Selecting Sugarbeet for Yellows Resistance on the Relative Concentration of Three Amino Acids in Leaves of Infected Plants

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The beet yellows disease is capable of causing severe losses to the sugarbeet crop in Europe and in certain areas in the United States. In Europe, losses in yield of from 35 to 50%, and as high as 61%, have been reported (4,8,9)[2]. In areas in California, losses in yield ranged from 2.0 to 47.0%, with a reduction in the percentage sucrose ranging from 0.1 to 3.1 percentage points (1,2).

McFarlane and Bennett (10) reported that neither stunting, nor yellowing, nor necrosis of the tops will serve as a reliable selection criterion. In their field program greatest emphasis was, therefore, placed on making successive selections based primarily on superior root size. Superior yields of beets showed their third and fourth successive selections to be significantly more resistant to beet yellows than the parent variety, US 75. Percentage sucrose in the roots of these selections was similar to that in the parent variety, indicating that some criterion for resistance other than root size is needed if the percentage sucrose is to be improved.

Probably, the amino acids are involved in the most important biochemical changes that take place in the leaves of beet plants infected with beet yellows or with beet western yellows (5,6). Tests have shown that the concentrations of free aspartic acid and glutamic acid are frequently reduced as much as 70%, while in the same leaf, the concentration of glutamine sometimes was more than double that found in healthy control leaves. The amino acid ratio (concentration: $\frac{\text{aspartic acid} + \text{glutamic acid}}{\text{glutamine}}$) varied from 0.34 to 0.67 in newly matured leaves of beet yellows-infected plants, grown in the greenhouse or in the field, as compared to a variation in the ratio of from 1.00 to 3.00 among healthy plants grown in the greenhouse under controlled nutritional conditions.

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[2] Numbers in parentheses refer to literature cited.

The concentrations of aspartic acid, glutamic acid and glutamine are, to a large extent, genetically controlled in the leaves of beet yellows-infected plants (7). Infected plants, selected on the basis of the magnitude of the above amino acid ratio, produced progenies having significantly higher concentrations of aspartic acid and glutamic acid and a significantly lower concentration of glutamine (consequently a higher amino acid ratio) than infected plants of the parent variety, US 75.

This highly significant shift (in the concentrations of these three amino acids in leaves of infected plants of the progenies toward that in healthy leaves) suggested that the magnitude of the amino acid ratio may be a reliable selection criterion for resistance to beet yellows.

This communication summarizes the results of 7 years of field testing of selections which were made on the basis of a combination of the amino acid ratio and root weight. It reports the correlations of the amino acid ratios of the selections with root yield and percentage sucrose.

Methods

The methods used in making the selections have been outlined (7). The selections (or lines) were tested along with the parent variety at Spence Field, Salinas, California, from 1960 through 1966. All agronomic and cultural practices were the same as those used by the plant breeders in testing their varieties. The plot design was either a 6, 7, or an 8×8 latin square with two-row plots 45 or 50 feet long. The planting dates were between April 8, and April 30, and with harvest dates between September 25, and October 21, resulting in a short growing season, varying from 160 to 178 days. The plants were inoculated 5 to 8 weeks after emergence with the same virus strain, as that used to inoculate the plant populations from which the selections were made, or with a more virulent strain. An effective spray program was carried out to control insects such as caterpillars and leaf miners. At harvest, two 20-beet samples were taken from each plot for sucrose determinations.

Experimental Results

Performance of Selections Made on the Basis of the Magnitude of the Amino Acid Ratio

Selections having amino acid ratios superior to that of the parent variety showed more tolerance to beet yellows than the parent variety (Table 1). Selection R-6 was tested for 4 years. In 3 of the years, the percentage sucrose and yield of beets was significantly greater ($P = 0.01$ and $P = 0.05$ respectively) than

Table 1.—Summary of five years of testing sugarbeet selections made on the basis of the magnitude of the amino acid ratio in the mature leaves of beet yellows-inoculated plants of variety, US 75.

Selection	Selection basis: Amino acid ratio[1]	Selection basis: Root weight	Amino acid ratio of progeny	Change relative to parent: Sucrose	Change relative to parent: Acre yield: Beets	Change relative to parent: Acre yield: Sugar
				%-Points	Tons	Pounds
US 75	(Parent)		1.20			
R-6	High	$\bar{X} \pm s$	3.50**	+ 1.25**	+ 1.7	+ 868**
DS-7	Low	$\bar{X} \pm s$	0.95*	— 0.28	+ 0.2	— 51
RS-C	High	$>\bar{X} + 2s$	3.00**	+ 0.80**	+ 2.0	+ 777**

[1] Concentration: $\frac{\text{aspartic acid} + \text{glutamic acid}}{\text{glutamine}}$

**, * Significantly greater, or less, than the parent at the 1% and 5% levels respectively.

the parent. The fourth test was inoculated late in the season with the BYV. In this test, the percentage sucrose and the yield of beets was greater than the parent but not significantly so. Of the 5 tests involving selection DS-7, the percentage sucrose was lower in 3 tests, in one it was equal to, and in the other test it was higher than that of the parent variety. In no test was the percentage sucrose or the yield significantly different from that of the parent variety. Selection pressure applied for both a high amino acid ratio and a high root weight (selection RS-C) caused only a slight increase in yield over that of selection R-6, but resulted in a significant decrease in the percentage sucrose.

Comparison of First and Second Successive Selections for Resistance to Beet Yellows

Thirteen first selection sibs, of the 17 tested in the field, had amino acid ratios significantly greater than the parent variety. The performance of these 13 selections are compared with the performance of 5 sibs of the second selection cycle and the parent variety. The greatest improvement in tolerance of sibs of the second selection cycle, over the sibs of the first selection cycle, is shown by the significant gain in the percentage sucrose (Table 2). This improvement in percentage sucrose was no doubt due to the increased selection pressure applied for the amino acid ratio in making the second successive selections.

Correlation Between Amino Acid Ratio and Percent Sucrose and Yield

A greenhouse test was conducted in 1959 to determine the amino acid ratios of the 17 first selections that were field tested and the parent variety, as follows. Twenty-five plants of each selection were grown under controlled nutritional conditions and inoculated with the same strain of the virus that was used in

making the selections. The concentrations of the amino acids were determined in a two-leaf sample taken from each plant. The amino acid ratio was calculated for each plant and the mean ratio for each selection computed. In 1961, the test was repeated with 6 sibs of the first selection (tested earlier) and 6 sibs of the second successive selection and the parent variety. Correlation coefficients were computed between the ratio of the amino acid ratios (selection to parent, S/P) and the percent sucrose ratio (S/P) and the yield ratio (S/P) from the field tests for each selection. The correlation coefficients between the amino acid ratio and the percent sucrose ratio are both positive and highly significant (Table 3). The correlation coefficients, between the amino acid ratio and the yield ratio, are positive and significant at the 10% level in the tests involving the 6 sibs of the second selection cycle.

Table 2.—Summary of seven years of field testing first and second selection cycles made on the basis of the magnitude of the amino acid ratio and root weight under severe beet yellows conditions.

Selection	Sel. pressure for		Selections		Field tests	Sucrose % ratio sel./75	Acre yield	
	A. acid ratio[1]	Root wt.	Made	Tested			Beets ratio sel./75	Sugar ratio sel./75
			No	No	No	X 100	X 100	X 100
Parent US 75						100	100	100
1st	$>\bar{X}$	$>\bar{X} + 2s$	28	13	47	101.1	111.6	112.3
2nd Suc.	$>\bar{X} + 2s$	$>\bar{X} + 2s$	10	5	17	106.8	116.4	124.0

[1] Concentration: $\frac{\text{aspartic acid + glutamic acid}}{\text{glutamine}}$

Table 3.—Correlation between the ratio of the amino acid ratios, selection to parent, and the percent sucrose ratio, and the yield ratio of selection to parent.

Ratios correlated	Selections tested			Field tests	Cor. coeff.
	1st	2nd Suc.	Total		
Amino acid ratios[1]	No	No	No	No	r
1959-S/P & % Suc. ratio: S/P	17	0	17	56	+ .459**
1961-S/P & % Suc. ratio: S/P	6	6	12	55	+ .501**
1959-S/P & Yield ratio: S/P	17	0	17	56	+ .188
1961-S/P & Yield ratio: S/P	6	6	12	55	+ .237*

[1] Ratio of amino acid ratios (concentration: $\frac{\text{aspartic acid + glutamic acid}}{\text{glutamine}}$) of selection to parent.

**, *Significant at the 1% and 10% levels respectively.

Summary and Conclusions

Seven years of field testing first and second successive selections, made on the basis of the magnitude of the amino acid ratio and root weight, has shown a progressive increase in resistance to beet yellows over that of the parent variety, US 75.

The second successive selections were significantly more resistant to beet yellows than the parent variety as shown by superior yields and also by a highly significant increase in the percentage sucrose.

The correlation between the amino acid ratio of the yellows-resistant selections and the percentage sucrose is positive and highly significant.

The correlation between the amino acid ratio and yield of beets is positive and significant at the 10% level in tests involving the second successive selections.

The superior performance of the selections over that of the parent variety, for a short growing season (160 to 180 days), suggests that early maturing varieties may be developed by selecting plants on the basis of the amino acid ratio.

Rapid progress may be made in breeding for resistance to beet yellows, and possibly to beet western yellows, by selecting plants having both a superior amino acid ratio and a superior root weight from populations (grown in the greenhouse) infected with a virulent strain of the virus.

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