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I am submitting herewith a dissertation written by Johnie Benjamin Sikes, Jr., entitled "Catfacing of Tomatoes as Influenced by Pruning and Growth Regulator Applications." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plant and Soil Science.

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CATFACING OF TOMATOES AS INFLUENCED BY PRUNING AND GROWTH REGULATOR APPLICATIONS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee

Johnie Benjamin Sikes, Jr.

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ABSTRACT

Field studies were conducted at the University of Tennessee Agricultural Experiment Station at Knoxville in 1974 and 1975 to determine the influence of pruning and auxin on the incidence of catfacing in fresh market tomatoes (Lycopersicon esculentum, cv. Manapal). It was found that time of pruning affected catfacing more than did the amount of pruning. A 2 stem, delayed pruning system produced a lower percentage of catfaced fruit than either 1 or 2 stem early pruning systems. Catfacing occurred on plants in an unpruned system equal to that of the delayed pruning system, but early marketable yields were lower with unpruned plants. Nitrogen fertilization had no effect on the incidence of catfacing.

Results indicated that certain concentrations of applied synthetic auxin (α -napthalene-acetic acid) could mitigate the increased catfacing response of early-pruned treatments. Plants receiving auxin applications were observed to have vegetative characteristics similar to those of delay-pruned plants which had no auxin applied. These findings and the characteristic nature of the deformity suggest that growth regulator balance may influence the information of catfaced fruit.

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CHAPTER I

LITERATURE REVIEW

Catfacing is usually manifested as an abnormally large scar or opening on the blossom end, but may also extend up the sides to cause deformity of the entire tomato fruit. This results in lowering of fruit quality, and the fruits affected are often unacceptable for the market. Since this reduces profits to growers, the disorder is of economic concern.

Various environmental stress factors have been implicated as possible causes for catfacing. Although there are few studies to be found in the literature which deal specifically with this problem, the concensus seems to be that stress factors are most critical at the time of flower bud initiation. Initiation for the first fruit clusters is at approximately the fourth true leaf stage in terms of vegetative development (8). Some of the stress factors which have been suggested to influence catfacing include: (1) cold temperatures experienced in the field soon after transplanting (3, 8); (2) high night temperatures (Paul Thomas, personal communication); and (3) exposures to excessive wind agitation (5). The objective of this study was to identify a common physiological component through which these and other possible stress factors act to influence catfacing.

Recent developments in the literature concerning both fruit quality and vegetative characteristics have contributed to a new line of thought on the identification of the physiological component in question. Knavel

and Mohr (8) studied the effects of cold temperature on fruit quality in tomatoes and found that plants grown at a 42° to 56° F. regime yielded more catfaced fruit than those grown at 68° to 72° F. Histological examination of abnormal pistils from the cold-treated plants revealed a region at the base of the style where cell division and enlargement had failed to occur, resulting in incomplete development of the ovary wall. They suggested that the cold temperatures may have inhibited either the synthesis or transport of growth regulating substances during the development of this region. The failure of the carpels to close would result in the catfacing scar as this region expanded with normal growth and enlargement of other portions of the fruit during later development.

Greig et al. (5) found that catfacing was increased when tomato seedlings were exposed to 13.4 m/sec. wind speeds for 15 minutes. Mitchell et al. (10) used mechanical agitation to simulate wind, and found that vegetative responses resembling growth retardant applications were obtained. Rudich and Rabinowitch (12) conducted studies on the use of chloroflurenol as a method for increasing fruit set on processing tomatoes grown for mechanical harvest. They reported that this auxin transport inhibitor caused increases in the number of rough and malformed fruit.

Growth regulator involvement has also been implied for later stages of fruit development. Guard (6) reported that fruit containing carpels with few or no seeds tended to be puffy or malformed. Developing seeds are known to be a rich source of endogenous auxin in tomato fruit (13). This has led to suggestions that faulty pollination could be related to

catfacing since an unequal distribution of seeds, as auxin sources, might result in abnormal fruit growth (15).

CHAPTER II

MATERIALS AND METHODS

The study consisted of 2 separate field experiments at the University of Tennessee Agricultural Experiment Station at Knoxville on an Etowah silt loam soil. This chapter is divided into 2 parts to give a concise presentation of materials and methods applicable to each experiment. The 1974 portion of the study is referred to as Experiment A and the 1975 portion as Experiment B.

I. EXPERIMENT A

General Information

Plants of Manapal, a cultivar with high incidence of catfacing, were seeded in the greenhouse on March 15 and transplanted to the field on April 25, 1974. A split plot experimental design with 4 replications was used. Time of nitrogen application was varied between the 2 main plots, and pruning systems among the 4 subplots. The main plot treatments were: (1) 135 kg/ha nitrogen applied as preplant ammonium nitrate and (2) 135 kg/ha nitrogen applied 22.5 kg/ha preplant with 3 sidedressings of 22.5, 45.0, 45.0 kg/ha, respectively. The first sidedress was applied as the first cluster of fruit reached 3.5 to 4.0 cm diameter. The remaining nitrogen was sidedressed at 2 week intervals. Subplot treatments were (1) unpruned, supported by stakes and weaved; (1) early-pruned to 1 stem (not allowing suckers to exceed 5 cm length

before removal) and staked; (3) early pruned to 2 stems and staked; and (4) delay pruned to 2 stems (with all pruning delayed until after initial fruit set) and staked.

Tomato Leaf Tissue Samples

Beginning 3 weeks after transplanting into the field, tissue samples were collected 6 times at 10 day intervals for laboratory analysis of total nonstructural carbohydrates and nitrate-nitrogen. The fourth leaf from the stem tip was collected from 10 plants per treatment on each occasion. The samples were sealed in polyethylene bags, placed on dry ice immediately and stored at -20° C. Samples were then freeze-dried, ground to 20-mesh, and returned to -20° C. for storage until analysis was performed.

Nitrate-Nitrogen Determination

An Orion Model 92-07 nitrate ion activity electrode and a single junction reference electrode, Orion Model 90-01, filled with saturated KCl, were used with an Orion Model 701 digital pH Meter having expanded mv scale and direct display for monovalent anion electrodes. A standard calibration curve was constructed using 10 to 100 mg NO_3-N standards derived from KNO_3 in a 0.01 N KH_2PO_4 buffering solution. De-ionized, cold water was used as the extracting solution. The analysis procedures were after those described by Brown (2).

Total Nonstructural Carbohydrate Determination

A quantitative determination of total nonstructural carbohydrates was made using the anthrone method (11). Carbohydrates were extracted

with .02 N H_2SO_4 in a boiling water bath for 1 hour, and filtered through Whatman's No. 2 filter paper. The standard curve was constructed using 0 to .1 mg/ml glucose solutions. The instrument used was a Perkin-Elmer Model 202 Ultraviolet-Visible spectorphotometer.

Seed Count Data

On each of 4 dates, 24 tomato fruits were collected for comparison of fruit characteristics based on relative severity of the catfacing scar. Figure 1 illustrates the varying degrees of catfacing noted and the numerical rating assigned to each grouping. The numerical ratings assigned ranged from 1 to 6 with a rating of 1 representing normal fruit with no catfacing and 6 representing fruit which were severely deformed by catfacing. The ratings of 2 through 5 were assigned to order of increasing severity based on increasing size of the catfacing scar and overall fruit shape.

The data determined for each fruit were number of carpels, total number of seed, fruit weight, number of empty carpels, average weight per carpel, and average seed per carpel. At each sampling date 4 fruit of each of the 6 catfacing categories were selected. Selections were based entirely on the appearance of the fruit in regard to catfacing with no consideration being given to treatment variables.

Field Harvest Data

Tomatoes were harvested twice weekly in the pink stage. The data collected were total number, number catfaced, and number and weight of U.S. Standard grade marketable fruit. The harvest period was of 6 weeks duration. Figure 2 depicts the various forms and severity of catfacing



Figure 1. The varying degrees of catfacing and the corresponding ratings assigned for seed-count purposes.



Figure 2. The various forms of catfacing observed.

observed in the study. Equal consideration was given to any catfaced fruit considered, regardless of the relative differences in severity, when determining percentage of catfaced fruit. Severity of catfacing was taken into consideration in determining the marketable yield.

II. EXPERIMENT B

Manapal tomato plants were seeded in the greenhouse on March 18 and transplanted to the field on April 23, 1975. A randomized complete block design with 14 treatments and 6 replications was used. One half of the treatments were early-pruned to 2 stems (not allowing suckers to exceed 5 cm in length before removal) and staked. The second half were delay-pruned to 2 stems (with all pruning delayed until after initial fruit set) and staked. Other treatment variables were the concentrations of synthetic auxin applied and the time of application. The following is a grouping of treatments according to the variables applied:

1. Early-pruned treatments were: 1, 2, 3, 4, 5, 6, and 7.
2. Delay-pruned treatments were: 8, 9, 10, 11, 12, 13, and 14.
3. Early auxin applications were received by: 2, 3, 4, 9, 10, and 11.
4. Late auxin treatments were received by: 5, 6, 7, 12, 13, and 14.
5. Auxin concentration of 10^{-2}M were applied to: 2, 5, 9, and 12.
6. Auxin concentration of 10^{-3}M were applied to: 3, 6, 10, and 13.
7. Auxin concentration of 10^{-4}M were applied to: 4, 7, 11 and 14.
8. No auxin was applied to: 1 and 8.

Early auxin applications were made at the third leaf axil below the first blossom cluster 20 days after transplanting to the field.

Treatments receiving the early auxin applications had one additional application 6 days later at the first leaf axil above the first blossom cluster. Late auxin applications were begun 26 days after transplanting to the field at the first leaf axil above the first blossom cluster. Treatments receiving the late auxin applications had three additional applications at the following times and locations: (1) 33 days after transplanting at first leaf axil above second cluster of main stem, (2) 36 days after transplanting at first leaf axil above third cluster of main stem, and (3) 36 days after transplant at first leaf axil above first cluster of secondary stem.

The auxin solutions to be used were prepared by dissolving α -napthalene-acetic acid (NAA) in 95 percent ethanol. The method for application was after that of Looney and McIntosh (9). This method made quantitative applications at desired locations possible. Toothpicks were cut into 1 cm sections and soaked for 24 hours in the NAA solution. The toothpick sections were then inserted into the stem of the treated plants at the prescribed time and position on the plant.

Tomatoes were harvested twice weekly in the pink stage. Data collected were total number, number catfaced, and number and weight of marketable fruit. The harvest period covered 6 weeks. Harvests were begun June 24 and 25 for 1974 and 1975, respectively.

III. STATISTICAL ANALYSIS

The statistical analysis was performed in the same manner for both Experiments A and B. Treatment effects were determined by Analysis of

Variance and means were separated by Duncan's New Multiple Range Test. Treatment means within each test followed by the same letter are not significantly different at the 5 percent level of probability.

CHAPTER III

RESULTS

I. EXPERIMENT A

Table 1 lists the results of the laboratory analysis of leaf tissue samples for nitrate-nitrogen (NO_3-N) and total nonstructural carbohydrate (TNS-CHO) Content. The unpruned treatment had a lower NO_3-N content and greater TNS-CHO content over the entire season than did any of the pruned systems. There were no significant differences for these two parameters among the three pruned systems. Between main plot treatments, as expected, plants with all nitrogen applied preplant had significantly higher NO_3-N and lower TNS-CHO than those receiving nitrogen as preplant plus sidedress. There were no significant main plot X subplot interactions.

Differences obtained among treatments for yield are presented in Table 2. In terms of marketable yield, expressed in metric tons per ha, all pruned systems had significantly higher yields for the first 3 weeks of harvest than the unpruned system. Total marketable yield for the 6 weeks harvest period was greater for the unpruned than any pruned system and greater for both the 2 stem systems than for the 1 stem. Average weight per marketable fruit was less in the unpruned system as compared with the 3 pruned systems. No differences in yield were obtained between the main plot nitrogen treatments. The interactions among main plots and subplots also did not differ significantly.

TABLE 1

NITRATE-NITROGEN AND TOTAL NONSTRUCTURAL CARBOHYDRATE CONTENT OF TOMATO LEAF TISSUE FROM THE DIFFERENT NITROGEN AND PRUNING TREATMENTS IN 1974

Treatment	NO_3-N (%)[y]	TNS-CHO (%)
Pruning System		
1 Stem, Early	.81 a[z]	2.03 b
2 Stem, Early	.78 a	2.31 b
2 Stem, Delay	.73 a	2.21 b
Unpruned	.52 b	2.64 a
Nitrogen Application		
Preplant	.74 a	2.07 b
Preplant + Sidedress	.62 b	2.48 a
Nitrogen Application X Pruning System		
Preplant		
1 Stem, Early	.81 a	2.04 a
2 Stem, Early	.77 a	2.09 a
2 Stem, Delay	.79 a	2.03 a
Unpruned	.63 a	2.22 a
Preplant + Sidedress		
1 Stem, Early	.70 a	2.12 a
2 Stem, Early	.73 a	2.58 a
2 Stem, Delay	.74 a	2.34 a
Unpruned	.44 a	3.11 a

[z]Means separated by Duncan's Multiple Range Test, 5 percent level.

[y]NO_3-N and TNS-CHO expressed on dry weight basis.

TABLE 2

EARLY AND TOTAL MARKETABLE YIELDS AND AVERAGE WEIGHT PER MARKETABLE FRUIT FROM THE DIFFERENT NITROGEN AND PRUNING TREATMENTS IN 1974

Treatment	Marketable Yield[z] (Metric Tons/Ha) Early[y]	Total	Avg. Wt./ Marketable Fruit (g)
Pruning System			
1 Stem, Early	13.2 a[x]	41.7 c	210.5 a
2 Stem, Early	13.9 a	57.7 b	199.1 a
2 Stem, Delay	13.5 a	58.1 b	194.8 a
Unpruned	7.8 b	84.8 a	143.8 b
Nitrogen Application			
Preplant	11.7 a	59.9 a	190.3 a
Preplant + Sidedress	11.7 a	58.1 a	183.4 a
Nitrogen Application X Pruning System			
Preplant			
1 Stem, Early	13.0 a	38.3 a	207.5 a
2 Stem, Early	13.6 a	56.9 a	206.9 a
2 Stem, Delay	13.0 a	60.6 a	205.5 a
Unpruned	8.0 a	84.7 a	141.4 a
Preplant + Sidedress			
1 Stem, Early	13.0 a	42.6 a	213.1 a
2 Stem, Early	13.6 a	56.2 a	191.0 a
2 Stem, Delay	13.0 a	53.1 a	183.7 a
Unpruned	7.4 a	81.0 a	146.0 a

[z]Yield for U.S. Standard Grades 1 and 2.

[y]Yield from first 3 weeks of harvest.

[x]Means separated by Duncan's Multiple Range Test, 5 percent level.

Table 3 presents the values obtained for catfacing during the early and late harvest periods and total for the season. No differences were obtained among treatments for catfacing during the early harvest period. However, during the late harvest period, the 2 stem delay-pruned and the unpruned systems both produced less catfacing than either of the early-pruned systems. The unpruned and 2 stem delay-pruned systems also produced a lower percentage of catfaced fruit than either of the early-pruned systems over the entire season. The 1 stem early-pruned system produced a lower percentage of catfacing than the 2 stem early-pruned over the total season harvest period. No significant differences were detected between nitrogen application treatments, nor among nitrogen X pruning interactions for any of the harvest periods shown in Table 3.

Data for individual fruit characteristics according to the relative severity of the catfacing deformity are presented in Table 4. Significant differences were obtained among the 6 catfacing ratings for all parameters observed except number of seed per fruit. The relative association of these fruit characteristics and their bearing on the catfacing deformity are discussed further in Chapter IV of this text.

II. EXPERIMENT B

The reader is referred to Chapter II for delineation of treatment variables according to treatment number. Means for marketable yield and the early, late and total percentage of catfaced fruits are presented in Table 5.

The general trend for differences in marketable yield was toward higher yields for the early pruned treatments than for the delay pruned

TABLE 3

EARLY, LATE AND SEASON PERCENT CATFACED TOMATO FRUIT FROM THE DIFFERENT NITROGEN AND PRUNING TREATMENTS IN 1974

Treatment	Catfaced Early[y] (%)[z]	Catfaced Late[x] (%)[z]	Catfaced Season (%)[z]
Pruning Systems			
1 Stem, Early	48.3 a[w]	67.8 a	59.1 b
2 Stem, Early	57.1 a	70.7 a	66.4 a
2 Stem, Delay	48.1 a	47.6 b	47.8 c
Unpruned	47.3 a	45.6 b	45.9 c
Nitrogen Application			
Preplant	50.7 a	63.4 a	58.9 a
Preplant + Sidedress	49.7 a	52.5 a	50.7 a
Nitrogen Application X Pruning System			
Preplant			
1 Stem, Early	49.5 a	69.3 a	60.3 a
2 Stem, Early	58.8 a	81.9 a	74.5 a
2 Stem, Delay	47.0 a	52.8 a	51.5 a
Unpruned	47.3 a	49.4 a	49.3 a
Preplant + Sidedress			
1 Stem, Early	47.1 a	66.3 a	57.8 a
2 Stem, Early	55.4 a	59.5 a	58.3 a
2 Stem, Delay	49.2 a	42.3 a	44.2 a
Unpruned	47.2 a	41.8 a	42.4 a

[z]Total number of fruit harvested.

[y]First 3 weeks of harvest.

[x]Last 3 weeks of harvest.

[w]Means separated by Duncan's Multiple Range Test, 5 percent level.

TABLE 4

NUMBER OF CARPELS PER FRUIT, NUMBER OF SEED PER FRUIT, FRUIT WEIGHT, NUMBER OF EMPTY CARPELS, AVERAGE WEIGHT PER CARPEL, AND AVERAGE SEED PER CARPEL FOR 6 CATEGORIES OF CATFACING SEVERITY IN 1974

Rating	Carpels/ Fruit (No.)	Seed/ Fruit (No.)	Fruit Wt. (g)	Empty Carpels/ Fruit (No.)	Avg. Wt./ Carpel (g)	Avg. Seed/ Carpel (No.)
1	5.3 c[z]	221.1 a	214.8 c	0.1 c	42.3 a	45.2 a
2	7.9 bc	188.9 a	245.7 bc	1.1 bc	32.6 b	26.3 b
3	9.8 ab	211.3 a	287.5 ab	0.7 bc	29.6 b	21.6 bc
4	12.0 ab	206.0 a	320.5 a	1.6 abc	27.5 b	17.3 bc
5	12.5 a	240.9 a	286.2 ab	1.8 ab	23.8 bc	21.1 bc
6	13.9 a	150.9 a	221.8 bc	3.9 a	16.2 c	10.3 c

[z]Means separated by Duncan's Multiple Range Test, 5 percent level.

TABLE 5

MARKETABLE YIELD AND EARLY, LATE AND SEASON PERCENT CATFACED TOMATO FRUIT FROM DIFFERENT AUXIN APPLICATIONS AND PRUNING TREATMENTS IN 1975

Treatment No.	Treatment	Marketable Yield[z] (Metric Tons/ha)	Catfaced Early[x] (%)[v]	Catfaced Late[w] (%)[v]	Catfaced Season (%)[v]
	Early Pruned				
1	No Auxin	47.9 abcd[y]	61.9 a	53.1 a	56.3 a
	Early Auxin				
	10^{-2}M	50.1 a	61.1 a	46.0 abcd	50.6 abc
	10^{-3}M	49.9 ab	61.4 a	42.0 bcd	49.7 abc
	10^{-4}M	49.3 abc	59.0 a	50.9 ab	54.1 ab
	Late Auxin				
5	10^{-2}M	44.3 bcde	52.2 a	39.8 cd	43.6 c
6	10^{-3}M	47.2 abcd	54.4 a	49.1 abc	51.2 abc
7	10^{-4}M	47.8 abcd	61.1 a	46.1 abcd	51.9 abc
	Delay Pruned				
8	No Auxin	43.8 cde	65.0 a	37.2 d	47.7 abc
	Early Auxin				
9	10^{-2}M	40.9 e	61.2 a	38.4 d	46.5 bc
10	10^{-3}M	44.9 abcde	65.9 a	44.6 abcd	52.7 abc
11	10^{-4}M	45.9 abcde	55.1 a	40.1 cd	47.3 abc
	Late Auxin				
12	10^{-2}M	43.1 de	55.1 a	39.9 cd	46.9 abc
13	10^{-3}M	46.1 abcde	61.0 a	41.5 bcd	48.8 abc
14	10^{-4}M	46.9 abcd	58.9 a	39.3 cd	46.4 bc

[z]Yield for U.S. Standard grades 1 and 2.

[y]Means separated by Duncan's Multiple Range Test, 5 percent level.

[x]First 3 weeks of harvest.

[w]Last 3 weeks of harvest.

[v]Total number of fruit harvested.

treatments. Within pruning treatments, the early prune, early auxin application at the highest rate yielded greater than the early prune late auxin application at the highest rate. Conversely within the delay pruned treatments, the late auxin application at the lowest rate had a higher yield than the early auxin application at the highest rate. This indicates that auxin levels may have become too high in delay-pruned treatments due to their maintenance of higher endogenous levels with suckers left on longer.

No significant differences were found among treatments for percentage of catfaced fruits during the first 3 weeks of the harvest period. During the last 3 weeks of harvest, however, the early-pruned treatments with auxin applied early at the lower rates and the no-auxin treatment produced more catfacing than most of the delay pruned treatments and early pruned treatments with auxin applied late at the higher rates. Over the entire 6-week harvest period, early-pruned treatments with no auxin and with auxin applied early at the lowest rate produced the greatest amount of catfacing. The treatment with late auxin application at the highest rate produced the least amount. Treatment 14, which was delay pruned with the lowest rate of auxin applied late was an exception.

Figures 3, 4, 5, and 6 depict representative differences observed in vegetative characteristics among some selected treatments. Figures 3, 4, and 5 were selected to demonstrate relationships which existed in terms of epinasty. Figure 3 is an example of plants from treatment 1 which was early-pruned with no auxin applied. No epinasty is present. Figure 4 is representative of treatment 2 which was early-pruned with



Figure 3. A plant exhibiting no epinasty of lower petioles when early-pruned with no auxin applied.



Figure 4. A plant exhibiting an exaggerated form of epinasty on lower petioles when early-pruned with 10^{-2}M NAA applied.



Figure 5. A plant exhibiting a moderate form of epinasty on lower petioles when delay-pruned with no auxin applied.

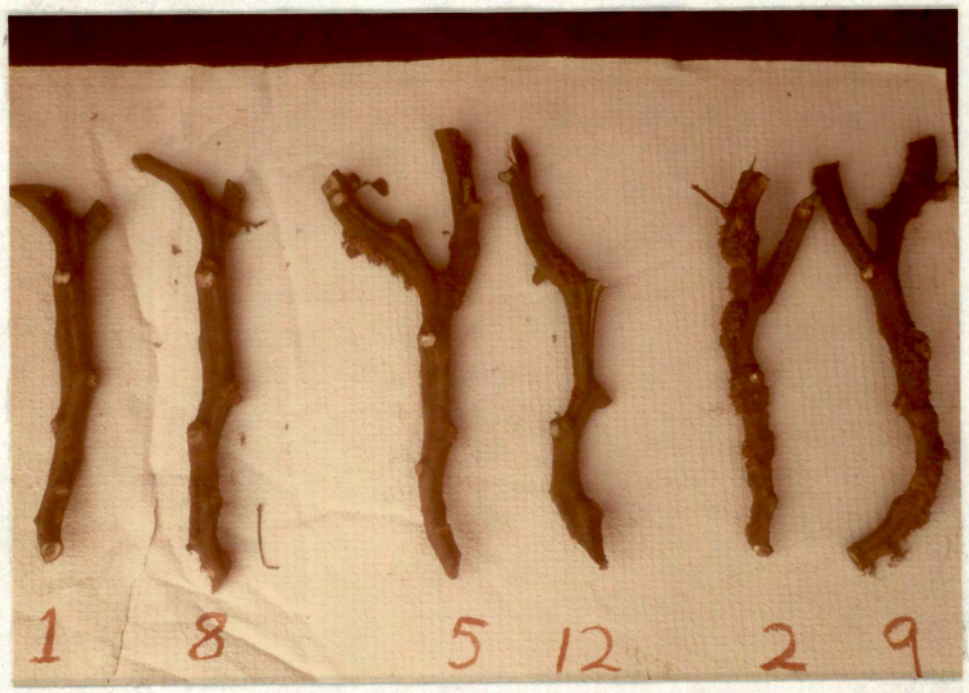


Figure 6. Cut-stem sections showing adventitious root development as being: (1) heavy with 10^{-2}M NAA applied early to both early and delay pruned plants (2, 9); (2) moderate with 10^{-2}M NAA applied late to both early and delay-pruned plants (5, 12); (3) light with delay-pruned plants and no auxin applied (8); and (4) none with early-pruned plants and no auxin applied (1).

10^{-2}M NAA applied early. An exaggerated form of epinasty is present. Figure 5 is a plant from treatment 8, which was delay-pruned with no auxin applied. The degree of epinasty observed was intermediate between that of treatments 1 and 2.

Figure 6 shows adventitious root development as being heavy, with treatments 2 and 9; and moderate with treatments 5 and 12. Treatments 2 and 9 were early-pruned and delay-pruned respectively with auxin applied late at the highest rate. Treatment 1, which was early-pruned with no auxin, had no adventitious root development. Treatment 8, which was delay-pruned with no auxin, displayed a light amount of adventitious root development, however.

CHAPTER IV

DISCUSSION

Although the data presented in Table 1, page 13, contained means which were significantly different, it does not appear that the carbohydrate or NO_3-N level in the plant tissue was related to the percentage of catfaced fruits produced. The unpruned system had significantly less NO_3-N and more carbohydrate content in the tissue than any of the pruned systems. Table 3, page 16, however, shows that the unpruned treatment behaved the same as the 2 stem delay-pruned system in terms of percentage of catfaced fruits. Likewise, although the 2 stem delay-pruned system was the same as the two early-pruned systems for NO_3-N and carbohydrate levels, it produced a significantly lower percentage of catfaced fruits.

In addition to differences noted in catfacing, there were also differences in yield among pruning treatments. The lower early marketable yield in the unpruned system was a reflection of the greater amount of vegetative growth and heavier fruit set on this treatment. Both of these factors would tend to delay maturity and shift yields to a later period. The heavier fruit set was also manifested in total marketable yield with the unpruned out-yielding all pruned systems and both 2 stem systems outyielding the 1 stem. The heavier set resulted in a reduction in fruit size which could be of some consequence depending on market demands.

The differences observed among pruning treatments for catfacing in Experiment A can be explained better in terms of the timing of the pruning operation than the amount of pruning. If the amount of pruning was critical, both 2 stem systems should have responded similarly for catfacing, but as shown in Table 3, page 16, they did not. Instead, the critical factor seems to have been that the suckers were left on the plants producing the least amount of catfacing until at least the time of initial fruit set, whereas treatments producing a greater amount of catfacing had suckers removed at an earlier developmental stage. This indicates that a substance which is needed for proper fruit development was removed with the suckers prior to a critical stage in the ontogeny of the fruit resulting in insufficient quantities of the substance for normal cell division and structural tissue formation. Differences obtained between the two early-pruned systems show that the 1 stem system produced a lower percentage of catfacing than the 2 stem over the season total. It is possible that the reduced quantities of the substance in question were nearer to the optimum in the 1 stem system due to the fewer number of fruit clusters and thus the smaller sink for growth substances needed than in the 2 stem plants.

As discussed in Chapter I, the implications of several independent studies have resulted in a line of thought which indicates growth regulator involvement in the formation of rough and malformed fruit. In considering the study conducted on catfacing as affected by wind agitation (5) together with the observations of Mitchell (10) on vegetative characteristics due to mechanical agitation, increased

endogenous growth retardant levels could be suspected as a cause of increased catfacing. The work by Rudich and Rabinowitch (12), indicating that chloroflurenol caused increases in catfacing, supplies more evidence for this hypothesis.

The activity of growth regulators in the plant, however, is seldom a simple all-or-none function governed by a single growth substance. Rather, it is usually a situation of proper balance among several substances at a critical developmental stage that is important (13). It is plausible to assume that removal of suckers constituted a removal of one or more of these substances in amounts significant enough to upset this balance. Since the primary sources for endogenous auxin production are removed by pruning away the meristematic regions of axillary shoots, the consequent reduction in auxin levels could be responsible for upsetting the balance. Kazemi and Kefford (7) reported that removal of the apical meristem resulted in hyponasty of petioles due to auxin deficiency in tomato plants. Vieth (14) determined the carpels are especially sensitive to endogenous levels of IAA during floral development in tomatoes which could increase the incidence of catfacing by either of the following: (1) incomplete closure of carpel walls at the blossom end resulting in the catfacing scar or opening as the fruit enlarges (as discussed in Chapter I); or (2) by interfering with the normal growth and penetration of pollen tubes, in an orderly and equally distributed fashion into the ovary, due to incomplete tissue formation near the base of the style as reported by Knavel and Mohr (8).

The former of the two above mentioned effects would be considered a direct injury and requires little explanation. An incomplete tissue

development in this region would almost certainly enlarge into a scar or opening as the fruit enlarged. Catfacing is expressed in varying degrees of severity, however (Figure 1, page 7), and the direct effect of a tissue void in the region may or may not serve to account for the amount of deformity noted in all instances.

The latter of the two effects discussed above could be termed as an indirect injury or effect, and might be of some importance in explaining differences noted in severity of catfacing. Once the tissue malformation has occurred in the region at the base of the style, it is assumed that a catfacing scar will result. If, however, this underdeveloped region also interferes with the normal growth and distribution of pollen tubes as they enter the ovary through the base of the style, further malformation of the fruit is likely to result. The more severe deformity would be the result of an unequal distribution of seeds within the fruit due to the interrupted direction of pollen tube growth in the region where the carpel walls had failed to develop properly. An unequal distribution of seeds would produce unequal fruit growth due to the unbalanced apportionment of auxin associated with developing seeds (6, 13, 15). The resulting pressure of unequal growth could result in a longitudinal split in the fruit wall at an early stage and the deformed overall appearance of fruit rated as 5 and 6 in Figure 1.

The growth of pollen tubes was apparently not affected since there was no significant difference noted among catfacing ratings for number of seeds per fruit (Table 4, page 17). Although differences were obtained among severity ratings for fruit weight, in Table 4, the

differences do not correspond to severity of catfacing since the largest fruit are those with a medium rating while the two ratings having the lowest fruit weights are those with no catfacing and those with the most severe catfacing. The general trend was toward a greater number of carpels, containing fewer seeds and weighing less with an increase in catfacing severity.

The parameter in Table 4, page 17, which perhaps relates most directly to catfacing severity is the number of empty carpels per fruit. It is noted that fruit with the 2 most severe catfacing ratings, of 5 and 6, have a significantly greater number of empty carpels than fruit with little or no catfacing. This is in accordance with what should be expected to occur in following the preceding line of thought. This would mean that the fruit which were catfaced as a result of direct injury, due to the failure of carpels to develop properly, fell into the 2 through 4 severity rating range. Seed distribution in the 2, 3 and 4 severity rating range was not affected by the incomplete carpel development since the number of empty carpels present was not significantly greater than that found in fruit with no catfacing. Those fruit having a rating of 5 and 6, however, were apparently affected indirectly by the influence of the underdeveloped region at the base of the style on the direction of pollen tube growth and subsequent seed location. This type of secondary effect could explain the differences noted in form and severity of catfacing. The severity of catfacing present could be of economic concern since mild forms of catfacing scars are acceptable as U.S. standard grade no. 1 fruit, whereas severely catfaced fruits are culled.

The time and rate of auxin application and the timing of the pruning operation were the variables considered in the 1975 portion of the study. Significant differences were obtained during the last 3 weeks of harvest, as opposed to none for the first 3 weeks. This indicates that the treatments were applied after the critical stage had passed for the development of early fruit, and differences obtained for the entire harvest period were probably moderated somewhat due to the lack of effect on the early harvest. This is consistent with other studies which have indicated that the early fruit clusters are affected during the 4 to 6 true leaf stage (5, 8, 10). Plants had reached the 10 to 12 leaf stage at the first auxin application. This was necessitated by the need for larger stem diameter to accommodate the auxin-soaked toothpick sections. In accordance with normal cultural operations, plants were not pruned until the 8 to 10 leaf stage. These time factors provided additional evidence for establishing the developmental stage at which the fruit are most susceptible to the initiation of the catfacing deformity. Table 3, page 16, shows that the same situation existed for differences in catfacing among pruning treatments in Experiment A. It is noted that in that portion of the study, the percentage of catfaced fruit remained relatively constant for both the early and late harvest periods for the delay-pruned and unpruned systems, whereas the early-pruned systems both produced an increase in catfacing in the late as compared to the early portion of the harvest. This again indicates that only the later fruit clusters were affected at the time of treatment application.

The early-pruned, no auxin treatment produced a higher percentage of catfaced fruit for the last 3 weeks of harvest than all delay-pruned

treatments regardless of auxin application times or rates. The exception to this was treatment 10 which, although not less than treatment 1, was not significantly different from the other delayed pruning treatments. Treatments 3 and 5, which were early-pruned with the middle to higher rates of auxin applied, were also significantly less than the early-pruned no-auxin treatment.

All early-pruned systems which had auxin applied, with the exception of treatments 4 and 6, performed on the same level with the delay-pruned systems in terms of catfacing. This implies that the supplemental auxin application mitigated the effects of early pruning which caused increased catfacing. Treatments 4 and 6 had auxin applied early at the lowest rate and late at the middle rate respectively. The failure of these two treatments to respond according to the trend was probably the result of insufficient amounts of auxin reaching the developing fruit at the critical stage. This could have been due to either the low rate, in the case of treatment 4, or the late application time for treatment 6.

The vegetative characteristics shown in Figures 3 through 6, pages 20 through 23, are consistent with the auxin-catfacing relationship. The treatments which had the characteristics of high auxin levels (i.e., epinasty of petioles and adventitious root formation on the stem) were those that also had the lower catfacing rates.

This is not to say, however, that auxin levels are low in absolute terms, but rather that possibly its relationship to other growth substances is important. Gibberellin, for example, would likely be an integral part of growth regulator activity involving auxin (13, 15).

Gibberellin and auxin often act synergistically to accelerate growth. The synergism is presumed to occur in 2 ways: (1) by gibberellin increasing auxin levels through inhibition of auxin-destroying systems or stimulation of auxin production systems, and (2) by acting on enzyme systems to cause an increase in cell osmotic potential after auxin has promoted a loosening of the cell wall structure for elongation (4). It has also been noted that, while auxin alone can cause parthenocarpic fruit set in tomatoes, the use of auxin in combination with gibberellin produced fruit of higher quality (13). The auxin-gibberellin concentration, like many growth substance relationships, appears to be an interacting balance control. For example, gibberellin stimulates lateral shoot development when its concentration relationship to auxin is high. The production of new lateral shoots provides new meristematic regions for auxin production, and the ensuing rise in auxin levels suppresses further lateral bud development and hence the further development of new auxin production sites.

The consideration of general relationships which have been shown to exist between growth inhibiting and growth promoting substances is also of importance. Independent studies have shown that mechanical agitation, such as that due to wind, results in both an increase in catfacing and vegetative characteristics typical of growth retardant application (5, 10). In many systems it has been shown that the effects of promoting hormones are counteracted by growth inhibitor complexes involving substances such as abscisic acid (1). In this instance the inhibiting substances act as a biological brake to promotive systems. With this type of relationship, the proper balance needed at the critical stage of fruit development

could be upset in either of 2 directions: (1) the synthesis or transport of growth promoters could either be inhibited by external factors such as wind or temperature, or sources of these substances could be removed by pruning; or (2) the synthesis or transport of growth inhibitors could be enhanced by the influence of these same external factors.

CHAPTER V

SUMMARY AND CONCLUSIONS

Results of the 1974 field study showed that the timing of the pruning operation was an influencing factor on the rate of catfacing on tomato fruits. Removal of suckers prior to the first fruit set resulted in a greater percentage of catfacing; and, within early-pruned systems, the 1 stem plants had less catfacing than the 2 stem over the total season. A reduction in early yield and average fruit weight occurred when suckers were left on for the entire season, but unpruned plants had a greater total yield. No relationship was established between NO_3-N or carbohydrate levels in the leaf tissue and the differences obtained in catfacing rates among treatments.

It was concluded that a substance critical to the development of normal fruit was removed by pruning of the suckers, and that the effects of the reduced growth substance levels on catfacing could be somewhat reduced by pruning to 1 stem to decrease the number of fruit clusters acting as sinks. These effects were further compensated for in the later fruit clusters when suckers were still on the plant at the time of fruit set for the first cluster. Based on evidence from the 1974 study, the independent variables for the 1975 study were time of pruning and time and rate of synthetic auxin application.

The 1975 study revealed that the exogenous auxin application had no effect on the rate of catfacing among the delay-pruned treatments, but

would reduce the deleterious effects of early pruning at certain application rates. It was also observed that the vegetative response to delayed pruning was similar to that obtained by auxin applications, but in a less exaggerated form. The differences obtained in catfacing rates were during the last 3 weeks of the 6-week harvest period for both years of study. This led to the conclusion that the critical time for affecting the morphological development of the early fruit clusters had passed before treatments were imposed.

The critical period of development, during which catfacing is probably initiated, is during floral bud formation. It is likely that growth regulator balance is critical to the growth and closure of carpels during this period, and that a region will occur near the base of the style where these tissues fail to develop if the balance is not maintained. The resulting injury will develop into the catfacing scar or opening with the severity of the catfacing being dependent upon whether the injury is only direct or involves secondary, indirect injury as well (as discussed in Chapter IV).

The results of these studies support earlier suggestions of growth regulator involvement in the formation of catfaced fruits. Although catfacing rates were reduced by as much as 16 percent in some cases when auxin was applied, it is probable that growth regulators other than auxin are also involved. Existing literature on the interactions of auxin with other growth regulating substances justifies further study on the relationship of growth regulator balance to the rate of catfacing in tomatoes.

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VITA

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His military service included enlistment in the Texas Army National Guard in February, 1963 and enlistment in the United States Air Force in June, 1964. He served in Germany from March, 1965 to February, 1968 and held the rank of E-4. He received an honorable discharge from the Armed Forces of the United States in February, 1969. His area of specialty while in the Air Force was missile guidance and control electronics Specialist.

While stationed in Germany he attended the European Division of the University of Maryland. In September, 1968 he enrolled part-time at West Texas State University in Canyon, Texas while working as a communications/ navigation specialist with Bell Helicopter Company of Amarillo, Texas. He received his B.S. degree from West Texas State University in May, 1971 with a major in biology and minor in Chemistry and English. He was employed as a science teacher with Claude Independent Schools of Claude, Texas until May, 1972 when he accepted a graduate teaching assistantship to work on his M.S. degree in biology at West Texas State University. After receiving his M.S. degree in May, 1973, he entered

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He is married to the former Judith Lauree Estes of Broken Bow, Nebraska and has two sons: Johnie B. III, and Jeremy Bill.