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Heritability Estimates for Resistances in Sweet Potato to Soil Insects[1]

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Abstract. **Twenty-two sweet potato (*Ipomoea batatas* (L.) Lam.) breeding lines and 19 open-pollinated offspring from each were used to estimate the heritabilities of 7 measures of soil insect injury. Four measures of injury by the wireworm, *Diabrotica* spp., and *Systena* spp. (WDS) complex and h^2 (± SE) were: percentage of roots injured, 0.45 ± 0.12; holes per root, 0.32 ± 0.09; severity index, 0.37 ± 0.11; and damage score, 0.39 ± 0.17. Two measures of injury by the sweetpotato flea beetle, *Chaetocnema confinis* Crotch, and h^2 were: percentage of roots injured, 0.40 ± 0.07, and tunnels per root, 0.25 ± 0.08. The h^2 of percentage of roots injured by all insects was 0.51 ± 0.12. The percentage measures were more easily obtained and were as effective as the other measures under the conditions of natural infestation that occurred in this test. Further advances in selection for high levels of resistance to soil insects are possible within the breeding materials tested.**

At least 18 species of soil-inhabiting insect larvae damage sweet potatoes grown in the United States (1). Genetic resistance to most of these pests is available (2, 8, 9). However, it is often difficult when roots are harvested to determine which insect species caused the damage because the causal species may no longer be present and the continuous growth of the roots changes the appearance of the injuries. Fortunately, resistance to a number of species seems to be conditioned by common genetic factors (2).

The use of a WDS index to denote damage by a complex including the southern potato wireworm, *Diabrotica* spp., and *Systena* spp. has been effective in previous studies (3, 4, 7, 9). Damage by the sweetpotato flea beetle, *Chaetocnema confinis* Crotch, and a white grub, *Plectris aliena* Chapin, were rated separately in those studies.

Even low or moderate levels of resistance to insects can increase the effectiveness of insecticide treatment in prevention of economic losses (4). The frequency and levels of resistance to insect damage in sweet potato can be increased by mass selection techniques (3). However, when insect-resistant selections were used to generate a mass selection population in which the insect resistance was just one of many criteria for selection, no increase in the frequency of resistance occurred after 6 generations of selection (9). Apparently the precision for evaluation of insect injury was not sufficient, and new approaches need to be investigated. In this study we consider 7 ways of measuring damage from WDS and sweet potato flea beetle larvae and present heritability estimates for each.

Materials and Methods

Vine cuttings for this test were taken from roots used in a previously reported parent-offspring study of fiber and other traits (10). The test, planted at Charleston on May 24, 1977, consisted of 3 replicates of 10 vine cuttings from each of 22 parental lines and, in a nonreplicated block next to it, 5 vine cuttings from each of 19 open-pollinated offspring from each parent. Roots were harvested September 28-30, 1977, after a growth period of 127-129 days. Control plots of 'Centennial', 'Jewel', and SC 1149-19 were included in each replicate of the parental planting and 4 times each randomly within the offspring planting. Roots were cured and stored in paper bags under standard storage conditions until rated for insect damage (11).

Root damage by the WDS complex was rated in 4 ways for each line. (a) The holes or scars on each root were counted, totaled, and divided by the number of roots rated to obtain the average number of holes per root. (b) The number of roots with injury was divided by the number of roots rated to yield the percent injured. (c) A severity index was obtained by assigning each root a score based on the number of feeding scars (no scars = 0, 1-5 scars = 1, 6-10 scars = 2, more than 10 scars = 4) and averaging the scores (3). (d) Each root was assigned a subjective damage score (1 = no damage, or scars shallow and of little economic concern, to 5 = severe economic effect from large or deep holes) and all scores were averaged.

Sweetpotato flea beetle damage to each line was recorded in 2 ways: (a) as the number of tunnels per root, by counting the number of scars on each root and averaging; and (b) as the percentage of roots injured, as described above. We also noted damage by a white grub, *Plectris aliena,* which was assigned a damage score like that used for WDS injury. Also recorded was the percentage of roots of each line with damage from any 1 or more of the 3 groups of insects.

As expected, the number of roots harvested from each line varied considerably. Means for the parental lines therefore represent 30-117 roots each. Means for offspring were obtained by rating each of the 19 offspring from each parent (about 300 roots) and then averaging the ratings. Twice the regression of offspring means on parent means provided narrow-sense heritability ($h^2 = 2b$) estimates (6). Simple correlations among the 7 ways of scoring WDS and sweetpotato flea beetle injury were calculated from the 22 parent means and from the 22 offspring means.

Results and Discussion

A wide range of reaction to soil insects was manifested by the parental lines (Table 1). These lines were selected from our breeding program for use in a polycross nursery for development of multiple disease and insect resistances. Some lines, such as W-51, were included because of their known high levels of nematode resistance (5). Others, such as W-13, which could be considered a resistant control were selected because of their known high levels of insect resistance or known moderate levels of insect resistance, as in W-3 (4). Because offspring

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Table 1. Means for insect damage caused by the wireworm-*Diabrotica-Systena* (WDS) complex, the sweet potato flea beetle, and all soil insects (WDS, flea beetle and white grub) in parental (P)[z], offspring (O)[y], and control[x] lines of sweet potatoes.

	Injury by WDS complex								Injury by sweet potato flea beetle				Injury by all insects	
	% roots injured[w]		Holes per root[w]		Severity index[v]		Damage score[u]		% roots injured[w]		Tunnels per root[w]		% roots injured[w]	
Parental line	P	O	P	O	P	O	P	O	P	O	P	O	P	O
W-178	64.0	37.8	2.50	0.87	0.81	0.43	1.59	1.34	63.3	18.4	1.52	0.26	70.3	47.6
W-2	68.0	38.7	1.97	1.12	0.79	0.45	1.41	1.48	25.0	19.9	0.31	0.40	72.7	47.6
W-3	63.3	31.2	2.03	0.94	0.73	0.38	1.59	1.29	2.0	10.9	0.02	0.09	63.3	38.1
W-4	41.3	33.0	1.22	1.06	0.49	0.40	1.59	1.40	20.0	11.5	0.28	0.13	63.0	39.0
W-8	14.0	23.2	0.19	0.45	0.14	0.24	1.05	1.19	2.3	6.9	0.02	0.10	20.3	27.3
W-9	16.0	30.3	0.25	0.60	0.17	0.31	1.03	1.40	0.0	9.0	0.00	0.16	16.0	39.0
W-11	31.3	19.4	0.57	0.46	0.31	0.20	1.29	1.24	5.0	5.3	0.06	0.06	41.7	27.7
W-12	84.3	37.3	4.83	0.98	1.39	0.40	2.04	1.27	9.3	10.1	0.09	0.25	87.3	41.8
W-13	40.0	21.5	1.23	0.49	0.44	0.23	1.37	1.15	18.7	8.8	0.21	0.10	54.0	28.5
W-15	37.3	30.1	0.94	0.54	0.42	0.26	1.33	1.28	36.3	15.3	0.66	0.29	62.3	34.9
W-23	36.3	25.1	1.14	0.56	0.48	0.27	1.36	1.18	13.7	10.9	0.32	0.13	45.7	36.2
W-33	38.7	21.3	1.10	0.53	0.45	0.24	1.36	1.26	6.3	10.8	0.06	0.12	38.7	30.1
W-36	81.0	47.0	3.43	1.51	1.10	0.59	1.85	1.75	56.7	18.2	1.36	0.27	94.7	53.7
W-39	49.3	26.7	1.63	0.97	0.59	0.30	1.07	1.33	3.0	8.5	0.03	0.22	52.3	36.6
W-41	44.3	34.8	0.79	0.89	0.44	0.39	1.36	1.32	28.7	11.3	0.50	0.15	56.0	44.0
W-42	46.0	36.6	1.03	1.01	0.46	0.47	1.47	1.37	34.0	20.0	0.71	0.34	66.7	48.2
W-43	10.3	22.3	0.35	0.39	0.12	0.23	1.11	1.19	0.0	6.5	0.00	0.07	22.0	26.2
W-45	77.0	23.6	3.68	0.73	1.17	0.26	1.73	1.23	21.0	8.5	0.28	0.19	79.0	29.2
W-48	65.0	35.4	2.29	1.09	0.77	0.44	1.52	1.34	8.3	9.5	0.11	0.14	66.3	43.8
W-50	65.7	31.6	2.09	1.00	0.84	0.39	1.76	1.32	59.0	16.8	1.30	0.27	85.0	44.4
W-51	89.7	40.3	2.94	1.16	0.99	0.47	2.28	1.50	40.0	23.4	0.76	0.36	92.7	51.8
W-52	41.7	16.7	0.68	0.45	0.41	0.20	1.33	1.13	18.3	6.7	0.25	0.09	45.0	27.0
Mean	50.2	30.2	1.68	0.81	0.61	0.34	1.48	1.32	21.4	12.1	0.40	0.19	58.0	38.3
LSD 5%	25.7	--	1.40	--	0.38	--	0.60	--	24.6	--	0.75	--	25.4	--
Controls														
Centennial	87.7	63.9	4.29	2.77	1.32	0.84	2.31	1.79	11.7	2.3	0.19	0.02	90.0	65.2
Jewel	77.7	44.8	3.07	1.54	1.03	0.54	2.09	1.42	10.0	4.6	0.11	0.05	83.0	58.1
Cherokee	56.3	35.0	1.11	0.56	0.58	0.35	1.46	1.30	9.7	2.4	0.11	0.02	65.0	37.3
SC 1149-19	81.3	63.4	3.52	2.29	1.20	0.77	2.01	1.85	74.7	41.2	2.04	0.86	88.7	75.2

[z]Three replicates of 10-plant plots.

[y]Five-plant plots of 19 offspring.

[x]W-13 may be considered a resistant control.

[w]Of all harvested roots.

[v]Severity index: 1 = 1-5 scars, 2 = 6-10 scars, 4 = more than 10 scars; averaged over all harvested roots.

[u]Damage on each root scored subjectively as : 1 = no damage, or scars shallow and of little economic concern, to 5 = severe economic effect from large or deep holes, averaged over all harvested roots.

Table 2. Heritability (h^2)[z] estimates for the various measures of insect injury in sweet potatoes.

Measure of root damage	$h^2 \pm$ SE
By the wireworm-Diabrotica Systena (WDS complex)	
% of roots injured[y]	0.45 ± 0.12
Holes/root[y]	0.32 ± 0.09
Severity index	0.37 ± 0.11
Damage score	0.39 ± 0.17
By the sweetpotato flea beetle	
% of roots injured[y]	0.40 ± 0.07
Tunnels/root[y]	0.25 ± 0.08
By all insects[y x]	
% of roots damaged	0.51 ± 0.12

[z]Estimates of h^2 from twice the regression of offspring means on parent means.

[y]Of all harvested roots.

[x]Includes injury by the WDS complex, sweetpotato flea beetle, and white grub.

means are averages from 19 different genotypes, the range of offspring means is narrower than that of the parental means.

Insect infestations of the WDS complex were similar to those generally experienced in the test area, as indicated by comparison of results with W-3 and W-13 with published results from 1974 and 1975 (4). Sweetpotato flea beetle injury was higher than in the 1974-75 tests. In general, injury levels on the controls were as expected, with somewhat heavier insect infestations in the parental test than in the offspring test (Table 1).

Injury from white grub was too inconsistent to demonstrate differences in the parental lines, and heritability estimates were not made. Grub infestations are generally variable in the test area (3, 4). Thus our ability to select for resistance is limited to discarding any line with severe damage in even one replicate of a test. Apparently this culling technique has been effective, since the mean damage score of the controls was 0.22 and that of the parents was 0.05 (difference significant at the 5% level).

The h^2 estimates we calculated, the first available for resistance to soil insects, are encouraging, particularly in view of the

Table 3. Correlations of means for various measures of injury by soil insects in roots of sweet potato parental lines and offspring.

Measurement of root damage	Measurement of root damage						
	By WDS complex				By sweetpotato flea beetle		By all insects
	1.	2.	3.	4.	5.	6.	7.
By WDS complex							
1. (% of roots injured)	---	0.91**	0.96**	0.88**	0.52*	0.46*	0.95**
2. (Holes/root)	0.89**	---	0.99**	0.83**	0.36	0.34	0.84**
3. (Severity index)	0.97**	0.94**	---	0.85**	0.43*	0.39	0.90**
4. (Damage score)	0.85**	0.85**	0.85**	---	0.53*	0.48*	0.87**
By sweetpotato flea beelte							
5. (% of roots injured)	0.78**	0.66**	0.76**	0.68**	---	0.98**	0.68**
6. (tunnels/root)	0.72**	0.64**	0.66**	0.62**	0.88**	---	0.61**
By all insects							
7. (% of roots injured)	0.95**	0.88**	0.96**	0.82**	0.84**	0.76**	---

*,**Significant at 5% levels, respectively. Parental correlations above diagonal; offspring, below. Controls not included.

history of selection for resistance in the parental lines used (Table 2). Correlations between the various measures were high in most cases (Table 3). The percentage of roots with injury was as good an index of WDS damage as was the more exacting count of scars. Also, the percentage of roots injured by the sweetpotato flea beetle appeared to be as good a measure as the number of tunnels per root. In both cases the percentage data are easier to obtain. Before this study we expected that the actual counts of scars would be more precise than the percentage of injury. Apparently, once a root is damaged, the number of scars is subject to considerable variation. These results may not hold true when artificial infestations are used to provide more uniform distributions of insects. Sweetpotato flea beetle injury was marginally correlated with WDS injury in the parents and strongly correlated in the offspring. This association is likely a result of previous selection for both kinds of resistance. A similar association was observed after combined selection in a previous study (7).

We conclude that further advances in selection for high levels of resistance to soil insects are possible in this breeding material for any of the different measures studied. With the natural infestations usually encountered in our test area, the percentage of roots injured by larvae of the WDS complex or the sweetpotato flea beetle are adequate measures of line differences in preliminary evaluations and are to be preferred, because of their relative ease of calculation, to the tedious method of counting scars.

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