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Genotypic and Chemical Influences on Fruit Growth of Tomato

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Abstract. **A relationship between ovary size at anthesis and final fruit diameter of 12 tomato** *(Lycopersicon esculentum* **Mill.) cultivars with a range of fruit sizes, shapes, and maturation rates was determined. 'Fireball', 'Michigan/Ohio Hybrid', and 'New Yorker' produced nonfasciated, spherical fruits of intermediate maturation rate and showed a significantly higher correlation between ovary diameter at anthesis and final fruit diameter than 'Small Fry', 'Roma VF', 'Early Cascade', 'Campbell 1327', or 'Ponderosa'. A linear regression of final fruit diameter at maturity on ovary diameter at anthesis of the cultivars was highly significant (r^2 = 0.92**; ŷ = 22.5X - 0.3). Continuous root application of 0.01 µM BA to seedlings of 'Fireball' significantly delayed anthesis. A single foliar application of 0.37 mM NOA to 'Fireball' plants at the appearance of the first inflorescence significantly increased ovary diameter on the first inflorescence, but decreased ovary diameter on the second inflorescence. Treatment with NOA altered final fruit shape but not final fruit diameter. Single foliar applications of 0.1 mM GA stimulated stem and peduncle elongation but did not affect fruit size. Chemical names used: ß-naphthoxyacetic acid (NOA), N^6-benzylaminopurine (BA), gibberellic acid, (GA).**

Fruit size in plants is not usually correlated with the size of the entire plant, but it is related to the size of the meristem. A positive relationship has been demonstrated between tomato ovary size at anthesis and final fruit size (Houghtaling, 1935). Early ovarian growth is mainly a result of cell division; thereafter, fruit growth is influenced primarily by cell expansion (Geelen et al., 1987; Bohner and Bangerth, 1988). Many morphological and environmental factors influence tomato fruit growth, including fruit shape, maturation rate, and the application of plant growth regulators.

Genetically inherited traits for shape influence the direction of cell division (MacArthur and Butler, 1938). Genes for elongated fruit tend to decrease fruit size, whereas those for flatness tend to increase fruit size. In addition, traits for maturation rate affect final fruit size. Tomato cultivars characterized by a relatively long cell division stage or fast rate of cell division generally produce relatively large fruits (MacArthur and Butler, 1938).

Cytokinins have been shown to stimulate floral initiation and delay senescence of floral parts in tomato (Wittwer and Dedolph, 1963; Kinet et al., 1985). There have been few studies on the effects of exogeneously applied cytokinins on early tomato fruit growth. Foliar application of NOA, a synthetic auxin, increased the first harvest yield of several tomato cultivars, but decreased the yield of subsequent harvests (Wittwer and Schmidt, 1950). Treatment of prefloral tomato plants with 1 mM GA increased ovary diameter at anthesis, and this increase carried over to the mature fruit and subsequent harvests (Sawhney and Dabbs, 1978).

Our objectives were to examine the relationship between ovary size at anthesis and final fruit size of several tomato cultivars representing a range of fruit sizes, shapes, and maturation rates. Additionally, we examined the individual effects of an exogenously applied auxin (NOA), cytokinin (BA), and gibberellin (GA) on fruit growth of 'Fireball' tomato to determine if an increase or decrease in ovary size at anthesis would result in a corresponding change in final fruit size.

Tomato seeds were germinated in 2-liter clay pots and thinned after 27 days to one plant per pot. Plants for three of the experiments (cultivar test, auxin treatment, and gibberellin treatment) were grown in Pro-Mix (Premier Brands, New Rochelle, N. Y.) and fertilized with Miracle-Grow (Stern's Garden Products, Geneva, N. Y.) at 3 g·liter^{-1} with Hoagland micronutrients (Hoagland and Arnon, 1950). Plants for the cytokinin experiment were grown in water-leached, steam-sterilized; coarse sand (All Star Concrete Co., Blacksburg, Va.) to minimize potential binding of the root-applied cytokinin to organic components of the medium. These plants were fertilized with Hoagland nutrient solution 1, except that Fe was supplied as 5 mg NaFeEDTA/liter of solution. Nutrient solutions were applied in 100-ml aliquots to all plants (daily, or as needed). The plants were grown at a 28C day/20C night cycle under natural light conditions in a greenhouse. Each treatment in each experiment consisted of 10 single-plant replicates in a randomized complete-block design. The General Linear Model of the Statistical Analysis System (SAS Institute, 1982) was used for analysis of variance.

Ovary size was recorded for the first two fruits on the first orescence of the main

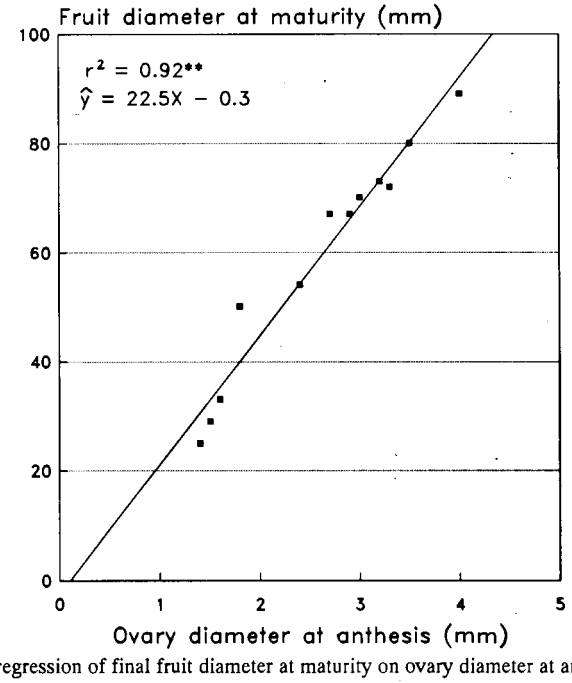

Fig. 1. Linear regression of final fruit diameter at maturity on ovary diameter at anthesis of 12 tomato cultivars.

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Table 1. Initial and final fruit sizes and their correlation for 12 tomato cultivars.

Cultivar	N	Ovary size at anthesis (mm)	Fruit size at maturity (mm)	r
Small Red Cherry	17	1.4	25	−0.45
Yellow Plum	19	1.5	29	−0.13
Small Fry	18	1.5	33	−0.13
Roma VF	17	1.8	50	0.20
Early Cascade	16	2.4	54	0.06
New Yorker	20	2.7	67	0.51*
Fireball	14	2.9	67	0.75**
Michigan/Ohio Hybrid	15	3.0	70	0.61*
Ramapo	12	3.2	73	0.46
Heinz 1350	14	3.3	62	−0.32
Campbell 1327	15	3.5	80	0.26
Ponderosa	17	4.0	89	0.33

*.** Significant correlation at $P = 0.05$ and 0.01, respectively.

stem, except where noted. Flower buds at anthesis were emasculated with forceps to expose the ovary for initial measurement and were self-pollinated by hand to ensure maximum pollination. Equatorial ovary diameter at anthesis was measured with a vernier caliper. Fruits were harvested and weighed at the pink stage of maturity and their diameters were recorded by taking the average of two measurements at right angles to each other.

Cultivar test. Twelve cultivars representing a range of fruit shapes, sizes, and maturation rates were used: 'Small Red Cherry', 'Yellow Plum', 'Small Fry', 'Roma VF', 'Early Cascade", 'New Yorker', 'Fireball', 'Michigan/Ohio Hybrid', 'Ramapo', 'Heinz 1350', 'Campbell 1327', and 'Ponderosa'. Mature fruits were harvested 85 and 120 days after seed planting.

Cytokinin experiment. BA (Sigma, St. Louis) was solubilized using 0.1 ml of 1 N KOH, diluted to 0.01 mM, and added to the nutrient solution to obtain a final concentration of 0.01 μM. Ovary diameters were measured at anthesis and at 3- to 4-day intervals until maturity.

Auxin and gibberellin experiments. NOA (Nutritional Biochemical Corp., Cleveland, Ohio) and GA (Sigma) were solubilized in warm water and diluted to 0.37 mM (NOA) and 0.10 mM (GA) with 0.05% 'Tween 80' (polyoxyethylene sorbitan mono-oleate). Foliar treatments of 2.0 ml/inflorescence were applied with an atomizer 38 days after planting, before anthesis of the first flower on the first inflorescence. Ovary diameter was measured for the first two fruits on the first and second inflorescence at anthesis at 7, 14, 21, and 35 days after anthesis and at maturity. Untreated and 'Tween 80'-sprayed plants were used as controls.

Correlation coefficients between ovary diameter at anthesis and final fruit diameter were significant and positive ($P = 0.05$) for 'Michigan/Ohio Hybrid' and 'New Yorker' tomatoes, and highly significant and positive ($P = 0.01$) for 'Fireball' (Table 1). Correlation coefficients for the nine remaining cultivars were not statistically significant. The 12 tomato cultivars exhibited a wide range of initial ovary sizes. The smallest ovaries (<2-mm diameter) were produced by 'Small Red Cherry', 'Yellow Plum', 'Small Fry', and 'Roma VF'. Intermediate ovary sizes (2 to 3 mm) were produced by 'Early Cascade', 'New Yorker', 'Fireball', and 'Michigan/Ohio Hybrid'. The largest ovaries (> 3 mm) were produced by 'Ramapo', 'Heinz 1350', 'Campbell 1327', and 'Ponderosa'. When a linear regression of final fruit diameter at maturity on ovary size at anthesis of the cultivars was calculated, the correlation was highly significant (Fig. 1). Such a relationship indicated that the estimation of final tomato fruit size could be estimated from a measure of ovary diameter at anthesis.

Continuous root application of 0.01 μM BA had no significant effect on ovary diameter at anthesis or final fruit diameter of 'Fireball'. The average number of days to anthesis of the first two flowers on the first inflorescence for untreated and BA-treated plants, however, was 51 and 53 days, respectively (significant at $P = 0.05$).

Foliar application of 0.37 mM NOA significantly increased ovary diameter at anthesis of fruits on the first inflorescence, but decreased ovary diameter at anthesis of fruits on the second inflorescence. No significant difference was found between untreated and 'Tween 80'-sprayed plants. Mean ovary diameter at anthesis for fruits on the first inflorescence of untreated and NOA-treated plants were 2.5 and 4.1 mm, respectively (significant at $P = 0.05$). Mean ovary diameters at anthesis for fruits on the second inflorescence of untreated and NOA-treated plants were 2.8 and 2.2 mm, respectively (significant at $P = 0.05$). At maturity, no differences in fruit size and fruit weight were found. As fruit growth progressed, NOA-treated plants exhibited a beaked or pointed fruit shape, indicating continued growth of stylar tissue proximal to the ovary.

Single foliar applications of 0.1 mM GA had no influence on ovary diameter at anthesis, final fruit diameter, or final fruit weight. Treatment with GA, however, caused a paler coloration of stem and leaf tissue in comparison to untreated plants, and increased stem and peduncle elongation, particularly noticeable at flowering of the first inflorescence. These observations are similar to those reported by other workers (Jupe et al., 1988).

'Fireball', 'Michigan/Ohio Hybrid', and 'New Yorker' tomatoes, with nonfasciated, spherical fruits of intermediate maturation rate, showed higher correlations between ovary diameter at anthesis and final fruit diameter than small-fruited, early maturing cultivars such as 'Small Red Cherry' and 'Small Fry', or elongated-fruited cultivars 'Yellow Plum'. and 'Roma VF'.

Cytokinins have been shown to influence many plant processes, including cell division, shoot development, and organ maturation. In this investigation, continuous exposure to 0.01 μM BA was effective in delaying the reflexing of the calyx and corolla, but it was not sufficient to affect significantly the early cell division stage of ovary development.

Two conclusions can be drawn from the NOA data: 1) single growth regulator treatments that decrease or increase ovary size during early stages of growth may not be sufficient to carry over to the mature fruit; and 2) predictions concerning the effect of NOA on later growth responses may require multiple or continuous treatment, higher concentrations of NOA, or both.

Similarly, a single foliar application of 0.1 mM GA did not increase net cell expansion of the fruit, although stem and peduncle elongation was increased. It is apparent that tomato stem and fruit tissues have different sensitivities to exogenous GA treatment.

Areas for further study may be to determine if repeated plant growth regulator treatments or combined growth regulator treatments are effective in increasing both cell division and cell enlargement phases of tomato fruit growth.

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