Sugar Beet Varietal Trials in the San Joaquin, Sacramento, and Salinas Valleys of California

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From 1939 to 1944, inclusive, rather extensive sugar beet varietal trials have been conducted by the Spreckels Sugar Company. These tests were located in the San Joaquin, Sacramento, and Salinas Valleys. The purpose of this article is to report the results of these trials.

The most obvious major factors limiting yield of sugar per acre are diseases and bolting; and the two most important diseases are curly top and downy mildew. In some years bolting may limit production in those fields planted early (December and January). Such being the case the tests will be separated and analyzed on the basis of those in which disease and bolting are negligible, those in which curly top is a factor but bolting and mildew are not, and finally those in which bolting and mildew are factors but curly top is not. Bolting and mildew are considered together in these tests because a definite separation is not possible. Finally, the data for the five varieties and selections will be averaged for locations and dates of planting and studied to obtain information concerning the environmental variability.

Materials and Methods

Five varieties were carried for the duration of the tests. These were U. S. 22, U. S. 33, Improved U. S. 33, U. S. 15, and Old Type (R & G).

In discussing the data, any differences mentioned will have been shown to be statistically significant (odds as great as or greater than **19 to 1).**

Genetic Variability

The averages given in table 1 are for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when disease and bolting are not factors. The data are for the 5-year period from 1939 to 1944, not including 1942; and the averages given are for the 13 locations and dates of planting shown in table 4. The five varieties do not differ significantly in yield of available sugar per acre. U. S. 22 tends to be high in tons of beets

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Table 1.—Averages for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when disease and bolting are not factors—1939 to 1944, inclusive.

Variety or selection	Tons per acre		Percentage sucrose	Coefficients of apparent purity
	Available sugar	Beets		
U. S. 22	3.781	27.18	10.17	85.01
U. S. 33	3.768	28.42	10.48	85.54
U. S. 15	3.760	29.17	10.52	85.42
Old Type (R & G)	3.806	26.90	10.37	85.25
Imp. U. S. 33	3.744	26.07	10.44	85.38
Standard error of mean	0.046	0.279	0.078	0.157
Sig. Diff. (Odds 19:1)	0.130	0.789	0.221	0.444

per acre but low in percentage sucrose and coefficient of apparent purity. None of the differences between the remaining four varieties for any of the four characters are statistically significant.

The data for the same four characters when curly top is a factor but bolting and mildew are not factors arc given in table 2. The varieties fall into three classes in respect 1o their resistance to the virus causing curly top. Comparatively speaking, as determined by tons of beets per acre, Old Type (R & G) is very susceptible, U. S. 15 possesses a slight degree of resistance, U. S. 33 possesses a fair degree of resistance, and U. S. 22 and Improved U. S. 33 are highly resistant. Percentage sucrose and coefficient of apparent purity do not seem to be influenced by the degree of curly top prevalent in this test.

Table 3 gives the tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when bolting is a factor and mildew may be. The two tests included in the averages were conducted at Salinas, Calif., in 1939 and 1940. U. S.

Table 2.—Averages for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity when curly top is a factor—Vernalis and King City, 1940.

Variety or selection	Tons per acre		Percentage sucrose	Coefficients of apparent purity	Percentage of plants with curly top
	Available sugar	Beets			
U. S. 22	2.797	20.96	15.86	84.6	12
Imp. U. S. 33	2.782	19.29	16.90	85.4	19
U. S. 33	2.643	18.04	17.01	85.0	38
U. S. 15	2.005	14.30	16.34	85.1	70
Old Type (R & G)	1.517	10.61	16.68	85.5	74
Standard error of mean	0.096	0.875	0.222	0.340	
Sig. Diff. (Odds 19:1)	0.272	2.474	0.625	0.962	

Table 3.—Averages for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent pnrity when bolting is a factor and mildew may be—Salinas, Calif., 1939 and 1040.

Variety or selection	Tons per acre		Percentage sucrose	Coefficients of apparent purity	Percentage of	
	Available sugar	Beets			Plants that bolted	Plants with mildew
U. S. 15	5.176	40.17	15.49	83.16	2	23
Old Type (R & G)	4.904	40.77	15.11	81.58	10	24
U. S. 33	3.762	30.64	14.85	82.48	32	31
U. S 22	3.088	34.36	13.51	79.35	20	37
Imp. U. S. 33	3.423	29.23	14.42	81.24	33	27
Standard error of mean	0.111	0.615	0.231	0.682		
Sig. Diff. (odds 19:1)	0.314	1.739	0.653	1.929		

15 and Old Type (R & G) comprise a class having the greatest degree of resistance to bolting and they do not differ materially in respect to tons of available sugar per acre, tons of beets per acre, percentage sucrose, coefficient of apparent purity, and percentage of plants with mildew. The second most resistant class contains *V.* S. 22. This variety is lower than U. S. 15 and Old Type (R & G) in tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficient of apparent purity; and it is higher in percentage of plants with mildew. U. S. 33 and Improved U. S. 33 comprise the third class. The only satistically significant difference between these two varieties is in tons of available sugar per acre and this difference is only just statistically significant. The coefficients of apparent purity are not significantly lower than those of U. S. 15 and Old Type (R & G), but tons of available sugar per acre and tons of beets per acre are materially lower.

The comparisons between U. S. 22 and U. S. 33 and Improved U. S. 33 are interesting. U. S. 22 is lower than these two varieties in percentage sucrose and coefficient of apparent purity and higher in tons of beets per acre, but not materially different in tons of available sugar per acre. From the data of this table it is evident that the effects of bolting and possibly those of mildew are two-fold, tons of available sugar per acre being lowered by a reduction in both tons of beets per acre and percentage sucrose. Furthermore, the effects are multiplicative rather than additive which gives greater weight to simultaneous changes.

Environmental Variability

The averages for tons of available sugar per acre, ton of beets per acre, percentage sucrose and coefficients of apparent purity for the different locations and dates of planting are given in table 4.

Table 4.—Averages for tons of available sugar per acre, tons of beets per acre, percentage sucrose, and coefficients of apparent purity for the different locations and dates of planting. The averages are for the five varieties and selections given in table 1.

Locations and dates of planting			Tons per acre		Percentage sucrose	Coefficients of apparent purity
			Available sugar	Beets		
Salinas	March	1939	5.000±0.073	37.15±0.250	15.98±0.158	84.20±0.392
Woodland	January	1939	4.515± .093	30.84± .428	16.83± .148	86.99± .279
Woodland	March	1941	3.100± .056	20.02± .353	12.36± .135	83.54± .228
Santa Carbona	April	1941	4.251± .095	28.83± .622	17.22± .127	85.62± .223
King City	March	1941	4.391± .037	28.67± .210	18.23± .076	84.02± .180
Woodland	April	1941	2.093± .060	26.85± .477	12.28± .119	81.08± .291
Salinas	April	1940	5.097± .044	25.06± .253	14.74± .114	80.94± .234
Davis	March	1944	3.529± .093	24.98± .558	16.40± .075	86.14± .077
Woodland	March	1939	3.209± .073	24.91± .502	16.06± .173	85.33± .269
Woodland	April	1940	5.269± .055	28.76± .443	16.01± .166	85.84± .268
King City	March	1944	3.009±	21.89± .891	18.44± .078	89.42± .....
King City	February	1941	3.450± .053	21.40± .275	18.73± .142	89.51± .228
Woodland	May	1943	3.444± .141	20.11± .744	19.24± .063	89.62± .044
Average			3.674	26.49	16.39	85.32

Since each entry is an average for the five varieties and selections, the differences noted for any one character can be attributed to environmental variability when disease and bolting are not factors. This is that portion of the variability that the sugar beet producer attempts to control through better agronomic practices. The range in tons of available sugar per acre is from 2.693 to 5.000, in tons of beets per acre is from 20.11 to 37.13, in percentage of sucrose is from 12.28 to 19.24, and in coefficient of apparent purity from 80.94 to 89.42. That the variation between individual farms is even greater cannot be doubted.

Even though much is already known concerning those factors causing variability, much remains to be learned and can be learned by well-designed and executed agronomic experiments. For example, the effects of dates of planting, irrigation practices, fertilizers, and other cultural practices upon the percentage sucrose is not definitely known. The need for such information is emphasized by the range of the means for this character.

In designing a plant breeding program and in designing agronomic experiments it is helpful, if not essential, to have in mind the inter-relationship of the various characters concerned. The relationship between tons of available sugar per acre as calculated in the variety test plots from 1939 to date is evident, since tons of available sugar per acre is the product of tons of beets per acre times percentage sucrose times coefficient of apparent purity. Such being the case information as to the relative importance of these three characters and their inter-relationship is of decided value. The data from which table 4 was calculated furnish considerable information on this point in respect to the territory in which the Spreckles Sugar Company operates.

The method of multiple regression was used to determine the relative importance of tons of beets per acre, percentage sucrose and coefficient of apparent purity. The standard regression coefficients were 0.9688 for tons of beets per acre, 0.8145 for percentage sucrose, and 0.1660 for coefficients of apparent purity. These regression values show that tons of beets per acre and percentage sucrose are about equally effective in determining tons of available sugar per acre, the former being only 1.2 times as effective as the latter. But tons of beets per acre and percentage sucrose are considerably more important than the coefficient of apparent purity in determining tons of available sugar per acre, the corresponding numerical values being 5.8 and 4.9, respectively. This information permits placing the proper emphasis on these characters in a breeding program and in recommending certain agronomic practices.

Of considerable importance 1o both breeding and agronomic procedure is the relationship betwen ions of beets per acre, percentage sucrose, and coefficient of apparent purity. To determine this, analyses of covariance were made. Only 18 percent of the variances of tons of beets per acre and percentage sucrose was accounted for by covariance. The relationship was negative. This means that some of the environmental conditions were favorable to one of these characters but not to the other. Looking at the brighter side, the 82 percent of the variances that was not accounted for by covariance would indicate that some of the environmental conditions probably were favorable to both. Such conditions prevailed in the tests planted at King City in March 1941, since both a high yield and high percentage, of sucrose were obtained. The same was true of the Woodland planting for January 1939. The relation between tons of beets per acre and the coefficient of apparent purity was negative, also ; and 24 percent of the two variances was accounted for by covariance. It is evident that these two characters are not mutually exclusive; certain conditions may be favorable to both even though the predominating tendency is for an increase in one to be accompanied by a decrease in the other. The relationship between the percentage sucrose and the coefficient of apparent purity was positive, and 55 percent of the variances of these two characters was accounted for by covariance. This means that a number of those environmental factors favorable to one character were also favorable to the other.

These facts clearly point to the need of agronomic experiments to determine what conditions produce such results. Indications from these data are that early dates of planting may be favorable to both characters. If so, breeding a variety more resistant to those conditions causing bolting is desirable so thai earlier plantings can be made.

Discussion

These data rather conclusively show that the varieties being grown in those areas in which the Spreckels Sugar Company operates fall into three main groups as follows: Those possessing a high degree of resistance to the attacks of the virus causing curly top, those possessing a moderate degree of resistance to the attacks of the organism causing downy mildew; and those possessing resistance to the conditions causing bolting. The first group is designated as the "curly top resistant group" and includes U. S. 22, U. S. 33, and Improved U. S. 33. The second is designated as the "downy miklcm resistant group" and includes U. S. 15 and Old Type (R & G).

Breeding Problems

The data from the varietal trials aid in evaluating the breeding problems. Since varieties with a high degree of resistance to the

attacks of the virus causing curly top are now available, it is advisable at; this time to shift some of the emphasis to improving other characters and to obtain varieties recombining desirable characters.

Although varieties with some degree of resistance to *P. schachtii* are being grown, too frequently this disease still exacts a large toll from the producer of sugar beets. In fact, obtaining a satisfactory degree of resistance to the attacks of *P. schachtii* is at present one of the most important breeding problems in the area in which the Spreckels Sugar Company operates.

Of most importance is a greater resistance to those environmental factors conducive to bolting. U. S. 15 rates highest in this respect but in some years when this variety is planted in December and January, yields of sugar per acre are materially reduced by too many plants bolting. Also, there is definite need for a variety that can be planted in October and November without undue losses occurring because of bolting. Such early plantings may materially increase the yield of sugar per acre, and in the Bakersfield area early planting is particularly desired by growers so that the growing of sugar beets will fit more advantageously into farming operations. In reality such a variety of sugar beet would receive a hearty welcome over the entire territory in which the Spreckels Sugar Company operates.

Under the environmental conditions of the San Joaquin, Sacramento, and Salinas Valleys any differences between varieties in the production of tons of sugar per acre were found to be due to differences in the ability of varieties to resist the attacks of disease-causing organisms or to resist those environmental factors conducive to bolting. This fact points to the desirability of emphasizing yielding ability in the breeding program. Apart from disease and bolting, increases in yielding ability obtained by limiting the material to the varieties and selections included in these tests may be expected to be small. Hence, the need for including a greater diversity of genetic material is evident.

Much can be gained by recombining resistance to the attacks of the virus causing curly top, resistance to the attacks of *P. schachtii* (downy mildew), and resistance to those factors causing boilting. A variety possessing these characteristics could be planted anytime from December to the end of the planting season without undue risks of losses from disease or bolting.

Acknowledgments

Acknowledgments are due the members of the Agricultural Department of the Spreckels Sugar Company for collecting the data.