involved in snapdragon senescence.

When the concn of SB was 0.2 mM, peak ethylene production was 30% less than that of the control (Fig. 3). This reduction, however, did not delay senescence (Table 2). Ethylene production in MRo-treated samples was reduced for the first 3 days and then gradually increased (Fig. 3). Thus MRo did not completely inhibit the rise of ethylene production, but greatly suppressed and delayed the peak.

Solution absorption. Except for the DW control treatment, solution absorption patterns for all treatments containing HQC were comparable (Fig. 5). Absorption increased for 3 or 4 days then declined and leveled off. The beneficial effect of HQC in retarding microbial growth and reducing physiological plugging of vascular tissues has been demonstrated by Larsen and Scholes (9) and Marousky (13). Our results of the absorption of HQC solution suggest that the rhizobitoxine analogs prolonged vase life by a mechanism other than by preventing vascular blockage. The evidence presented suggests that Ro and MRo lengthened vase life of snapdragons by inhibiting ethylene production.

Literature Cited

1. Baker, J. E., C. Y. Wang, M. Lieberman, and R. E. Hardenburg. 1977. Delay of senescence in carnations by a rhizobitoxine analog and sodium benzoate. *HortScience* 12:38-39.
2. Beyer, E., Jr. 1976. Ethylene antidote. *HortScience* 11:174.
3. Carpenter, W. J. and D. R. Dilley. 1973. A benzothiadiazole extends cut carnation flower life. *HortScience* 8:334-335.
4. Fischer, C. W., Jr. 1950. Ethylene gas a problem in cut flower storage. *N.Y. Flower Growers Bul.* 61:1, 4.
5. ________. 1950. Production of a toxic volatile by flowering stems of common snapdragon and calceolaria. *Proc. Amer. Soc. Hort. Sci.* 55:447-454.
6. Halevy, A. H. and S. Mayak. 1974. Improvement of cut flower quality, opening and longevity by preshipment treatments. *Acta Hort.* 43:335-347.
7. Johnson, C. R. 1972. Effectiveness of floral preservatives on increasing the vase-life of snapdragons. *Flor. Rev.* 149(3868):47, 95-97.
8. Larsen, F. E. and R. W. Cromarty. 1967. Micro-organism inhibition by 8-hydroxyquinoline citrate as related to cut flower senescence. *Proc. Amer. Soc. Hort. Sci.* 90:546-549.
9. ________ and J. F. Scholes. 1966. Effects of 8-hydroxyquinoline citrate, N-dimethyl amino succinamic acid, and sucrose on vase life and spike characteristics of cut snapdragons. *Proc. Amer. Soc. Hort. Sci.* 89:694-701.
10. ________ and ________. 1967. Chemical stimulation of cut snapdragon development and increased vase-life. *Flor. Rev.* 141(3648): 22-23, 81-82.
11. Lieberman, M., A. T. Kunishi, and L. D. Owens. 1974. Specific inhibitors of ethylene production as retardants of the ripening process in fruits, p. 161-170. *In* R. Ulrich (ed.), Facteurs et regulation de la maturation des fruits, Colloques Int. C.N.R.S., 238, Paris.
12. Lumsden, D. V., R. C. Wright, T. M. Whiteman, and J. W. Byrnes. 1940. Ethylene injury to cut flowers in cold storage rooms. *Science* 92:243-244.
13. Marousky, F. J. 1962. Water relations, effects of floral preservatives on bud opening, and keeping quality of cut flowers. *HortScience* 7:114-116.
14. ________ and J. C. Raulston. 1970. Interaction of flower preservative components and light on fresh weight and longevity of snapdragon cut flowers. *Proc. Florida State Hort. Soc.* 83:446-448.
15. Meigh, D. F., K. H. Norris, C. C. Craft, and M. Lieberman. 1960. Ethylene production by tomato and apple fruits. *Nature* 186:902-903.
16. Parups, E. V. 1975. Inhibition of ethylene synthesis by benzylisothiocyanate and its use to delay the senescence of carnations. *HortScience* 10:221-222.
17. Raulston, J. C. and F. J. Marousky. 1970. Effects of 8-10 day 5°C storage and floral preservatives on snapdragon cut flowers. *Proc. Florida State Hort. Soc.* 83:415-419.
18. Wilkins, H. F. 1965. Factors affecting carbon dioxide and ethylene gas production in flowers of the carnation (*Dianthus caryophyllus*, L.) cultivar 'Red Gayety'. PhD Thesis. Univ. of Illinois, Urbana.

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Impact of Single Seed Descent in Selecting for Fruit Size, Earliness, and Total Yield in Tomato[1]

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Abstract. **Single seed descent (SSD) produced generally inferior fruit size, earliness and total yield among progenies as compared with pedigree (PED) selection alone and single seed descent following one cycle of pedigree selection (PDSD). The latter two systems were essentially equal in performance, but the PDSD system provided increased efficiency of time and space. Progeny tests in 1976 generally reflected the superiority that had been selected in 1975, regardless of selection system. In each system, acceptable performance was attained in at least one line. The data suggest, however, that chances of recovering high-performance lines are reduced in SSD as compared to PED or PDSD.**

Improvement of most vegetable crop cultivars has been accomplished through PED and progeny testing. This system has given the breeder maximum control of selection generations, but has involved substantial inputs of time and space. Mass selection has similar time and space restrictions and also risks the loss of good genotypes through intergenotypic competition. Brim (1) suggested a modified pedigree system, termed SSD, in which random F_2 plants would be advanced to successive generations by a single seed, thus minimizing natural selection.

The SSD system has been used extensively in soybean breeding. Empig et al. (5), Boerma and Cooper (2) and others have determined that SSD is more efficient than pedigree systems per unit of time. Computer simulation studies by Casali and Tigchelaar (4) suggested that SSD is most effective where several traits of differing heritabilities are under simultaneous selection. Their results, confirmed by field tests with tomato (3) indicated that PED in F_2 and F_3 generations, followed by SSD, would maximize progress.

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The study reported herein was designed to test the impact of 3 selection systems in tomato for improvement of fruit size, early yield, and total yield.

Materials and Methods

Three determinate F_2 tomato populations were chosen from among 7 tested in 1973. The 3 populations included 1 with 2 unrelated parents (110 × 101), 1 in which the 2 parents had 1 ancestor in common (215 × 109), and 1 in which the 2 parents had both ancestors in common (210 × 211 sib). Within each of the 3 F_2 populations, a single fruit from each of 64 plants taken at random was saved for single seed descent. At the same time, single plants showing superior earliness; fruit size, shape, and smoothness; concentrated fruit load; reasonable vine growth; and leaf cover, were selected visually and maintained by the pedigree system.

SSD procedure. Several F_3 seeds derived from each F_2 plant were sown in the greenhouse. Seedlings were thinned to a single plant in 15 cm pots or in ground beds at 15 cm spacing and advanced to the F_4 generation. With the dense planting, up to 20% of the plants failed to produce seeds.

In 1974, 48 F_4 plants of each of 3 F_2-derived lines were planted in the field for SSD. Seed again was saved from each plant and sown in the greenhouse as in the previous year. Thirty-six F_5 single plants of each F_2-derived line yielded F_6 seeds, and these were sown in 1975 in separate 4-plant plots, each plot derived from a single plant. In one derived line, only 24 plots were utilized because of suspected transplanting error.

Based upon fruit size and appearance, early yield, and general plant characteristics, 2 F_6 plots were selected within each of the F_2-derived lines. Seed from the single best plant within each selected plot was saved for subsequent replicated testing.

PED procedure. In 1974, 16 F_3 lines, derived from each of the 3 F_2 lines used for SSD selection, as single-plant selections were field planted in 24-plant plots. Each was rated visually for fruit size, shape and color; freedom from defects; and general plant appearance.

Within each group of F_3 lines, the 2 superior lines were identified and the best 4 individual plants in each line were selected. Progenies of these 24 single plant selections, grouped according to the line from which they were taken, were field-planted as separate 24-plant plots in 1975. Average fruit size and early yield were determined for each plot. The superior plot within each of the 6 groups was identified, and the best plant within each was saved for seed. Selection was therefore based first upon average of a progeny row, then on individual plants within that row. Ten plants of each of the 6 F_5 selections were grown in the greenhouse and seeds obtained from each plant were bulked within each line for subsequent replicated tests.

PDSD procedure. In 1974, after the best selections within each F_2 had been identified by F_3 progeny tests, remnant F_3 seeds of these lines were sown in the greenhouse. Of 60 plants grown of each line, about 48 yielded F_4 seed. A single F_4 plant derived from each greenhouse plant was grown in the field in 1975. Based upon individual plant early yield and fruit size in that trial, the best 6 plants in each line were saved, advanced to the F_6 in the greenhouse, and bulked for 1976 replicated tests.

Replicated test. Six lines each, developed by SSD, PED and PDSD, were tested with remnant F_2 and F_2 material in a replicated randomized block trial in 1976. The design consisted of 4 replicates of the 24 entires with plants spaced 90 × 150 cm. Of the 10 plants in a plot, only the 8 interior plants in each plot were measured. The traits recorded were early and total yield (g), fruit size (g/fruit) and a general rating of plant appearance (fruit shape, freedom from defect, color, vine cover, concentration) using a scale of 1-5.

Data were recorded on separate 2-plant segments within each plot in order to provide a measure of residual variation within each selection group. The analysis of variance was a "nested" form in which variation between families within groups and within family within a group (between selections) could be assessed.

Experimental Results

1975 selection. For each plant grown in 1975, total weight and mean size of fruit from breaker stage to full ripe before August 20 were determined. These data (Table 1) provided the primary bases for selection of entries for the replicated trial. While concurrent improvement was sought, negative correlation of fruit size with earliness occasionally resulted in sacrificing one trait for the other. Fruit size and early yield means, recorded for lines in each group prior to selection, showed generally inferior performance within the SSD (F_5) group. Differences between PDSD (F_4) and PED (F_4) were small except for fruit size of material derived from the cross 110 × 101.

Estimates of variation between lines and within lines grown in 1975 were inconclusive. Between-line variation was moderately high for each F_2-derived family selected by SSD. Coefficients of variability ranged from 40 to 46%. A wide range in

Table 1. Mean fruit size and early yield per plant of source populations and of selections made in 1975.

F_2 derived family	SSD (F_5)				PDSD (F_4)				PED (F_4)			
	Mean		CV		Mean		CV		Mean		CV	
	Population	Selection	Between line	Within line	Population	Selection	Between line	Within line	Population	Selection	Between line	Within line
					Fruit size (g)							
110 × 101	138.4	139.3	23.8	12.2	142.9	150.2			163.9	172.6		14.1
					141.4	156.5	5.2	20.5	163.6	214.5	36.1	
215 × 109	147.5	175.9	26.5	5.8	147.5	148.5			144.3	156.3		14.6
					159.2	160.9	38.1	11.9	162.3	175.5	36.2	
210 × 211	111.9	120.3	31.9	12.6	122.5	130.3			116.5	94.2		12.8
					114.6	115.3	32.7	14.7	120.0	127.7	30.2	
					Early yield (g/plant)							
110 × 101	3672	5475	43.3	28.6	3778	4985			3904	5350		29.1
					3840	4703	8.0	29.5	4497	6650	62.3	
215 × 109	3826	3695	46.6	34.4	4738	6150			4513	6250		26.9
					4392	5395	37.1	27.1	4115	5790	35.1	
210 × 211	4193	4765	40.1	22.9	4774	5394			4449	6780		22.7
					4698	5092	7.9	17.2	4689	6000	37.4	

Table 2. Mean fruit size, early yield and total yield in 3 selection groups and F_1 and F_2 checks for each of 3 families.

Family & selection groups	Fruit size (g/fruit)	Early yield (MT/ha)	Total yield (MT/ha)
110 x 101			
SSD	147	18.6	54.6
PDSD	167	27.0	61.1
PED	179	24.1	61.5
F_1	150	31.1	76.4
F_2	160	24.8	64.5
215 x 109			
SSD	168	23.2	54.9
PDSD	171	25.1	58.1
PED	168	26.7	59.0
F_1	173	31.5	70.8
F_2	172	25.5	61.0
210 x 211			
SSD	119	20.5	53.2
PDSD	122	25.9	56.0
PED	109	26.6	50.7
F_1	147	27.3	59.1
F_2	143	29.0	60.7
LSD (5%) Groups within families	8	4.0	6.2

CV's was found among F_2-derived families when 1 or more generation of pedigree selection was involved. This range probably reflects early selection pressure and rapid isolation of distinct phenotypes. Variation within lines, however, showed no meaningful differences among the selection groups.

Replicated trial. The differences among selection systems revealed by analysis of variance were primarily due to inferior response to SSD. There were major differences among the 3 selection groups (Table 2). No difference for any trait was obtained between the PED and PDSD systems. The cross of unrelated parents (110 x 101) was most consistent in response, while the sib cross (210 x 211) was the least consistent. None of the selected groups attained the average size or yields of the original F_1 and F_2. In total yield and early yield, however, both the F_1 and F_2 apparently exhibited substantial heterosis, accounting for this average superiority. The slight decline in fruit size during selection very likely was due to the emphasis placed on earliness. Selection of early segregates normally will depress average fruit size (6).

A comparison of means for fruit size of selections in 1975 (Table 1) with those of progenies in 1976 (Table 2) shows that this selection was effective. In each instance, the progeny performance closely matched that of selected parents. The relative early yield of families in 1976 was not as consistent as the data for fruit size, but there seemed to be improvement in 2 of the 3 families. Early yield was difficult to compare directly because the no. of days of fruit production differed in the 2 years.

Analysis of variance showed no difference in earliness among the F_2 source populations. The original differences among F_2 families for fruit size persisted through all selection systems, but only pedigree selection maintained original differences in total yield (Table 2). Fruit size is of moderately high heritability, and some selection pressure was applied toward preserving and enhancing size. Yield, a trait low in heritability, was not selected directly, particularly where the SSD system had been used.

F_2 and F_2 yield comparisons showed about the same degree of heterosis in each family, except for the 210 x 211 sib cross. There, no difference between F_1 and F_2 yields was observed.

Means of each 2-plant segment were used to calculate coefficients of variation (CV) within each line in each selection group. The results showed no consistent differences attributable to family or group. Residual variation in the sib cross (210 x 211) was the lowest of all families, but differences among families

Table 3. Maximum mean fruit size, early yield, and total yield in 3 selection groups as compared with parental F_1 and F_2 means.

Selection group	Fruit size (g/fruit)	Early yield (MT/ha)	Total yield (MT/ha)
SSD	178	29.6[z]	61.9
PDSD	182	28.7	62.4
PED	184	30.1	65.6
F_1	173	31.1	59.1
F_2	172	24.8	60.7
LSD (5%)	11	5.7	8.8

[z]Parental F_1 = 31.5, and F_2 = 25.5 MT/ha in this group.

were small.

Discussion and Conclusions

This experiment was designed to measure response in plant populations to several different selection systems. On average performance, gains under SSD were smaller than within PED and PDSD. Within each selection group, however, superior lines could be secured (Table 3). The results suggested that the number of these lines was increased with at least one early cycle of progeny evaluation.

Casali and Tigchelaar (3) reported SSD to be effective when preceded by 2 generations of PED selection. Our SSD system began with a test of F_3 progenies, returning to remnant F_3 seed of the selected lines for SSD. This system allows the breeder to use small plots for the progeny test and to expand potential range of genotypes through remnant seed of the best lines.

The mechanics of SSD selection should pose no difficult problems in a breeding program. More fruit are harvested for seed processing than for PED selection. However, record-keeping is not a factor. While SSD does not permit natural selection under field conditions, this force may affect survival in dense greenhouse plantings. It was not possible to determine if loss of plants suffered under crowded greenhouse conditions may have had a bearing on mean field performance, or if this loss was completely at random. Survival could be associated with traits used to compare selection systems. However, losses of plants were encountered in both SSD and PDSD material, yet the PDSD differed little from PED response. The differences in final performance as determined by replicated trial, therefore, seem to be related primarily to differing systems of field selection. In spite of this problem, the rapid advance in generations and relatively small space requirement in SSD system provide a major advantage to the breeder. Results strongly indicate that a single year of PED selection, combined with SSD, will result in progress equal to that afforded by a PED system alone.

Literature Cited

1. Brim, C. A. 1966. A modified pedigree method of selection in soybean. *Crop Sci.* 6:220.
2. Boerma, H. R. and R. L. Cooper. 1975. Comparison of three selection procedures for yield in soybeans. *Crop Sci.* 15:225-229.
3. Casali, V. W. D. and E. C. Tigchelaar. 1975. Breeding progress in tomato with pedigree selection and single seed descent. *J. Amer. Soc. Hort. Sci.* 100:362-367.
4. ________ and ________ . 1975. Computer simulation studies comparing pedigree, bulk, and single seed descent selection in self pollinated populations. *J. Amer. Soc. Hort. Sci.* 100:364-367.
5. Empig, L. T. and W. R. Fehr. 1971. Evaluation of methods for generation advance in bulk hybrid soybean populations. *Crop Sci.* 11:51-54.
6. Peirce, L. C. and T. M. Currence. 1959. The efficiency of selecting for earliness, yield, and fruit size in a tomato cross. *Proc. Amer. Soc. Hort. Sci.* 73:294-304.

J. Amer. Soc. Hort. Sci. 102(5):520–522. 1977.