softening of the fruit. Similar results were obtained with fruit of 'Fuerte' (unpublished data).

The suppression of the endogenous ethylene production at 20°C by the previous exogenous ethylene treatment at 6°C (Fig. 1) is most striking. It seems that the enzymatic apparatus which is producing ethylene is affected irreversibly, since ethylene production remained low throughout the experiment. It should be noted, however, that the experimental procedures did not enable the measurement of endogenous ethylene production during the period of the ethylene treatment itself. It is suspected that in the first determination of fruit under continuous ethylene treatment, our measurements were primarily of that ethylene which was applied and absorbed by the fruit and then evolved by diffusion to the atmosphere, rather than of the ethylene produced by the fruit. Similar inhibitory effects of ethylene treatment at 20°C on the endogenous ethylene production of banana were reported recently by Vendrell and McGlasson (5).

Respiration rate was accelerated by continuous treatment with ethylene (Fig. 2). This is in contrast to what was reported previously (1), but it does agree with, and substantiate our other findings (Figs. 3 and 4) that polygalacturonase activity and softening rate were accelerated by ethylene treatment.

These findings are in accord with those of Hatton and Reeder (4), who showed that the removal of ethylene from controlled atmosphere storage chambers (10°C) increased the percentage of acceptable fruit at the end of the storage period. It has been reported that ethylene had an effect on apple fruits in controlled atmosphere cold storage (3). However, Blanpied et al. (2) claim that no effect of ethylene was evident in controlled atmosphere cold storage of apples. It should be noted that in this report the fruit was kept under regular storage atmosphere containing less than 0.5% CO_2 rather than under controlled atmosphere as described in the above mentioned papers (2, 3, 4).

From the data presented in Figs. 1 and 2 it is evident that the ethylene peak did not precede the respiration peak, while in normal ripening of avocado fruit at 20°C the respiratory peak always follows that of the ethylene.

From the practical point of view it is suggested that at 10°C (4) and also at 6°C, ethylene should be avoided whenever long shelf-life of avocado fruit is desired.

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Associated Effects of Mass Selection for Soil-Insect Resistances in Sweet Potato[1]

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Abstract. Character associations in a sweet potato [*Ipomoea batatas* (L.) Lam.] population after 4 cycles of selection for resistance to soil insects and in a control population with no selection were studied by use of contingency tables of pairs of traits. Possible common factors were indicated for resistances to the sweet potato flea beetle and the wireworm-*Diabrotica-Systena* (WDS) complex. Selection changed the means and distributions of 6 of 13 unselected root and vine traits. None of these changes were directly associated with insect resistances, but that in root cracking was caused by the grading techniques. Two traits appeared genetically associated (cortex thickness and leaf-whorl color), and 2 appeared to be expressions of the same character change (flesh-color changes were also expressed as skin-color changes). The selected population had shorter internodes than the unselected. These changes in unselected traits were probably due to drift caused by small population sizes in the selected generations. No barriers to development of insect-resistant cultivars were detected.

A randomly intercrossing sweet potato [*Ipomoea batatas* (L.) Lam.] population was initiated in 1963 for use in studies of mass-selection breeding procedures. In accordance with the proposed procedure (4), parent-offspring and selection studies were begun in the 4th generation, and results from 2 controlled-selection studies are now available. In the first study (6), rapid increases in proportions of plants with low oxidative root-discoloration scores were obtained with both of 2 mass-selection schemes: equivalent to 1-year and 2-year cycles when adapted to practical breeding programs. The second study (2) involved selection for resistances to a complex of root-damaging insects: the southern potato wireworm, *Conoderus falli* Lane; the banded cucumber beetle, *Diabrotica balteata* LeConte; the spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber; the elongate flea beetle, *Systena elongata* (F.); *Systena frontalis* (F.); the grub, *Plectris aliena* Chapin; and the sweet potato flea beetle, *Chaetocnema confinis* Crotch. As in the previous study, very rapid progress was made with the selected traits. In both of these experiments, every effort was made to avoid selection for any trait not under study, thus providing an opportunity to detect associated changes in other characters and to evaluate better the suitability of the breeding procedure for applied breeding programs.

Observations of 16 traits in the population under selection for soil-insect resistances and implications of observed changes

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to the adaptation of mass selection to sweet potato breeding are presented here.

Materials and Methods

Mass selection was initiated in the 4th generation of a randomly intercrossing sweet potato population. Selection was for absence of 3 kinds of root injury as observed at harvest: that caused by the wireworm-*Diabrotica-Systena* (WDS) complex; that caused by a white grub; and that caused by the sweet potato flea beetle. Procedures were published (2). Selection for characters other than for insect resistance was avoided. Photographic representation of the kinds of injury involved are available elsewhere (1, 3). After 4 cycles of selection, characters were compared with those of an unselected, control population. Progress resulting from selection was determined by comparing 93 seedling clones taken at random from each of the selected and the control populations. Four replications of 5-plant plots were obtained from vine cuttings of each seedling (clone).

Evaluation of 13 unselected traits (Table 1) allowed study of the associated effects of mass selection for soil-insect resistances. Plant vigor 30 days after planting was scored subjectively from 1-7, indicating increasing degrees of vigor. Scoring of other traits was consistent with that published (6). Means were tested for change by standard analyses of variance. Previous studies, using similar plant materials, have shown frequency-distribution changes in the absence of demonstrable mean changes (6). Since frequency-distribution changes are important in selection experiments, these were tested for by chi-square techniques. Data from each seedling clone were averaged over replications to establish distributions for chi-square tests of differences in the control and selected populations and to construct contingency tables of pairs of traits. Chi-square tests of the contingency tables from both the selected and control populations were used to detect character associations.

Results and Discussion

Selected traits. As reported earlier (2), good progress was made in resistances to soil insects (Table 1). The chi-square test for distributional changes detected an important change in flea-beetle injury not detected by mean comparisons and indicates significant progress toward resistance. The WDS complex of insects caused the most injury, reflected in the contingency tests as associations with the index of injury by all insects in both populations (Table 2). Selection pressure against flea-beetle injury was increased as progress for resistance to the other insects was made. Thus the contingency tests showed an association between flea-beetle injury and injury from all species in the selected population, which was not present in the unselected population. In the selected population, there was an association between flea-beetle and WDS injuries, possibly indicating common factors for both kinds of resistance.

Unselected traits. Means and distributions changed in 6 of 13 traits measured (Table 1). This number of changes was more than expected, according to previous observations on materials of the same origin (5, 6). As noted earlier (2), difficulties in grading severely cracked roots resulted in unplanned selection for noncracking. In the selected population, there were no individuals in classes 4 and 5 (representing the highest degrees of cracking), compared to 4 plants in these classes in the control population. There was some evidence that flea-beetle susceptibility and cracking are associated, although not strongly enough to account for the mean and distributional changes noted in cracking. Since the reduction in cracking was a function of the evaluation techniques, the observed change is an example of a spurious effect that easily could have been misinterpreted.

The selected population had an increased frequency of thin-cortex types, and the contingency test indicated a weak association with WDS resistance. However, we cannot conceive a direct cause-and-effect relationship, and the association noted does not seem sufficient to explain the observed magnitude of reduction in cortex thickness. Chance factors were probably of greatest importance.

In the contingency tables of the unselected population, there were slightly more of the flea beetle- and WDS-susceptible plants with higher hill weights. There was also an association between flea-beetle susceptibility and large-size roots in

Table 1. Character means of sweet potato populations selected and unselected for soil-insect resistances and significance levels of mean and distributional changes observed.

Traits	Scale	Means		Significance levels	
		Selected	Unselected	Means[z]	Distributions[y]
Selected traits					
WDS	0–4	0.80	1.37	**	**
Grub injury	%x	5.9	13.9	**	**
Flea beetle injury	%x	6.5	8.2	N.S.	**
All insects injury	%x	56.0	75.5	**	**
Unselected traits					
Root size	(lb.)	0.32	0.35	N.S.	N.S.
Hill weight	(lb.)	1.4	1.5	N.S.	N.S.
Root veining	1–4	1.8	1.6	N.S.	N.S.
Root cracking	1–4	1.2	1.4	**	**
Flesh color	1–5	2.8	3.4	**	**
Flesh purpling	1–5	1.1	1.1	N.S.	N.S.
Cortex thickness	(mm)	3.6	4.2	**	**
Root-skin color	1–25	9.7	12.9	**	**
Plant vigor	1–7	5.5	5.6	N.S.	N.S.
Vine diameter	1–5	3.5	3.3	N.S.	N.S.
Internode length	(cm)	4.3	5.0	**	**
Leaf length	(cm)	11.1	10.9	N.S.	N.S.
Leaf-whorl purple	1–5	2.7	1.5	**	**

[z]Means tested by standard analyses of variance of 4 replications.

[y]Tested by chi-square after averaging over replications to detect possible frequency-distribution changes in the absence of mean changes.

[x]Injured roots/all roots.

**Indicates that means or distributions of the selected and unselected populations were different from each other at the 0.01 probability level. N.S. indicates the 2 populations did not differ.

Table 2. Significant character associations detected by chi-square tests of contingency tables of pairs of traits in selected and unselected sweet potato populations.

Character pairs[z]	Significance of association[y]	
WDS injury vs. flea-beetle injury	S**	
WDS injury vs. all-insects injury	S**	U**
Flea-beetle injury vs. all-insects injury	S**	
Root size vs. flea-beetle injury		U*
Hill weight vs. WDS injury		U*
Hill weight vs. flea-beetle injury		U*
Root veining vs. all-insects injury		U*
Root cracking vs. flea-beetle injury	S*	U*
Cortex thickness vs. WDS injury	S*	
Cortex thickness vs. leaf-whorl purpling	S**	
Flesh color vs. skin color	S**	U**
Flesh color vs. cortex thickness		U*

[z]Pairs without mean or distributional changes in either trait (Table 1) were not studied. No associations were detected for pairs not listed.

[y]S = population after 4 cycles of selection
U = unselected or control population
*,** = character association detected at 0.05 and 0.01 probability levels, respectively.

the control population. These relationships are probably caused by the earlier enlargement and greater surface area of larger roots. Awareness of these factors led us to be more tolerant of injury on large than on small roots during selection (2). Consequently, these associations were not evident in the selected population, apparently because of the reduced frequency of susceptible plants. In the control population, more plants than expected expressed both root veining and moderate resistance to all species. After selection, this association was not detected.

Contingency tests gave no indication of associations between the other traits and soil-insect ratings. Flesh color and root-skin color, both of which had important mean and distributional changes, were found to be intimately associated in both populations. Skin color was measured on intact roots. There were no orange or dark-orange roots with cream or white skin in either population. Most tan-skinned types had flesh with orange pigment. Copper-skinned types had a high frequency of flesh with orange color. Apparently, the skin color of many lightly pigmented roots was influenced by flesh color. Thus, the changes observed in skin color may be due to flesh-color changes.

In the selected population, there was an excess of green leaf-whorl types in thick-cortex plants and an excess of dark-purple leaf whorls in thin-cortex plants. This association apparently was detectable in the selected population because of the wider range of leaf-whorl color expressed there than in the control population. It may represent genetic association. In the unselected population there was a high proportion of thick-cortex types with dark-orange flesh. Both the increased leaf-whorl purpling and the decreased internode length of the selected population are probably caused by drift.

Thus, 6 traits of 13 had significant mean and distributional changes after 4 generations of selection for soil-insect resistances: one of these, root cracking, was clearly associated with the grading methods; 2 others, flesh color and skin color, probably were expressions of the same character change; 2, cortex thickness and leaf-whorl color, were apparently genetically associated, and thus may represent one basic change; and the other trait, internode length, was apparently independent of changes in other traits. However, based on previous observations (5, 6), even 3 character changes are more than expected by chance. In the 4 cycles of selection, population sizes graded for insect injury were 361, 175, 400, and 220. These small population sizes probably account for the rather high frequency of character changes observed.

A major implication of this study for improvement of sweet potatoes through mass selection is that, while rapid progress may be achieved for selected traits, important changes in unselected traits are highly probable unless adequate population sizes are maintained. Perhaps of greater importance to breeders (whether following mass-selection procedures or not) was the independence of the soil-insect resistances and other desirable characteristics. There appears to be no barrier to the development of insect-resistant cultivars equivalent in all other respects to those presently under cultivation.

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