DEVELOPMENT OF SUGARBEET BREEDING LINES RESISTANT TO CERCOSPORA LEAF SPOT AND BLACK ROOT

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One hazard in selecting plants for improvement is the probable association of desirable characteristics with undesirable ones. Many such undesirable associations are encountered in sugarbeet. To do a thorough job, the plant breeder must evaluate his material for all the characteristics he wishes to improve or maintain. He must also know the factors influencing these characteristics in each test, particularly if improvement of one desired characteristic favorably affects another characteristic in a particular environment. For example, a line of sugarbeet highly resistant to leaf spot may appear to be the best in root yield when the disease epidemic is severe; however, if leaf spot is not a factor, the line may be relatively low in root yield. Therefore, the breeder must test his material under a variety of conditions and check all the important characteristics. He can then study the interaction of the characteristics in each test to determine the effects of previous selections.

The improvements made by selecting sugarbeet lines for resistance to leaf spot and black root and the effects of these improvements on important production characteristics, as revealed by the nursery tests at Beltsville, Maryland, and East Lansing, Michigan, are reported in this paper. The performances of a few varieties of sugarbeet in field trials are also presented as examples of simultaneous improvement in two or more desirable characteristics.

METHODS OF EVALUATION

The reaction of progenies to the leaf spot pathogen *Cercospora beticola* is probably evaluated with greater reliability than the other characters discussed. The leaf spot evaluation tests were made at Beltsville, Maryland, where the disease epidemic is severe every year. Black root (*Aphanomyces cochlicides*) evaluations are made in the greenhouse at Beltsville. The resistance of progenies is given in relation to the amount of disease damage on US 401. Each year the disease damage on US 401 is taken as 100. Entries damaged more than US 401 receive values less than 100; and, conversely, entries damaged less than US 401 receive values greater than 100. A progeny having disease tolerance halfway between immunity and that of US 401 would get a numerical rating of 150; therefore, the maximum numerical rating for resistance (short of immunity) is 199. A progeny performing halfway between total loss of plants due to disease and that of US 401 would receive a numerical rating of 50; hence, performance ratings decrease with increased damage from disease.

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Other characteristics are rated similarly in relation to the performance of US 401. High performance ratings for root yield and sugar percentage represent high tonnage and high sugar percentage, but high ratings for nonsugar solids represent low content of soluble nonsugar constituents.

EFFECTS OF SELECTION ON SUGARBEET LINES

Improvement in disease resistance. In 1955, the average leaf spot resistance performance of multigerm lines was 110 (graph 1), reflecting the improvement made since US 401 was produced in 1953. An average performance rating of 128 was reached in 1962. The dotted line depicts the improvement of multigerm varieties in resistance to black root. Ninety-two multigerm sugarbeet breeding lines produced in 1956 were tested in the greenhouse for resistance to black root. By 1959, the number of lines tested each year had increased to over 800. Only 31 select multigerm progenies produced in 1955 were tested, and non were eliminated from the nursery plantings on the basis of this test. Therefore, 1959 and 1960 were the first years wherein improvement could have become manifest from selections based on greenhouse tests for black root resistance. The 1961 and 1962 tests indicate little or no improvement of the lines over the parental material tested in 1959 and 1960.

The improvement of the monogerm lines in resistance to Cercospora leaf spot (graph 2) follows the same trend as shown for the multigerm lines. The monogerm and multigerm breeding material showed essentially the same level of leaf spot tolerance in 1962.

The improvement of the monogerm lines in resistance to black root has been more spectacular than that of the multigerm lines, primarily because they started with much less resistance and, also, because they have acquired resistance both by direct selection and from resistant multigerm lines as a result of backcrossing procedures.

Root-yield performance. The root-tonnage performances of multigerm progenies are presented in graph 3. Since most of the lines are grown under their natural biennial cycle, the lines of descent in all graphs dealing with multigerm lines are continuous in alternate years. The selections of 1955 showed a decrease for root tonnage in 1957 tests. The 1956 selections in 1958 tests indicated an improvement in root yield at Beltsville but a decrease at East Lansing. Since 1958 there has been some improvement in root tonnage. The good root yields of selections at Beltsville are undoubtedly related to improvement in leaf spot resistance and cannot be attributed entirely to enhancement of inherent yield potential.

The root tonnage performance of monogerm lines increased until 1959 (graph 4) but has fluctuated considerably since then. Marked improvement in monogerm lines previous to 1960 was expected, because the original monogerm parent was extremely low in vigor. Backcrosses to higher yielding multigerm lines resulted in higher producing monogerm lines. In addition, the early monogerm lines had little resistance to leaf spot and black root. Improvement in resistance to diseases also is reflected in increased tonnage.

Each year a different multigerm line with desirable characters was used in outcrossing the monogerm lines, and this accounts for some of the variation in tonnage performance rating since 1959. Usually, tonnage performance can be roughly predicted from parentage. In contrast to the curves for multigerm lines, the root tonnage curve for monogerm lines at the East Lansing nursery is similar to the one for monogerms at the Beltsville nursery.

Sugar-Percentage performance. Two factors must be taken into consideration for a satisfactory explanation of sucrose performance at Beltsville: First, the inverse relation between tonnage and percent sugar; and second, the beneficial effect of increased leaf spot resistance when tests are conducted where leaf spot is severe.

The trend toward a decrease in sugar percentage of multigerm lines at Beltsville from 1955 to 1960 (graph 5) is probably related to the increase in root yields. That the multigerm breeding material was better in sugar percentage than US 401 is partly due to superior leaf spot resistance. The upward trend of sugar percentage in 1961 and 1962 might be attributed to selection pressure for improvement of this character.

From 1956 to 1960, the sugar percentage of the multigerm lines at East Lansing was essentially the same as that of US 401. The performance in 1961 may represent actual improvement in this characteristic or merely another expression of leaf spot resistance.

The sugar percentage of monogerm lines is presented in graph 6. This character remained rather constant at East Lansing, which may be an accomplishment, because one would expect improvement in root yield to result in a numerical reduction in sucrose percentage. At Beltsville, the sugar percentage curve is related to leaf spot damage. Performance ratings for sugar percentage at Beltsville have undoubtedly been influenced by improvement in leaf spot resistance. The high performance rating in 1960 is mostly a result of relatively low yield and not actual improvement in percent sugar.

Nonsugar constituents. Quality is influenced by sugar percentage as well as by concentration and kind of other soluble chemical constituents in the sugarbeet root. If sugar percentage is increased or nonsugar constituents decreased, purity improves. Proper evaluation of the potential nonsugar solids of sugarbeet lines is difficult, because the concentration of these constituents is influenced by nutrition and environment, as well as by genetic factors. Selections for low nonsugar solids were included in the breeding program in 1957. This need was evident, because the monogerm lines have been high in soluble nonsugar constituents; consequently, they have performed rather poorly in this respect, as compared with US 401. The performances of multigerm lines with respect to nonsugar solids are presented in graph 7 and those of monogerm lines in graph 8. It appears that selections for this characteristic have resulted in some improvement.

NOTEWORTHY VARIETIES WITH IMPROVEMENT IN SEVERAL CHARACTERS

Several varieties of sugarbeet resistant to leaf spot and black root have been developed in the breeding program at Beltsville with the assistance of cooperative field test evaluations, especially those conducted in Michigan and at Waseca, Minnesota. The greenhouse test for resistance to *Aphanomyces cochlioides*, devised by C. L. Schneider, was effective in revealing black-root-resistant lines among those evaluated. Several varieties having two or more improved characteristics have been produced (Table 1). The performance ratings in Table 1 were calculated in the same manner as they were for the data presented in graphs 1 through 8.

Good leaf spot resistance was established in SP 5460-0, which was produced by the interpollination of plants selected from a progeny outstanding in leaf spot resistance and yield at Beltsville. This multigerm variety has been used as a pollinator in the production of commercial monogerm hybrids such as SL 122MS mm X SP 5460-0. In some hybridizations, SP 5460-0 has exhibited good combining ability.

SP 5822-0 is one of the most promising multigerm varieties produced at Beltsville. It was produced by the interpollination of clones of plants with outstanding leaf-spot-resistant progenies. Although the potential root yield of SP 5822-0 is probably no greater than that of US 401, it is more resistant to leaf spot and black root, higher in sucrose percentage, and lower in soluble nonsugar constituents. The excellent leaf spot resistance, high sugar percentage, and low nonsugar constituents of SP 5822-0 are especially attractive. The calculated leaf spot performance rating of 155 undoubtedly reflects more inherent leaf spot resistance than SP 5822-0 has, because field trials with only moderate leaf spot epidemics were included in the calculations. In comparison with US 401, varieties with greater resistance perform relatively better when the leaf spot epidemic is light or moderate than when it is severe. In preliminary evaluations, SP 5822-0 was superior to SP 5460-0 as a pollen parent in hybridizations.

The current varieties SP 6122-0 and SP 61151-0 are selections from SP 5822-0. Leaf spot resistance and root size were emphasized in the mother plants of SP 6122-0; leaf spot resistance and low soluble nonsugar constituents were emphasized in mother plants of SP 61151-0. The data in Table 1 again reflect more inherent resistance to leaf spot in these two varieties than they actually have, because the leaf spot epidemic was only moderate in most of the field trials. The performance rating of 130 for percent of soluble nonsugar constituents of SP 61151-0 indicated that selection against these constituents was effective.

Two open-pollinated monogerm varieties, SP 60194-01 and SP 60195-01, did not differ significantly from the monogerm check, SP 5481-0, in root yield and sugar percentage in the 1961 and 1962 trials. Both varieties were recovered in the F_2 generation of crosses involving monogerm and multigerm lines. The mother plants were unselected except for the monogerm character. SP 60195-01 was better in leaf spot resistance than SP 60194-01. However, the latter was better in root yield. Both were significantly better than the multigerm check in leaf spot resistance.

Two new monogerm varieties, SP 6161-0 and SP 61624-0, were included in the uniform variety tests in 1962. The sucrose percentage of these monogerm varieties was about the same as that of the multigerm check. The mean root yield of SP 61624-0 was almost equal to that of the multigerm check, and both were better in leaf spot resistance. SP 61624-0 is an open-pollinated variety recovered in an F_2 generation without selection except for the monogerm character. SP 6161-0 is a synthetic variety produced by the interpollination of 6 clones of plants whose open-pollinated progenies gave good performances at Beltsville and East Lansing.

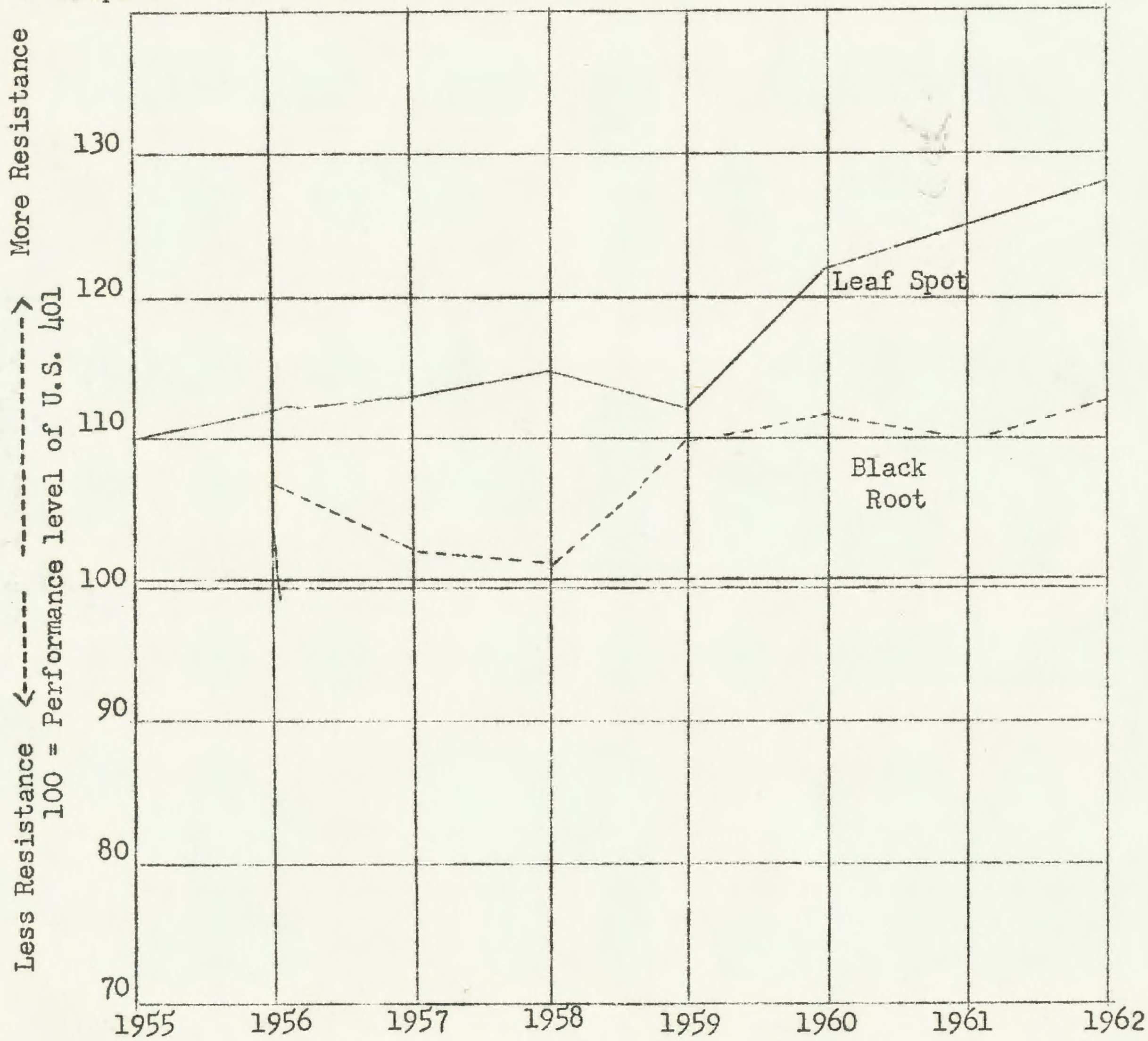
The monogerm male-sterile line SP 6123-01 MSmm was good as a female parent in three hybrid combinations tested in the 1962 trials. These hybrids were among the high-performing ones in the field tests at Beltsville and East Lansing.

CONCLUSIONS

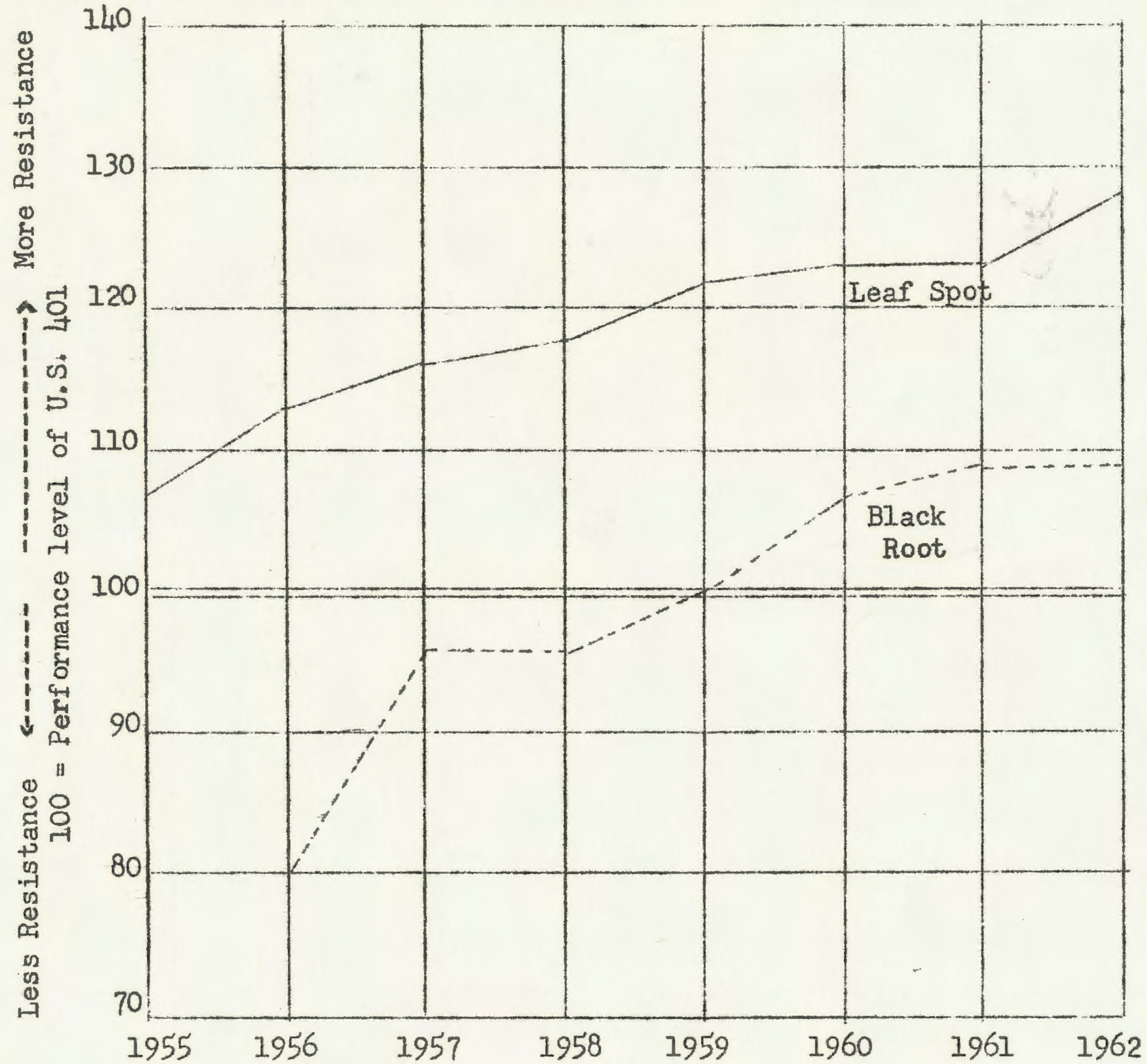
Good progress has been made over a period of several years in increasing the resistance of sugarbeet breeding lines to Cercospora leaf spot without any reduction in root yield or sugar percentage. Some progress also has been made in increasing resistance to black root. The multigerm breeding lines have more resistance than the monogerm lines. Although improvement has been made in root yield of monogerm breeding lines, as a group they are still below the multigerm lines in this character, excluding, of course, multigerm hybrids that often perform better than multigerm lines. Since the multigerm lines are superior to the monogerm lines in several desirable characters, they will be utilized as a source of germ plasm. The possibility of decreasing the concentration of soluble nonsugar constituents in the sugarbeet was indicated in tests of multigerm lines at Beltsville, and this finding is being applied to monogerm breeding. Concurrent improvement in all the characters for which selections are made has not been possible, but some multigerm lines have shown improvement in leaf spot resistance, black root resistance, sugar percentage, and lower nonsugar solids without any loss of root yield.

The use of proper breeding methods, good testing techniques, and effective selection procedures will undoubtedly result in the further improvement of breeding lines and varieties.

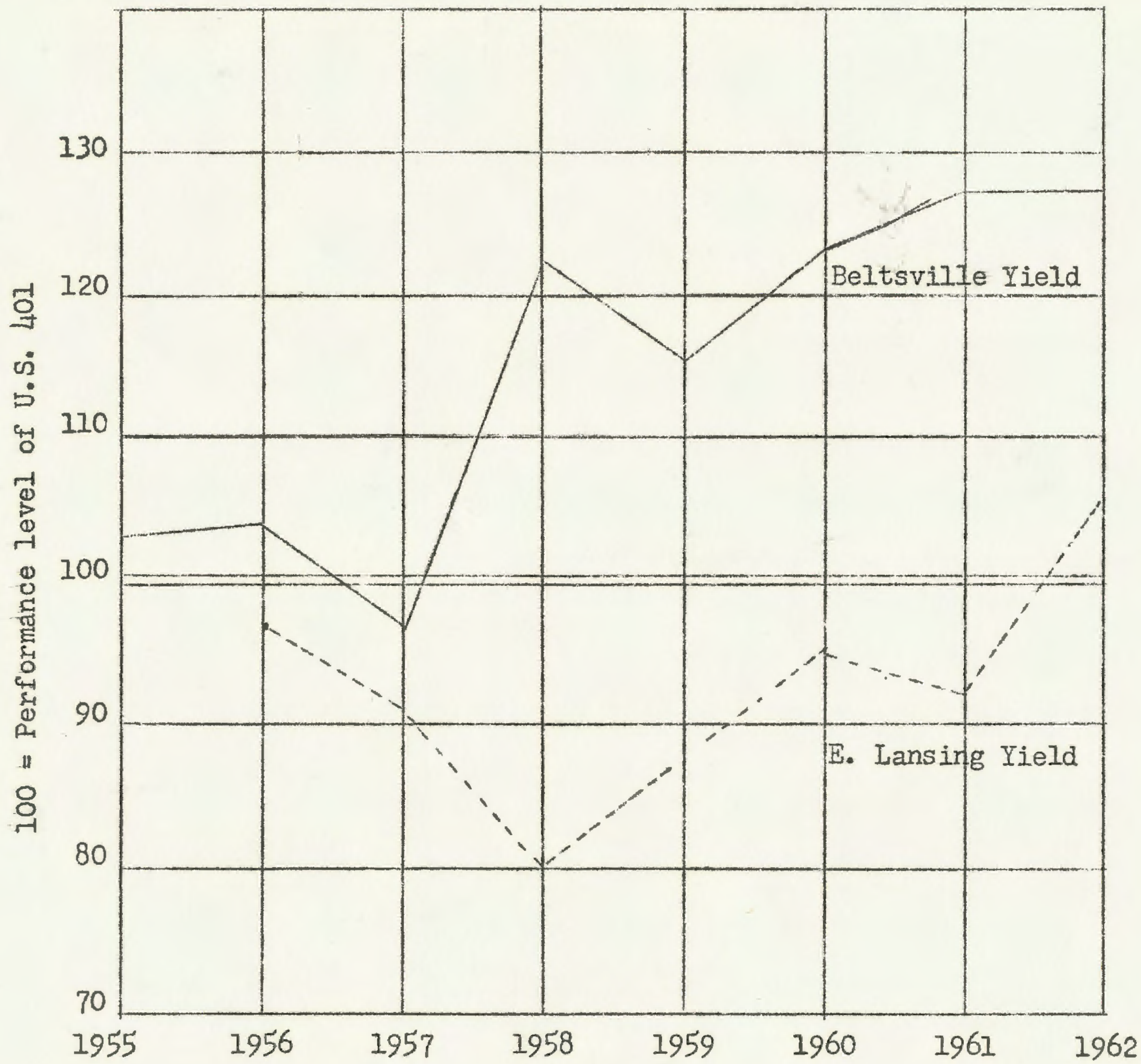
Graph 1. Disease resistance performance of multigerm breeding lines.



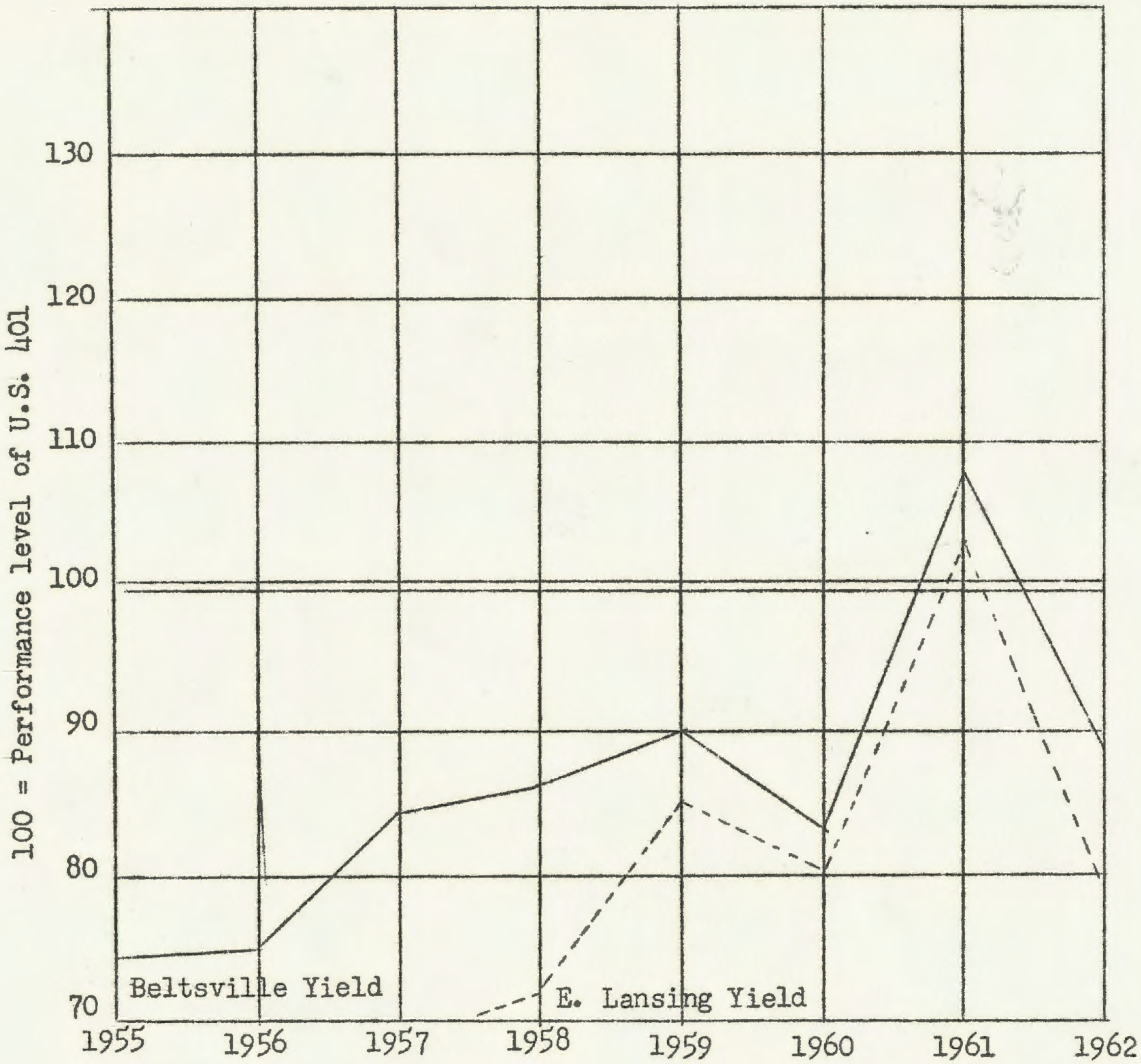
Graph 2. Disease resistance performance of monogerm breeding lines.



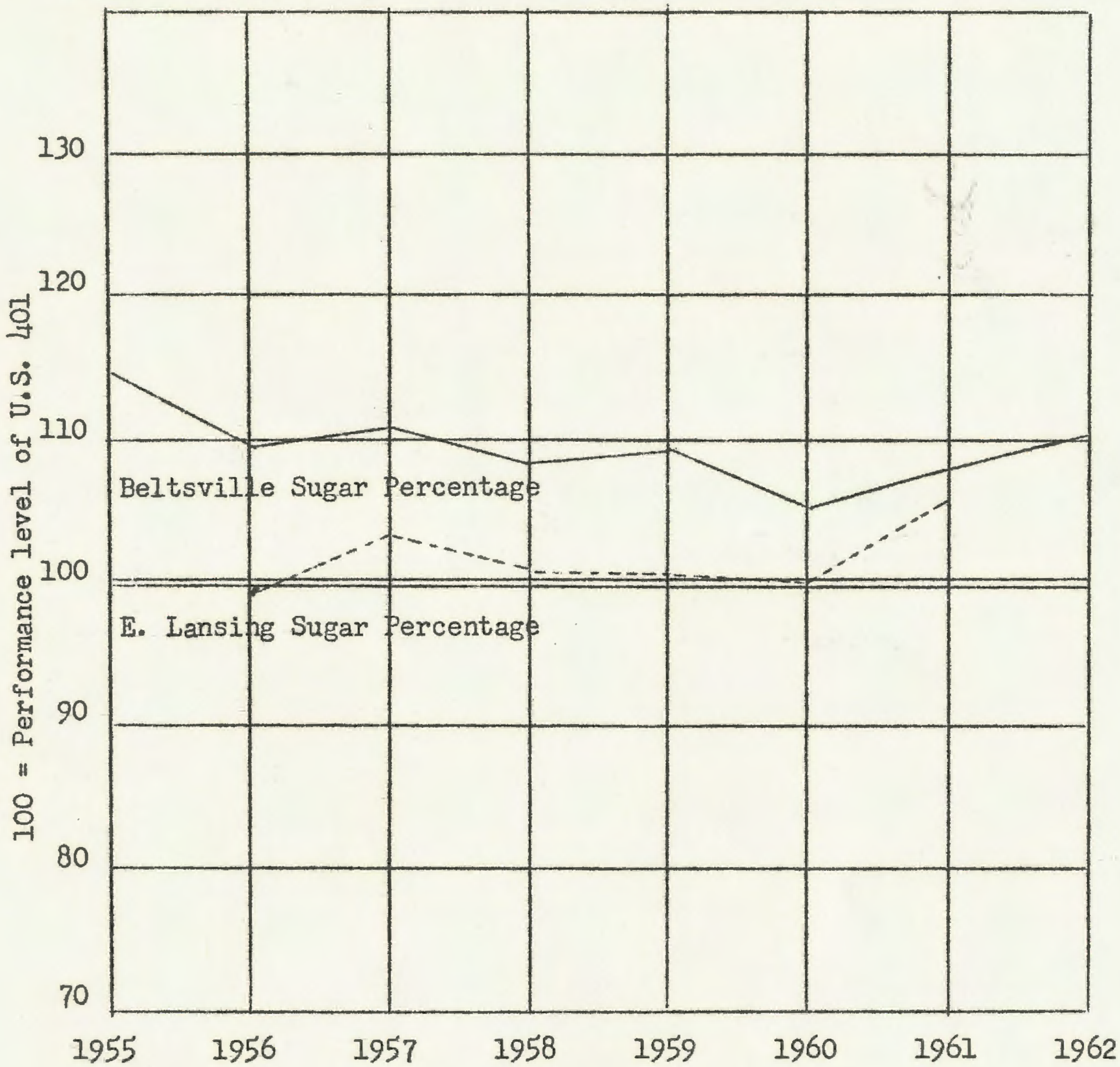
Graph 3. Yield Performance of multigerm breeding lines.



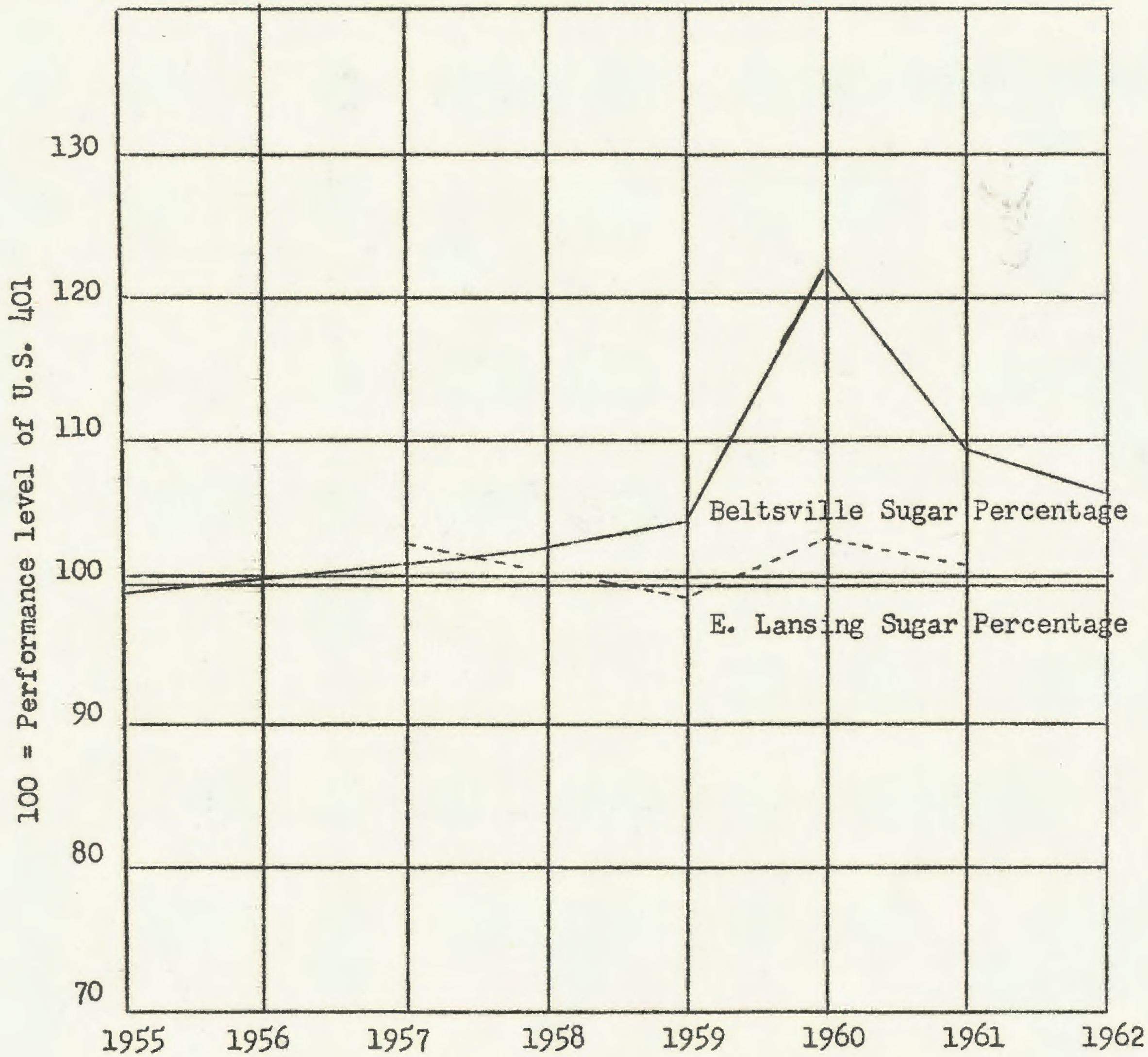
Graph 4. Yield Performance of monogerm breeding lines.



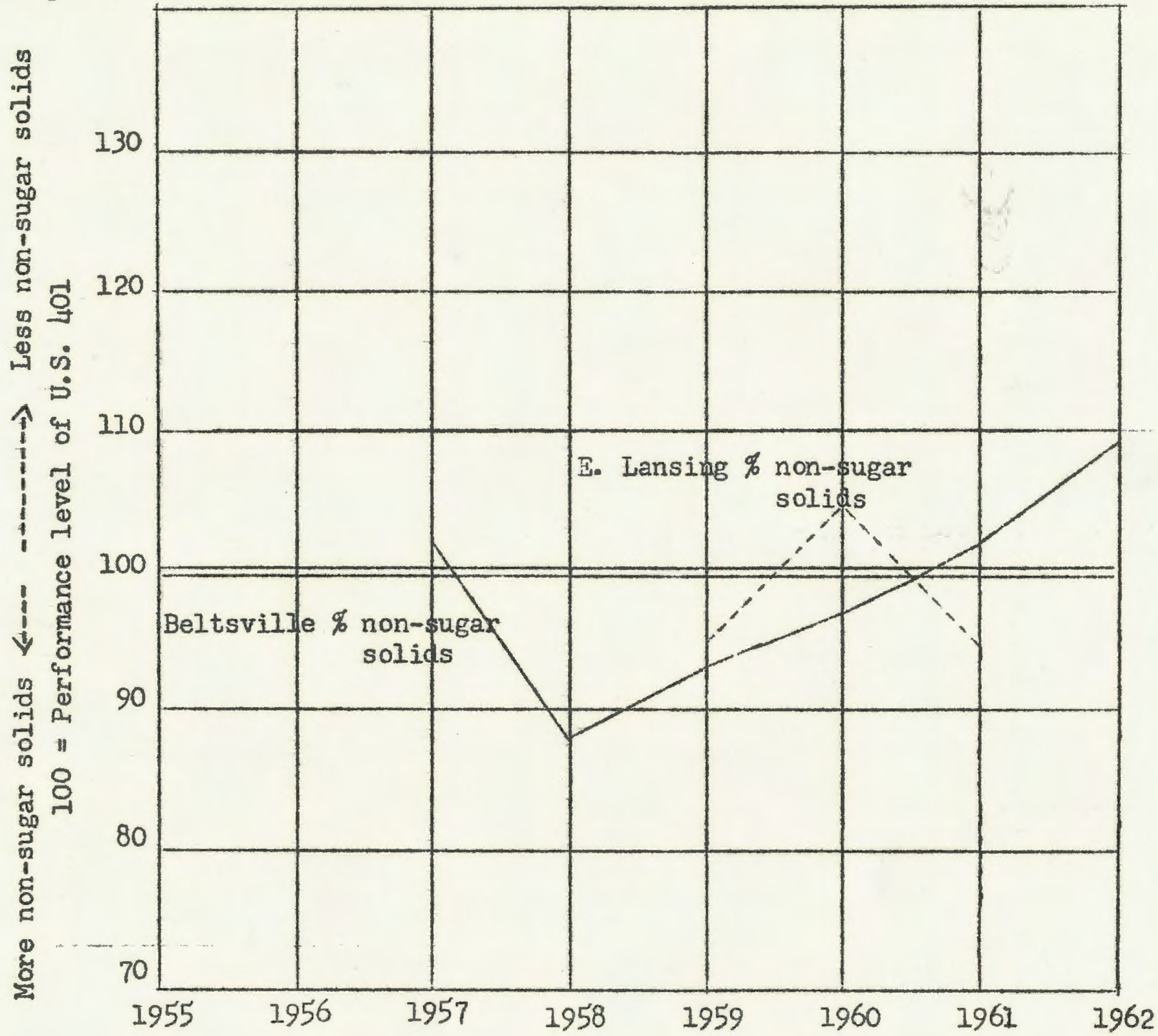
Graph 5. Sugar percentage performance of multigerm breeding lines.



Graph 6. Sugar percentage performance of monogerm breeding lines.



Graph 7. Percentage soluble non-sugar performance of multigerm breeding lines.



Graph 8. Percentage soluble non-sugar solids performance of monogerm breeding lines.

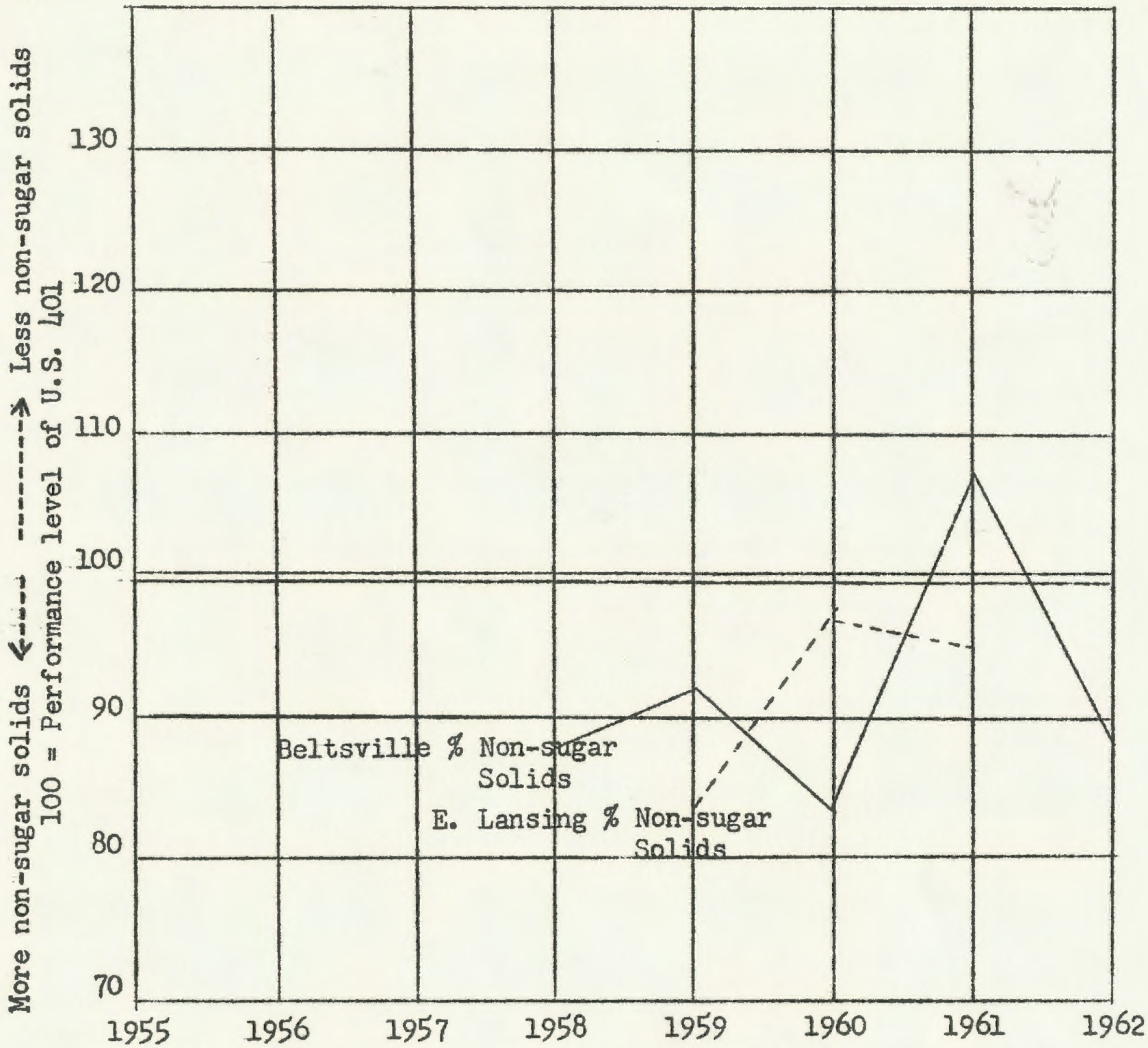


TABLE 1.--Performance rating of sugarbeet varieties and hybrids as compared to US 401[1/]

Variety	Root yield	Percent sugar	Percent soluble nonsugar constituents	Leaf spot resistance	Black root resistance
Multigerm:					
US 401	100	100	100	100	100
SP 5460-0	94	103	92	123	90
SP 5822-0	99	110	105	155	106
SP 6122-0	100	106	114	156	106
SP 61151-0	97	107	130	163	---
Monogerm:					
SP 60194-01	99	100	104	127	108
SP 60195-01	95	101	100	137	106
SP 6161-0	92	100	104	122	114
SP 61624-0	98	100	103	129	---
Monogerm hybrids:					
SP 6123-01 X 02 00 00 clone	103	105	104	100	---
SP 6123-01 X SP 5822-0	105	105	102	127	---
SP 6123-01 X SP 5460-0	104	105	98	109	---

1/ Numerical ratings greater than 100 indicate better performance than US 401.