HortScience 15(6):749–750. 1980.

Seed Germination and Early Seedling Vigor in Progenies of Inbred Strawberry Selections[1]

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Additional index words. Fragaria x *ananassa,* hybrid vigor, heterosis

Abstract. **Most progenies from intercrossed or outcrossed inbred selections of strawberry (*Fragaria* x *ananassa* Duch.), germinated as well or better than a control outcross between 2 vigorous noninbred clones. Germination of an S_3 progeny was lower than the control. In general, inbreeding reduced seedling vigor while intercrossing or outcrossing of inbreds restored vigor. Germination total and rate as expressed by an index were unrelated to subsequent seedling growth.**

The cultivated strawberry is commercially propagated asexually; thus the heterozygosity and vigor of parental clones are retained. Strawberry breeders have occasionally used inbreeding to produce lines with increased homozygosity. When intercrossed, these lines produce heterozygous but relatively homogeneous progenies (1,9). Inbreeding allows undesirable characters to be eliminated and desirable characters to be retained or increased (5). Successful uses of limited inbreeding include the origin of cultivars 'Albritton' (4), 'Aliso' and 'Sequoia' (3), and the increase of Vitamin C content in certain strawberry selections (2). Yet, on the average, inbred strawberries exhibit reduced plant size, fewer crowns, smaller stems and leaves, and reduced yield (5). Morrow and Darrow (7) established that field grown seedlings of inbreds are less vigorous than either parent.

The objective of this study was to determine whether differences in total germination, rate of germination, and seedling vigor exist among progenies of inbred and noninbred selections resistant to red stele root rot, and whether intercrossing or outcrossing inbred selections can restore vigor to their progenies. Plants having common traits, such as red stele resistance, often have some common parentage. This study has been designed to establish if these inbreds behave similarly to inbreds from other parents selected for different traits.

Four inbred strawberry selections were selfed, intercrossed, and outcrossed to 2 noninbred selections. The noninbred selections were also intercrossed and selfed. Complete pedigrees for the parents of the resulting diallel were presented by Melville et al. (6). Nine progenies were selected from the diallel series for subsequent seed germination and seedling growth tests. These progenies represented the following pollination types: intercross of 2 noninbreds (control cross, N x N); intercrosses of first geneneration inbreds (S_1 x S_1), of second generation inbreds (S_2 x S_2), of first and second generation inbreds (S_1 x S_2); outcrosses of inbreds and noninbreds (S_1 x N and S_2 x N); and self-pollinations of a noninbred (S_1 seed), a first generation inbred (S_2 seed) and a second generation inbred (S_3 seed). The strawberry clones used as parents in this study were as follows:

First generation inbreds (S_1)
- Md-US 4509 (Md-US 2856 x self)
- Md-US 4515 ('Surecrop' x self)

Second generation inbreds (S_2)
- Md-US 4519 (Md-US 4461 x self)
- Md-US 4520 (Md-US 4461 x self)

Noninbreds (N)
- Md-US 4355 ('Raritan' x Md-US 3413)
- Md-US 4426 (Md-US 3700 x 'Redchief')

Seeds for the germination study were sown in August 1978 to provide a randomized complete block design with 8 replications of 50 seeds per plot. The seeds were distributed evenly on the surface of flats filled with moist milled sphagnum moss and stratified for 2 months at 3°C. In October the seed flats were placed under mist in a greenhouse and given 2 hr of supplemental light at night. The number of germinated seeds was counted on the 9th day. Subsequent counts were taken on days 11, 13, 16, and 18. Seeds were considered to have germinated when the cotyledons were visible. A germination index (GI), similar to that of Ng and Tigchelaar (8), that accounted for both rate of germination and total germination was calculated for each cross using the formula:

$$GI = \frac{(K-R1)N1}{S} + \frac{(K-R2)N2}{S} + \ldots + \frac{(K-Rf)Nf}{S}$$

where GI = germination index,
- K = total number of days in germination test + 1,
- R1, R2, Rf = number of days until the 1st, 2nd and final readings, respectively,
- N1, N2, Nf = number of seeds germinated in test periods 1, 2 and final respectively,
- and S = total number of seeds germinated during the entire test period

In interpreting this index, higher values indicate more and/or more rapid germination.

Weights of shoots and roots were taken after 6 weeks growth to determine whether the 3 types of measurements, with the germination index, gave similar indications of plant vigor. Eighty seedlings of each progeny that had reached the 1st true-leaf stage were transplanted into a 2:1 (by volume) mixture of sand and soil and arranged on a greenhouse bench in a randomized complete block design with 8 replications of 10 seedlings of each progeny per plot.

After 40 days of growth in the greenhouse each seedling was cut off at the soil line, and its fresh weight was determined. Dry weights of the tops were taken after a 24 hr period in an oven-dryer at 70°C. Roots from 4 replications were also harvested, dried for 24 hr at 70°C and weighed.

Mean percentage of seed germination and germination indices of the 9 progenies are summarized in Table 1. The intercrossed or outcrossed inbred progenies, and the first and second generation selfed progenies generally showed as good or better (Md-US 4509 x Md-US 4519) rate of germination or total germination when compared to that of the control cross (Md-US 4355 x Md-US 4426). Three generations of self-pollination (Md-US 4520 x self) exhibited decreased total germination and rate of germination. Results may have been partially confounded by the tendency of certain parents to give a high (Md-US

[1]Received for publication January 28, 1980. Scientific Article A2722, Contribution Number 5765 of the Maryland Agricultural Experiment Station, Department of Horticulture. This study was a portion of a thesis submitted by the senior author in partial fulfillment of the requirements for receiving a Master of Science Degree from the University of Maryland.
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Table 1. Seed germination of crosses of selected inbred and noninbred strawberry selections.[z]

Cross	Type of progeny	Mean germination (%)	Germination index
4509 x 4519	$S_1 \times S_2$	79.2a[y]	17.7a
4509 x 4515	$S_1 \times S_1$	74.0ab	14.7b
4515 x 4426	$S_1 \times N$	70.0b	14.4bc
4509 x self	S_2	66.2bc	12.7bc
4355 x 4426[x]	N x N	66.2bc	12.4c
4426 x self	S_1	59.6cd	12.4c
4520 x 4519	$S_2 \times S_2$	58.2cd	12.6c
4520 x 4426	$S_2 \times N$	55.6d	11.1cd
4520 x self	S_3	53.6d	10.0d

[z]50 seeds germinated per plot with 8 replications. Correlation coefficient between germination % and germination index was +0.9.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

[x]Control, cross between 2 vigorous noninbred clones.

Table 2. Mean vigor of strawberry seedlings from crosses of inbreds and noninbreds expressed as mean dry or fresh weights of plant parts.[z]

Cross	Type of progeny	Shoot dry wt (mg)	Shoot fresh wt (mg)	Root dry wt (mg)
4355 x 4426[x]	N x N	88a[y]	533a	14ab
4520 x 4426	$S_2 \times N$	86a	522a	11abc
4520 x 4519	$S_2 \times S_2$	82ab	503ab	13abc
4515 x 4426	$S_1 \times N$	78ab	484ab	14a
4509 x 4519	$S_1 \times S_2$	75ab	478ab	12abc
4426 x self	S_1	71b	380c	10cd
4509 x 4515	$S_1 \times S_1$	70b	445b	11bc
4520 x self	S_3	49c	263d	6e
4509 x self	S_2	47c	299d	8de

[z]Tops of 720 plants and roots of 360 plants were weighed to estimate vigor.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

[x]Control or check cross between 2 vigorous noninbred clones.

4509) or low (Md-US 4520) germination percentage. In this study the germination index was highly and positively correlated with total germination. This correlation may reflect the more rapid germination of viable seeds following stratification.

Selfed progenies from inbred and noninbred parents showed less early shoot growth or root growth than did the control cross (Table 2). Selfing for 2 or 3 generations (Md-US 4509 or 4520) depressed early seedling growth compared to that of cross-pollinated progenies or to selfing or a vigorous clone for 1 generation. Most inbred x inbred and inbred x noninbred crosses recovered vigor equivalent to that of the control, indicating that vigor was largely restored by hybridization or outcrossing, even between full sibs. However, note that the control progeny showed the most vigor, even though the other crosses did not differ significantly. The better early growth of outcrossed seedlings compared to that of crosses among inbreds was often visible in young seedlings in the greenhouse. The shoot growth of cross 4509 x 4515 ($S_1 \times S_1$) was apparently poorer than that of the control, but root growth was apparently equal.

Correlation coefficients among shoot fresh and dry weight and root dry weight were all highly significant. Correlation coefficients were: shoot dry weight with shoot fresh weight, r = .73; shoot dry weight with root dry weight, r = .72; shoot fresh weight with root dry weight, r = .74. However, the germination index was not correlated with any of the plant weight measures. This result indicated that any one of the growth criteria except the germination index could be used as a measure of strawberry seedling vigor.

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HortScience 15(6):750–751. 1980.

Low Temperature and Flowering of Primocane-fruiting Red Raspberries[1]

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Additional index words. Rubus idaeus, flower induction

Abstract. **Low temperature was not a requirement for flowering in 'Heritage', a primocane-fruiting red raspberry, as non-cold treated primocanes flowered at about 80 nodes. The amount of growth before flowering was inversely related to the amount of growth before cold exposure. Cold exposure (7°C) for 25 days at the 10-12 or 14-16 nodes stages of growth was followed by flowering at 32 and 28 nodes, respectively. Winter cold exposure until mid-December at the stage of adventitious buds on the root resulted in flowering at 41 nodes. Cold treatment did not influence the number of nodes that developed inflorescences on any one primocane.**

In primocane-fruiting red raspberry cultivars flowering occurs in the apical region of the primocane during summer. All buds are potentially flower buds (2) but all do not become flower buds in the first year. Buds below the fall-fruiting region become flower buds on the floricane during late fall and winter. Flower induction in mature canes of 'Heritage' is temperature independent (1), but flower bud differentiation is influenced by low temperature. Williams and Hudson (3) showed that flowering could be induced on elongated canes of 'Lloyd George' a primocane-fruiting cultivar by a cold treatment of 2.5-4.5°C for periods up to 6 weeks. In contrast flowering could not be induced by

[1]Received for publication August 23, 1978. Research supported by the College of Agricultural and Life Sciences. Hatch project 2171. This research was conducted in partial fulfillment of the requirement for the Ph.D. degree by the senior author.

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