BREEDING FOR RESISTANCE TO LEAF SPOT AND OTHER CHARACTERS

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I believe this group may be interested in a brief statement of the objectives of the breeding program of The Great Western Sugar Company and the policies which we try to follow in attaining those objectives. Our main objective is the development of varieties that we may be reasonably sure will produce high quality beets and the maximum sugar per acre in all territories and under varying conditions.

It will be readily understood that each area producing sugar beets should have the varieties which, on the average, give the best all round results for that particular area. For example, all the areas in the West subject to curly top disease must choose, first of all, a variety highly resistant to this disease, as this factor of curly top resistance outweighs all other considerations. In other words, this one factor largely governs the sugar production per acre, and other factors such as sugar content and purity are of secondary importance.

In the same way, for the states of Michigan, Ohio, Indiana, and the beet growing sections of Ontario, I would say that the matter of resistance to blight, or leaf spot, largely determines the choice of varieties. The Cercospora disease is sufficiently wide-spread and persistent in these areas so that in any breeding program for the Eastern section, leaf spot resistance must be given first consideration.

In the four states in which the Great Western operates, we have a somewhat different situation in that we have no disease which is uniformly important in all districts. For our areas we need three different varieties, which I am listing in the order of their importance.

1. Our G. W. Yield variety, needed for 60% of our acreage.

2. Our Leaf Spot Resistant variety, needed for 30 to 35% of our acreage.

3. A new variety being developed for resistance to Rhizoctonia, needed for 3 to 5% of our acreage.

At the present time our G. W. Yield variety is the best all round variety for general use in our areas. Where no diseases are involved, it gives the maximum yield of sugar per acre, in the form of a well-shaped root of high purity and good sugar content. It has been tested all the way from the Imperial Valley of California to Michigan and Ontario and under these widely different conditions was outstanding in many cases.

Eastern Colorado and some sections of Nebraska are subject to attacks of leaf spot about one year out of two, on the average, so it is important that we have a resistant variety for these areas. We are rather proud of our new G. W. leaf spot resistant variety, seed of which is now being produced on a large scale. It has very find resistance and is of outstanding performance under leaf spot conditions. We began the breeding of this variety in 1931 but made our big im-

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provement in resistance in the year 1936 when we were able to select strongly resistant individuals in the families previously selected for a fair degree of resistance.

In the sugar beet growing areas east of the Rocky Mountains resistance to leaf spot, Cercospora beticola, offers more promise of early and significant contributions to the successful production of sugar beets than does any other single character subject to breeding control. While certain rather expensive sections of this general area, as, for example, Montana and the San Luis Valley in Colorado, are quite free of this disease, it is generally recognized as a serious limiting factor in production in favorable years over most of the area.

In studies previously reported by LeClerg (4)[2/]; Gaskill at the 1935 Sugar Beet Round Table meetings at Fort Collins; Brown at the 1938 General meeting of this Society; and by Young, Eskilson and Calland at the 1939 Eastern Regional meeting of this Society; it appears that gains of up to 25% in yield of sugar per acre are not uncommon as a result of protection against leaf spot by spraying or dusting.

Brewbaker and McGreevy(3) reported for the year 1937, a regression of 3.62% in yield and .80% in sugar (in per cent of the Standard variety used in the test, which was very susceptible to leaf spot) for each unit change in leaf spot rating from 0 - none to 10 - very susceptible. Comparable regression figures for the 1938 tests at Fort Morgan were 4.22% for yield and 1.33% for sugar, giving an average for the two years of about 4% for yield and 1% for sugar. The percentage increases for yield and per cent sugar added together approximates the total sugar increase. For an average of the two years this would be about 5%. Under heavy leaf spot conditions, susceptible commercial varieties will differ from the more resistant breeding strains by as many as 6 or 7 units on the resistance scale of 0-10, thus accounting for as much as 30 to 35% difference in total yield of sugar.

Methods Used in Breeding for Leaf Spot Resistance

There are several major lines of approach being followed in breeding for leaf spot resistance by The Great Western Sugar Company, viz.,

1. Intensive family and group breeding. Individuals are selected for freedom from leaf spot under epidemic conditions. These selections are made mostly in the regular breeding strains which are basic to the G. W. commercial variety, although selections are also being made in Cesena and other commercials which show considerable leaf spot resistance but are relatively low yielders, or are otherwise undesirable commercially. These selected individuals are grouped into various combinations of from a few to over 100 roots. Open-pollinated seed, harvested individually, provides the basis for extensive progeny testing in replicated trials.

The purification of resistance has proceeded very rapidly by this method, the process having been accelerated materially through greenhouse groupings, thus completing a generation in one year. These results indicate relative simplicity of inheritance for this character, specific information for which is still unavailable to the industry.

2/ Figures in parenthesis refer to "Literature Cited".

2. Mass selection of a large number of individuals to be increased immediately into basic material for commercial production. This has not been used to any considerable extent since it is much less efficient in the production of a high degree of resistance than the family and group method.

3. First generation crosses between resistant commercials or pedigreed lots from widely different sources. Several such wide crosses have been made looking toward the possibility of hybrid vigor but maintaining the resistance characteristic of the parents.

4. Crosses of G. W. elite stock material with B. maritima, particularly North Sea types which are ordinarily biennials, and other wild relatives followed by successive backcrosses to the commercial parent.

5. Selection in self-fertilized lines or inbreeding through self-pollination. Uniformity for resistance can be obtained more rapidly by the inbreeding mode of attack than by any other but it is accomplished at the sacrifice of the balance of other characters necessary for commercial value, hence the necessity of later testing of various combinations of inbreds to restore this balance.

Results

1937

The first grouping (Group 3642) of quite resistant individuals included 51 roots planted into the greenhouse during the winter 1936-37. Sufficient seed was obtained from only 4 roots to plant in a replicated progeny test. In per cent of the Standard (GW18) these 4 families showed average increases of 10.4% in weight of roots, 4.5% in per cent sugar, and 15.2% in total sugar. The average leaf spot rating was 1.5 for these families and 6.4 for Standard.

1938

Individuals selected in 1937 under leaf spot epidemic conditions were again planted to the greenhouses in the fall with seed being harvested for testing in 1938. In these increases B15 constituted a wide L.S.R. selection (58 roots) from Group 3642, and B17 was planted to 15 roots from Group 3642 and 15 very L.S.R. individuals from Cesena. The briefly summarized results are as follows:

Table 1 - Variety test at Fort Morgan, 1938

Variety	Yield of Roots		Sugar		Total Sugar		App. Pur	Leaf spot
	T. per A.	% of Std.	%	% of Std.	T. per A.	% of Std.		
B17	14.77	105.6	15.92*	116.3	2.354*	123.0*	87.3*	1.4*
B15	15.40*	110.0*	14.86*	108.5*	2.289*	119.6*	85.6*	2.4*
Cesena	13.19	94.3	14.92*	108.9*	1.968	102.8	85.0*	4.0*
U.S. 200 x 215	14.35	102.6	13.61	99.4	1.948	101.8	84.0	6.0*
GW18 (Std.)	13.99	100.0	13.69	100.0	1.914	100.0	83.9	7.6
Dif. for Sig.	.99	7.1	.40	2.9	.149	7.8	1.1	0.5

*Significantly above Standard.

The results show striking increases in yielding ability and quality for the L.S.R. production B17 and B15 as compared with GW18, the European variety Cesena, or the Government production U.S. 200 x 215, which has been released as a resistant variety. These two groupings show extreme resistance to leaf

spot, the ratings for these two groups and the Standard being, respectively, 1.4, 2.4, and 7.6. This difference in leaf spot might account for increases of from 25 to 30% in yield of sugar per acre on the basis of the regression of 5% per unit of leaf spot rating, as previously given in this paper.

There were a number of families in the 1938 test which resulted from grouping of very resistant individuals. Those originating in Group 3711, in which 8 roots out of 15 included in the group produced sufficient seed for replicated trial, showed an average increase of 25.73% of total sugar per acre over the Standard. The comparative ratings for leaf spot were 2.09 for the average of the 8 families and 7.6 for Standard.

1939

This year was unusual in Northern Colorado, the rainfall being about 50% of normal, with leaf spot failing to reach serious epidemic conditions except where artificially stimulated as by overhead irrigation. Approximately 3600 plots were planted in one field nursery of 13½ acres near Fort Morgan, most of which were of some interest for resistance to leaf spot. Of these plots about 1000 should have exhibited extreme resistance. At no time during the season did leaf spot reach sufficient proportions to take notes on its incidence.

All was not lost, however, since the yield results under non-leaf spot conditions provided an opportunity to observe the performance on an extensive scale in the absence of the disease factor. It served also as a caution to extravagant claims for major contributions resulting from a series of flushing victories -- such as sometimes occur in other and possibly even more exciting games such as football.

A broad mass increase (GW1051) of the original leaf spot resistant Group 3642 was tested at 5 locations including 3 in Colorado and 2 in Montana. The average results for all 5 locations in comparison with the regular pedigreed strain of Great Western (GW1053) and the Standard (GW18) are presented as follows:

Table 2 -- Results averaged for 5 locations in 1939

Variety	Yield of Roots		Sugar		Total Sugar	
	T. per Acre	% of Std.	%	% of Std.	T. per Acre	% of Std.
GW1051	16.89**	93.80**	16.26**	98.13**	2.743**	92.03**
GW1053	19.11*	107.37*	16.33**	98.50**	3.117*	105.72*
GW18 (Std.)	17.75	100.00	16.57	100.00	2.943	100.00
Diff. for Sig.	.62	3.53	.20	1.26	.108	3.72

* = significantly above and ** = significantly below Standard.

Under the conditions existing for these tests with leaf spot occurring as a very light attack at only the Longmont station, the resistant variety GW1051 appears at some disadvantage with a yield of 92.03% of Standard in total sugar. Applying the regression figure of 5% total sugar for each unit in leaf spot rating, it would require less than 2 units of leaf spot to depress the total sugar yield of Standard below GW1051 and less than 3 units to place GW1051 and GW1053 on a corresponding equal basis. Under leaf spot conditions similar to those existing in 1937 and 1938, GW1051 would be expected to exceed Standard by 10 to 15 per cent, and the susceptible GW1053 by 5 to 10 per cent in total sugar.

Another production from Group 3642 (B40), which originated as the second increase of but two families, was tested at the Longmont and Fort Morgan locations. The results obtained for the original families in 1937 and the first increase (Gr. 3718) in 1938, both under heavy leaf spot epidemic conditions, and the mass increase of Gr. 3718 (B40) are given in per cent of the Standard (GW18) for all characters except leaf spot in Table 3:

Table 3 - Comparison of parental strains with 1st and 2nd increase of very resistant material.

Variety	Year Tested	Yield of Roots	% Sugar	Total Sugar	Leaf spot (a Strain	Standard
Parental strain 15345	1937	119.8	101.5	121.7	1.9	6.4
" " 15369	"	107.7	107.8	116.1	1.1	6.4
1st increase, Gr. 3718	1938	110.2	108.1	119.1	1.6	6.8
2nd increase, B40 (Ave. 2 locations)	1939	90.4	98.4	88.9	.03(b	2.7

a) The comparison for leaf spot is made directly in terms of the 0-10 scale of resistance to susceptibility.
b) For Longmont only, no leaf spot at Fort Morgan.

The apparent drop in yield from the parental strains and the first increase to the second increase is greater than would be expected based on the prediction of 5% loss for each increase of one unit of leaf spot. It is quite probable that the narrow origin of B40 may be responsible for some of this loss. Under leaf spot conditions similar to those existing in 1937 and 1938, B40 should yield upwards of 10 to 15 per cent increase over Standard on the basis of this prediction.

Two broad increases of very resistant selections from Group 3642 have been made; namely, B15, a greenhouse increase (See Table 1) and B42, a field grouping. The roots were selected similarly to those used for B40 (See Table 3), except that only 2 families are represented in B40 and 34 families in both B15 and B42. The results obtained at Fort Morgan for B15 for both 1938 and 1939, and B42 for 1939 are summarized in Table 4:

Table 4 - Results obtained for two resistant selections from Group 3642 as expressed in % of Standard.

Variety	Year	Yield of roots	% Sugar	Total Sugar
B15	1938	110.0	108.5	119.6
B15	1939	97.7	97.3	95.0
B42	1939	97.3	97.6	94.9

In 1938 leaf spot was rated at 2.4 on B15 and 7.6 on Standard. This difference would be expected to result in 25% difference in total sugar yield. There was an actual reduction of 24.6% in total sugar in 1939 as compared with the 1938 results for B15 in per cent of Standard, which closely approaches the expected on the basis of the prediction figure of 5% for each unit of leaf spot, as given above. The two increases B15 and B42 are approximately equal in every respect under non-leafspot conditions.

Varietal crosses for leaf spot resistance

There was some indication of hybrid vigor in a relatively wide cross, Cesena x Group 3642, in the above 1938 tests at Fort Morgan. Group 3642 was also crossed with Cesena and the two U. S. leaf spot resistant releases U. S. 217 and U. S. 200 x 215. These crosses were made by merely grouping roots of the two parents, hence by random mating 50% of sib-pollination was possible. The test was conducted in this manner in order to determine the commercial possibility of such an incomplete hybrid, since complete hybridization as in corn is impractical for sugar beets except through the possible employment of one male sterile parent. The crosses were planted at both Longmont and Fort Morgan, the results being summarized in Table 5:

Table 5 - Performance of wide crosses and certain of the parents in per cent of Standard, 1939.

Variety	Yield of Roots	% Sugar	Total Sugar
B36 and 37 - US 217 x Gr.3642, F_1	95.37	100.09	95.45
B38 and 39 - (US200x215) x Gr.3642, F_1	99.20	99.25	98.45
B35 - Cesena x Gr. 3642, F_1 (a	91.30	102.02	93.14
B70 - Cesena x Gr. 3642, F_2 (b	83.37	102.65	85.58
A8 - Commercial Cesena (c	73.87	99.12	73.22
A36 - U.S. 200 x 215	98.12	98.24	96.37
GW1051 (Gr. 3642)	98.26	97.55	95.84
Diff. for Significance	6.33	4.21	8.44

a) Not the same origin as B70, the roots used for B35 being more carefully selected for leaf spot resistance, size and shape.
b) Similar to B17, see Table 1.
c) Results for Longmont only, all others are averages for Longmont and Fort Morgan.

The yield and per cent sugar for the cross (U.S. 200x215) x Gr. 3642 are both slightly higher than either parent, the difference, however, being statistically insignificant.

Cesena was tested only at Longmont, the results at this Station for the two parents and the F_1 hybrid, Cesena x Gr. 3642, being presented in Table 6:

Table 6 - Performance of parents and F_1 hybrid expressed in per cent of Standard

Variety	Yield of Roots	% Sugar	Total Sugar
GW1051 (Gr. 3642)	93.50	97.42	91.08
Cesena	73.87	99.12	73.22
Ave. of parents	83.69	98.27	82.15
F_1 hybrid	89.10	101.56	90.50
Increase F_1 over Ave. of parents (a	5.41 (3.58)(a)	3.29	8.35(6.54)(a)
Diff. for Sig.	5.41	3.60	7.21

a) Recorded yield for one plot of Cesena was so low as to be of questionable accuracy. Figures in parenthesis indicate the results obtained when a calculated plot value was used in place of the recorded one.

The F_1 hybrid is above the average of the two parents in yield of roots, total sugar and per cent sugar, the difference approaching significance. These results suggest heterosis or hybrid vigor for this varietal cross. The F_1 would be expected to exhibit greater resistance to leaf spot than the GW1051 parent, and in a leaf spot year this fact alone would tend to give the hybrid a real advantage.

Selection in self-fertilized lines

The work on inbreeding is necessarily based on a long time program looking toward ultimate improvement in several characters. Since the parentage is under complete control it is possible to produce lines pure for certain characters and use these for rebuilding a variety based on certain specifications. By no other method of breeding will this control be possible. In the Kodachrome slides presented some of the characteristics of inbred lines are shown.

Other Characters of Interest in Improvement Through Breeding

Recent studies have shown certain characters to be of more or less immediate interest from the standpoint of breeding for improvement in the sugar beet. Previously no particular emphasis had been placed on these so far as our breeding work was concerned. The evidence as to possibilities will be briefly presented.

Cold resistance, strength of seed stalk, and seed production

In connection with overwintering increases of Great Western lots severe winter killing was experienced during the winter of 1936-37. Not more than 2% of the entire population survived in two fields. Plants which were not damaged were grouped for increase, and for progeny tests in 1937-38 in comparison with the parental stock. Of the 137 such families tested 104 or 75.9% showed less than 5% winter killing, while the 20 plots of parental check material ranged from 5 to 20% with an average 11.1% killing.

Further evidence of the increase in winter hardiness accomplished by this one selection may be seen from Table 7 in which varieties 4 and 5 are the mass collections of seed from apparent cold resistant individuals selected in the spring of 1937 as described above.

Table 7 - Results obtained for overwintering test of varieties at Windsor.

Variety	% Winter Killing 3/18/38	Lbs. Clean Seed per Acre
1 - U. S. 12	10.4	1938
2 - European Commercial	13.2	1215
3 - Parent of 3 and 4	12.4	1390
4 - Seed mixture 100 plants	4.4	1407
5 - " " 25 "	3.4	1760
F	3.86*	2.08

* = significant difference between varieties.

Varieties 4 and 5 showed significantly less winter killing than varieties 1, 2, and 3, indicating further evidence of the heritability of cold resistance.

Strength of seed stalk

In the strain test discussed under "cold resistance" there appeared very striking differences in strength of seed stalk just previous to harvest. These were rated on the basis of 1 - strong to 5 - weak, with results as follows:

Strength Rating	No. Families in each class	No. parental plots in each class
1	8	0
2	47	6
3	54	7
4	23	6
5	4	1
Total	136	20

These results show a very wide range for strength of stalk.

Yield of seed

Yields of clean seed per 30 ft. of row obtained for the strains included in the test discussed under "cold resistance" are distributed in classes as follows:

Oz. Seed	No. Families in each class	No. parental plots in each class
16-20	1	
21-25	4	2
26-30	9	8
31-35	11	5
36-40	26	3
41-45	34	1
46-50	32	1
51-55	8	
56-60	7	
61-65	2	
66-70	2	
Total	136	20

Nineteen families ranged above the highest yielding parental plot indicating possibilities of material increase in seed yielding ability through breeding methods.

Correlation of strength of seed stalk and yield of seed

In order to determine whether the apparent weakness of the seed stalk was due to the weight of seed which it carried, the correlation was calculated, with an obtained r value of -.1280, which proved to be not significant. Hence, these characters would appear to be independent in inheritance, and certainly worth considering in a breeding program.

Rhizoctonia resistance

Conservative estimates based on studies conducted during 1938 and 1939 show that diseases caused a loss of at least 2000 tons of beets in the Great Western Sugar Company territory during those years. These same studies show that at least 35.75%, or 715 tons, of this loss was due to Rhizoctonia root-rot.

This loss is not very impressive when thought of as the result of Rhizoctonia root-rot over a period of two years and over an area of more than 400,000 acres of beets. However, there are local areas where the losses reach serious proportions. Each year there are individual fields where the damage results in serious financial losses to the grower.

The need for maintaining sugar beet acreages in badly affected areas and on farms subject to serious damage seems to justify an attempt to produce a Rhizoctonia resistant strain of sugar beets. The Great Western Sugar Company's attempt to produce such a strain of sugar beets is still in its infancy.

In this work the possibility that beets resistant to Rhizoctonia in the seedling stage (black-root) may not be resistant to the summer root-rot and vice versa has not been considered. This paper deals with the summer form of root-rot and the possibility of producing strains of sugar beets resistant to it.

The first selection was made the fall of 1937 from a field that had grown potatoes in 1936. The loss on the entire area was in excess of 75%. On that part where the selections were made, and this covered a large part of the field, not over 10% of the beets remained alive at the time the selection was made.

In making the selection only healthy beets completely surrounded by dead ones for considerable distance were chosen. These selected roots were stored in a pit silo until the spring of 1938.

As soon as conditions permitted 49 of the best of the selected roots were set out in an isolated location. Fourty-four of these produced seed. The seed of each individual root was harvested separately.

The spring of 1939 a mixture composed of aliquot parts of the seed of each of the individuals harvested in 1938 was planted. The field selected for this planting grew sugar beets in 1938. By harvest time that year, the crop was almost entirely destroyed by Rhizoctonia root-rot.

The planting was so planned that 3 plots of seed from the selected roots alternated with two plots of Great Western Home grown commercial seed. This arrangement gave 5 plats; Nos. 1, 3, and 5 planted with selected seed and 2 and 4 with G. W. Commercial-39.

There was no visible differences in the germination or thinned stands. Actual determinations of these stands were not made. Immediately after thinning beets began to die. This loss of plants continued throughout the season and was still in progress at the time the final observation was made which was just a few days before harvest.

The final observation was made by laying out a strip 100 ft. wide across the field at right angles to the rows. The number of living beets in 3 rows (300 ft. of row) was determined in each of the 5 plots.

Rhizoctonia had destroyed many plants in all plots so that at the time this observation was made the stands were 22.5% and 44.3%, respectively, for the plots planted with commercial and selected seed.

The number of plants in 300 ft. of row for each of the plots is given in the following table:

	Type of Seed				
	Select.	Commercial	Select.	Commercial	Select.
No. Plants	144	61	122	74	133

The mean for the selected seed was 133 living plants per 300 ft. of row and 67 for a corresponding length of row of the commercial seed. The selected seed had a stand nearly twice (198.5%) that of the beets grown from the commercial seed at harvest.

The commercial value of the selected strain was not determined. The principal object of the 1939 study was to learn if selections such as were made in 1937 would result in the segregation of strains tolerant or resistant to the summer form of Rhizoctonia root-rot.

The observations recorded above suggest the existence of Rhizoctonia resistant strains in our present commercial seeds and the possibility of developing such strains through the medium of selection.

Root-knot nematode resistance

During the growing seasons of 1937-38 and 39, 25791 beet fields were examined for sugar beet nematode. At the same time root-knot nematode infestations were noted and reported. It is probable that a small number of fields were examined more than once during the three years. However, this number would be so small that it may be ignored. Of the 25791 fields examined, 6.11% were found infested with root-knot nematode.

The total loss due to root-knot cannot be estimated. However, every year many fields are seriously damaged even to the point of a total loss. These losses are more or less confined to certain portions of Great Western Sugar Company territory. Because of this localization of the loss and the difficulty attending control by field practice and our inability to prevent the spread of this pest, it seems best to give some attention to the possibility of producing resistant or tolerant strains of sugar beets.

Steiner (5) distinguishes between host resistance to nematode attack and host tolerance. Plants that actually resist the entrance of nematodes, he considers resistant. Hosts that have the ability of developing with little signs of distress in spite of presence of root-knot galls, he calls tolerant.

If the plant breeder accepts Steiner's definitions of resistance and tolerance it is important that he know what plant characters are associated with resistance and tolerance.

Artzberger (1) has attempted to account for root-knot resistance by comparing the morphology of the roots of two resistant and two susceptible cow peas. The resistant varieties (Iron and Brabham) had roots that were better guarded by protective tissue than the two susceptible varieties (Whippoorwill and early Buff). In the resistant varieties the cork layer was better developed, had fewer broken areas and the cell walls were more suberized. The mechanical tissue was more uniformly distributed in the resistant varieties.

Barrons (2) defines root-knot resistance as "any perceptible ability on the part of a plant to grow in nematode-infested soil without the formation of root-knot galls". This conception entirely disregards Steiner's host tolerance and host resistance. He found that there was no significant difference in the rate of entry in the most resistant and susceptible plants in the seedling stage. He also observed that the root-knot galls on Henderson Bush Lima and Hopi 155 Lima beans were the same size in the seedling stage but that later they are much smaller on the roots of Hopi 155. He concludes that this indicates the development of some substance within the root of the variety that retarded the development of galls.

Nematologists seem to be agreed that the root-knot nematode feeds upon the contents of the giant cells which are apparently induced by salivary secretions of the nematode.

Barrons advances this speculative hypothesis, "that resistance may be due to certain chemicals within the roots of resistant plants that counteract or neutralize the giant-cell-inducing effect of the salivary secretions of the nematode".

Work of the Great Western Sugar Research Department began with a selection of seed from sugar beets grown in a field in Arizona. These plants were located in areas where all surrounding plants killed, or were so stunted by root-knot that practically no seed was produced. The seed thus selected was planted on a field so heavily infested with root-knot nematodes that two plantings of sugar beets were completely destroyed in 1938. Several commercial strains were also planted in this field.

The nematode infestation in 1939 was not nearly as severe as in 1938. It was also rather irregularly distributed which made it difficult to determine the effect, if any, of the selection on resistance.

Just before the field was harvested 4 plots each containing 66 ft. of row from the selected strain and each of the two adjoining commercial strains were selected at random, and the number of beets in each plot determined. Weights and sugar contents were not compared since they would be of no value in determining relative resistance to nematode in this instance.

The number of beets living at harvest was smaller in the case of both commercial strains than in the selected one by nearly 10%. An examination of the roots revealed the fact that certain individuals grew to good size and form even though surrounded by roots very seriously affected by root-knot. It is hardly probable that such roots were escapes. If they were not, then we must assume that they are either resistant or tolerant to root-knot.

Further study is necessary before it can be said that resistance or tolerance to root-knot nematodes exists in sugar beets.

Future Breeding Problems

Among future refinements in the breeding program of The Great Western Sugar Company are the following:

1. Further improvement in the purity of beets. Up to the present time we have made a gain of about 1.5 points in purity over foreign varieties. Careful analysis of our extraction figures at the factories shows that this increase in purity with the sugar content which accompanies it, means an additional recovery of about 7 lbs. more granulated per ton of beets, a goal well worth striving for. In years of severe leaf spot this increase in purity will be still greater because of the serious effect the disease has on purity of beets.

2. The introduction of more vigor and disease resistance into our present commercial varieties by means of genes coming from Beta maritima. This work is now far along and we already have hybrid varieties which are about equal to good commercial varieties. This phase of our work was discussed more fully in the Genetic Section of this meeting.

3. The possible development of a variety sufficiently flexible to meet all conditions of 80% or more of our acreage. This may or may not be attainable, but offers an interesting and exciting goal for any breeding program.

LITERATURE CITED

1. Artzberger, E. G.
A comparative morphological study of cow pea roots resistant and non-resistant to nematode infestation. Unpublished.

2. Barrons, Keith C.
Studies of the nature of root-knot resistance. Jour. Agr. Research 58:263-271, 1939.

3. Brewbaker, H. E. and McGreevy, B. F.
A critical study of family and group breeding methods for sugar beets. Proc. First Gen. Meeting of the A.S.S.B.T., Salt Lake City, Utah, 1938.

4. LeClerg, E. L.
Control of sugar beet leaf spot. Phytopathology 25:234-243, 1935.

5. Steiner, G.
The problem of host selection and host specialization of certain plant infesting nemas and its application in the study of nemic pests. Phytopathology 15:499-534, 1925.