6-1983

Effects of daminozide and ethephon on maturity of Red Delicious and Rome apples in Tennessee

Lauretta K. Warlick

To the Graduate Council:

I am submitting herewith a thesis written by Lauretta K. Warlick entitled "Effects of daminozide and ethephon on maturity of Red Delicious and Rome apples in Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Dennis E. Deyton, Major Professor

We have read this thesis and recommend its acceptance:

David L. Coffey, John R. Mount

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis
and recommend its acceptance:

John R. Mount

David L. Coffey

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

EFFECTS OF DAMINOZIDE AND ETHEPHON ON MATURITY OF RED DELICIOUS AND ROME APPLES IN TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Lauretta K. Warlick

June 1983

ACKNOWLEDGEMENTS

The author is sincerely grateful and appreciative for the assistance, guidance, and patience of many people. Foremost among them is Dr. Dennis E. Deyton, her major professor, for his encouragement, friendship, and continuous support in the completion of this manuscript. The author also expresses appreciation to Drs. David L. Coffey and John R. Mount for their assistance and guidance during the course of this research and for serving as members of the author's graduate committee.

The author would also like to thank Mr. Bill Kilpatrick and Dr. Charles A. Mullins for their guidance in planning and implementing the field research, and their assistance throughout the study.

The author is appreciative for the cooperation of Dr. Lloyd Seatz and the fellowship of all other members of the Plant and Soil Science Department.

Special thanks are extended to Douglas S. McSpadden for his patience and encouragement which he unselfishly gave.

Finally, the author would like to express her special appreciation for the guidance and support of her parents, Mr. and Mrs. William Lewis Warlick.

ABSTRACT

Succinic acid 2,2-dimethylhydrazide daminozide was applied at 0, 750, 1000, 1500, and 2000 ppm to 'Redchief Red Delicious' apple trees in 1981; and in 1982 at 0, 1000, 1500, and 2000 ppm to 'NuRed Rome' apple trees. About two weeks before normal harvest, daminozide-treated trees were sprayed with 0 to 300 ppm of 2-chloroethylphosphonic acid (ethephon) as an ethylene source and 10 ppm of sodium 1 napthalene acetate (Fruitone N), a synthetic auxin. The fruit samples were evaluated to determine treatment effects on maturity and quality.

In 1981, fruits harvested at time of ethephon treatment and for six weeks thereafter revealed that ethephon applied to fruit previously treated with daminozide increased soluble solids and percent red color. Daminozide, alone, reduced endogenous ethylene formation, and increased fruit firmness. Soluble solids were reduced as a result of daminozide applied at 1000 ppm or greater; however, with an application of ethephon, soluble solids were equal to that of the control fruit.

In 1982, fruit samples were harvested at time of ethephon treatment and for five weeks thereafter. Ethephon applied on fruit from trees previously treated with daminozide increased soluble solids and red color development, as observed by the Hunter color difference meter "a," "a/b." and "$\tan^{-1}$ a/b" values. Ethephon decreased firmness and weight on these fruits previously treated with daminozide. All daminozide treatments increased fruit firmness.

Soluble solids were reduced from an application of daminozide at 2000 ppm. In 1982, the ethephon application overcame the increased fruit firmness imparted by the 1000 and 1500 ppm daminozide treatments.

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CHAPTER I

INTRODUCTION

The success of apple growers is often related to their abilities to achieve consistency in apple quality and to have a competitive edge for early production on the apple markets. To achieve the kind of consistency in apple quality that the consumer and the market demand, the ability to control fruit maturity and ripening would be most beneficial to the apple industry. Various fruit indices, i.e., fruit firmness, fruit color, and soluble solids content are used to indicate apple maturity and quality.

Growth regulators used to effect maturity, ripening, and fruit quality have been studied on a regional basis. Growth regulator interactions have revealed the possibilities of controlling fruit maturity, and therefore of advancing or delaying harvest. To meet grower needs and consumer or market demands, growth regulator spray programs need to be developed on a local basis.

The objectives of the following study were to examine the effect of succinic acid 2,2-dimethyl hydrazide (daminozide), and 2 chloroethyl phosphonic acid (ethephon), on fruit maturity and quality of 'Red Delicious' and 'NuRed Rome' apple fruit in Tennessee. The practical intent of such treatments is to use daminozide as a fruit abscission retardent, followed by an ethephon application that could facilitate harvesting by advancing fruit maturity.

CHAPTER II

LITERATURE REVIEW

Proper maturity at harvest is important for success in growing apples. Maturity often refers to those conditions or changes in the fruit that would influence quality after harvest (55), but may apply to the entire course of fruit development.

The balance of natural hormones is necessary for sufficient development of an apple. The influence of this balance of natural hormones with exogenous growth regulators allows the grower to achieve specific objectives, such as regulating fruit ripening, or manipulating harvest dates. There are several phases of fruit growth that are important for the efficient use of plant growth regulators. After pollination, fruit growth begins and proceeds rapidly. Concurrent with cell enlargement, intercellular air spaces develop and increase in size. Cell division, cell enlargement, and air space formation result in the sigmoidal (s-shaped) growth curve normally associated with apple fruit growth (55). The internal hormone balance changes throughout the course of maturation or fruit development. A decreasing level of gibberellin and increasing level of abscisic acid mark the onset of the ripening process (36, 55). As the abscisic acid level dominates gibberellic acid level, ethylene synthesis increases. It has been demonstrated that ethylene reduces both the synthesis of and the amount of auxin in leaves (54). The auxin-ethylene balance, suggests Carns (11), controls fruit abscission. In this system auxin delays the initiation of the process while ethylene stimulates and initiates it. Ripening, therefore, proceeds only when this proper internal level of natural hormones is balanced.

Ethylene is produced at a low and constant rate as fruit develops on the tree. During the last few weeks of fruit development the ethylene production rate increases, initiating the ripening process (9, 10, 38, 42, 43). Over the course of 7 to 10 days, the ethylene content may increase from a level of 0.1 to above 10 ppm as ripening begins. This increase in endogenous ethylene content is usually followed by a sharp rise in fruit respiration. Respiration of the fruit is initially high during the cell division stage, then declines as maturity is approached, and remains relatively low until it rises with the onset of the respiratory climacteric. This rapid rise in respiration marks the onset of the ripening process and the physiological maturity of the fruit.

Burg and Stolwijk (7) were the first to describe the design and construction of a gas chromatograph for the measurement of ethylene. Burg and Thimann (8) were the first to apply the technique to ethylene physiology in fruit. Ethylene measurements have recently been determined to assess fruit ripening. A small portable gas chromatograph, the "Snoopy" Ethylene Detector, was developed in 1978 in the Post-Harvest Research Laboratory of the Horticulture Department at Michigan State University to assess fruit ethylene content and thus fruit ripening (14). Ethylene determinations on 'Red Delicious' apples in 1979 allowed growers in Washington to delay harvest dates, which resulted in improved fruit grade to 95% extra fancy quality (14).

Seeley increased D'Anjou pear yield 25% by sampling ethylene and delaying harvest one week (14). "Snoopy" has also been used to detect gases in storage and to assess storability of late season 'Red Delicious' apples (14).

Fruit Maturity Indices

Fruit growth involves several changes during maturation which culminate in optimal harvest maturity. Maturity varies with the intended use of the fruit, i.e., fresh market, canning, freezing, or drying. Maturity indices are factors commonly measured to indicate the stage of fruit development for a particular use (54).

In addition to increased respiration and ethylene content, the following factors have contributed to estimating harvest maturity: days from full bloom (24, 25), fruit firmness (25, 44), fruit red peel and ground color (25, 37), and content of soluble solids and acids (26, 44).

Results of studies in Virginia suggested 'Delicious' apples should have no more than 8.4 kg (18.5 lbs.) fruit firmness and no less than 11% soluble solids to be ready for harvest (37). However, this scale should be adjusted down 1.0 lb. (0.4 kg) in firmness for each 0.5% soluble solids greater than 11%. In West Virginia, Ingle (27) found 10.5% soluble solids content was the most reliable index of maturity for 'Delicious' apples. Climate and variety, however, will often cause these figures to vary.

The number of days from full bloom (DFFB) to picking maturity is rather constant over a wide range of climatic and cultural conditions. According to Haller, this is one of the most reliable indexes of maturity (24). The time required to mature 'McIntosh' and 'Delicious' apples varied according to occurrence of bloom date. A two day delay from average bloom date resulted in a decrease of one day to mature 'Delicious' apples. According to the sliding scale for firmness and soluble solids suggested by Mattus, harvest for 'Delicious' utilize the range of 135 to 140 DFFB (37).

Fruit color has been shown to change as quality improved and stage of maturity advanced. Surface color varies with each cultivar. Often, cultivars were harvested at an overmature stage because they were left on the tree too long in the hope of developing better color. It has been suggested that fruit skin color alone is too variable to be recommended as an accurate indicator of maturity (25). Until recently, color was rated subjectively. Evaluation by more than one evaluator probably induced more variability in color ratings. With the use of the HunterLab Color Meter, objective measurements for the skin color of apples can be determined (23). The Hunter L, a and b scales are used in several commercial colormeters. The "L" value represents the range from 100 (perfect white) to 0 for black. The "a" measures red intensity when positive, gray when zero, and green when negative. Positive "b" values measure yellow intensity, gray when zero, and blue when negative. Francis (23) recorded "a" and "b" values for each apple and determined that $\tan^{-1} a/b$ provided a better evaluation of apple color than a, b, or the ratio of a to b.

Influence on Ethephon

A major problem in growing apples is knowing when to harvest the fruit for optimum fresh market or storage qualities. As discussed previously, apples increase ethylene production just before ripening. Exogenous applications of ethylene encourage an early release of endogenous ethylene. The release of ethylene by ethephon has been shown to promote uniform red color, hasten ripening, and precipitate fruit loosening (5, 10, 18, 32). A uniformly ripened fruit at harvest means fewer trips for pickers and lower machine costs for mechanical harvest. Edgerton and Blanpied (18, 19) and Looney (33, 34) reported that ethephon advanced fruit maturity by accelerating color development and fruit abscission on 'McIntosh' apples. Unrath's results on 'Delicious' apples also support the color promotion and abscission stimulation responses credited to ethephon (51). However, fruit color was stimulated only when ethephon was applied to the fruit surface, and a direct relationship existed between coverage and color response (52). Unrath (51) observed that ethephon reduced the acidity of 'Starkrimson Delicious' fruit, which increased the soluble solids-acid ratio. Schumacher (41) reported that the ethephon-treated apples were often preferred by taste panels. No odor defects were found in the juice or wine made from the treated apples. All these responses occurred within the time span between application of ethephon and harvest. Early harvests can enable growers to supply the apple market one to two weeks earlier than normal and take advantage of higher prices. Uniform red color and better flavor could mean a higher percentage of extra fancy fruit as opposed to fancy fruit (market grades) (53).

Because of the strong effect of ethephon on red color development of apples its use in fruit production is desirable. However, ethephon used alone results in excessive dropping of fruit before harvest can be completed. The synthetic auxins 2,4,5-TP and NAA have been shown to counteract the abscission of mature fruit induced by ethephon (1, 19, 31, 36, 45, 49, 50), while permitting ethylene to accelerate maturity and color. Southwick and Anderson (45) reported that 2,4,5-TP applied three weeks prior to harvest stimulated ripening and color development of early and mid-season apple varieties. However, to take full advantage of fruit drop control, he suggested that 2,4,5-TP should be applied nearer to the time drop normally began. Application of 2,4,5-TP one week before harvest has been suggested; however it was noted that at least three days were required before 2,4,5-TP effectively controlled drop (45). Unrath's (51, 52) studies on 'Delicious' apples, and Pollard's (39) work on 'McIntosh,' reported the effect of ethephon plus 2,4,5-TP significantly increased red color development. The combination of ethephon and 2,4,5-TP has allowed growers to increase and obtain more uniform red color at harvest, as well as control fruit drop.

Looney (31), using 'McIntosh,' indicated that 20 ppm of Fenoprop [2-(2,4,5-Trichlorophenoxypropionic acid)] accelerated fruit softening considerably, in addition to preventing fruit abscission. Both Fenoprop and ethephon have been reported to soften fruit (15, 31, 32). Unrath reported that the combined effect of ethephon and

Fenoprop was responsible for the accelerated softening, but only when both fruit and leaves receive an application of these materials (52). His studies also indicate the level of softening would be substantially reduced if the Fenoprop concentration is reduced to 10 ppm.

Influence of Daminozide

One of the most consistent effects of daminozide has been excellent control of pre-harvest drop (3, 4, 16, 20, 21, 22, 40, 45). Daminozide sprays of 500 to 4000 ppm have been shown to reduce pre-harvest drop to a significant degree (17, 22, 45, 46). This has been reportedly achieved by daminozide's suppression of ethylene production (19, 33, 34). Studies of the effect of daminozide alone on optimum harvest dates and the keeping quality of apples revealed increased fruit firmness (4, 22, 46, 47, 56), and coloring on red varieties (16). There has been some evidence, however, that this firmness is reduced with prolonged storage, and that this advantage had disappeared by mid-January (4, 46).

Daminozide sprays have reduced fruit size (2, 16, 21, 22, 28, 55), but it has been suggested that this effect may be minimized by using concentrations of 1000 ppm or lower or by withholding applications until August. Daminozide (1000 ppm) applied to 'Red Delicious' apple trees at 80 and 125 days after full bloom caused flattened, misshapen fruit the following season (58). However, only the fruit on trees treated with daminozide at 125 days after full bloom were flattened enough to significantly affect the commercial grade. The daminozide treatments increased fruit set and decreased the size of the fruit the following year. It has been suggested that fruit size responses to growth regulators were usually caused indirectly, by altering the crop load, or time of fruit maturity (20).

Daminozide delayed harvest drop, according to Looney (30), while also delaying the onset of the respitatory climateric. A delay in respiration rate might account for the improvements in storage and shelf life observed by Fisher and Looney (21). Aside from maintaining fruit firmness, daminozide has shown little effect on the more common indices such as soluble solids (21, 46) and titratable acidity, and soluble solid/acid ratio (45, 46).

In relation to storage disorders, reports have related daminozide treatment to the occurrence of scald, indicating that in most cases daminozide reduced scald severity and watercore (4, 57). Storage scald is associated with fruit immaturity and watercore with advanced maturity. This effect is probably accomplished by daminozide's delay of the rise in ethylene production and the climateric rise which characterizes ripening; however, daminozide sprays would not be expected to reduce both of these storage disorders if delayed maturity was the only determining factor. Williams (57) has recently explored the decline in leaf sorbitol (sugar alcohol) levels in relation to watercore in apples. As watercore developed, the sorbitol level in the fruit increased. The possibility of deminozide altering this relationship is currently under study.

Daminozide and Ethephon Interactions

Experiments by Edgerton and Blanpied using daminozide and ethephon revealed that the appearance of large amount of ethylene in daminozide-treated fruit was delayed a week or more (19). Endogenous ethylene increased in the control fruit as the normal harvest drop was initiated. They suggested that daminozide delayed ethylene evolution, which resulted in delayed fruit abscission. When ethephon was applied 10 days before normal harvest to daminozide-treated fruit, ethylene synthesis increased and abscission followed its normal course (11, 19, 20). Thus it seems apparent that the auxin level is not responsible for the abscission delaying effect induced by the daminozide.

Daminozide has been shown to delay the onset of the respiratory climacteric by decreasing CO_2 production (respiration) (4, 21, 29, 30, 31, 34, 46, 48). With the addition of ethephon and an auxin, this delay in respiration was eliminated.

Looney (30, 31) reported the combination of daminozide and ethephon increased red color significantly. In fact, the brightest red color (as opposed to the waxy, dull appearance of fruit picked during late harvests) resulted from a combination of the daminozide, ethephon, and 2,4,5-TP treatments. Foliar sprays of daminozide and ethephon, alone or in combination, have been used to influence red color development and quality of apples. Daminozide enhanced red color development, but not to the same extent as ethephon (12, 14, 19, 31, 39). By increasing harvest drop, a pre-harvest spray of ethephon and 2,4,5-TP on trees which had previously received daminozide overcame the abscission delay imparted by the daminozide (15, 19, 32). Fruit firmness and percentage of red color were significantly increased. However, fruit was less firm than fruit that received only the daminozide treatment.

When daminozide and ethephon were combined, greater red color development occurred than when either was used alone, and the combination resulted in partial cancellation of the individual effects of fruit firmness and fruit drop (19, 30, 48).

The abscission delaying effect of daminozide, as evidenced by the delayed rise in CO_2 and ethylene production, indicates a delay in ripening. With the application of ethephon, ethylene is released within the fruit to offset the delay in ripening. As a result, this increases coloring of daminozide-treated fruit. The abscission stimulated by ethephon can be offset with the use of an auxin, i.e., 2,4,5-TP resulting in a continuation of fruit ripening and coloring on the tree for higher quality and market value.

CHAPTER III

MATERIALS AND METHODS

Spray Schedules and Harvest Techniques

The 1981 experiment was conducted at the commercial apple orchard of Bill Kilpatrick in Sevierville, Tennessee. Daminozide and ethephon were applied as full dilute foliar sprays by an air-blast sprayer on June 18 and August 6, respectively. Three-year-old 'Redchief Red Delicious' trees on a 14' x 22' spacing were assigned a randomized complete block design with split plot arrangement of treatments. Five replicates consisting of 10 trees each were used in this test. Two weeks before anticipated harvest, the main plot was treated with 0 or 300 ppm ethephon (2-chloroethylphosphonic acid) plus 10 ppm Fruitone (Sodium 1-napthalene acetate) applied within one week of the ethephon application. Subplot treatments were 0, 750, 1000, 1500, and 2000 ppm daminozide. At the time of ethephon application, and for six consecutive weeks thereafter, four apples were selected at random from each tree and evaluated for fruit maturity.

As a result of a late spring frost in 1982, the experiment could not be repeated on 'Redchief Red Delicious.' Therefore, 'NuRed Rome,' a later-maturing variety than 'Redchief Red Delicious,' was chosen at another location for evaluation in 1982.

The 1982 experiment was conducted at the Plateau Experiment Station in Crossville, Tennessee. Daminozide and ethephon plus 10 ppm Fruitone were applied as foliar sprays on July 6 and September 7, respectively, to nine-year-old 'NuRed Rome' apple trees spaced 20' x 20'. A randomized complete block design with split plot arrangement of treatments with four replications was used in this test. Each replication consisted of eight trees. The main plot was treated with 0 to 300 ppm ethephon two weeks before anticipated harvest. Subplot treatments used 0, 1000, 1500, or 2000 ppm daminozide. Both treatments were applied to full dilute with a three-gallon, compressed CO_2 sprayer at 40 psi. At the time of ethephon application, and for five consecutive weeks thereafter, five apples were selected at random from each tree and evaluated by the same quality variables as in the 1981 test. Due to mechanical difficulties, the test for ethylene was not repeated in the 1982 evaluation. Additional color readings were obtained with the use of a Hunter Color/Difference Meter (D25M-2).

Quality Parameters Evaluated

Seven parameters were measured for each fruit sample within 24 hours after harvest. Red surface color was estimated visually to the nearest 5% in 1981. In 1982, color readings were measured by rotating the apple approximately at 200 rpm above the exposure port of the Hunterlab Color Meter (D25M-2). Color was calibrated against a white enamel tile and values for Hunter "a" (+red, -green) and Hunter "b" (+yellow, -blue) were taken. Evaluations of Hunter "a," "b," "a/b," and "$\tan^{-1}$ a/b" values were recorded after each harvest with the exception of the initial harvest (117 DFFB). All color values were recorded beginning with the second harvest (125 DFFB). A transformation of these values was done by performing an inverse tangent of the "a/b" ratio. Fruit firmness was measured with a hand-held fruit pressure tester (Effegi, Model FT 327, 3-27 lbs.), using two readings per apple on opposite sides of the fruit. Fruit weight was recorded to the nearest gram. Diameter was measured with a ban sizer (Cranston Machinery Corporation), and length was recorded with a dial caliper (Mitutoyo, Model 505, ± .02 mm accuracy). Changes in fruit shape are reflected in the length diameter (l/d) ratio. Soluble solid content was determined by a hand refractometer (American Optical Corporation), with an index of 0-30%. In 1981, ethylene was recorded with the use of the "Snoopy" Ethylene Detector, a portable gas chromatograph which detected ethylene concentration from 0.1 to 10 ppm in a 1 ml. gas sample. Compressed breathing air from a high pressure cylinder was used as the carrier gas at 5 psi and a flow rate of 20-25 ml./min. Fruit was placed in 1 1/2 pint freezer containers and allowed to sit for one hour. Sampling was completed by withdrawing 1 ml. of gas with a syringe through a septum in the freezer container lid.

Definition of Date and Days from Full Bloom

In this study, date was defined as the Julian date. The interval of days from full bloom (when 80% of the flowers were fully open) to the date (Julian) when apples were harvested was defined as days from full bloom (DFFB).

Data Analyses

Analysis of variance as a split plot and Duncan's Multiple Range test (5% level) were performed to observe treatment effects among variable means. A GLM was performed to show the effect of daminozide treatment and harvest date on those variables influenced, as observed in the Duncan's Multiple Range test. If treatment and harvest data had significant interaction in the ANOVA, a multivariate analysis (MANOVA) was performed to determine if treatment influenced the relationship (curve) over the harvest season.

CHAPTER IV

RESULTS AND DISCUSSION

The 1981 'Redchief Red Delicious' study was conducted in Sevier County, Tennessee and the 1982 'NuRed Rome' study was conducted near Crossville, Tennessee at the Middle Tennessee Experiment Station. As previous research indicated, various cultivars respond differently to the concentration and timing of growth regulators. Due to this and the slight variation that existed between treatment procedure the two types of cultivars were analyzed separately. The data for expected growth changes of untreated fruit in 1981 and 1982 are included to aid the reader in understanding how differences in growth patterns occur during the normal harvest season.

1981 Results

'Redchief Red Delicious' Growth Patterns

The process of ripening proceeds throughout the harvest season with the transformation of physiologically mature fruit to a desired stage of ripeness. The following fruit indices were measured to show the rate and nature of growth changes of untreated 'Redchief Red Delicious' apples through the 1981 harvest season; ethylene content, skin color, soluble solid content, and fruit firmness, diameter, length, and shape. Actual mean values are recorded (Table I) and illustrated for each harvest (Figures 1, 2). Bloom date for 'Redchief Red Delicious' in 1981 was April 12.

TABLE I

CHANGE OF MATURITY INDICES WITH MATURATION OF 'REDCHIEF RED DELICIOUS' APPLES AT SEVIERVILLE, TENNESSEE 1981

Harvest	DFFB^z	Ethylene (ppm)	Soluble Solids (%)	Firmness (kg)	Diameter (cm)	Length (cm)	L/D^y	Weight (gm)	Red Color (%)
August 7	117	.01^{xw}	8.44a	10.57a	6.53a	5.26a	.806a	--	56.08a
August 15	125	.02a	9.19b	10.06b	6.84b	5.53b	.810a	132.28a	66.50b
August 20	130	--	9.37c	9.52c	6.97c	5.64c	.809a	140.41b	70.68c
August 26	136	.21b	9.79d	9.03d	7.06d	5.74d	.815a	147.15c	77.99d
September 1	142	.15b	10.15e	8.84e	7.13e	5.91e	.829b	154.62d	85.38e
September 9	150	.41c	10.50f	8.49f	7.37f	5.99ef	.813a	168.00e	92.15f
September 15	156	.78d	10.85g	8.34g	7.45g	6.01f	.808a	169.73e	92.28f

^{z}DFFB. Days from full bloom for each harvest.

^{y}L/D. Length/Diameter.

^{x}Means in a column not followed by the same letter are significantly different at the 5% level, Duncan's Multiple Range Test.

^{w}Mean of 200 observations.

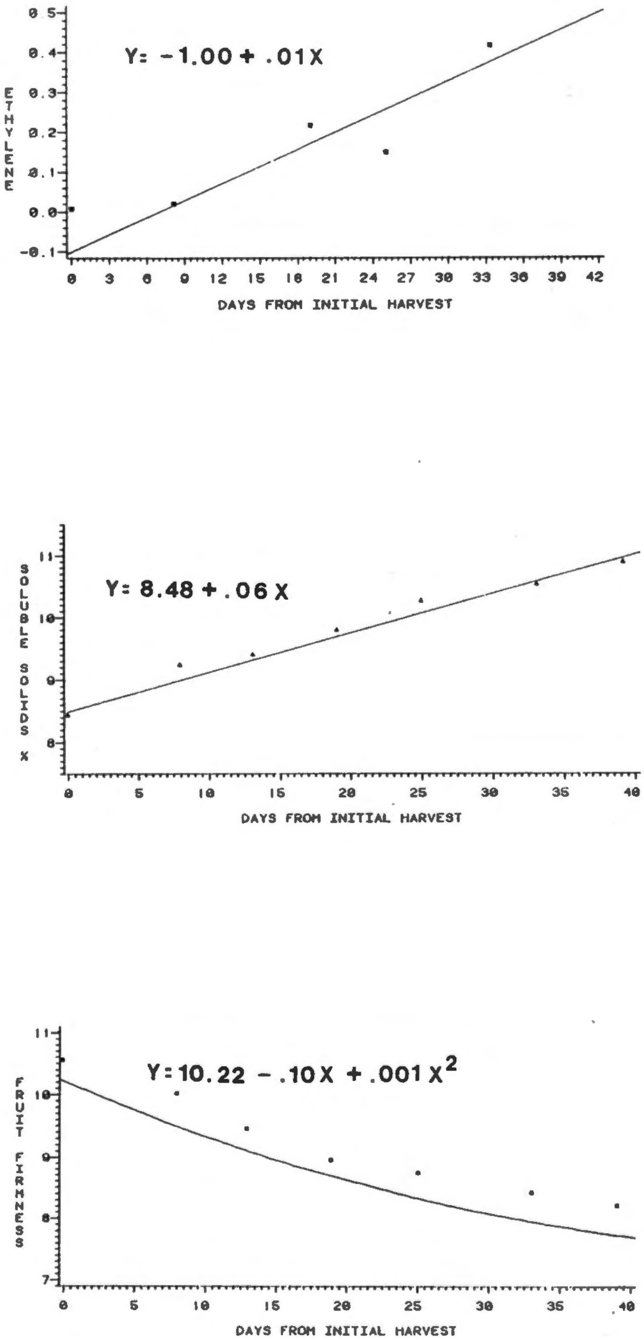


Figure 1. Change in fruit ethylene (ppm), firmness (kg) and soluble solids (%) on 'Redchief Red Delicious' over the 1981 harvest season at Sevierville, Tennessee. Initial harvest was 117 DFFB.

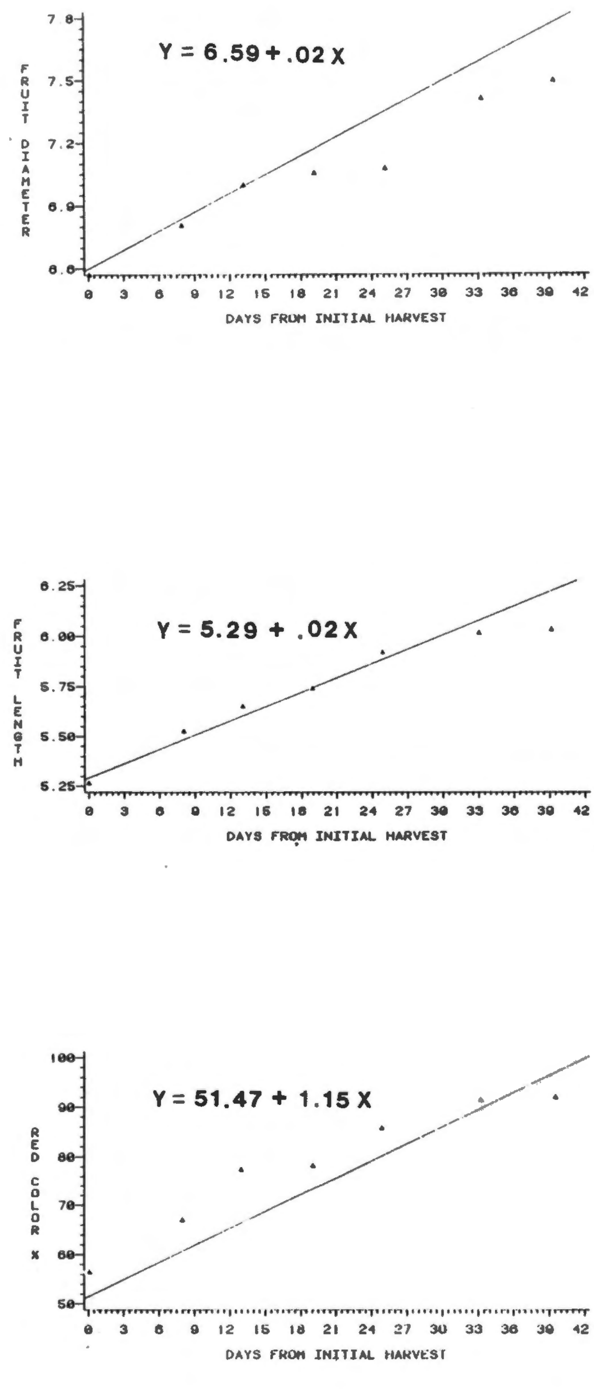


Figure 2. Change in fruit diameter (cm), length (cm), and red color (%) on 'Redchief Red Delicious' over the 1981 harvest season at Sevierville, Tennessee. Initial harvest was 117 DFFB.

Extensive studies on apple fruit by Dilley (13, 14) conclude that ethylene content is the best measure to assess maturity and ripening development. The ethylene content of all untreated apples remained initially low, about .01 ppm. Ethylene concentration then increased during each harvest with the exception of the fifth harvest (142 DFFB) when there was a slight decrease. For the final two harvests (150, 156 DFFB) the ethylene content increased significantly with each harvest when tested at the 5% level. Ethylene levels between 0.02 to 0.15 ppm have been noted by Smith et al. (43) during the period from 83 to 143 days from full bloom and sharply increased from 10 to 1000-fold within five days as internal ethylene production began. These values perhaps would have been observed if the harvest season had been extended another week. Percent red color increased significantly during each of the first six harvest periods. Color during the final harvest (156 DFFB), however, did not increase significantly relative to the preceding harvest (150 DFFB). The 66% minimum color requirement for U.S. extra fancy fruit was attained by the second harvest (125 DFFB). Fruit pressure tests revealed firmness significantly decreased over each harvest period. The lowest desirable level for fruit firmness of 8.4 kg (18.5 lbs.) at harvest was not attained until the sixth harvest (150 DFFB). Fruit sugar expressed as percent soluble solids increased significantly with each harvest date. Utilizing the 11% soluble solids index as suggested by Mattus (37), fruits were not ready for harvest until 156 DFFB. It has also been suggested that fruit intended for long term storage should be harvested before reaching 10.5% soluble solids (26). This would correspond with termination of harvest for storage by 150 DFFB.

Fruit length and fruit weight increased significantly over the first five harvests, and increased slowly over the final two harvests (150, 156 DFFB). Fruit diameter also increased significantly with each harvest. The U.S. No. 1 early grade which requires apples to be not less than 2 inches in diameter was met at initial harvest (117 DFFB). Fruit shape at harvest should be considered from the standpoint of the characteristic shape of a particular variety. The shape of 'Red Delicious' varies among different strains and different growing areas. Change in fruit shape over harvest dates of 'Redchief Red Delicious' in 1981 was not significant. Fruit, however, tended to continue growing as harvest was delayed, indicating early harvest would result in slightly smaller yields.

Influence of Ethephon Plus NAA

An analysis of variance (ANOVA) as a split plot design was performed to determine the pooled effects of ethephon (plus NAA) on fruit from trees previously treated with daminozide, and on fruit sampled over each harvest period. These effects were then separated and analyzed by Duncan's Multiple Range test, at the 5% level. Mean separation for each variable is listed in Table II. As observed in the ANOVA, an application of ethephon significantly increased percent soluble solids by .4 when compared with non-ethephon treated fruit at the 5% level (Table II). Ethephon increased percentage of red color of 'Redchief Red Delicious' apples by 4%. Data presented here support the increase in soluble solids and the color promotion responses of

TABLE II

THE EFFECT OF ETHEPHON ON FRUIT MATURITY PARAMETERS DURING THE 1981 HARVEST SEASON OF 'REDCHIEF RED DELICIOUS' APPLES AT SEVIERVILLE, TENNESSEE

Ethephon (conc.)	Ethylene (ppm)	Soluble Solids (%)	Red Color (%)	Firmness (kg)	Length (cm)	Diameter (cm)	L/D[z]
0 ppm	.2081a[y,x]	9.54a[w]	75.23a[w]	9.30a[w]	5.70a[w]	7.05a[w]	.8166a[w]
300 ppm	.2384a	9.93b	79.26b	9.23a	5.75a	7.05a	.8090a

[z]L/D. Length/Diameter.

[y]Means in a column not followed by the same letter are significantly different at the 5% level, Duncan's Multiple Range Test.

[x]Mean of 1200 observations.

[w]Mean of 1400 observations.

ethephon reported earlier (6, 18, 19, 31, 39, 48, 51, 52). An increase in ethylene production by ethephon, as reported previously, was not observed; however, ethephon treatment resulted in fruit higher in ethylene than daminozide-treated fruit. Ethephon did not significantly alter fruit firmness, diameter, length, or shape (L/D). The firmness and size of these fruit, therefore, were found to be of equal quality to nontreated fruit, but had increased soluble solids and percent red color.

If ethephon and date of harvest had significant interaction in the previous ANOVA, a multivariate analysis (MANOVA) was performed to determine if ethephon influenced the relationship (curve) of the harvest season. According to the MANOVA, significant interaction of ethephon and harvest date was observed only with the variable, soluble solids. The ethephon treatment significantly changed the shape of the curve for soluble solids over the harvest season (Figure 3). Soluble solids increased significantly over the entire harvest season due to ethephon treatment; however by the final harvest (156 DFFB) percent soluble solids were the same as that of untreated fruit. In retrospect, the author feels that the ethephon treatment was probably applied two weeks too soon. This would account for the lack of effect on many maturity variables that have been previously reported. Even an early ethephon application stimulated sugar accumulation without the apparent ethylene stimulation. Applications of 2,4,5-TP alone have been shown to advance ripening as evidenced by enhanced fruit color, ethylene production, and softening (1). Due to the early ethephon application the possibility exists that the above

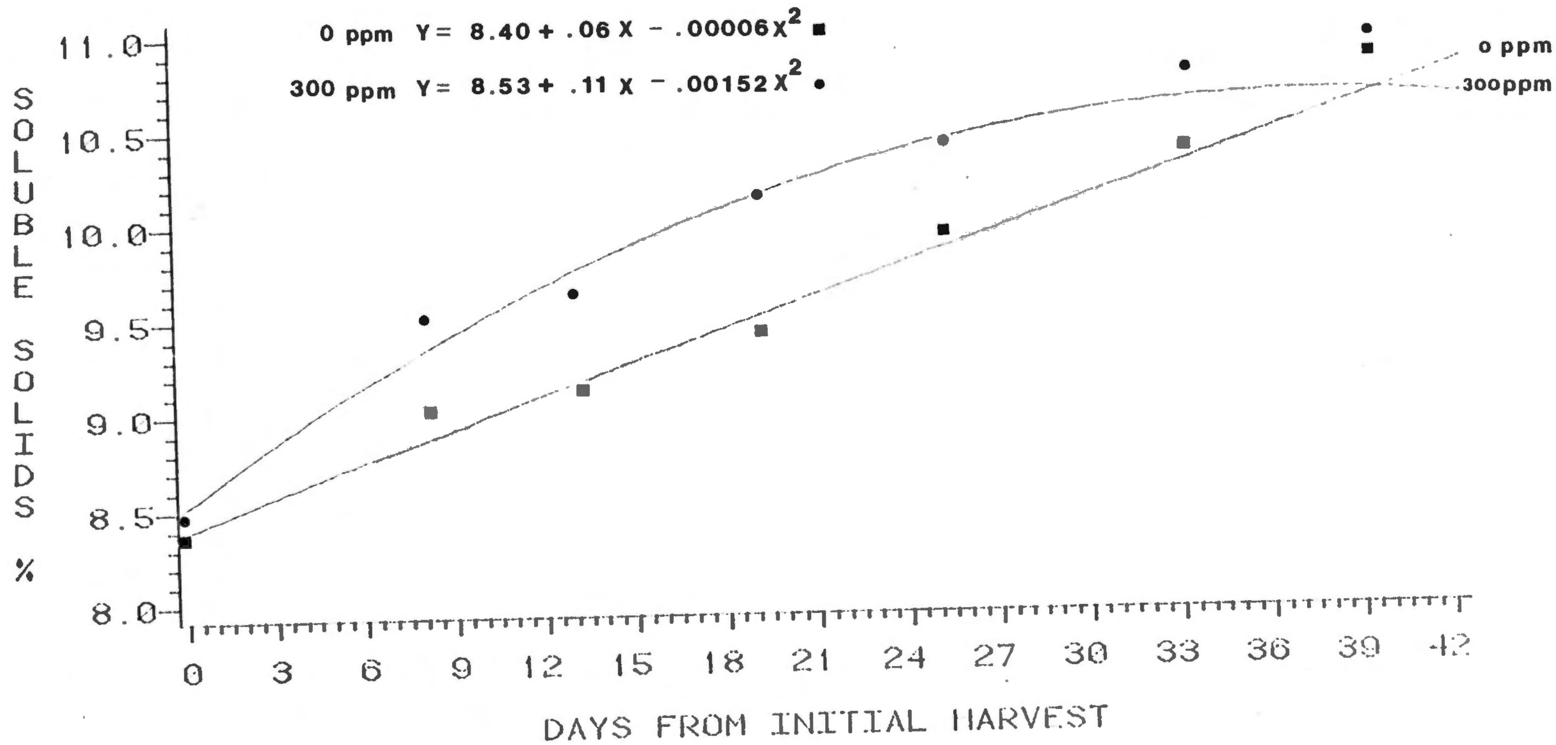


Figure 3. Effect of ethephon on soluble solids (%) of 'Redchief' apples throughout the 1981 harvest season at Sevierville, Tennessee. Initial harvest was 117 DFFB.

observed responses may have been due to the NAA and not the ethephon application.

Influence of Daminozide

As mentioned previously, internal ethylene concentration generally increased with each harvest; however the ANOVA indicated that the ethylene level was significantly higher in the control fruit than in the daminozide treated samples (Table III). Blanpied (4) also found daminozide suppressed ethylene production responses to ethephon. Increasing the daminozide concentration (from 750 to 2000 ppm) tended to reduce ethylene production, though not significantly. Reports have indicated that control fruit were consistently higher in ethylene content than comparable daminozide-treated samples (24, 48). Edgerton (20) suggests the physiological basis for the delay in fruit drop resulting from daminozide application is due to its reduced effect on ethylene synthesis in maturing apple tissues. All daminozide treatments significantly increased fruit firmness with 2000 ppm causing the firmest fruit. Increasing daminozide concentrations tended to reduce fruit diameter with the highest causing significant decreases. Fruit length tended to be reduced with increasing daminozide concentrations, although not significantly, and fruit shape was not affected by treatment. Increasing concentrations of daminozide tended to reduce fruit weight; however, significant differences among treatment concentrations were not evident. This coincides with the results of Sullivan's (47) work with daminozide on 'Richared Delicious' apples at New Mexico State. Dozier and

TABLE III

THE EFFECT OF DAMINOZIDE ON FRUIT MATURITY PARAMETERS DURING THE HARVEST SEASON OF 'REDCHIEF RED DELICIOUS' APPLES AT SEVIERVILLE, TENNESSEE 1981

	Harvest							
Daminozide (conc.)	Ethylene (ppm)	Soluble Solids (%)	Red Color (%)	Firmness (kg)	Weight (gm)	Diameter (cm)	Length (cm)	L/D[z]
0	.300a[yx]	9.93a	76.11a	8.71a	163.84a	7.21a	5.83a	.8095a
750	.217b	9.75ab	77.89a	9.21b	154.47ab	7.09ab	5.74a	.8100a
1000	.212b	9.72b	78.11a	9.38b	151.60b	7.05abc	5.74a	.8158a
1500	.203b	9.65b	77.18a	9.39b	146.41b	6.99bc	5.66a	.8102a
2000	.184b	9.63b	77.01a	9.65c	143.79b	6.92c	5.65a	.8186a

[z]L/D. Fruit shape expressed as Length/Diameter.

[y]Means in a column not followed by the same letter are significantly different at the 5% level, Duncan's Multiple Range Test.

[x]Mean of 1400 observations.

Burgess (15) also found fruit diameter and weight of daminozide-treated fruit to be less than that of the control fruit.

Contrary to previous reports the daminozide had little effect on fruit sugar, this study revealed percent soluble solids was reduced with increasing daminozide concentrations. However, only daminozide treatments above 1000 ppm showed a significant effect on this variable relative to the control fruit. There was no apparent difference in red color development due to daminozide treatment, however previous reports have shown daminozide to increase percent red color of 'McIntosh" and 'Delicious' apples (2, 4). The change in red color due to daminozide treatment seems to be dependent on the particular cultivar under study.

According to the ANOVA for 'Redchief Red Delicious' in 1981, the daminozide treatments significantly affected fruit firmness, soluble solids content, and ethylene content as expressed by the Duncan's Multiple Range test. A GLM was performed to determine daminozide's effect on these parameters (Figures 4, 5). Increasing daminozide concentrations were shown to result in a significant linear increase in fruit firmness. Increasing daminozide concentrations caused a reduced soluble solid content, fruit weight, and fruit diameter. According to the ANOVA, ethylene content was significantly greater in the non-daminozide-treated fruit. Daminozide treatment decreased ethylene accumulation over the harvest season.

If the influence of daminozide treatments interacted significantly with harvest date, than a multivariate analysis (MANOVA) was performed to determine if daminozide influenced the relationship

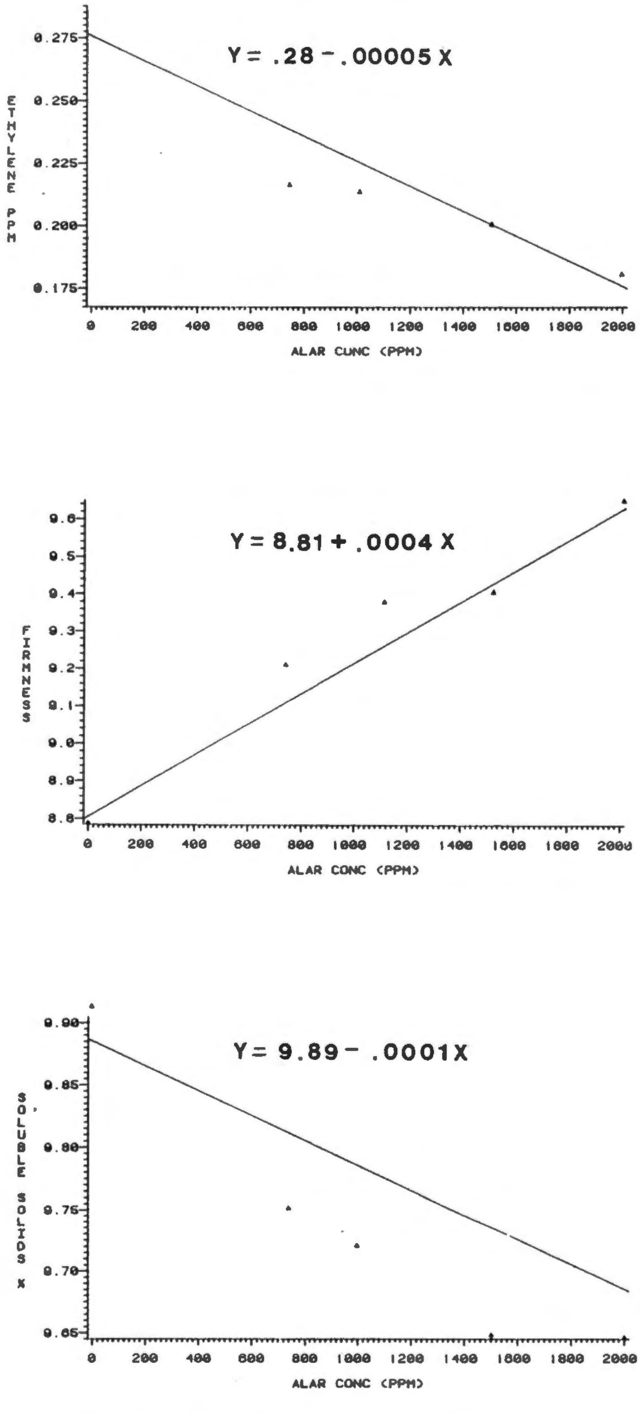


Figure 4. Effect of daminozide on ethylene (ppm), fruit firmness (kg) and soluble solids (%) of 'Redchief Red Delicious' in 1981 at Sevierville, Tennessee.

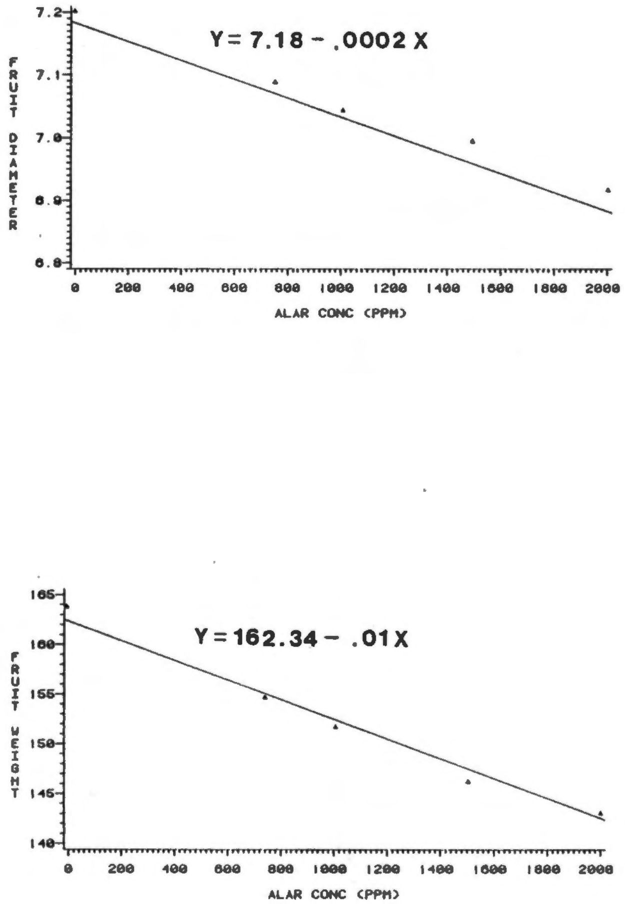


Figure 5. Effect of daminozide on fruit diameter and fruit weight throughout the 1981 harvest season for 'Redchief' apples at Sevierville, Tennessee.

(curve) over the harvest season. This test revealed a significant change in relationship of fruit diameter to daminozide treatments over the harvest season. The 2000 ppm daminozide treated fruit were initially larger in fruit diameter relative to all other treatments; however, by the final harvest (156 DFFB), the diameters were less than the fruit from the other treatments. Fruit not treated with daminozide were greater in diameter than treated fruit and continued to increase through the harvest season (Figure 6).

According to the ANOVA results, there was no evidence in 1981 of a daminozide-ethephon interaction influencing the fruit parameters studied on 'Redchief Red Delicious.'

1982 Results

'NuRed Rome' Fruit Growth Patterns

'NuRed Rome,' a later maturing variety than 'Red Delicious' was evaluated in 1982. Bloom date for 'NuRed Rome' in 1982 was April 11. Expected changes in the rate of growth and ripening of 'NuRed Rome' apples throughout the 1982 harvest season are indicated by the following fruit indices (Tables IV, V) and illustrated for each harvest (Figures 7, 8, 9, 10).

The change in percent red color as indicated by the Hunter "a" values was shown to increase linearly throughout the harvest period; however at 181 DFFB there was a significant decrease in red color relative to the previous harvest (174 DFFB). Yellow color, indicated by positive "b" values was still high at 156 DFFB, steadily decreased until the fifth harvest (174 DFFB), when there was a

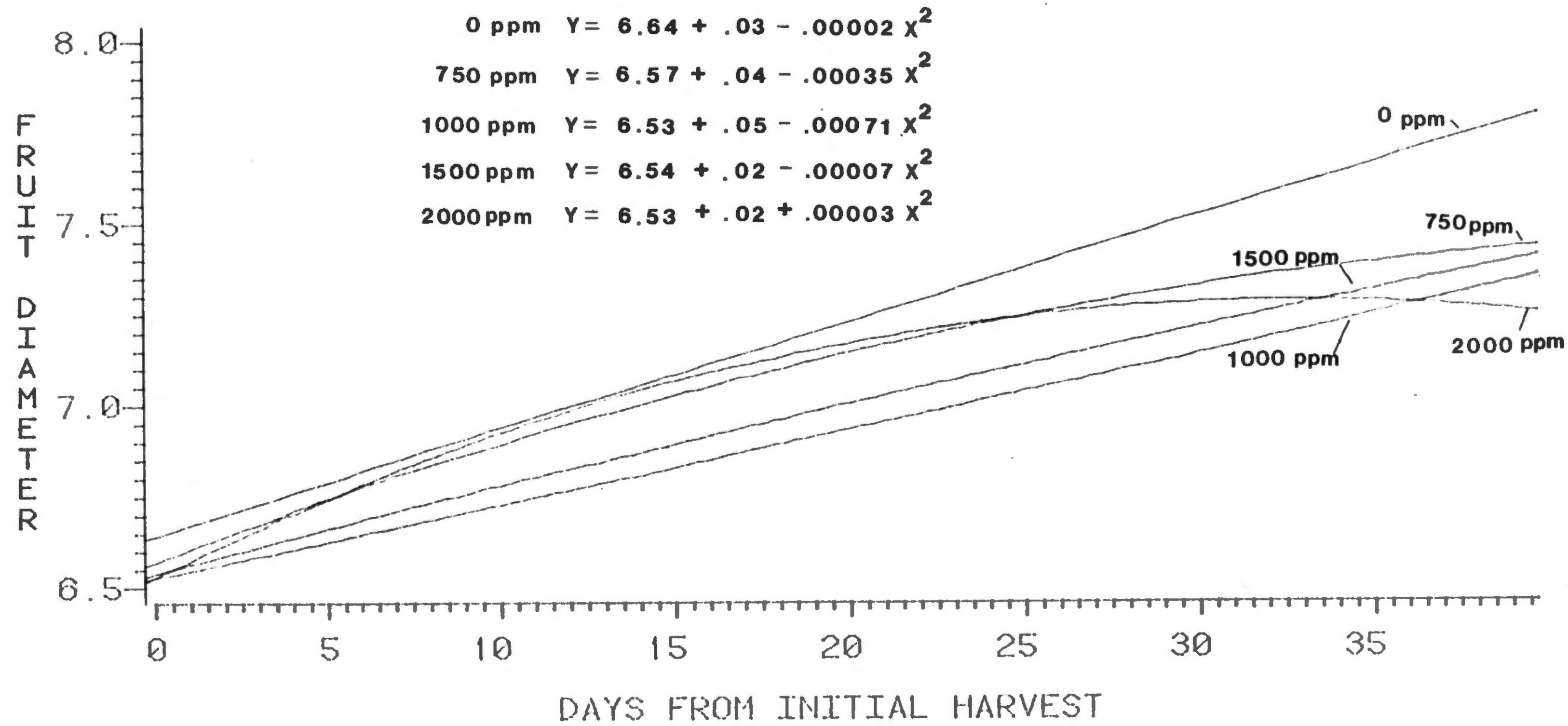


Figure 6. Effect of daminozide treatments on fruit diameter (cm) over the 1981 harvest season of 'Redchief' apples at Sevierville, Tennessee. Initial harvest was 117 DFFB.

TABLE IV

CHANGE OF HUNTER COLOR VALUES OF 'NURED ROME' APPLES AT CROSSVILLE, TENNESSEE 1982

		Hunter Color and Color-Difference Meter[z]			
Harvest Date	DFFB[y]	a	b	a/b	$\tan^{-1}$ a/b[x]
September 13	156	20.04a[wv]	33.41a	1.25a	26.05a
September 20	163	23.30ab	22.72b	1.09a	33.34b
September 27	170	24.35b	20.01b	1.40a	43.17c
October 1	174	48.18c	29.63c	2.22ab	55.94d
October 8	181	32.38d	16.44d	3.16b	52.19d

[z]Instrument was calibrated against white-enamel tile.

[y]DFFB. Days from full bloom for each harvest.

[x]$\tan^{-1}$ a/b = Hunter score, used to evaluate apple skin color, expressed in degrees.

[w]Means in a column not followed by the same letter are significantly different at the 5% level, Duncan's Multiple Range Test.

[v]Mean of 160 observations.

TABLE V

CHANGE OF MATURITY INDICES WITH MATURATION OF 'NURED ROME' APPLES AT CROSSVILLE, TENNESSEE 1982

Harvest Date	DFFB[z]	Soluble Solids (%)	Firmness (kg)	Diameter (cm)	Length (cm)	L/D[y]	Weight (gm)
September 7	150	12.13a[x,w]	9.63a	8.53a	6.27a	.737a	243.58ab
September 13	156	12.58b	9.53a	8.59ab	6.23a	.725a	244.78ab
September 20	163	12.93c	8.78b	8.69ab	6.34a	.729a	252.28bc
September 27	170	13.45d	8.31c	8.74b	6.33a	.726a	256.33c
October 1	174	13.70e	8.56bc	8.54a	6.29a	.736a	236.03a
October 8	181	14.59f	7.80d	8.52a	6.78b	.803b	256.02c

[z]DFFB. Days from full bloom for each harvest.

[y]L/D. Fruit shape expressed as Length/Diameter.

[x]Means in a column not followed by the same letter are significantly different at the 5% level, Duncan's Multiple Range Test.

[w]Mean of 160 observations.

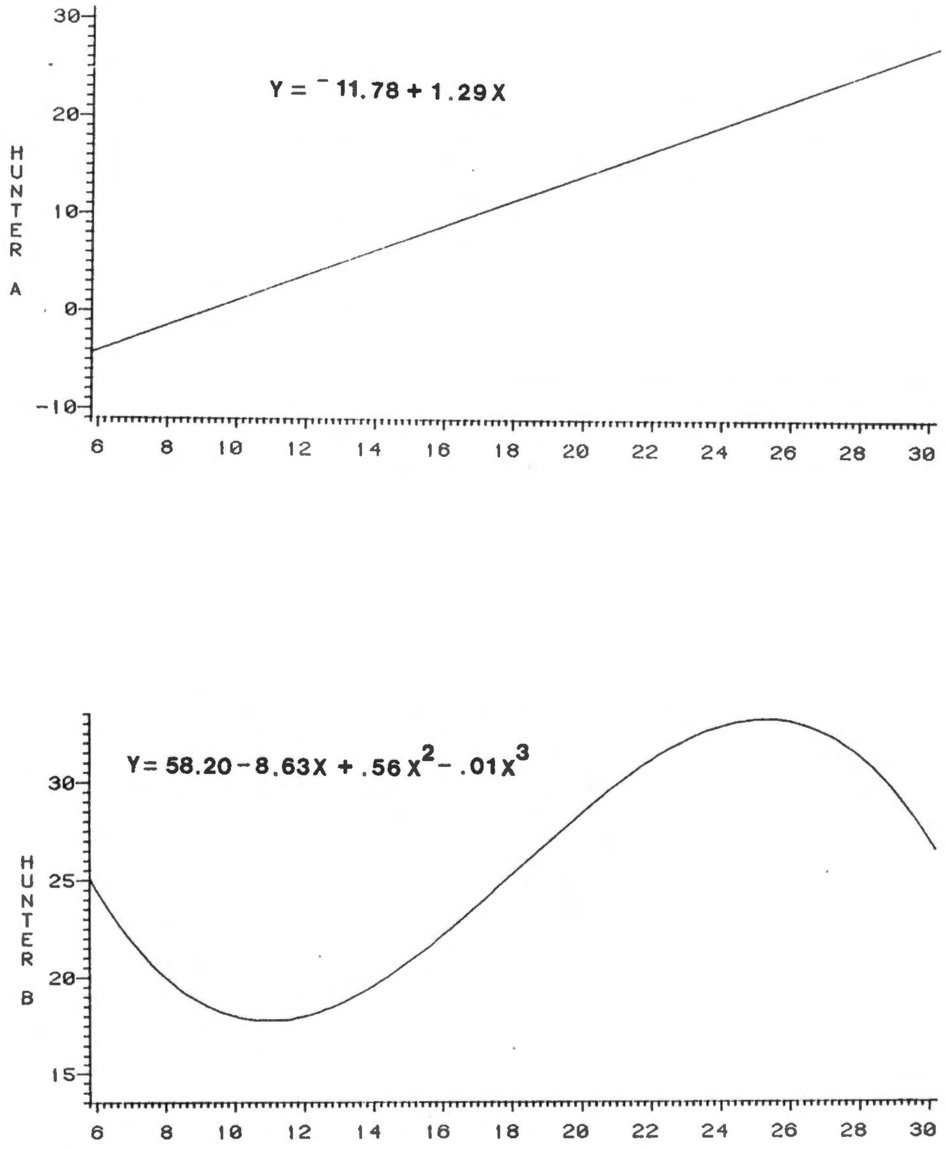
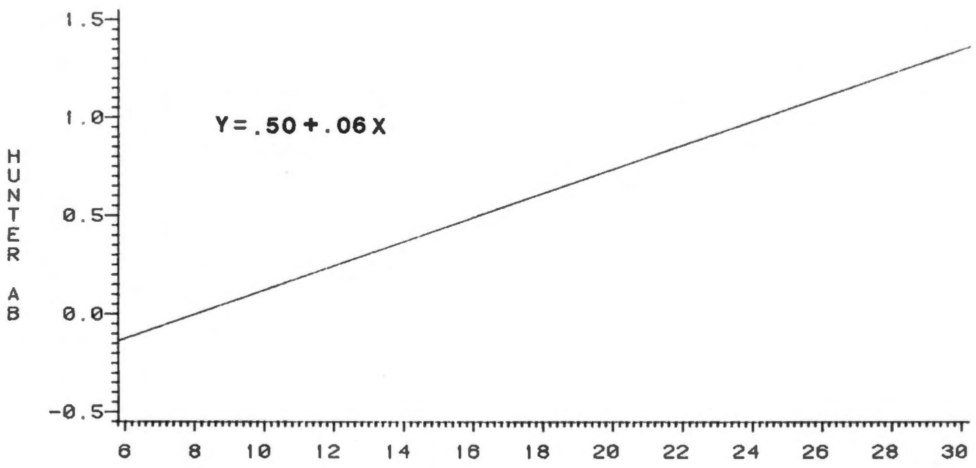


Figure 7. Change in Hunter color values "a" and "b" observed on 'NuRed Rome' over the 1982 harvest season at Crossville, Tennessee. Initial harvest was 150 DFFB.



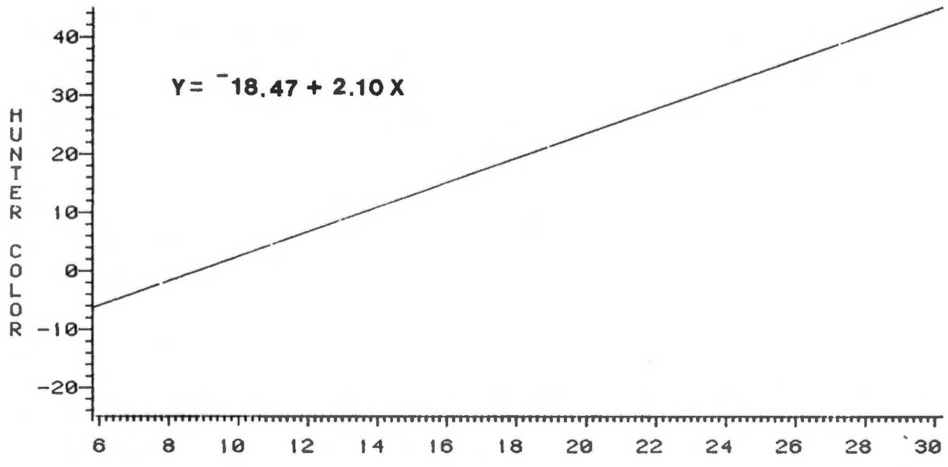


Figure 8. Change in Hunter color values a/b and tan^{-1}a/b over the 1982 harvest season for 'NuRed Rome' apples at Crossville, Tennessee. Initial harvest was 150 DFFB.

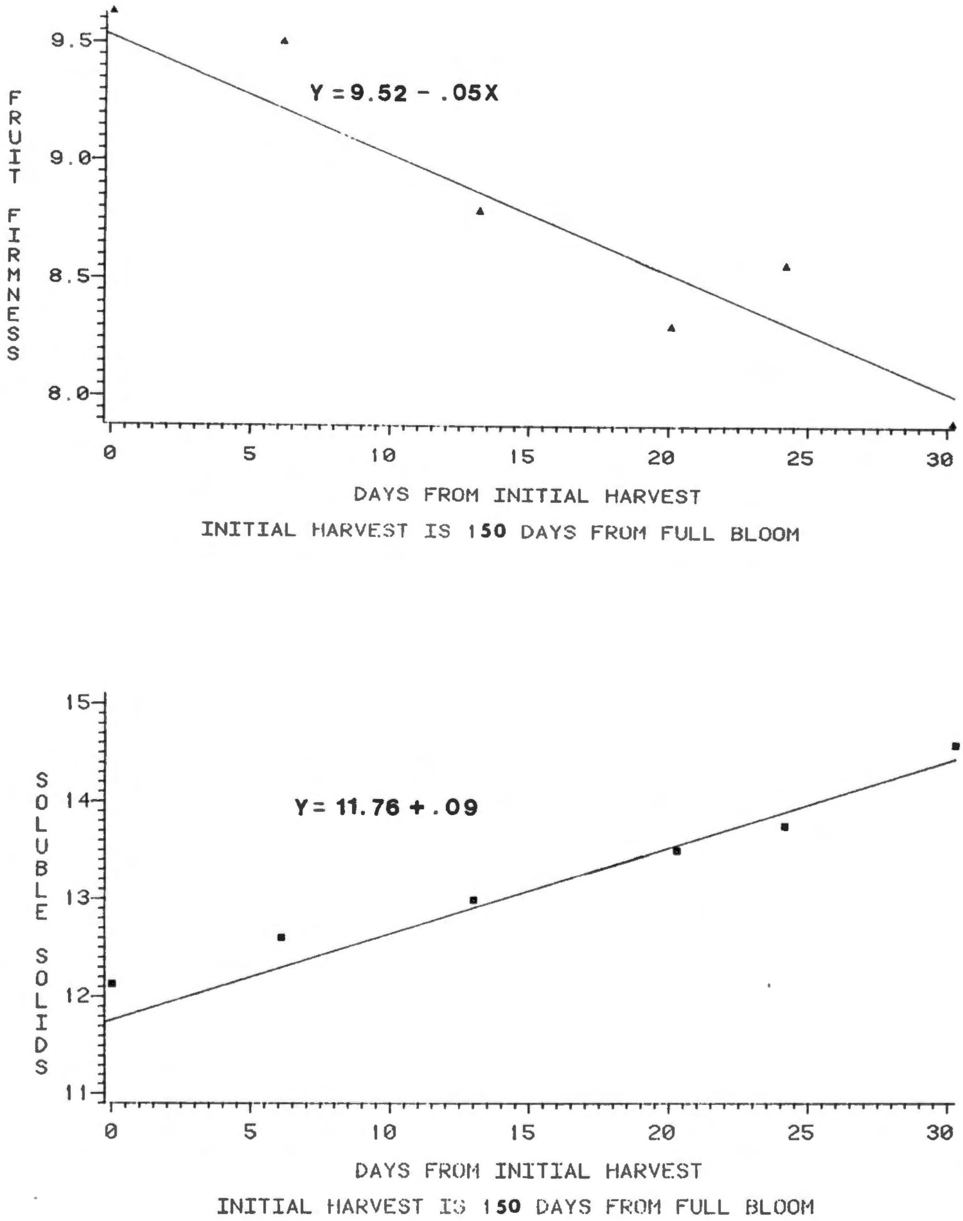
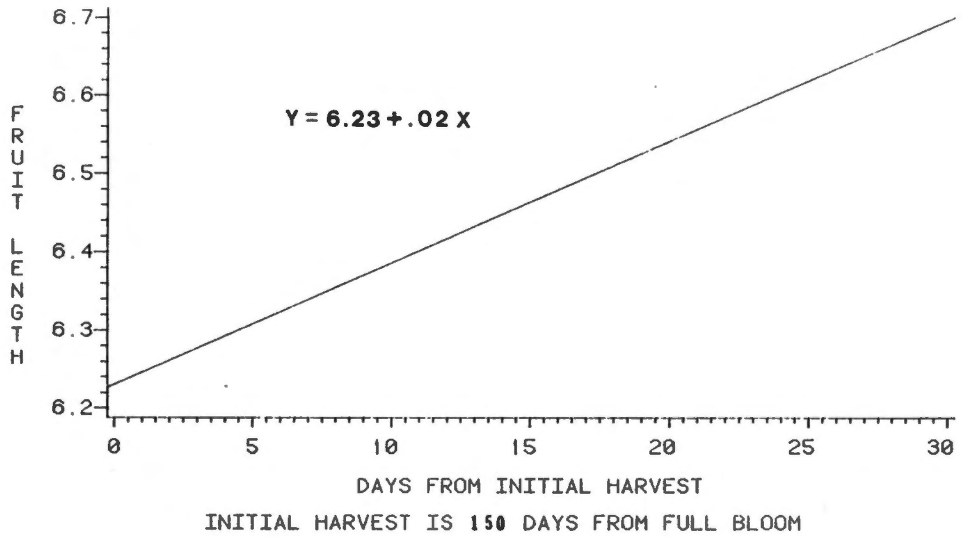


Figure 9. Change in fruit firmness (kg) and soluble solids (%) over the 1982 harvest season of 'NuRed Rome' apples grown at Crossville, Tennessee. Initial harvest was 150 DFFB.



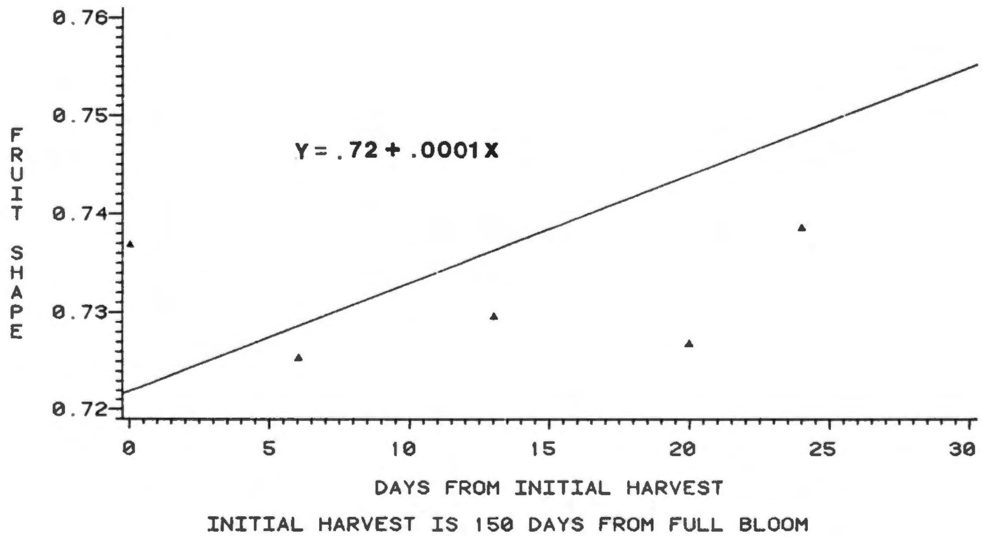


Figure 10. Change in fruit length (cm) and shape over the 1982 harvest season of 'NuRed Rome' apples at Crossville, Tennessee. Initial harvest was 150 DFFB.

significant increase in percentage of fruit with yellow ground color. Fruit harvested during the final harvest (181 DFFB) however were significantly lower in yellow color than all previous harvests. This may be partially explained by the significant decrease in fruit diameter and fruit weight during this same harvest period. According to Francis (23), if an irregularly-shaped apple is rotated, the distance between the instruments measuring cells and the apple skin surface will be greater in a large apple than in a small one. In addition, smaller apples may have had lower carbohydrate supplies, and thus formed less red pigment. The Hunter a/b ratio increased as a linear function throughout the harvest as did the $\tan^{-1}$ a/b with significant increases occurring throughout the season except for the final harvest (181 DFFB). The Hunter color score ($\tan^{-1}$ a/b) has been shown to decrease with apples of larger size (23). Possibly, these larger apples were still developing and lacked sufficient size and sugar content for red color development. According to Francis (23) the scores for the individual apples should be color rated according to their relative sizes (diameter).

Fruit length increased significantly during the final harvest period (181 DFFB) relative to all previous harvests; however, there was no significant change in fruit length among earlier harvests. There was also no significant change in fruit diameter over the harvest season. Fruit diameter generally increased over the first four harvest periods; however, by the final harvest (181 DFFB) average fruit diameter fell below that value recorded during the initial harvest. Fruit shape, expressed as length/diameter ratio generally increased during the harvest season with a significant increase, relative to all previous harvests, occurring during the final harvest period. This was apparently due to the significant increase observed in fruit length at 181 DFFB. Fruit weight increased steadily during the harvest season with significant increases occurring during the fourth and final harvests. During the fifth harvest (174 DFFB) there was a significant decrease in fruit weight with the mean value approaching that of the initial harvest. This may have been due to a limited number of fruit to choose for sampling.

Fruit sugar, expressed as percent soluble solids, increased significantly with each harvest period. The mean value of 12% soluble solids recorded during the initial harvest exceeded the suggested value of no less than 11% soluble solids to be ready for harvest. If fruit had been intended for long-term storage, the mean value of 12% soluble solids recorded at 150 DFFB exceeded the recommended value of 1.5%. Fruit firmness decreased linearly during the harvest season. The suggested minimum value of 8.4 kg (18.5 lbs.) for fruit firmness at harvest was reached during the fourth harvest (174 DFFB). By 181 DFFB, fruit firmness decreased significantly below this value by .7 kg (1.4 lbs.).

Influence of Ethephon Plus NAA

An analysis of variance (ANOVA) as a split plot design was performed to determine the pooled effects of ethephon (plus NAA) on fruit previously treated with daminozide, and on fruit sampled over each harvest period. These effects were then separated and analyzed by

Duncan's Multiple Range test, at the 5% level. Mean separation for each variable is listed in Table VI. According to the ANOVA, ethephon significantly influenced percent soluble solids, fruit firmness, shape, weight, and Hunter "a," "b," and "$\tan^{-1}$ a/b" values. Ethephon treatment at 300 ppm significantly increased percent soluble solids by .97 when compared with non-ethephon treated fruit. Hunter "a," "a/b," and "$\tan^{-1}$ a/b" values were also significantly increased. Fruit firmness and fruit weight significantly decreased as a result of the ethephon application. Fruit length and diameter were not significantly influenced by ethephon; however ethephon treatment did slightly flatten the apples as observed by a significant decrease in fruit shape (L/D).

If ethephon and harvest date had significant interaction in the ANOVA, a multivariate analysis (MANOVA) was performed to determine if ethephon influenced the variable response differently during the harvest season. Significant interaction of ethephon and harvest was noted with the Hunter "a" and Hunter "$\tan^{-1}$ a/b" values. An application of ethephon significantly changed the shape of the curves for Hunter "a" (Figure 11) and Hunter "$\tan^{-1}$ a/b" (Figure 12) values measured over the harvest season. Ethephon advanced and increased fruit development of red coloration as indicated by curves of "a" and "$\tan^{-1}$ a/b."

Ethephon significantly affected the shape of the curve for soluble solids over the entire harvest season causing accelerated early sugar accumulation (Figure 13). Ethephon also affected the shape of the curve for fruit firmness over the harvest season. Fruit

TABLE VI

THE EFFECT OF ETHEPHON ON FRUIT MATURITY PARAMETERS DURING THE 1982 HARVEST SEASON OF 'NURED ROME' APPLES AT CROSSVILLE, TENNESSEE

Ethephon (conc.)	Hunter Color Values[z]				Soluble Solids (%)	Firmness (kg)	Length (cm)	Diameter (cm)	L/D[y]	Weight (gm)
	a	b	a/b	$\tan^{-1}$ a/b[y]						
0 ppm	16.93a[x]	26.16a	0.99a	28.08a	12.74a	9.13a	6.40a	8.59a	.747a	251.13a
300 ppm	42.37b	22.72a	2.65b	56.15b	13.71b	8.40b	6.35a	8.61a	.738b	245.21b

[z]Instrument was calibrated against white enamel tile.

[y]$\tan^{-1}$ a/b. Hunter color value expressed in degrees.

[x]Means in a column not followed by the same letter are significantly different at the 5% level, Duncan's Multiple Range Test.

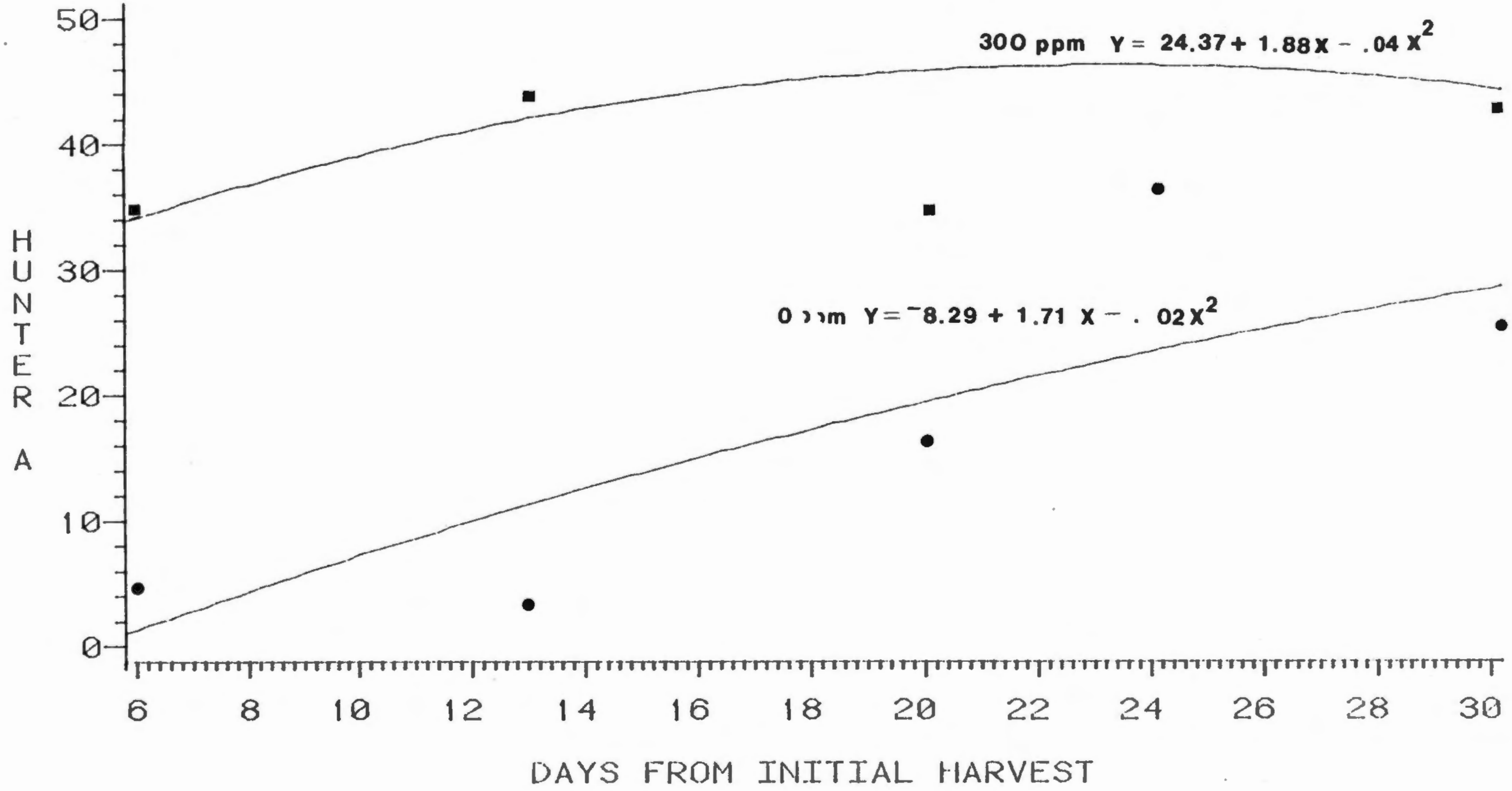


Figure 11. Effect of ethephon on Hunter "a" values throughout the 1982 harvest season for 'NuRed Rome' apples at Crossville, Tennessee. Initial harvest was 150 DFFB.

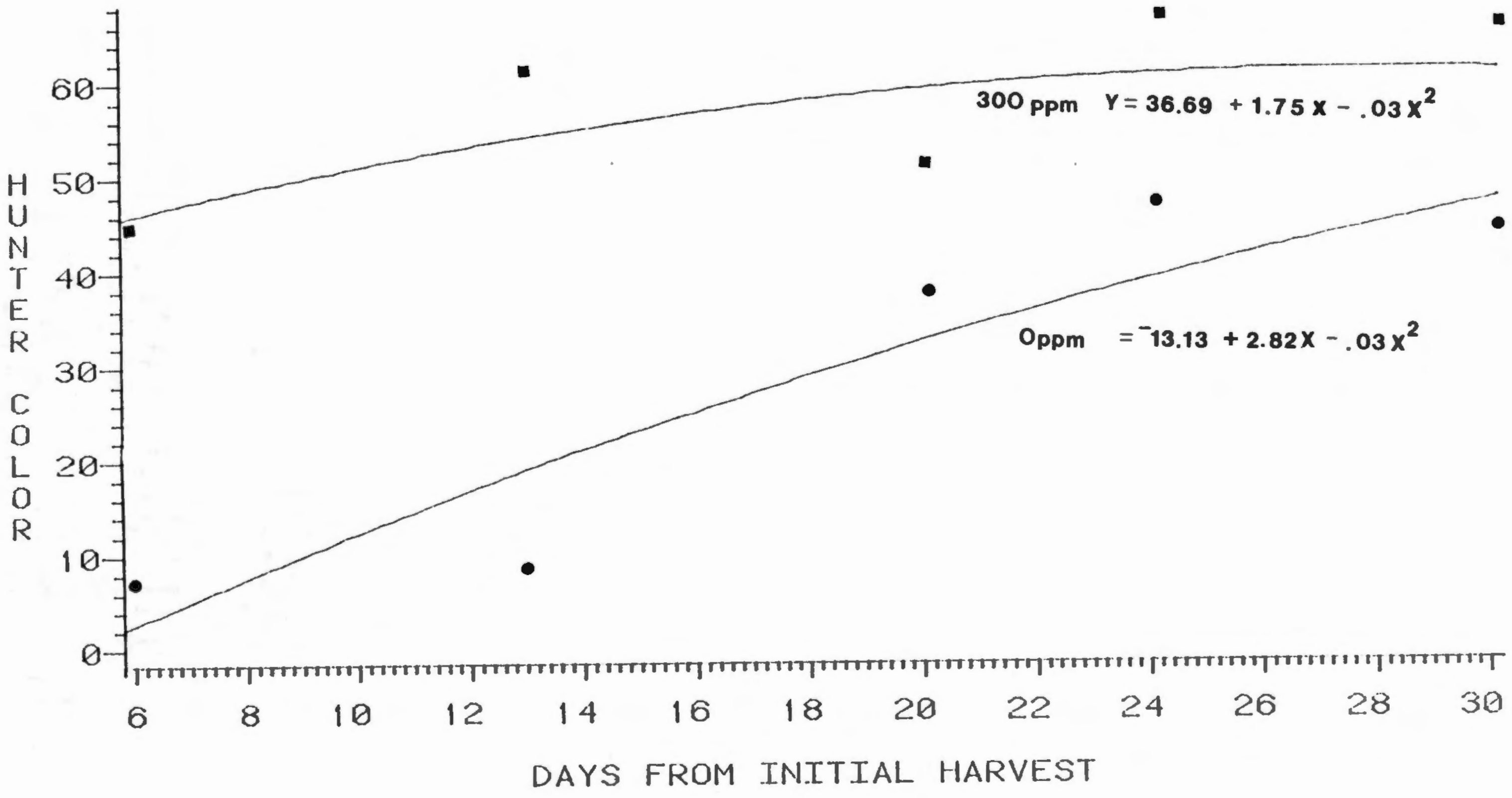


Figure 12. Effect of ethephon on Hunter $tan^{-1}a/b$ values throughout the 1982 harvest season for 'NuRed Rome' apples at Crossville, Tennessee. Initial harvest was 150 DFFB.

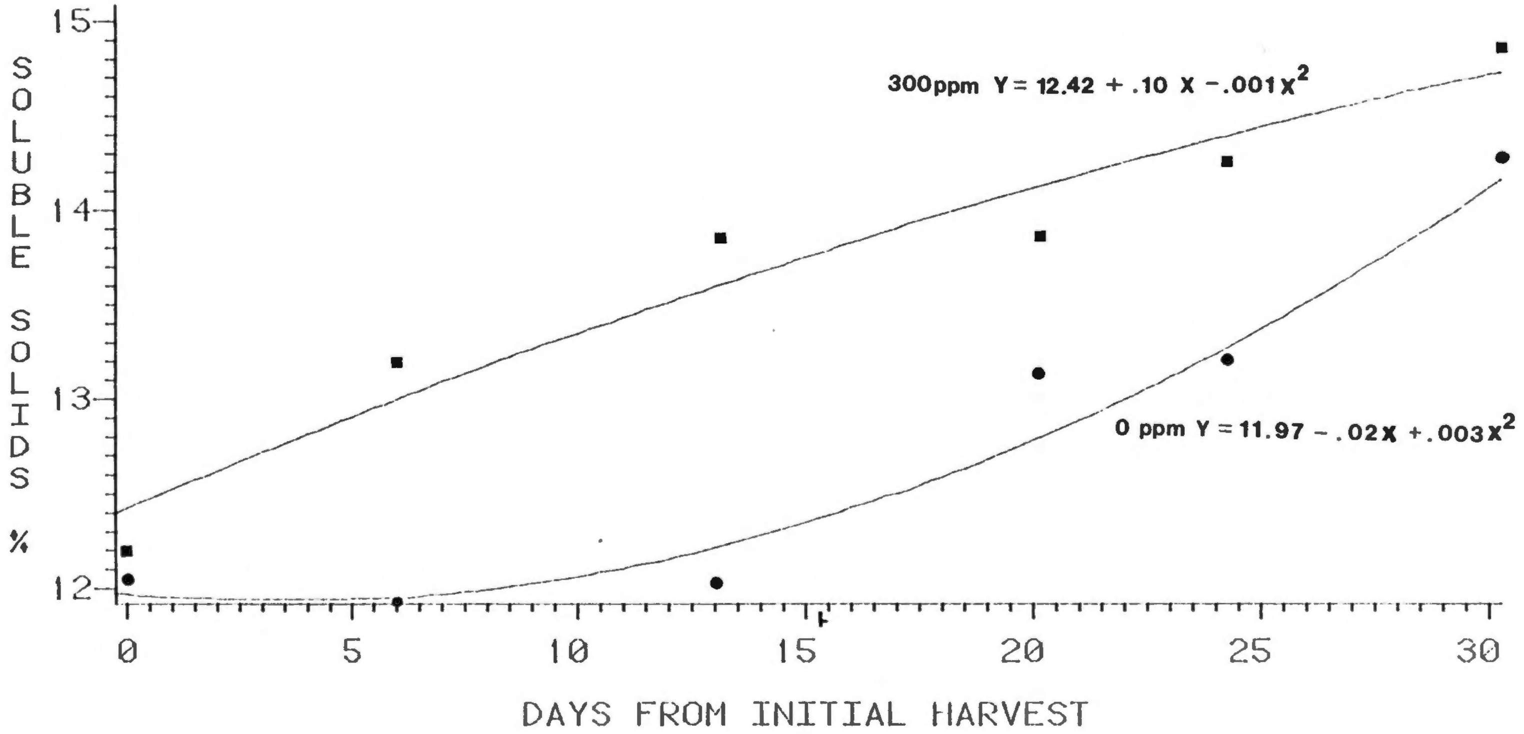


Figure 13. Effect of ethephon on soluble solids (%) throughout the 1982 harvest season for 'NuRed Rome' apples grown at Crossville, Tennessee. Initial harvest was 150 DFFB.

firmness values of ethephon treated fruit fell below those of the control fruit throughout the harvest season (Figure 14). Ethephon treatment initially resulted in increased fruit weight; however, by the fourth harvest (170 DFFB) mean weight of ethephon-treated fruit fell below that of the untreated fruit (Figure 15). The trend for fruit weight change was unexpected. Fruit number on the trees was limited for the last few harvests which may have resulted in wide variation in fruit size.

Influence of Daminozide

An ANOVA as a split plot was performed to determine daminozide's affect on each fruit parameter. Increasing daminozide concentrations tended to decrease soluble solids with a significant decrease being caused by 2000 ppm. Increasing daminozide concentrations also caused increased fruit firmness (Table VII). The somewhat lower soluble solids, and greater fruit firmness of treated fruit coincides with Williams (56) results on 'Delicious' and 'Winesap' apples, as well as the 1981 results presented on 'Redchief Red Delicious.'

Daminozide treatment did not significantly influence the Hunter "a," "b," "a/b," or "$\tan^{-1}$ a/b" color values, which coincides with 1981's results of daminozide treatment on percent red color development. Reports vary as to daminozide's influence on red color development, which supports the previous conclusion that daminozide treatment seems to be dependent on the cultivar under study. Fruit weight, length, diameter, and shape (L/D) also were not significantly

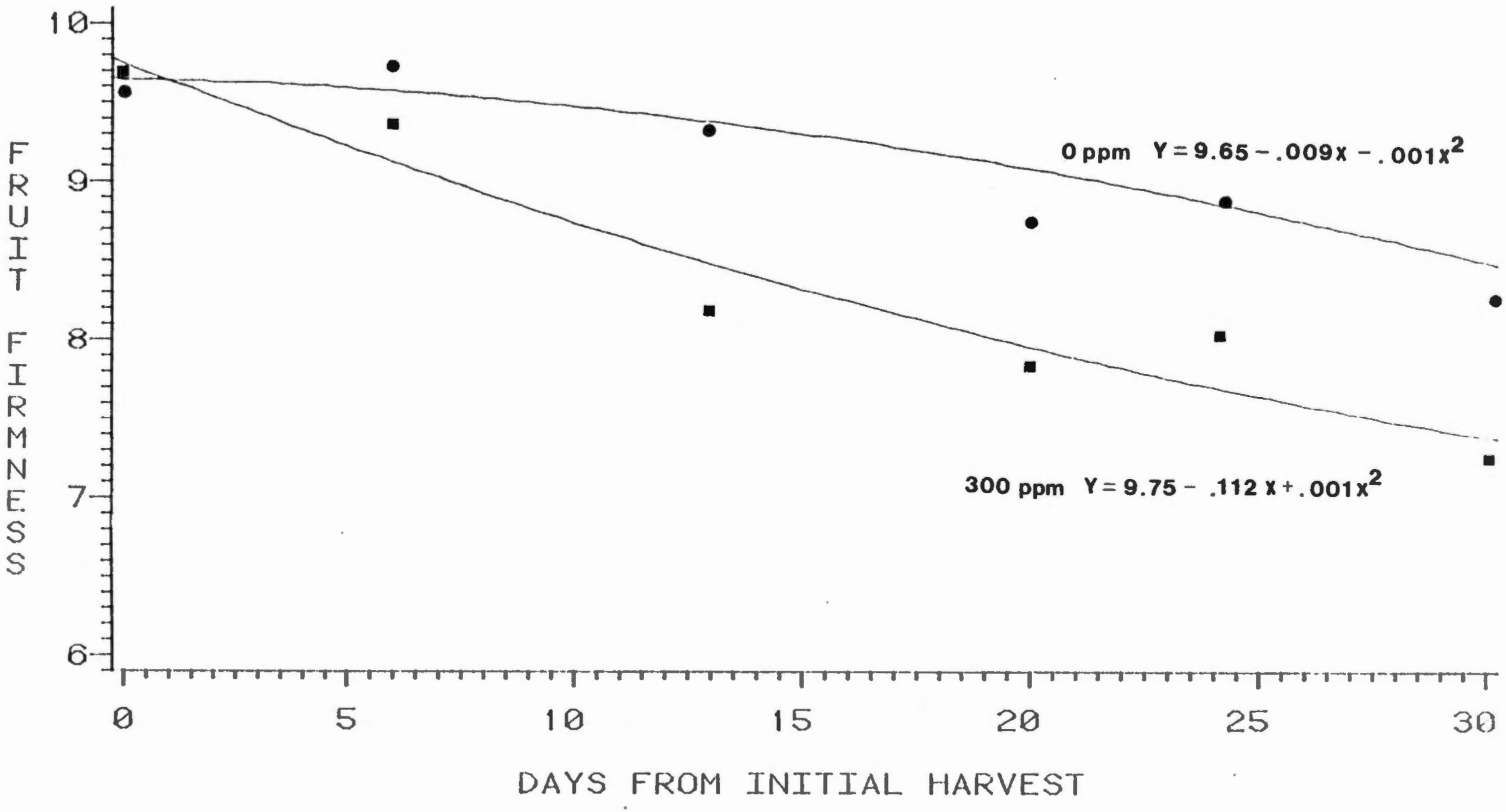


Figure 14. Effect of ethephon on fruit firmness (kg) throughout the 1982 harvest season for 'NuRed Rome' apples grown at Crossville, Tennessee. Initial harvest was 150 DFFB.

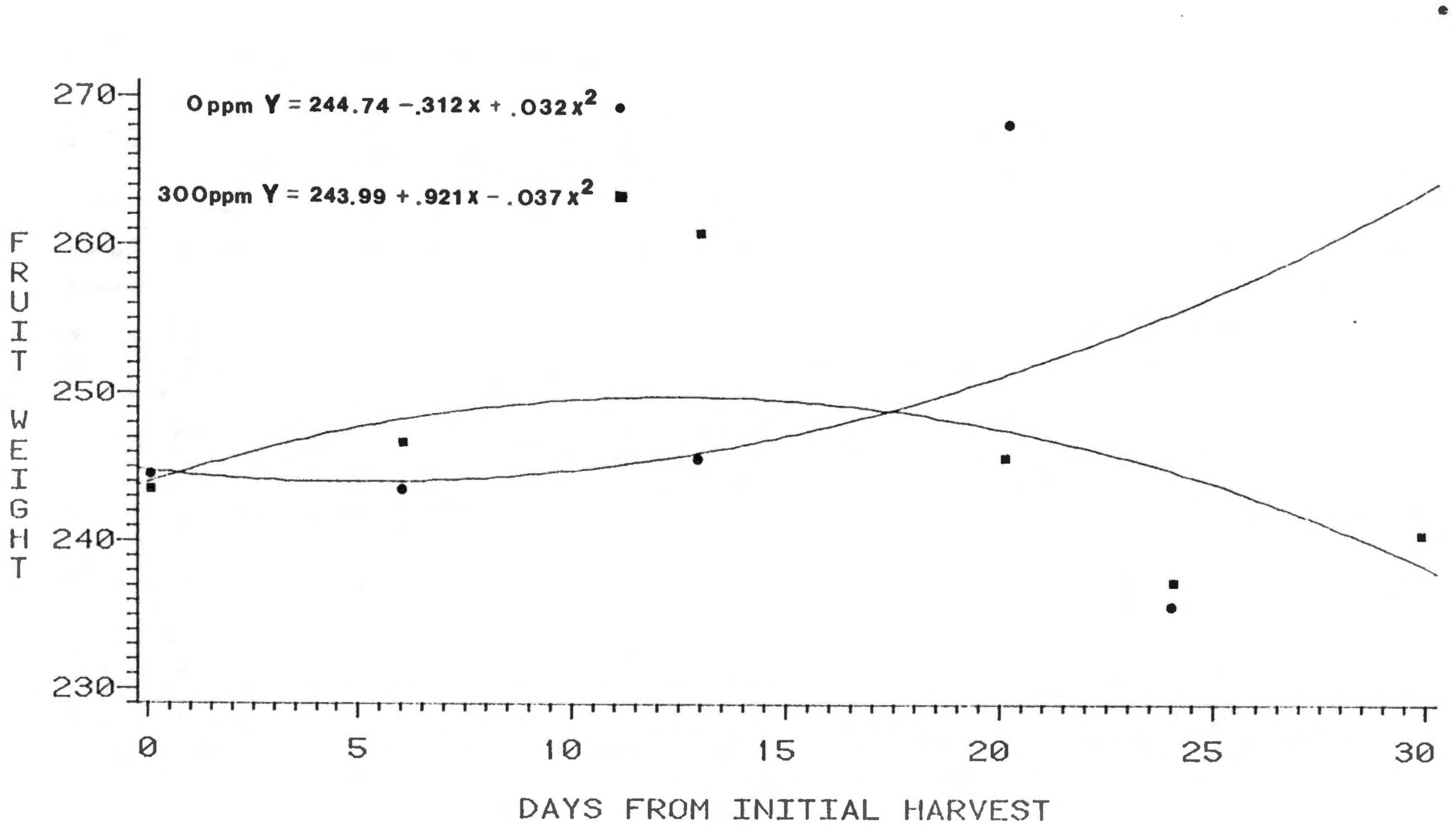


Figure 15. Effect of ethephon on fruit weight throughout the 1982 harvest season for 'NuRed Rome' apples at Crossville, Tennessee. Initial harvest was 150 DFFB.

TABLE VII

THE EFFECT OF DAMINOZIDE ON FRUIT MATURITY PARAMETERS DURING THE 1982 HARVEST SEASON OF 'NURED ROME' APPLES AT CROSSVILLE, TENNESSEE

Daminozide (conc.)	Hunter Color Values[z] a	b	a/b	$\tan^{-1}$ a/b	Soluble Solids (%)	Firmness (kg)	Length (cm)	Diameter (cm)	L/D[y]	Weight
0	26.77a[xw]	25.90a	1.26a	37.45a	13.42a	8.25a	6.43a	8.67a	.7436a	255.65a
1000	29.61a	25.85a	2.19a	40.74a	13.22ab	8.74b	6.32a	8.55a	.7426a	246.51a
1500	29.89a	23.56a	2.00a	46.31a	13.18ab	8.99b	6.42a	8.59a	.7486a	248.80a
2000	32.33a	22.46a	1.84a	44.05a	13.09b	9.10b	6.32a	8.60a	.7356a	241.72a

[z] Instrument was calibrated against white enamel tile.

[y] L/D. Length/Diameter.

[x] Means in a column not followed by the same letter are significantly different at the 5% level, Duncan's Multiple Range Test.

[w] Mean of 160 observations.

altered by an application of daminozide (Table VII). This is in agreement with Sullivan's (47) results which credit daminozide with increasing fruit firmness without significantly altering soluble solids, fruit length, diameter, shape, or weight.

According to the ANOVA for 'NuRed Rome' apples in 1982, the daminozide treatments significantly affected fruit firmness, and soluble solid content as expressed by the Duncan's Multiple Range test. A GLM was performed to determine daminozide's effect on these parameters (Figure 16). Fruit sugar decreased and fruit firmness increased with increasing daminozide concentrations. Each 500 ppm increase in daminozide resulted in .1 decrease in percent soluble solids and .3 kg increase in firmness of 'NuRed Rome' fruit.

If the daminozide treatments interacted significantly with harvest date, then a multivariate analysis (MANOVA) was performed to determine if varying daminozide concentrations influenced the variable response (curve) differently over the harvest season. All daminozide treatments increased fruit firmness levels during the 1982 harvest season (Figure 17). Daminozide applied at 1000 ppm maintained the firmest fruit during the harvest season with the 1500 ppm treatment producing the firmest fruit as of the final harvest (181 DFFB).

According to the ANOVA, there was a significant daminozide-ethephon interaction effect on fruit firmness. As previously mentioned, fruit treated with daminozide were firmer than untreated fruit. An application of ethephon to apples previously treated with

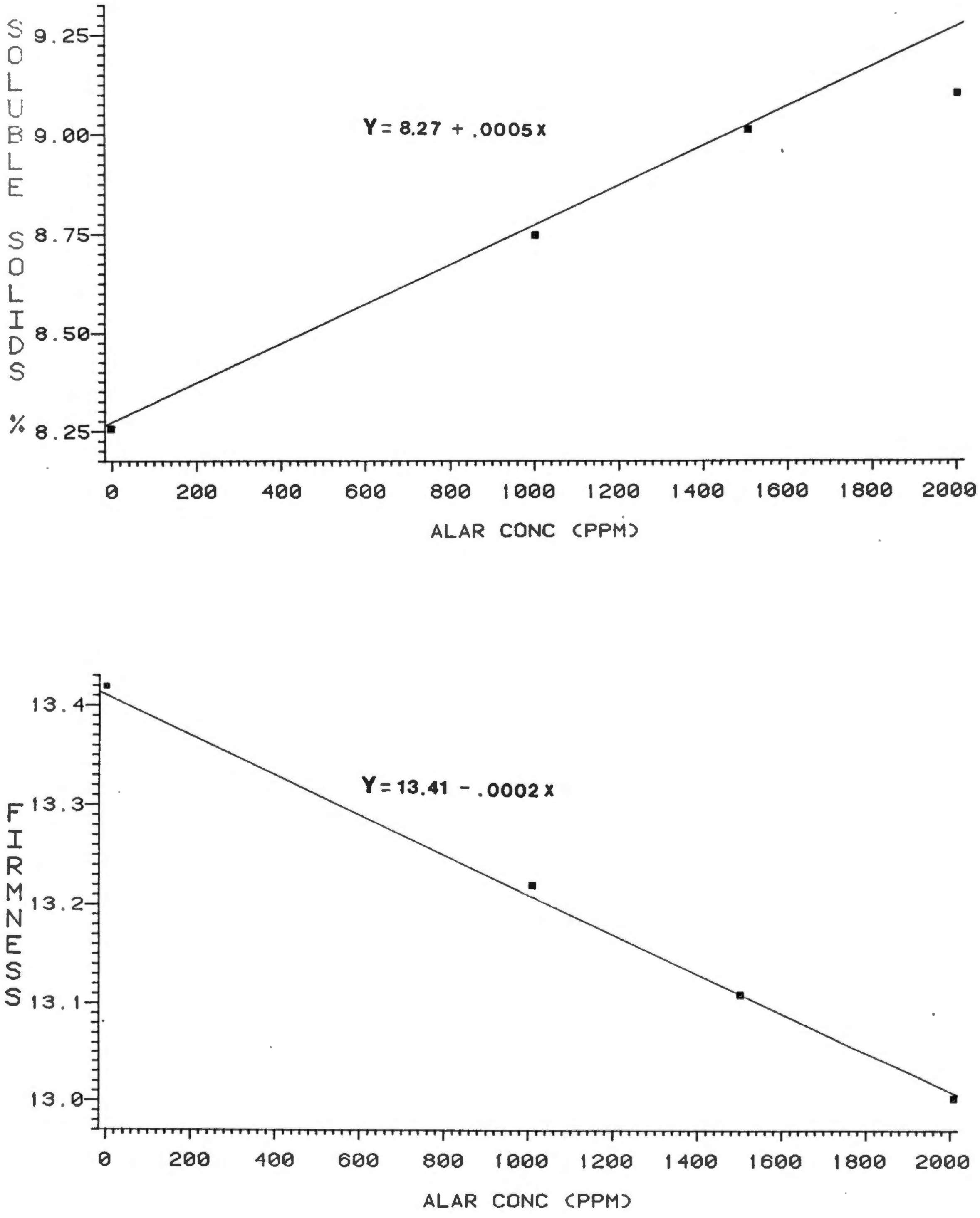


Figure 16. Effect of daminozide on fruit firmness and soluble solids of 'NuRed Rome' grown at Crossville, Tennessee 1982.

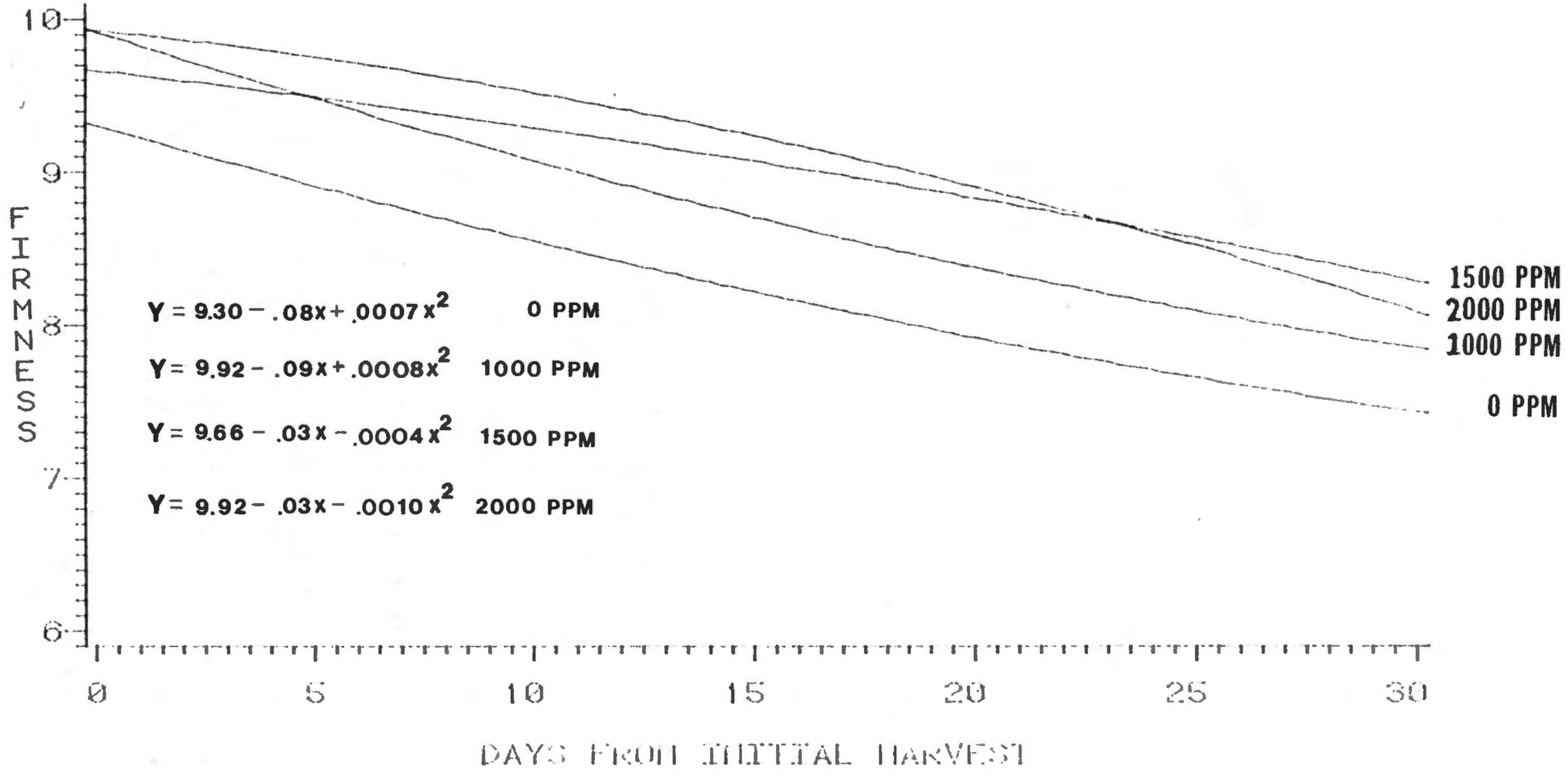


Figure 17. Effect of daminozide on fruit firmness (kg) throughout the 1982 harvest season of 'NuRed Rome' apples grown at Crossville, Tennessee. Initial harvest was 150 DFFB.

daminozide overcame this effect. With an application of ethephon, only the 2000 ppm daminozide-treated apples remained firmer than the untreated fruit (Figure 18).

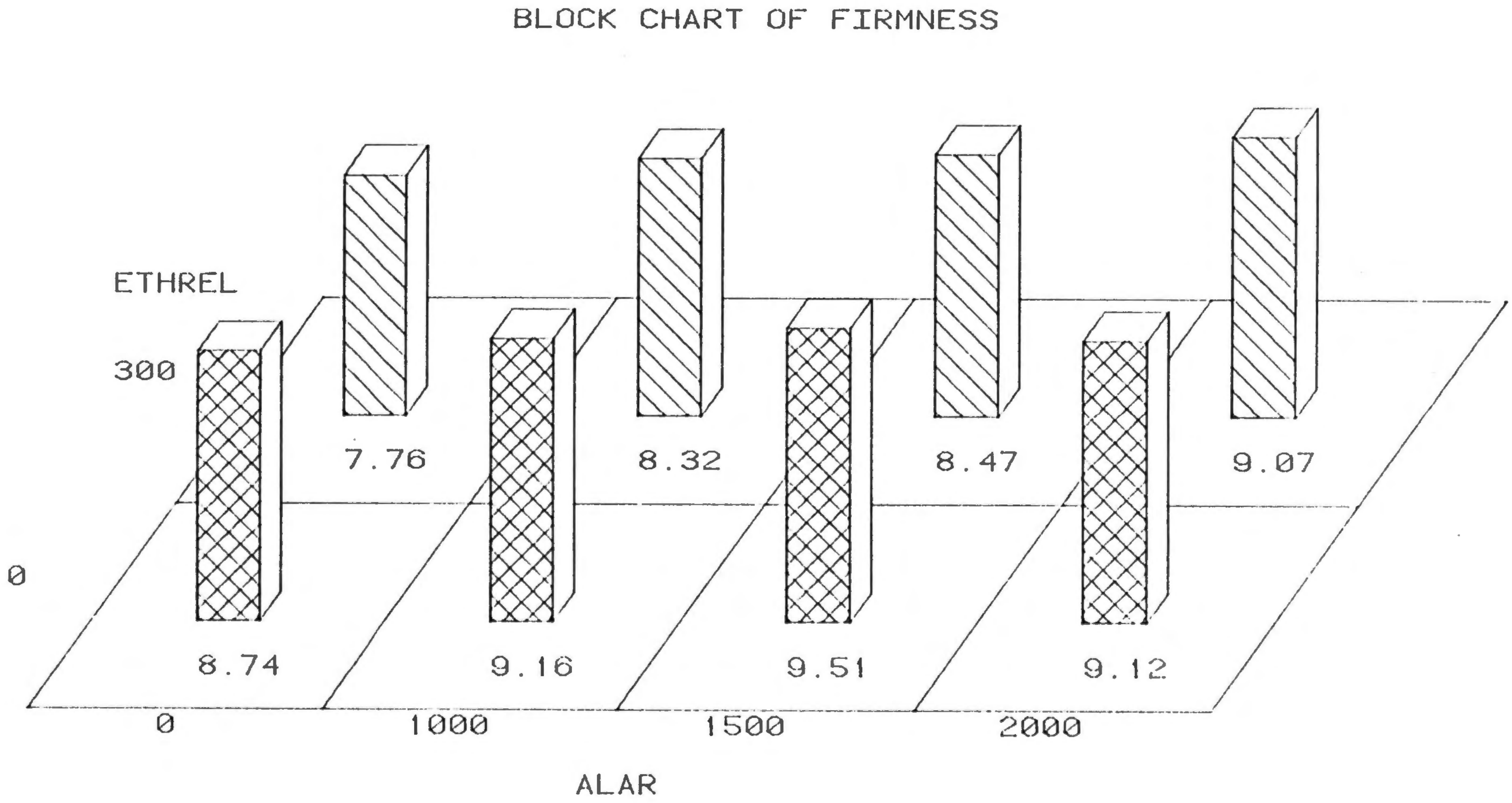


Figure 18. Effect of daminozide and ethephon on fruit firmness of 'NuRed Rome' apples grown at Crossville, Tennessee 1982.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were to examine the effects of succinic acid, 2,2-dimethylhydrazide (daminozide) and 2-chloroethylphosphonic acid (ethephon) plus sodium 1-napthalene acetate (NAA) on fruit maturity and quality of 'Redchief Red Delicious' and 'NuRed Rome' apple fruit in Tennessee.

The daminozide treatments on 'Redchief Red Delicious' fruit decreased ethylene production and percent soluble solids, while also increasing fruit firmness. The application of ethephon to fruit enhanced soluble solids and red skin color through the 1981 harvest season. Daminozide clearly had some effect on delaying the ripening process, given the increase in firmness which resulted from the daminozide treatment.

The 1982 study on 'NuRed Rome' apple fruit showed that fruit firmness was increased by daminozide treatment, and only the 2000 ppm daminozide concentration had a decreased effect on soluble solids. When ethephon was applied to fruit previously treated with daminozide, ethephon enhanced soluble solids, and caused fruit softening over the harvest season. Results of ethephon treatment show slightly flattened fruit as observed by a significant decrease in fruit shape (L/D). The application of ethephon in 1982 resulted in a significant increased effect on Hunter "a" and "$\tan^{-1}$ a/b" color values over the harvest season, indicating an increase in red skin color. Ethephon initially increased fruit weight over the harvest season, as well as causing an early acceleration in sugar accumulation. Fruit softening was also noted throughout the 1982 harvest season as a result of the ethephon treatment.

In summary, these data seem to support previous reports that when ethephon is applied to fruit previously treated with daminozide, it advances ripening by increasing soluble solids, red color development, and fruit softening. However, ethephon did not accelerate fruit softening in the 1981 study. Daminozide treatment in 1981 suppressed the effect of ethephon on ethylene production. However, even with previous daminozide treatment a clear pattern developed with other maturity indices which suggested ethephon's ability to advance this delay in maturity. With the exception that daminozide interfered with the effect of the ethephon application on increasing ethylene production, it did not appear to maintain a strong influence on fruit maturity. In the 1981 study, ethephon may have been applied too early to cause significant effects on the change in fruit parameters over the harvest season. This may have had some influence on the fact that the ethephon application did not overcome daminozide's effect on ethylene production, or significantly increase fruit softening.

These studies suggest that ethephon has practical implications on bringing 'Redchief Red Delicious' and 'NuRed Rome' apples to desirable color and quality without serious fruit softening. Data also indicate that red color and soluble solids may be greatly enhanced and the delayed ripening response to daminozide minimized by applications of ethephon (300 ppm) + NAA (10 ppm) after an application of daminozide at no more than 1500 ppm. However, more research in this area on the concentration and timing for specific cultivars would be needed to achieve optimum response, and to evaluate the ability to predict harvest dates.

LITERATURE CITED

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