

# Some Seed, Seedling, and Maternal Characters as Estimates of Commercial Performance in Sweet Potato Breeding<sup>1</sup>

Alfred Jones and P. D. Dukes<sup>2</sup>

*U.S. Vegetable Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Charleston, SC 29407*

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**Abstract.** Thirty random seedlings from each of 50 random parents of a sweet potato (*Ipomoea batatas* (L.) Lam.) mass selected population were evaluated in the greenhouse and their subsequent field performances were recorded. Simulated selection sequences were also studied. A sequence with mass selection first on maternal hill weight, high seed set, and high seed weight followed by a 50% culling level within families on the basis of low greenhouse seedling vigor resulted in average progeny field yields 45% above that of no selection. The results showed seed weight to be a potentially useful selection criterion for root yield. Individual seedling root weight in the greenhouse was not a good predictor of field yield.

Previous quantitative genetic studies of sweet potato have shown the presence of important phenotypic, genotypic, and environmental correlations of root weight and other character measurements (1). In some cases nonsignificant phenotypic correlations were due to significant genetic and environmental correlations of different sign. Also, correlated responses to selection sometimes occur as a result of genetic correlations (2). It was further shown that knowledge of such responses can assist the plant breeder in making prudent selections which would allow him to avoid an undesirable outcome or to reinforce a desirable one. The presence of and importance of associations other than correlations on selection results has been demonstrated (3). Selection usually involves saving only one tail of a distribution and associations with other traits may exist there that are not detected by correlation. Such associations can be detected by changes in unselected traits after a number of generations of selection on some other trait. Although the above kinds of quantitative genetic information are valuable to breeders, they are time consuming and difficult to obtain. The estimates obtained will vary with materials of differing origin, with the generation of selection, with the selection pressure used and all are subject to rather sizable environmental errors. In many situations such information is beyond the practical reach of the breeder.

Another approach to the study of selection response in sweet potatoes would be to collect data on randomly chosen individuals and then to simulate selection by imposing various hypothetical sequences of selection on the accumulated data. This approach could be used in most breeding programs with little additional cost and without resorting to complex statistical procedures. One would simulate culling according to some pattern and measure the effects on other characters of interest.

Each sweet potato cultivar is the vegetative increase from a single seedling and, in their search for improved cultivars and breeding stocks, sweet potato breeders must evaluate thousands of seedlings each year. In most breeding programs in the United States, the seedlings are started in the greenhouse during the winter and plants are moved to the field in the spring. Since the plants produce small tubers in the greenhouse, selection may be made for flesh color, skin color, or other traits of interest before the plants are set in the field. Root size is always variable in the greenhouse and it is tempting to select those with larger roots. However, MacDonald (6) found poor agreement between the root development of the original seedlings and their respective vegetative progeny. His tests were conducted under field condi-

tions without the use of greenhouses for starting the seedlings.

Greenhouse seedling vigor is also variable and might be expected to be associated with later field performance. Obviously, efficiency in the early greenhouse selection would benefit the total selection procedure. With efficient selection fewer plants would need field evaluation and a higher percentage of those evaluated would have cultivar potential.

We therefore compared greenhouse seedling root weights and various vigor measurements with subsequent field performance. We also examined maternal seed production traits to determine their possible association with greenhouse seedling vigor and subsequent field performance. Maternal root weight was included because root weight is a necessary component of yield selection in sweet potato. The influence of inheritance on root weight is complex, and heritability estimates have been low. Jones et al. (4) obtained a mean heritability estimate of .41 from a parent-offspring study grown in 3 locations for 2 years. Estimates within the 6 environments varied from .21 to .60. Li (5) reported more non-additive than additive genetic variance for root yield and Sakai (7) also reported relatively large non-additive effects, which suggest low heritability. We also investigated sequences of mass selection for root yield simulated from data collected either before seed germination or during seedling growth.

## Materials and Methods

In 1969, 50 sweet potato plants were randomly taken from 595 trellised second generation plants of the mass selection nursery at Tifton, Georgia. Root wt after 136 days were obtained from 5-hill plots of vine cuttings of each of the 50 plants grown in an adjacent test. The open-pollinated plants of the mass selection nursery provided seed set and seed wt data. Seeds were planted in the greenhouse on Feb. 1, 1970, vine cuttings were set in the field on June 1, and roots were harvested on Nov. 1. Seedling emergence data were taken from hand-scarified seed of each maternal line seeded on 10-cm centers directly in soil in greenhouse benches. Seedling height was recorded 3 weeks after seeding, and subjective vigor scores (1–5, increasing vigor) were taken at 6 weeks and expressed as a weighted average index on 0–100 scale for family comparisons. Greenhouse survival as percentage of emerged seedlings and root wt (g) were recorded when plants were uprooted for transplanting. A vine cutting from each of 30 random seedlings of each parental line was grown in the field along with 5 replicates of each of the maternal lines in 5-plant plots. Survival percentages and hill wt (total wt of all enlarged roots from 1 plant) were obtained.

Selection sequences were simulated with data available before seeding and with data obtained in the greenhouse. Individual seedlings were labeled in the greenhouse and their

<sup>1</sup>Received for publication May 19, 1975.

<sup>2</sup>Research Geneticist and Research Plant Pathologist, respectively.

Table 1. Effects of simulated culling of sweet potato seedlings at various greenhouse root wt on the no. of field transplants and their subsequent field performance.

Simulated greenhouse culling levels (root wt in g) <sup>z</sup>	Transplants (no.)	Field performance (hill wt) <sup>y</sup>				No. plants with high performance
		Died (%)	Low (%)	Medium (%)	High (%)	
0	1446	26	30	31	13	188
2	1228	22	31	33	14	172
5	771	19	28	37	16	123
10	596	20	24	38	18	107
15	442	20	23	38	19	84
20	367	18	22	39	21	77
25	283	17	22	38	23	65
30	233	18	23	37	22	51
35	177	16	23	39	22	39
40	143	16	20	39	25	36
45	115	15	18	40	27	31

<sup>z</sup>0 = All live plants set in the field plantings, 2 = discarded all plants with roots weighing less than 2 gms, etc.

<sup>y</sup>Died = not surviving to harvest. Low = hill wt < .45 kg. Medium = hill wt .50–1.36 kg. High = hill wt 1.41–3.90 kg.

Table 2. Summary of family greenhouse performance and subsequent field performance of sweet potato seedlings.

Simulated greenhouse selection	Greenhouse seedling (family mean)						Field		
	Emergence (%)	Vigor index <sup>y</sup> (6 wks)	Vigorous plants per 100 seed	Height 7 wks (mm)	Survival (% of germ.)	Root wt (g)	Survival to harvest (%)	Average hill wt (kg)	Hill wt change (%)
No selection (50 families)	79	41	55	47	76	16	74	0.80	–
Best 8 families (field hill wt.) <sup>z</sup>	84	40	63	45	78	22	80	1.17	46
High emergence (above 80%, 24 families)	87	42	60	46	74	14	75	0.80	0
Low emergence (below 80%, 26 families)	72	39	51	48	77	17	74	0.80	0
High seedling vigor (41.9 up, 25 families)	79	49	60	52	83	16	73	0.79	–1
Low seedling vigor (41.7 down, 25 families)	79	32	50	41	69	15	75	0.81	1
High root weight (14 g up, 25 families)	77	39	56	47	77	22	75	0.88	10
Low root weight (13.5 g down, 25 families)	81	42	55	47	74	10	73	0.72	–10
High height (47 mm up, 26 families)	78	47	57	54	80	15	71	0.75	–6
Low height (46 mm down, 24 families)	81	34	53	39	71	16	77	0.85	6
High survival (77% up, 25 families)	80	45	63	50	86	17	77	0.82	2
Low survival (76% down, 25 families)	79	36	47	43	66	15	71	0.78	–2
Vigorous/100 seed (53 up, 23 families)	83	45	66	49	84	17	79	0.84	5
Vigorous/100 seed (52 down, 27 families)	76	37	46	45	68	14	70	0.77	–4
High no. vigorous/100 seed with root wt above 14 g (12 families)	80	42	65	48	86	23	80	0.93	16
High no. vigorous/100 seed with height below 46 mm (8 families)	87	35	67	39	78	18	84	0.95	19
High survival with root wt above 14 g (14 families)	78	43	62	50	86	23	77	0.84	5
High survival with height below 46 mm (7 families)	81	35	64	39	82	20	81	0.89	11
Height above 47 mm with % vigorous above 53 (15 families)	81	50	66	55	88	15	76	0.78	–2
Height above 47 mm, % vigorous above 53, root wt above 14 g (7 families)	76	48	65	56	90	22	75	0.92	15

<sup>z</sup>Representative of maximum gain possible in terms of average hill wt of progeny.

<sup>y</sup>Increasing vigor on 0–100 scale obtained from a weighted average of individual seedling scores of 1 to 5.

Table 3. A summary of the response to alternative family selection sequences based on data available before planting sweet potato seed.

Selection sequence	Maternal avg		Avg seedling emergence (%)	Progeny avg			
	Seed set (no.)	Wt/100 seed (g)		Greenhouse surv. (%)	Field surv. (%)	Field hill wt	
						Avg (kg)	Change <sup>Z</sup> (%)
No selection (50 families)	76	2.0	79	76	74	0.80	—
Best 8 families (hill wt) <sup>Z</sup>	62	2.1	84	78	80	1.17	46
High maternal hill wt (24 families)	77	2.1	79	79	73	0.85	6
Low maternal hill wt (26 families)	76	1.9	79	73	75	0.76	-5
High seed set (>55; 25 families)	114	2.0	80	73	74	0.76	-5
Low seed set (<55; 25 families)	39	2.0	79	78	74	0.85	6
High seed wt (2.0 g/100; 23 families)	77	2.2	81	81	75	0.87	9
Low seed wt (<2.0 g/100; 27 families)	76	1.8	78	71	73	0.75	-6
1969 parental hill wts							
High hill wt (7 families)	60	2.1	76	82	73	0.77	-4
High hill wt—high seed set (11 families)	130	2.1	84	74	74	0.88	10
High hill wt—high seed set—high seed wt (7 families)	99	2.3	85	79	77	1.00	25

<sup>Z</sup>Represents maximum possible change in terms of average hill weight of progeny.

subsequent field yield measured. Greenhouse and field performances were compared individually and by family (maternal seed parent) averages through use of culling levels to simulate practical greenhouse selection procedures. Field performances were used to compare results of the various simulated selections. The families were divided about equally into high and low groups in relation to each trait studied and the other trait averages compared.

Average hill wt was of particular interest, and gain or loss from the various simulated selections was expressed in percent of the unselected averages. Simple correlations of maternal family averages were also computed.

### Results and Discussion

We evaluated the root wt of individual greenhouse seedlings as a criterion for yield selection by simulating culling levels and studying gross changes in field hill wt (Table 1). Apparently selection on the basis of flesh color, which would require discarding all plants with roots weighing less than 2 g, has no harmful effect on subsequent yield selection. Culling about half of the plants on the basis of their individual greenhouse root wt did little to improve subsequent field yield. If greenhouse space permitted 90% of the seedlings to be culled, the percentage of high-yielding plants in the field could be increased from about 13 to 25. This might be impractical, because greenhouse space is generally more limited than land and too many high-yielding plants would be discarded. However, families with higher average root weights in the greenhouse did have higher average hill weights in the field (Tables 2 and 3). Thus, selection on the basis of family root weight in the greenhouse appears to have some merit.

When about half the families tested were selected on the basis of family means, seedling measurements other than greenhouse root wt showed even less promise as selection criteria (Table 2). High seed germination, seedling emergence, and vigor were not indicative of high field yield potential. Average seedling height had little practical value. The no. of vigorous seedlings relative to the no. of seed planted served as an index of emergence, greenhouse survival, and vigor. The correlations (Table 4) suggested that maternal environmental effects were involved in these associations. Selection on the vigor index (Table 2) provided a small yield increase, but it was more effective when used in conjunction with other criteria. When about 75% of the families were culled—about 50% for one trait and then about 50% of those for a second trait—some gains in subsequent field hill weights were obtained. For instance, selection for more than

53 vigorous seedlings per 100 seed and root weight average above 14g improved field hill weights about 16% (Table 3). Thus, it appears that family selection in the greenhouse can increase subsequent field performance, but it is doubtful whether the increase is sufficient to offset the increased need for greenhouse data from each plant plus the severe 75% culling level.

The summary of selection schemes simulated from parental data available before planting seed provided interesting results (Table 3). A mass selection sequence based first on parental hill wt (obtained from 5-hill plots of vine cuttings), then on high seed set, and finally on high seed wt provided about 25% increase in average field hill weight of progeny, with an increased efficiency in use of greenhouse facilities of about 18% (based on survival data). Increased plant survival would allow evaluation of more plants for the same cost, and the increased hill wt would improve chances for obtaining high yield. With further selection, based on a 50% culling level for low greenhouse seedling vigor within each family, the gain in progeny hill wt was increased 45% over no selection and field survival was in-

Table 4. Correlations of maternal root yield and seed data with progeny greenhouse data and subsequent field performance.

	Progeny field performance		Maternal Hill wt 1970	Wt/100 seed
	% survived	Hill wt		
Maternal hill wt (1969)	-.04	.16	.53**	.20*
Maternal seed set (no.)	-.14	-.21	.14	-.13
Emergence (%)	.16	.09	-.07	.16
Avg greenhouse seedling ht (mm) at 3 wks	-.28*	-.18	.29*	.40**
Avg seedling vigor at 7 wk	-.16	-.14	.26	.54**
Avg greenhouse seedling root wt (0.1 g)	.23	.35**	.37**	.30**
Greenhouse survival (% of those emerging)	.31*	.11	.27	.25*
No. vigorous seedling/no. seed planted	.39**	.16	.18	.43**
Progeny field survival (%)	—	.28*	.06	.02
Progeny hill wt	—	—	.24	.05

\*Correlation significant at the 5% level.

\*\*Correlation significant at the 1% level.

creased 5%. This gain compares favorably with the 46% maximum gain in field hill wt from family selection (Table 2).

The above mass-selection sequence fits field and greenhouse procedures well. By evaluating root yield before completion of seed harvest, seed harvest can be concentrated on those plants with good root yield. After the seeds are cleaned, seed samples from each potential parent can be weighed and only those weighing at least 2g/100 seed planted. Before transplant, subjective vigor evaluations can be used to cull 50% of the seedlings from each family. Since this sequence requires no greenhouse notes and a culling level of only 50%, it represents a practical method for improved yield selection. Our data suggest that seed set is conditioned by factors unrelated to root yield, but improved seed set is important in sweet potato for increased breeding ease and efficiency.

The increase in progeny yields through inclusion of maternal seed wt in the selection sequence is not due to simple associations (Table 4). Obviously yield is conditioned much more by other genetic factors than by seed size. However, seed wt may be a good index of relative physiological balance within those plants that have high yield factors. Such improved physiological balance may represent lower genetic loads and could lead to improved long term gains. This conjecture is based on the theory that given yield genes would condition higher yields on a genetic background with a low genetic load than on one with a high load. On the other hand, seed size may be conditioned more by genetic factors than by physiological balance. In that

case, the inclusion of seed size in the selection index would rapidly approach a point of diminishing return.

Our study indicates the possible usefulness of seed wt as a selection criterion for root yield. On an individual plant basis, greenhouse root wt can be very misleading as an indicator of subsequent field yield. Accordingly, selection based on other characters, such as flesh color, vigor, or perhaps disease or nematode resistances, seems more promising.

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## Gibberellic and Abscisic Acid-like Substances and the Regulation of Apple Shoot Extension<sup>1</sup>

Henry A. Robitaille<sup>2</sup> and Robert F. Carlson

*Department of Horticulture, Michigan State University, East Lansing, MI 48823*

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**Abstract.** Shoots on interstem-dwarfed apple (*Malus domestica* Borkh.) trees ceased growing earlier and showed a stronger tendency towards becoming summer dormant than did corresponding shoots on vigorous trees. Substances similar to gibberellic acid (GA<sub>3</sub>) and abscisic acid (ABA) were extracted from 1-year-old stems at 7 stages during the growing season using the centrifugation technique. ABA-like activity was higher in stems from dwarf than vigorous trees at full bloom, and remained higher until after the onset of summer dormancy. GA-like activity also was significantly higher in dwarf tree stems at the tight flower cluster stage. Injection experiments demonstrated that increasing ABA concn decreased terminal elongation in a linear manner. ABA-induced inhibition was reduced in direct proportion to the concn of GA<sub>3</sub> in the injected solution.

Despite numerous studies (22) the mechanism of rootstock and interstock dwarfing is still not understood. Recently differences in growth substances have been measured in attempts to explain dwarfing. Both direct (5, 14) and indirect (21, 26, 28) evidence has accumulated indicating an auxin effect in dwarfing of apple trees. However, callus cultures derived from both vigorous and dwarfing apple rootstocks achieved maximum growth at the same concn of naphthaleneacetic acid (NAA)

and kinetin (13). Higher NAA levels neither stimulated nor inhibited the growth of the dwarf callus. There is less growth promoting activity and more growth inhibiting activity in the bark of a dwarf than vigorous rootstock (10). Progressively lower levels of an ABA-like inhibitor occurred in extracts of scions on malling (M) 9, M 7, M 1, and M 16 (29). Single stem trees on dwarfing, intermediate, and vigorous rootstocks all stopped elongating and set terminal buds characteristic of summer dormancy when injected with 100 mg/liter of ABA (23). Trees on the more dwarfing rootstocks responded more quickly. Injection of similar trees with 10 mg/liter of GA<sub>3</sub> stimulated shoot elongation, the stimulation increasing as rootstock vigor decreased. The dwarfing response may be due to a lower production or more rapid metabolism of GAs, since there is less GA-like activity in the root xylem exudate from a dwarfing than from more vigorous rootstocks (7). In the present study we examined further the role of ABA and GA<sub>3</sub> in the

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<sup>2</sup>Present address: Department of Horticulture, Purdue University, West Lafayette, Indiana.

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<sup>5</sup>Donated by Merck Chemical Division.