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Influence of Hormonal Chemicals and Genotypes on Fruit Growth of *Lycopersicon esculentum* Mill.

by

Henry R. Owen, Jr.

thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Horticulture

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INFLUENCE OF HORMONAL CHEMICALS AND GENOTYPES ON FRUIT GROWTH OF LYCOPERSICON ESCULENTUM MILL.

by

Henry R. Owen, Jr.

(ABSTRACT)

The effects of hormonal chemicals and different genotypes on fruit growth of greenhouse-grown tomatoes (Lycopersicon esculentum Mill.) were examined. Continuous root application of 10nM N^6-benzylaminopurine in Hoagland's nutrient solution to tomato seedlings of 'Fireball' and 'Red Cherry' significantly delayed anthesis of 'Fireball', but not 'Red Cherry'. Ovary diameter at anthesis, final fruit diameter, and fruit weight of both cultivars were unaffected. Irrespective of treatments, a significant positive correlation was obtained between ovary diameter at anthesis and final fruit diameter.

A single foliar application of 0.25mM or 0.37mM β-naphthoxyaceticacid (βNOA) at the appearance of the first inflorescence of 'Fireball' significantly increased ovary

diameter at anthesis, but had no effect on final fruit diameter. Flowers on the second inflorescence of tomato plants treated with 0.37mM βNOA had smaller ovary sizes at anthesis than those of untreated plants. Application of 0.125mM βNOA, and 1μM, 10μM, and 100μM gibberellin A_3 had no significant effect on ovary diameter at anthesis or final fruit diameter. A significant positive correlation was also shown between ovary diameter at anthesis and final fruit diameter of βNOA treated plants.

Among the twelve genotypes tested, significant correlations between ovary diameter at anthesis and final fruit diameter were found for 'Fireball', 'Michigan/Ohio Hybrid', and 'New Yorker'. The remaining genotypes showed no significant correlations between ovary diameter at anthesis and final fruit diameter. The average ovary diameter at anthesis (of all the genotypes) was significantly correlated with final fruit diameter, fruit weight, and locule number.

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INTRODUCTION

Plants are plastic organisms (Trewavas, 1979) and respond to various chemical and environmental stimuli. Thus, organ size in plants during development is not easily determined.

Sinnott (1921) observed that final organ size does not correlate with body size in plants, but final organ size correlated closely with the size of the meristem.

Houghtaling (1935) found a positive correlation between tomato ovary size at flowering (Figure 1) and final fruit size in five cultivars, representing both large and small fruited types. She further determined that final fruit size was dependent upon cell number and cell size.

Many factors, however, can affect the relationship between initial ovary size and final fruit size. Physical factors such as light (Hillman, 1956), temperature (Smith, 1932; Rappaport, 1960), and plant organ interrelationships (Gustafson and Laing, 1931; Gustafson and Stoldt, 1936; Fisher, 1975; Kinet, 1977; Starck, 1983) can affect fruit growth. In addition, chemical factors such as nutrients and hormones (Menary and van Staden, 1976), and genotypic differences in plant morphology have been shown to affect tomato fruit growth (MacArthur and Butler, 1938).

Figure 1. *Emasculated flower of 'Fireball' tomato at anthesis*

The objectives of this investigation were twofold: (1) to ascertain the relationship between initial ovary size at anthesis and fruit size at maturity of twelve genotypes, and (2) to determine the effects of hormones and genotypes in altering such a relationship.

LITERATURE REVIEW

TOMATO FRUIT GROWTH

Previous studies of tomato fruit growth have been mainly historical or taxonomic in nature (Luckwill, 1943; Hobson and Davies, 1970; Hogenboom, 1972), or have focused on flowering or maturation processes. Developmental studies on early tomato ovary growth are few. Houghtaling (1935) studied paraffin sections of tomato ovaries to determine that tomato fruit growth consisted of two distinct, but dependent phases. In the earliest primordium of the ovary, the cells are compact and meristematic, and ovarian growth is mainly by cell division. Shortly after flowering, cell division ceases and further growth is entirely by cell expansion. The shape of the growth curve both *in vivo* and *in vitro* is sigmoid (Nitsch, 1951; El-Beltagy et al., 1976; Asahira and Hosoki, 1977), and it is similar among tomato cultivars; larger-fruited types have both a longer stage of cell division and a larger degree of cell expansion.

INFLUENCE OF GROWTH SUBSTANCES

Cytokinins have been shown to stimulate floral initiation and delay senescence of floral parts in tomatoes. Root applications of cytokinins promoted tomato inflorescence development of 'King Plus' and 'Grosse Lisse' tomatoes (Kinet, 1977; Menary and van Staden, 1976) and delayed flowering of 'Bonnie Best' and 'Michigan/Ohio Hybrid' tomatoes, respectively (Kemp, 1957; Wittwer and Dedolph, 1963). The cytokinin N^6-benzylaminopurine was more effective than kinetin.

Root applications of 230nM kinetin to 'Michigan/Ohio hybrid' tomatoes had an insignificant effect on total vegetative growth rate (Bugbee and White, 1984). In addition, foliar sprays of kinetin showed very little response, possibly due to its low solubility in water and its limited foliar absorption (Wittwer and Dedolph, 1963; Bugbee and White, 1984).

Leonard and Kinet (1982) found that low levels of endogenous cytokinins (1.7ng g^{-1} f.wt.) in 'King Plus' were associated with flower abortion, and suggested that cytokinins were important in controlling floral development soon after the appearance of the inflorescence.

Studies on the effects of exogenously applied cytokinins on early ovarian development of tomato are few. Asahira and Hosoki (1977) found a slight promotion of fruit en-

largement with 2.3 μM BAP applied to 'Tiny Tim' tomato fruits grown *in vitro*, but its effect on the cell division stage of ovary growth *in vivo* remains to be studied.

The influence of auxins on tomato fruit growth has been studied extensively. The effects observed are dependent upon many factors. These factors include the type of auxin, the hormone concentration, the method of application, the genotype of the plant, the developmental stage of the plant organs, and the environmental conditions.

Nitsch (1951) found an increase in fruit diameter of excised 'Essex Wonder' ovaries with 2,4-dichloro- phenoxyacetic acid (2,4-D), 2,4,5-trichloro- phenoxyacetic acid (2,4,5-T), and β-naphthoxyacetic acid (βNOA), but with differing degrees of sensitivity depending on the concentration and type of hormone. For example, 0.1mg/l 2,4-D was found to increase tomato ovary diameter three weeks after planting, while 1.0mg/l βNOA was needed to increase ovary diameter to a similar degree.

Wittwer and Schmidt (1950) determined that 0.25mM βNOA increased yield of the first harvest of fourteen cultivars, differing in maturation rates, but decreased yield of subsequent harvests. He suggested that sensitivity to the chemical depends upon the developmental stage of the reproductive organ. Perez-Zapata and Oliveras (1979) found an increase in

fruit size of 'Floralou' and 'Marglobe' with 0.175mM βNOA if applied as a multiple, whole-plant spray, but only when light was a limiting factor. In addition, they noted that βNOA treatment reduced the number of developing fruits. Thus, a decrease in organ competition may be influencing fruit size as well as the hormone treatment. Varietal differences to βNOA treatment were also observed.

The effects of gibberellin A_3 (GA_3) on tomato flowering and fruit growth have been mixed. For example, Gustafson (1960) and Rappaport (1960) reported an increase in fruit set, but a decrease in fruit size with GA_3 treatment in 'John Baer' and 'Earlypak' tomatoes. Other investigators, however, have demonstrated an increase in ovary diameter after GA_3 treatment. Sawhney & Greyson (1971) found that 1mM GA_3 applied to prefloral 'Vantage' and 'Viceroy' tomato plants increased ovary diameter at anthesis and that this increase in ovary size carried over to the mature fruit (Sawhney & Greyson, 1972). Later studies (Sawhney & Dabbs, 1978) demonstrated that 1mM GA_3 increased fresh weight, final diameter, and locule number of tomatoes in subsequent inflorescences.

Other factors, however, such as fruit number, age of plant tissue, plant genotype, and hormone interaction may affect the plant response to GA_3 treatment. It has been

shown that sensitivity to GA_3 decreases in older plants, and differences in sensitivity exist between tomato varieties (Rappaport, 1957). Wittwer et al. (1957) demonstrated that GA_3 hastened early flowering in determinate cultivars, such as 'Earlypak', but indeterminate cultivars were relatively unaffected.

The effect of GA_3 may also be related to its relationship to other hormones, especially auxins. Nitsch and Nitsch (1959) found that GA_3 increased diffusable auxins in excised ovaries, and auxins are known to stimulate ovary growth. Endogenous GA_3 levels in intact developing fruits have been shown to increase prior to an increase in auxin levels, indicating that GA_3 may enhance auxin synthesis or inhibit IAA oxidase (El-Beltagy et al., 1976). Thus, the influence of GA_3 on fruit growth may lie in its ability to increase auxin levels.

INFLUENCE OF GENOTYPES

Many genotypic characteristics have been shown to influence ovary size, including fruit shape, maturation rate, and locule number. Genetically inherited characteristics for shape influence the direction of cell division (Houghtaling, 1935). Thus, they act very early in ovary development. Initial ovary shape had been shown to be highly corre-

lated with final fruit shape (Yeager, 1937), even though ovary shape diverged slightly as growth occurred and environmental conditions changed (Houghtaling, 1935). For example, oval shape of 'Ohio Red' was determined long before anthesis and pear shape of 'Red Pear' usually became apparent at the time of flowering (Yeager, 1937).

MacArthur & Butler (1938) indicated that genes for elongated fruit tended to decrease fruit size. Conversely, genes which predisposed fruit for a flattened fruit shape tended to increase fruit size.

Genetic characteristics which determine maturation rate also affected ovary size. For example, Houghtaling (1935) found that tomatoes which had a longer cell division stage also had larger fruits, since size differences were maintained throughout development. In addition to the duration of the pre-anthesis cell expansion stage, MacArthur and Butler (1938) indicated that the rate of the cell division stage affects the final size of the fruit. Houghtaling had suggested that these characteristics were inherited.

Genes for fasciation also influenced ovary size (Yeager, 1937). Fasciated fruits had more locules than non-fasciated fruits (Sawhney and Greyson, 1972) and increased locule number was shown to be highly correlated with an increase in fruit size (MacArthur and Butler, 1938; Sawhney

and Greyson, 1971; Sawhney and Dabbs, 1978). Moreover, locule number was not merely a secondary component of size, rather it was a determinant of fruit size (Yeager, 1937).

MATERIALS & METHODS

GENERAL PLANT CULTURE

Tomato, Lycopersicon esculentum Mill., seeds were germinated in 18-20cm clay pots and thinned after 27 days to one plant per pot. Plants for the sand culture experiment (Exp.1) were grown in water-leached, steam-sterilized, coarse sand (All Star Concrete Co., Blacksburg, VA 24060) and fertilized with Hoagland nutrient solution 1 (Hoagland & Arnon, 1950), except Fe was supplied as 5ppm NaFe EDTA. Plants used in experiments 2 and 3 were grown in Pro-Mix (Premier Brands, Inc., New Rochelle, NY 10801) and fertilized with Miracle-Grow (Stern's Garden Products, Inc., Geneva, NY) at 1 Tbsp./gal. with Hoagland micronutrients. A volume of 100ml nutrient solution was applied to all plants (daily or as needed). All three experiments were carried out in the greenhouse. The plants were grown at 28C day and 20C night temperatures under natural light conditions (see specific dates under each experiment). Each treatment consisted of ten single-plant replicates. A randomized complete block design was used.

SIZE AND WEIGHT DETERMINATIONS

Size of ovaries was recorded for the first two fruits on the first inflorescence of the main stem, except where noted. Flower buds at anthesis were emasculated with forceps to expose the ovary for initial measurement and hand pollinated to ensure maximum seed set (see Figure 1). Equatorial ovary diameter at anthesis was measured with a vernier caliper. Fruits were weighed at the pink stage of maturity and the equatorial diameter was recorded by taking one-half the sum of two equatorial readings at right angles to each other.

EXPERIMENT 1

The purpose of this experiment was to determine the influence of a cytokinin, N^6-benzylaminopurine (BAP; Sigma Chemical Co., St. Louis, MO), applied at 10nM in the nutrient solution, on ovary development and fruit growth.

Two tomato cultivars were used; 'Small Red Cherry', a small-fruited, indeterminate cultivar, and 'Fireball', a medium-fruited, determinate cultivar. Seeds were planted on January 21st, 1983. BAP treatments began two weeks after planting.

BAP was solubilized using 0.1ml of 1N KOH, diluted to 0.01mM concentration, and added to Hoagland's nutrient solu-

tion to obtain a final concentration of 10nM. Measurements of ovary diameter were taken at anthesis and at 3-4 day intervals thereafter until maturity. Mature 'Red Cherry' fruits were harvested between April 27th and May 5th, 1983. Mature 'Fireball' fruits were harvested between May 1st and May 13th, 1983. The plants were then separated into roots, main shoots, and axillary shoots and dried in an oven at 180 degrees for two days for dry weight determinations.

The General Linear Model (GLM) of the Statistical Analysis System (SAS) was used for analysis of variance for unbalanced data.

EXPERIMENT 2

The purpose of this experiment was to determine the influence of a synthetic auxin, β-naphthoxyacetic acid (βNOA, Nutritional Biochemicals Corp., Cleveland, OH) and the influence of Gibberellin A_3 (GA_3; Sigma Chemical Co., St. Louis, MO), applied as single, foliar sprays, on ovary development and fruit growth. 'Fireball' tomato plants were used in this experiment. Seeds were planted on May 20th, 1983.

βNOA solutions and GA_3 solutions were prepared by solubilizing the chemicals in warm water and diluting them to the concentrations listed below with 0.05% Tween 80 (polyox-

yethylene sorbitan mono-oleate). Foliar treatments of 2.0ml per inflorescence were applied with an atomizer 38 days after planting, prior to anthesis of the first flower bud of the first inflorescence on the main stem. The treatments were:

1. 0.37mM βNOA
2. 0.25mM βNOA
3. 0.125mM βNOA
4. 100μM GA_3
5. 10μM GA_3
6. 1μM GA_3
7. reagent control (Tween 80 solution)
8. water control

Measurements of ovary diameter were taken of the first two fruits on the first and second inflorescences at anthesis, at 7, 14, and 35 days after anthesis and at maturity. Mature fruits were harvested between August 4th and August 27th, 1983.

EXPERIMENT 3

The purpose of this experiment was to determine the influence of genotypes on the relationship between ovary size at anthesis and final fruit size. Seeds were planted on September 25th, 1983. Twelve cultivars, representing a wide

range of shapes, maturation rates, and locule numbers were used. Plants were hand pollinated with pollen from the same cultivar.

1. Small Fry
2. Small Red Cherry
3. Yellow Plum
4. Roma VF
5. Early Cascade
6. Fireball
7. Heinz 1350
8. Campbell 1327
9. Michigan/Ohio Hybrid
10. New Yorker
11. Ramapo
12. Ponderosa

Measurements of ovary diameter at anthesis and at maturity were taken. Locule numbers were counted after sectioning of the mature fruit equatorially. Mature fruits were harvested between December 19th, 1983 and January 23rd, 1984.

RESULTS

EXPERIMENT 1

Root application of 10nM BAP had no significant effect on ovary diameter at anthesis, final fruit diameter, and fruit fresh weight of 'Fireball' and 'Red Cherry'. The dry weights of root, main shoot, and axillary shoots of both cultivars were also unaffected. In addition, the growth curves were similar for treated and untreated plants of each cultivar. However, BAP significantly delayed anthesis of the first two flowers on the first inflorescence of the main shoot of 'Fireball', but not 'Red Cherry' (Table 1).

Correlation coefficients between ovary diameter at anthesis and final fruit diameter for both cultivars indicated a highly significant positive correlation (0.01 level) for untreated 'Fireball' tomatoes (Table 2). The combined correlation coefficient for all treatments was highly significant (Figure 2).

Table 1. *Influence of root application of 10nM N^6-benzylaminopurine (BAP) on anthesis of two tomato cultivars*

	Days to Anthesis[1]	
Cultivar	Control	BAP
Red Cherry	51.6	52.6
Fireball	51.1	53.0*

[1] days from seeding to 1st and 2nd flower opening on the 1st inflorescence of the main shoot

* denotes significant difference from control

Table 2. *Effects of root application of 10nM BAP on the correlation coefficients of initial and final fruit sizes of 'Red Cherry' and 'Fireball'*

Cultivar	Treatment	N	r
Red Cherry	Control	16	-0.28
	BAP	15	-0.39
Fireball	Control	20	+0.65**
	BAP	15	+0.18
Total		66	+0.80**

** denotes significant correlation at 0.01 level of probability

N= number of observations

r= correlation coefficient

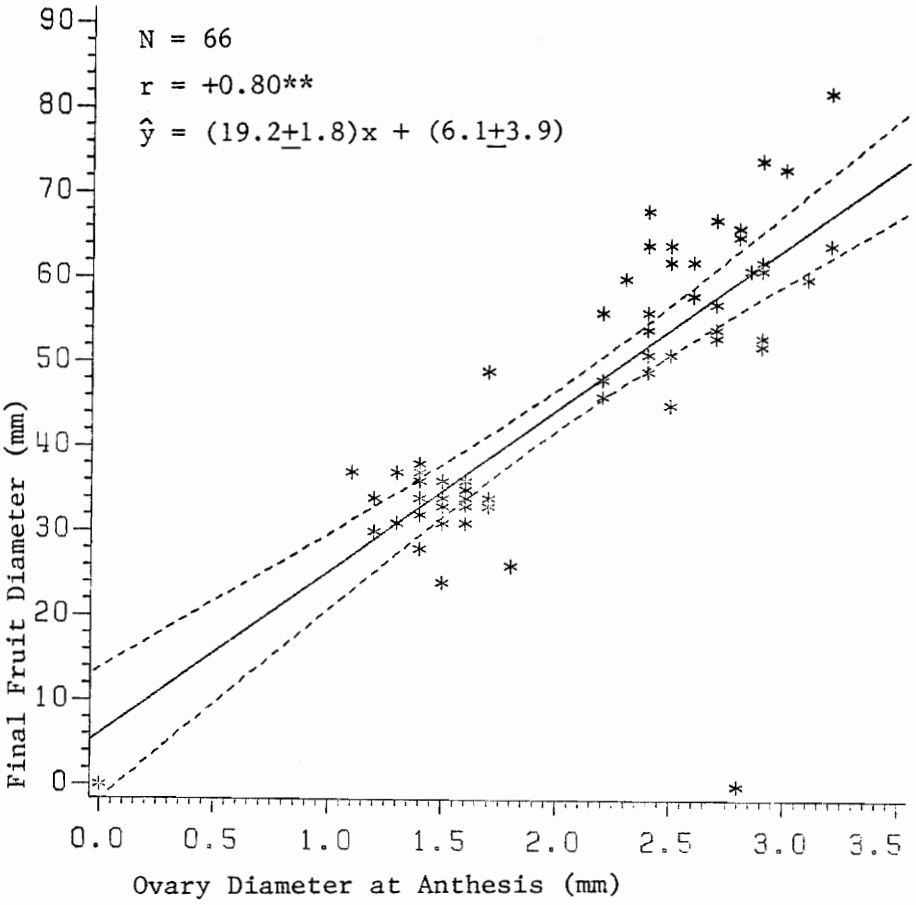

Figure 2. *The combined relationship of initial size to final size of 'Red Cherry' and 'Fireball' (with 95% confidence limits)*

** denotes significance at 0.01 level of probability

EXPERIMENT 2

Foliar application of 0.37mM and 0.25mM βNOA significantly increased ovary diameters at anthesis of fruits on the first inflorescence. A 0.37mM βNOA treatment, however, significantly decreased ovary diameters at anthesis of fruits on the second inflorescence. The effect of βNOA on ovary size did not persist beyond anthesis (Table 3). Similar results were obtained when the ovary measurements of the first and second inflorescences were analyzed together. Gibberellin A_3 had relatively little effect on ovary size (Table 4). The reagent control was not found to be significantly different from the water control.

Correlation coefficients between ovary diameter at anthesis and final fruit diameter for different hormonal treatments are indicated in Table 5. Foliar applications of βNOA,but not GA_3 treatments gave highly significant positive correlation coefficients. When the data were combined regardless of treatment a highly significant positive correlation coefficient was shown, but the value was smaller than the βNOA values (Table 5; Figure 3). Fruits at the mature green stage from control and βNOA-treated plants are shown in Figure 4.

Table 3. *Influence of foliar application of β-naphthoxyacetic acid (βNOA) on ovary diameter of 'Fireball', by inflorescence of the main shoot*

1st Inflorescence - Ovary Diameter (mm)					
Treatment	Anthesis	Day 7	Day 14	Day 35	Final
Water Control	2.5a[1]	14.5a	34.0a	54.1a	59.0a
0.25mM βNOA	4.0b	20.2a	35.9a	55.5a	58.9a
0.37mM βNOA	4.1b	19.7a	36.6a	53.7a	57.2a
2nd Inflorescence - Ovary Diameter (mm)					
Treatment	Anthesis	Day 7	Day 14	Day 35	Final
Water Control	2.8a	13.1a	29.9a	51.5a	55.5a
0.25mM βNOA	2.7a	10.5a	26.9a	47.5a	50.7a
0.37mM βNOA	2.2b	10.6a	29.3a	47.0a	48.6a

[1]mean separation by Student-Newman-Keuls' multiple-range test at 0.01 level of probability, by column; values followed by the same letter are not significantly different

Table 4. *Influence of foliar application of β-naphthoxyacetic acid (βNOA) and gibberellin A_3 (GA_3) on ovary diameter of 'Fireball', combining the first two inflorescences of the main shoot*

Treatment	Ovary Diameter (mm)				
	Anthesis	Day 7	Day 14	Day 35	Final
Water Control	2.6a[1]	13.8ab	32.0a	52.8a	57.2a
1μM GA_3	2.7a	12.0a	29.3a	52.5a	56.1a
10μM GA_3	2.8a	13.4ab	30.9a	51.2a	55.2a
100μM GA_3	2.9a	13.2ab	30.2a	50.4a	54.6a
0.125mM βNOA	2.9a	14.8ab	33.3a	54.3a	58.4a
0.25mM βNOA	3.4b	15.9ab	31.2a	51.0a	55.2a
0.37mM βNOA	3.6b	17.4b	34.8a	52.0a	55.0a

[1]mean separation by Student-Newman-Keuls' multiple-range test at 0.05 level of probability, by column; values followed by the same letter are not significantly different

Table 5. *Effects of foliar application of βNOA and GA_3 on the correlation coefficients of initial and final fruit sizes of 'Fireball'*

Chemical	Conc.	N	r
Control		38	+0.15
GA_3	1μM	34	+0.21
	10μM	35	-0.06
	100μM	35	+0.24
βNOA	0.125mM	34	+0.50**
	0.25mM	27	+0.61**
	0.37mM	16	+0.72**
Total		219	+0.37**

** denotes significant correlation at 0.01 level of probability

N= number of observations

r= correlation coefficient

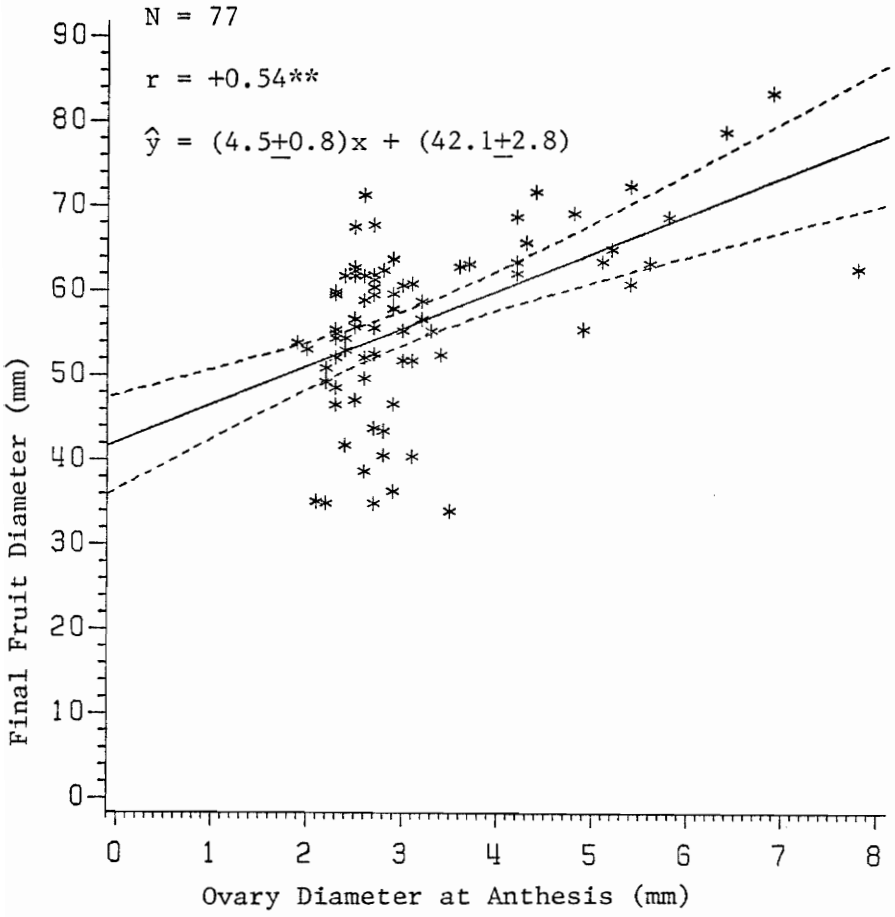

Figure 3. *The combined relationship of initial size to final size of BNOA treated 'Fireball' tomatoes (with 95% confidence limits)*

** denotes significance at 0.01 level of probability

Figure 4. *'Fireball' tomatoes at mature green stage; top, control; bottom, treated with 0.37mM β-naphthoxyacetic acid*

EXPERIMENT 3

The correlation coefficients between ovary diameter at anthesis and final fruit diameter of the twelve tomato cultivars are shown in Table 6. A significant positive correlation (0.05 level) was found for 'Michigan/Ohio Hybrid' and 'New Yorker' tomatoes and a highly significant positive correlation (0.01 level) for 'Fireball'. Correlation coefficients for the nine remaining cultivars were not significant. A combined correlation for all cultivars, however, demonstrated that there is a highly significant positive relationship between ovary diameter at anthesis and final fruit diameter (Figure 5). The combined correlation coefficient between ovary diameter at anthesis and final fruit fresh weight was not found to be significant ($r=+0.18$). The correlation coefficient between ovary diameter at anthesis and locule number, however, was highly significant ($r=+0.86$).

The twelve tomato cultivars showed a wide range of initial ovary sizes (Figure 6). The smallest (<2mm diameter) ovaries were shown by 'Small Red Cherry', 'Yellow Plum', 'Small Fry', and 'Roma VF'. Intermediate (2-3mm diameter) ovary sizes were found in 'Early Cascade', 'New Yorker', 'Fireball', and 'Michigan/Ohio Hybrid'. The largest (>3mm diameter) ovaries were found in 'Ramapo', 'Heinz 1350',

'Campbell 1327', and 'Ponderosa'. When the final fruit diameters of the cultivars were ranked in the same order as the initial size ranking, it indicated that a larger initial ovary size generally resulted in a relatively larger final fruit size (Figure 7). 'Roma VF' and 'Ponderosa' tomatoes at the early stage of ripening are shown in Figure 8.

Table 6. *Effects of genotypes on the correlation coefficients of initial and final fruit sizes*

Cultivar	N	r
Small Fry	18	-0.13
Small Red Cherry	17	-0.45
Yellow Plum	19	-0.13
Roma VF	17	+0.20
Early Cascade	16	-0.06
Fireball	14	+0.75**
Heinz 1350	14	-0.32
Campbell 1327	15	+0.26
Michigan/Ohio Hybrid	15	+0.61*
New Yorker	21	+0.51*
Ramapo	12	+0.46
Ponderosa	17	+0.33
Total	195	+0.85**

* and ** denote significant correlation at 0.05 and 0.01 level of probability, respectively

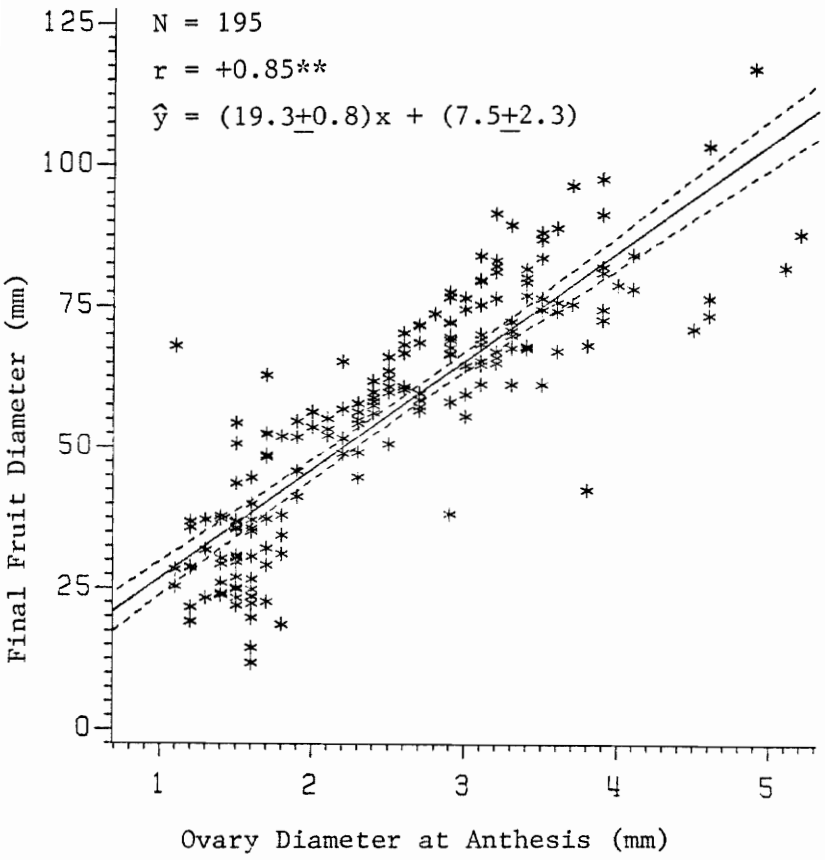

Figure 5. *The combined relationship of initial size to final size of twelve tomato cultivars (with 95% confidence limits)*

** denotes significance at 0.01 level of probability

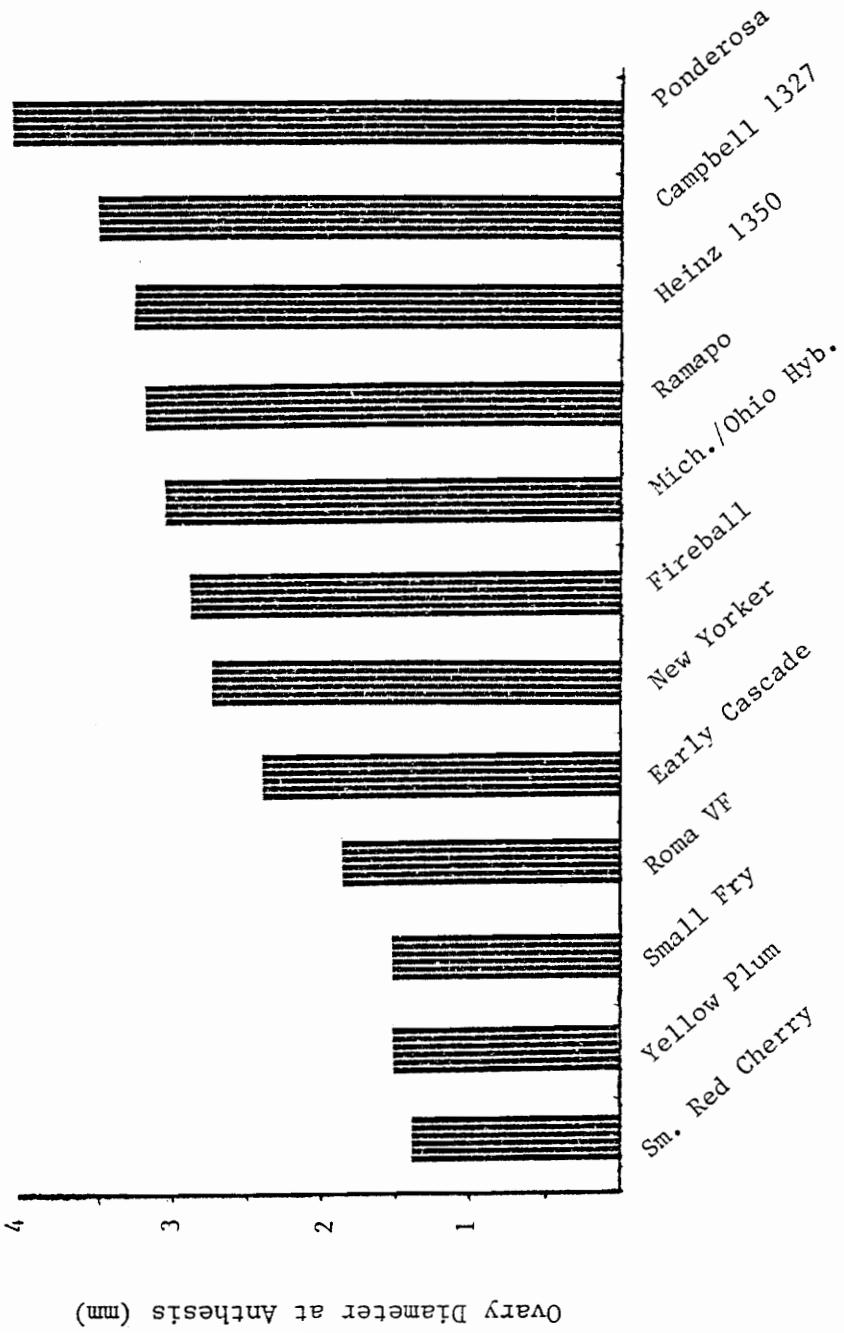

Figure 6. *Mean ovary diameters at anthesis of twelve tomato cultivars*

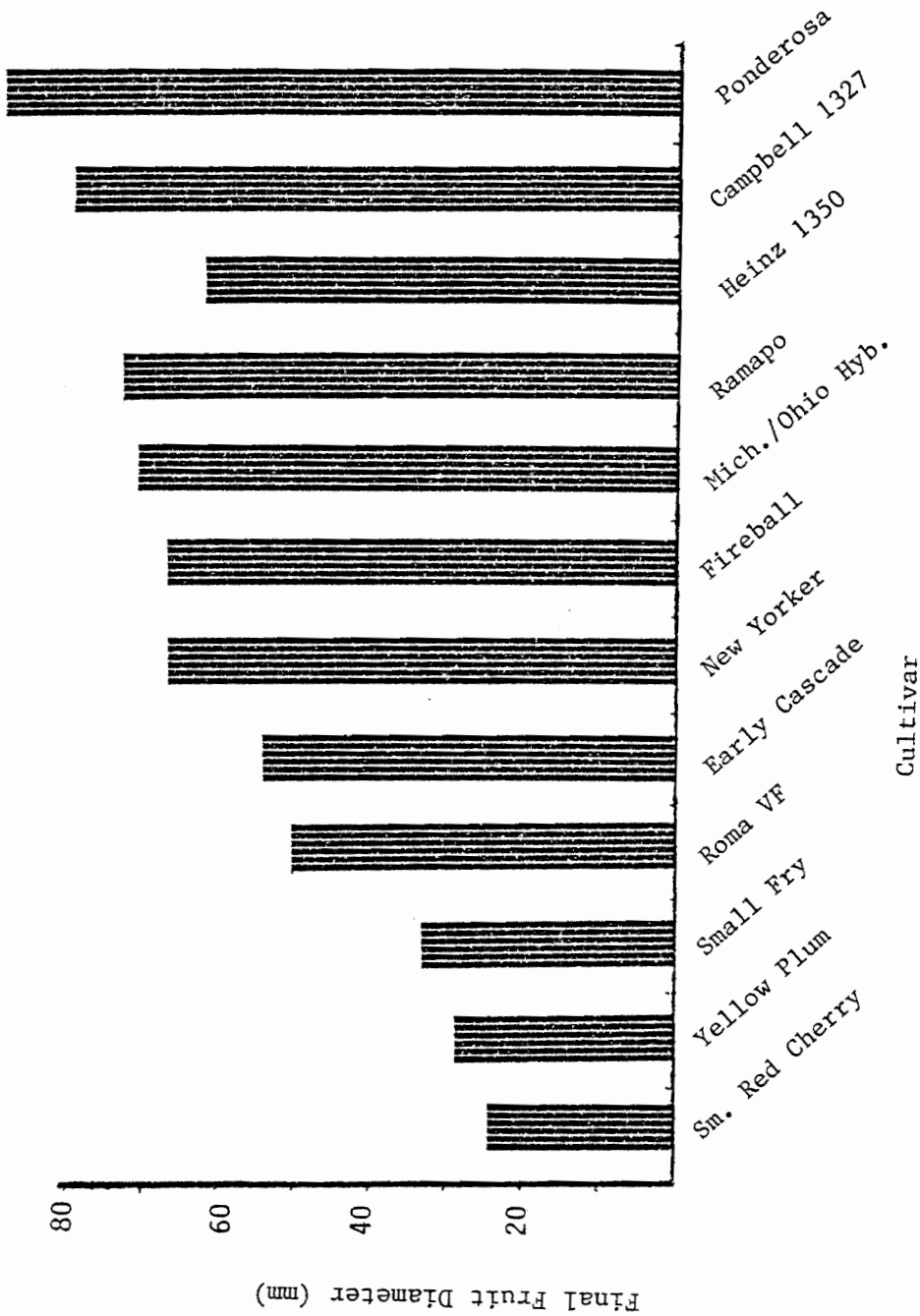

Figure 7. *Mean final fruit diameters of twelve tomato cultivars*

Figure 8. *Tomatoes at ripening stage; top, 'Roma VF'; bottom, 'Ponderosa'*

DISCUSSION

RELATIONSHIP OF INITIAL SIZE TO FINAL SIZE

In all three experiments, the overall relationship between ovary diameter at anthesis and final fruit diameter was significantly positive, indicating that initial ovary size was a determinant of final fruit size.

A 10nM BAP treatment did not significantly alter ovary diameter at anthesis, final fruit diameter, or the relationship between these two measurements for either 'Red Cherry' or 'Fireball' tomatoes. Therefore, a combined correlation among treated and untreated plants of both cultivars was determined, which indicated that final fruit diameter is proportional to ovary diameter at anthesis. This correlation, however, may be due to a large extent to genotypic effects.

Although plants treated with 0.25mM and 0.37mM βNOA exibited larger ovary diameters at anthesis with no corresponding increase in final fruit diameters, a positive relationship was found between these two measurements. This would indicate that chemical treatment can alter initial size without necessarily affecting final size, and that despite chemical alteration of initial size, the overall, combined, positive relationship between initial and final size

exists. This is also illustrated by the highly positive combined correlation among plants treated with βNOA, plants treated with GA_3, and untreated plants.

The combined correlation among cultivars, however, demonstrated a high, positive correlation between initial and final ovary sizes, when a variety of genotypic characteristics such as final fruit size, shape, locule number, and maturation rate are used.

EFFECTS OF HORMONES AND GENOTYPES

Many factors are involved in determining whether an organ responds to hormone treatment, including the type of hormone and its concentration, as well as the developmental stage, size, and location of the plant organ. The effects of continuous root application of 10nM BAP were limited to delaying the reflexing of the calyx and corolla. Growth of stem, root, leaf, and ovarian organs were found to be unaffected by this treatment.

Wittwer and Dedolph (1963) found that kinetin added to the nutrient solution at 1μM delayed flowering of Michigan/Ohio Hybrid tomatoes, and Bugbee and White (1984) indicated an insignificant effect on vegetative growth rate with 230nM kinetin applied in a similar manner. Perhaps 10nM BAP in this investigation was insufficient to affect cell division

or expansion, and thus organ growth (as measured by fresh and dry weight determinations), but was sufficient to affect opening of the calyx and corolla, and thus organ development (as measured by days to anthesis of floral organs). In addition, the calyx and corolla are located in relatively small and discrete locations in comparison to other vegetative organs such as the shoots and roots, and they are located closer to the source of hormone treatment than the ovary and mature prior to the ovary.

Foliar sprays of 0.25mM and 0.37mM βNOA, on the other hand, were shown to increase early ovarian growth. By day seven, however, differences between treated and untreated plants were insignificant. This could be due to treatment variability and/or plant organ interrelationships.

As tomato fruit growth progresses, the variability between treatments increases, due to differential cell expansion. This early increase in fruit diameter of plants treated with 0.25mM and 0.37mM βNOA is most probably due to an increase in early cell expansion, rather than an increase in cell division, since an increase in cell number would probably carry over to the mature fruit. Apparently this early increase in cell expansion is not sufficient to affect total cell expansion and, therefore, increase final cell size and fruit size. Foliar sprays of 0.125mM βNOA were in-

sufficient to increase even early fruit growth to a significant degree.

The developmental stage of the plant organ and its relationship to other organs of the plant may also affect its response to hormone treatment. Although a single treatment of 0.37mM βNOA increased ovary diameters of fruits on the first inflorescence, it decreased ovary diameters of fruits on the second inflorescence. It is unclear whether this decrease in mean ovary diameter of the second inflorescence is due to its earlier stage of development at the time of chemical treatment relative to the first inflorescence, or whether the fruits of the second inflorescence received a smaller amount of substrate as a compensation for larger fruits in the first inflorescence.

In addition to early size increases, βNOA was found to alter fruit shape. Fruits of βNOA-treated plants exibited a "beaking" or pointed shape proportional to the hormone concentration. This was probably due to partial maintenance of the stylar tissue closest to the ovary during development. This illustrates two factors which influence organ response to hormone treatment. First, response to hormone treatment is not limited to a single organ, and second, a response by one organ may affect the growth of another organ. In this investigation, an increase in ovary diameter by βNOA treat-

ment could have been a result of increased stylar tissue, or a change in fruit shape, or both.

Single foliar sprays of 1μM, 10μM, and 100μM GA_3 had an insignificant effect on ovarian growth. This may be due to many factors, including the hormone concentration, application frequency, and/or application time.

Millimolar concentrations of GA_3 have increased tomato ovary diameter (Sawhney and Greyson, 1971,1972; Sawhney and Dabbs, 1978). Micromolar concentrations of GA_3, on the other hand, have resulted in increased vegetative growth (Bugbee and White, 1984). In this investigation, micromolar concentrations of GA_3 resulted in a lighter green coloration of stem and leaf tissues in comparison to control plants, and a slight increase in stem elongation, particularly noticeable at flowering of the first inflorescence. In addition, peduncle elongation in the first inflorescence was evident, especially in the plants treated with 10μM and 100μM GA_3.

Multiple applications of GA_3 have increased ovary diameter, while single applications have been less effective (Sawhney and Greyson, 1971; Sawhney and Dabbs, 1978). In addition, GA_3 applied prior to initiation of the inflorescence has increased ovary size (Sawhney and Greyson, 1972), but GA_3 applied at anthesis resulted in decreased ovary size (Gustafson, 1960).

The relationship between initial size and final size is also influenced by genotypes (Houghtaling, 1935; Perez-Zapata and Oliveras, 1979). Significant correlations have been demonstrated between final fruit size of tomatoes and initial fruit size, shape, and locule number (Yeager, 1937; Butler, 1941). In addition, other factors such as the rate, duration, and direction of ovary growth influence final fruit size (MacArthur and Butler, 1937).

'Fireball', 'Michigan/Ohio Hybrid', and 'New Yorker' tomatoes demonstrated a significant positive correlation between ovary diameter at anthesis and final fruit diameter. These cultivars are characterized by having medium-sized, non-fasciated, spherical fruits of average maturation rate.

Correlations for small-fruited, early maturing cultivars such as 'Small Fry' and 'Small Red Cherry' were insignificant, possibly due to their rapid maturation rate, which would minimize final size differences. The elongated shape of 'Yellow Plum' and 'Roma VF' tomatoes affected the ability of using diameter, rather than other size parameters such as fruit weight, volume, or density to represent size. Fasciated fruits such as 'Ponderosa' have a somewhat flattened, irregular shape, making both an accurate measurement of fruit diameter and a representitive measurement of fruit size difficult. It is not clear why the correlation coefficients

for 'Early Cascade', 'Ramapo', 'Heinz 1350', or 'Campbell 1327' were insignificant. This could be a result of insufficient sample sizes or differences in their responses to greenhouse conditions.

It is evident that hormones and genotypes can affect initial ovary size and final fruit size. The underlying positive relationship between these two growth parameters, however, is maintained despite hormonal and genotypic influences.

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APPENDIX A

'Utilizing Budlength as a Measure of Pre-Anthesis Ovary Volume'

Prior to anthesis, tomato ovary growth is by cell division and the cells are compact and uniform in size. At this stage, differences in ovary volume result from differences in cell number rather than cell size. Therefore, ovary volume can be used as a measure of cell number.

It is not possible, however, to measure directly either ovary volume or cell number prior to anthesis without removing the surrounding floral parts, and this would disrupt normal flower development and prevent normal pollination. In order to determine a non-destructive technique for estimating pre-anthesis ovary volume or cell number in normally developing flowers, the relationship between ovary size and bud size was assessed.

Cultural conditions were the same as in Experiment 1. For each cultivar, fifteen sample inflorescences were removed prior to anthesis of the first bud. Only the first inflorescence of the main shoot of each plant was used. Measurements of bud length and width and ovary length and width were determined with a vernier caliper. Measurements of bud

volume and ovary volume were determined using the equation for an elliptical solid:

$$V = (w \times l)^2/4 - w^3/12$$

Correlations between bud measurements and ovary volume are listed in Table A1. In both cultivars, the relationship between bud length and ovary volume was found to have the highest correlation coefficient. The correlation between bud length and ovary volume for pre-anthesis 'Fireball' tomatoes is shown in Figure A1. The correlation between bud length and ovary volume for pre-anthesis 'Red Cherry' tomatoes is shown in Figure A2.

These data suggest that ovary volume can be estimated by using bud length, thus leaving the ovary and surrounding organs intact.

Table A1. *Correlation coefficients of bud measurements to ovary volume of 'Red Cherry' and 'Fireball' tomatoes*

	r
Red Cherry (N= 43)	
bud width	0.84**
bud length	0.90**
bud volume	0.88**
Fireball (N= 52)	
bud width	0.74**
bud length	0.76**
bud volume	0.68**

** denotes significance at 0.01 level of probability

N= number of observations

r= correlation coefficient

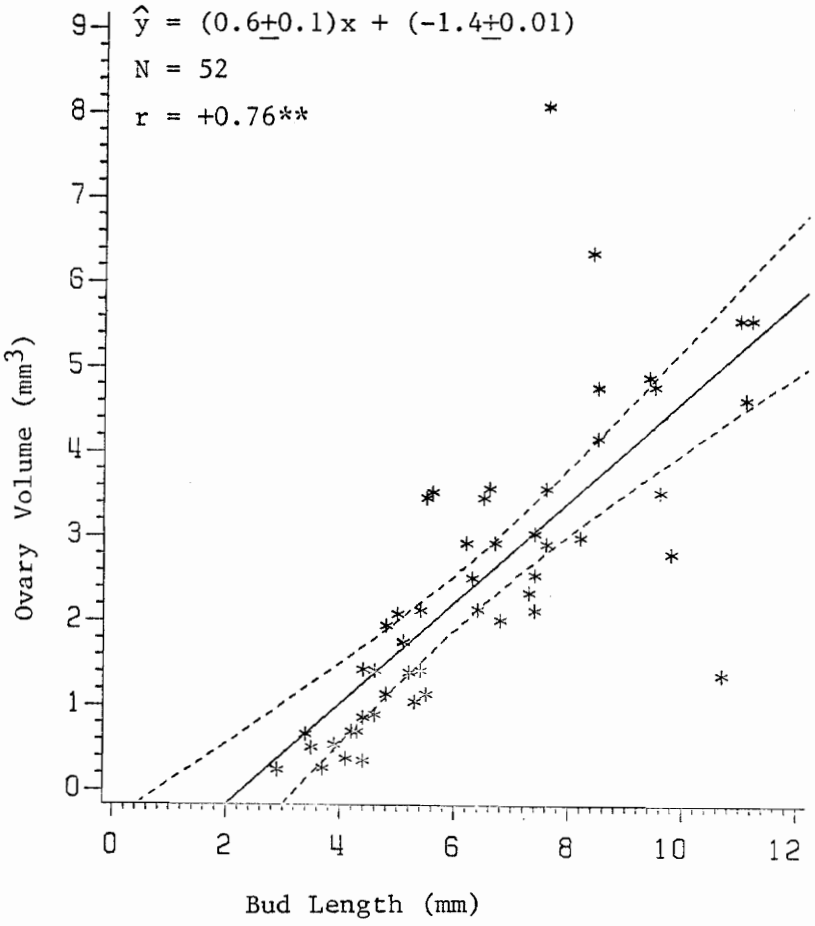

Figure A1. *The relationship of bud length to ovary volume of 'Fireball' tomatoes (with 95% confidence limits)*

** denotes significance at 0.01 level of probability

N= number of observations

r= correlation coefficient

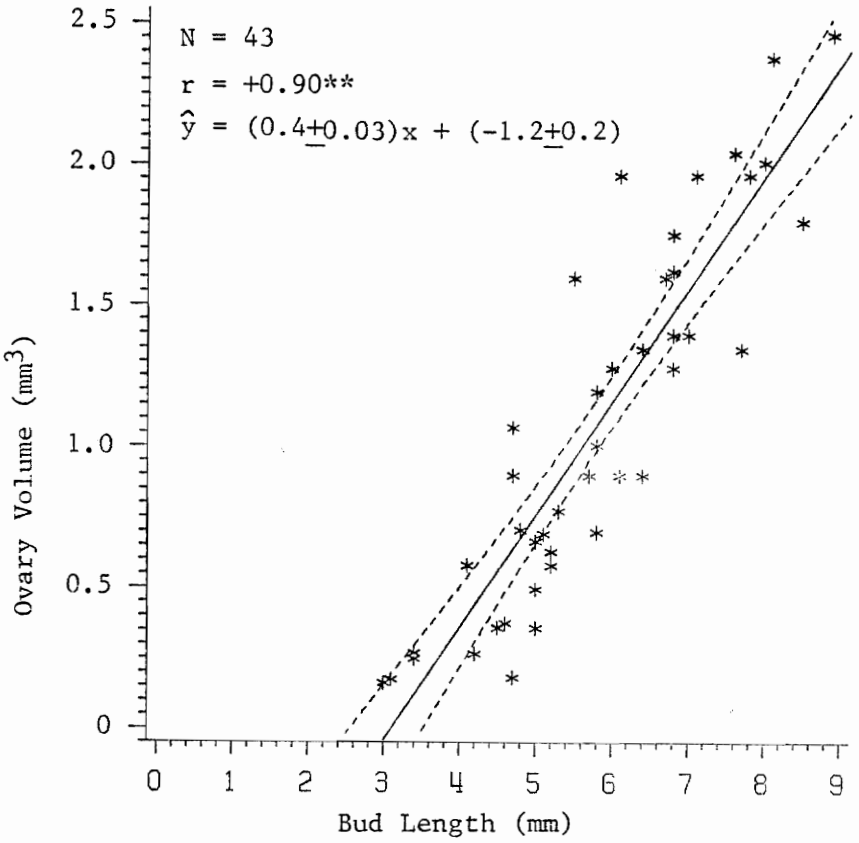

Figure A2. *The relationship of bud length to ovary volume of 'Red Cherry' tomatoes (with 95% confidence limits)*

** denotes significance at 0.01 level of probability

N= number of observations

r= correlation coefficient

APPENDIX B

Table B1. *Experiment 1 - Plant Dry Weights (g)*

	Roots	Main Shoot	Axillary Shoots
Red Cherry (N=5)			
Control	10.0	25.9	13.6
BAP	11.2	26.9	13.6
Fireball (N=5)			
Control	5.0	16.3	6.2
BAP	4.8	16.9	7.0

VITA

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