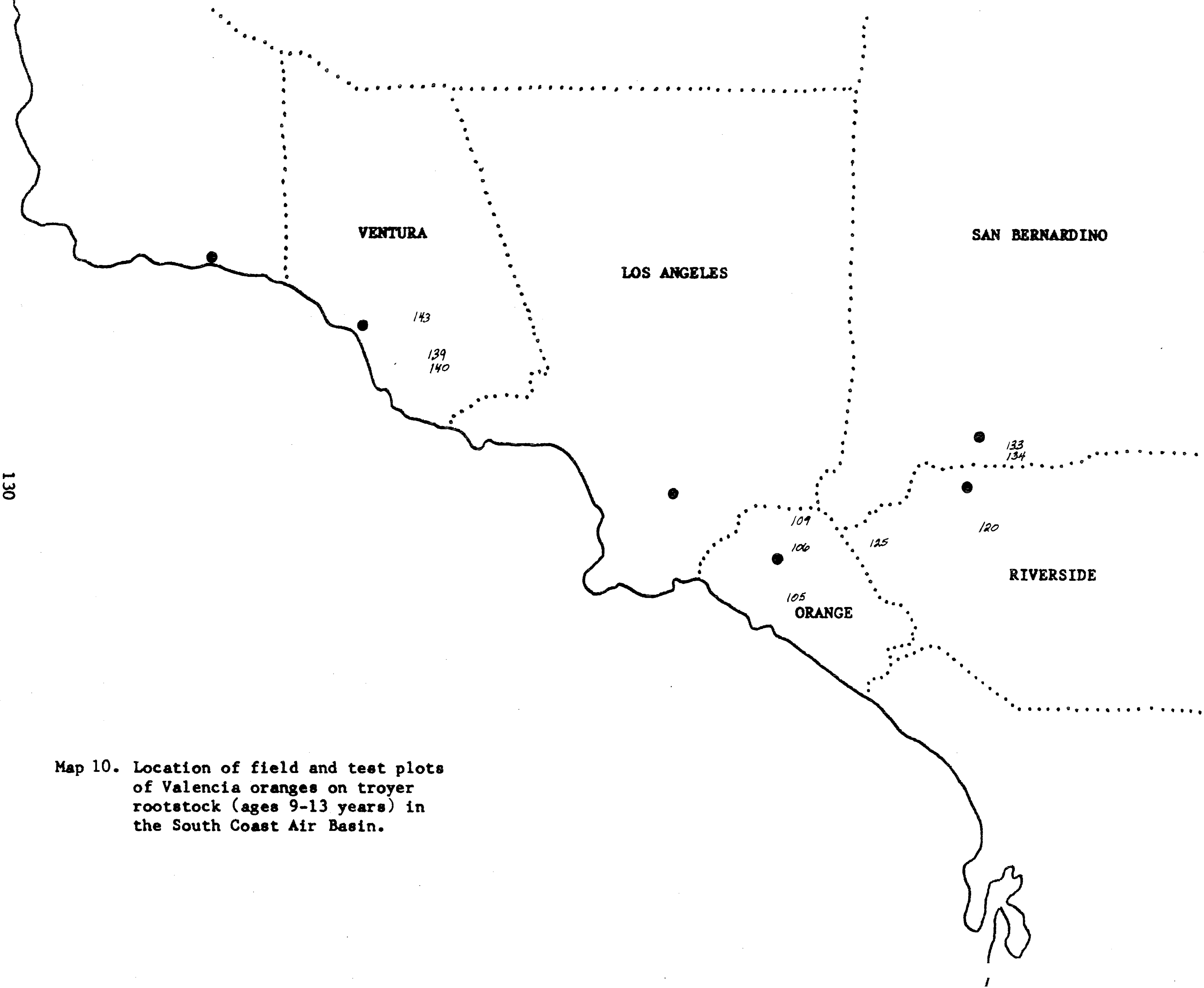


Figure 86. Correlation of the percent of harvested Valencia oranges displaying "smog damage" with the total ambient oxidant dosage present during growth.





Map 10. Location of field and test plots of Valencia oranges on troyer rootstock (ages 9-13 years) in the South Coast Air Basin.

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