Report of Indexing of Inbreds¹

Cooperative indexing of inbreds is one phase of a breeding program which sugar beet breeders are coming to recognize as inevitable if many essential or desirable characters are to be incorporated into any commercial variety in a reasonable length of time. This concept has become generally recognized. It follows the successful development of commercial varieties resistant to the two principal diseases in the United States—curly top and leaf spot—and coincides with the development of practical methods for testing certain other characters, and the acquisition of some new ones such as monogerm seed and male sterility.

The method of breeding by selection in inbred lines followed by hybridization for commercial release, so successfully used by the corn breeders, appears to be the only method adequate for the present sugar beet breeders' problem. Over a quarter of a century ago the corn breeders developed a coordinating agreement and organization $(3)^2$ which has been recently recognized by R. A. Crabb (1) as one of the principal reasons for the phenomenal success attained with hybrid corn.

Further significance has been given to the inbreeding method by R. A. Fisher (2) using a statistical approach in which he concludes: "—as the basis for future livestock and plant improvement there is required not a single inbred line, or a few only, but a deliberately planned multiplicity. The price paid for reliability of breeding behavior is the impoverishment of the genie content, due to the elimination of many genes. There need be no such impoverishment if many inbred lines are created simultaneously." Fisher cites as an example hybrid corn: "—in which thousands of inbred lines have been produced." He further states, "In species in which so far only a few inbred lines have become available, success has not been conspicuous."

Historical

A cooperative program supported by all interested parties for the development and testing of the required number of inbred lines and hybrids appears to be the only practical solution to the problem of handling the large volume of testing work involved in the development of commercial hybrid sugar beet varieties.

At the 1950 summer meeting of the Advisory Committee for the Curly Top Resistance Breeding Committee the need for cooperative effort on the problem of testing and indexing inbred lines for many characters was discussed. This was followed by a meeting at Beltsville, Maryland, February 1-3, 1951, of an informal so-called "Breeder's Forum" with Bion Tolman of the Utah-Idaho Sugar Company serving as chairman by action of the group. Mr. Tolman summarized the events and discussions at this meeting in a very comprehensive report. Several points were agreed upon and recommended, among these being:

¹ Report of committee meetings outlining and developing a program for indexing of inbreds. Numbers in parentheses refer to literature cited. 1. A definite cooperative program be set up for the indexing of inbred lines for many characters.

2. A summer meeting be held to visit the United States Department of Agriculture work at Fort Collins and such cooperative tests as possible.

3. That the "Breeder's Forum" be reconstituted as an industry-wide committee

4. Mr. Xolman was reelected to continue as temporary chairman for 1951 until such time as the committee might be reorganized.

Later developments included the acquisition of 50 inbred lines for cooperative indexing; specific plans for testing these at three locations, viz., Rocky Ford and Longmont, Colorado, and Sheridan, Wyoming; a definite date (September 10-13) for a summer meeting, and the assignment for coordination of these activities to H. E. Brewbaker.

The Beltsville meeting was attended by G. H. Coons, Dewey Stewart, J. S. McFarlane and Geo. Arceneaux (U.S.D.A.), H. L. Kohls (Michigan State Experiment Station), C. W. Doxtator (American Crystal Sugar Company), C. A. Lavis and Don Peterson (Holly Sugar Corporation), G. S. Rush (Amalgamated Sugar Company), Bion Tolman (Utah-Idaho Sugar Company), H. E. Brewbaker (Great Western Sugar Company) and Henk Rietberg of the Netherlands.

At the summer meeting thirty-three people attended, including representatives from U.S.D.A., 10; Farmers & Manufacturers Beet Sugar Association, 1; Colorado A & M College, 1; International Minerals & Chemicals Corporation, 2; Canada Sugar Factories, 1; Utah-Idaho Sugar Company, 2; Amalgamated Sugar Company, 1; Spreckels Sugar Company, 1; Holly Sugar Corporation, 3; American Crystal Sugar Company, 6; and the Great Western Sugar Company, 5. The group observed the testing plots at Rocky Ford and Longmont, Colorado. One day was spent looking over the U.S.D.A. plots at Fort Collins, Colorado.

Report of the Proceedings at the A.S.S.B.T. Meeting, Salt Lake City, February 4-7, 1952

Two sessions were held—the first being a panel discussion of the inbred indexing program, with particular reference to the principles involved, and the other an informal round table to discuss methods and future testing.

The members of the panel included C. W. Doxtator, D. F. Peterson, G. W. Deming, R. K. Oldemeyer (Secretary), H. L. Kohls, F. V. Owen, Lucile Hac and H. E. Brewbaker (Chairman).

Included in the cooperative studies with tests at three locations, as indicated above, were three inbreds from the U.S.D.A. Station at Salt Lake City contributed by F. V. Owen, 37 from the U.S.D.A. at Fort Collins, Colorado, by G. W. Deming, and 10 from the Michigan State Experiment Station by H. L. Kohls. The origin of these were discussed by the contributors with comments as follows:

F. V. Owen cited the use of the Connecticut method involving the lumping together of several good lines and selecting on a wide basis as a

possible method for securing large numbers of inbred lines. He also cited the use of the self-fertility (S^{f}) gene in inbreds to facilitate selfing.

G. W. Deming reported that about one-third of his lines were derived from "Flat Foliage" tracing to R 8c G numbers. Others were derived from Hilleshog, Cesena, Frederikson and red garden beet. A number of the lines are five to eight generations selfed. Selfing was accomplished by space isolation or bagging with no particular attention paid to the self fertility, S^1 gene. Seed for testing was produced by sib-pollination.

H. L. Kohls reported that his lines were up to seven generations selfed, and were inbred only to uniformity. In early work all roots were tested for sugar, this being eliminated in recent years. A number of lines stem from Dippe. The lines were increased by sib-pollination.

Field Tests

Field tests at Rocky Ford, Longmont and Sheridan were planned as triple-rectangular lattice designs with three replications, in plots four rows wide x 25 feet long. The field plan was identical for each test, the results being discussed respectively by C. W. Doxtator (Am. Gr. Sugar Co.), R. K. Oldemeyer (G.W.) and Don Peterson (Holly). Stands were very poor at Rocky Ford, the result of two heavy hail storms; fairly good to excellent at Longmont, and generally excellent at Sheridan. Soil fertility and cultural conditions were of good uniformity for each field, and there was no material amount of leaf spot or other serious complicating diseases at any of the locations. For these reasons these tests may be regarded as rather satisfactory as a basis for indexing this series of inbreds for a number of characters.

Table	1.—Correlation	Coefficients	Determined	from	Data	in	the	1951	Inbred	Indexing
Program.										

Characters	Longmont	Sheridan	Rocky Ford		
Na, Sugar	7568	6415	8160		
Na, Yleid	.2587	.0725			
Na, K	.5271	.4781	.1892		
K. Sugar	4748	5301	4588		
K, Yield	.3495	.1580			
Yield, Sugar		.1489			
Total N, Yield	1788				
Total N. Sugar	1561				
Total N, Na	.2799	5-65-65			
Total N. K	.2672				
Total N, Raffinose	1952				
Raffinose, Yield	.1587				
Raffinose, Sugar	5248				
Raffinose, Na	.\$679				
Raffinose, K	0185				
	Sheridan	Rocky Ford	Rocky Ford		
	Longmont-	Longmont-	Sheridau-		
Yield	.6722				
Sugar	.6922	.7918	.6489		
Na	.8033	.7821	.8712		
K.	.9094	.5674	.4123		
r for significance at 5%	point = .276				
r for significance at 1%	point = .358				

In addition to the sugar and vield tests at Longmont, Colorado, and Sheridan, Wyoming, sodium, potassium, nitrogen, raffinose and glutamic acid content were determined for each of the fifty lines. Respiration and storage rot resistance tests were also made. Extremely wide variations were noted for every character.

H. L. Bush (Great Western Sugar Co.) discussed the correlation coefficients he calculated from the data reported. The r values are reported in Table 1

The rather high positive r values existing between locations, if they continue to hold, may allow the reduction in number of tests, at least for vield and sugar content.

The glutamic acid determinations had not been made at the time of the meetings. Dr. Lucile Hac of International Minerals & Chemicals discussed briefly previous investigations involving 43 inbreds furnished by Deming. A complete report is given in this Proceedings. She pointed out the large variation between lines and the lack of correlation between percent of sucrose and G.A. In this connection, Dr. Coons (U.S.D.A.) reported U. S. 216 to be high in both G.A. and percent of sucrose. Dr. Hac noted that G.A. content may tell something about the amount of nitrogen available to the beet. Low sugar, high G.A. indicates too much nitrogen; high sugar, low weight and low G.A. indicate too little nitrogen.

Variability in inbred lines appears much greater for weight of root than for some chemical characters. "Climate" studies at Earhart Laboratories, California Tech., were cited as showing wide variability in size of root for certain inbreds used. Dr. R. K. Oldemeyer gave a theoretical explanation of this in which he pointed out how the segregating of one size gene might result in considerable variation in weight of root, and he ascribed obtained variability to 1. gene segregation in a below optimum gene complex, and/or 2. poor adaptability of inbreds to variations in environment.

Round Table on Methods and Further Tests

This meeting, held February 7, consisted of an informal discussion mainly of details in connection with further cooperative efforts on indexing.

Seed and Roots for Inbreds Tested in 1951

For any further testing, there was insufficient seed of some lines and ample seed of others as reported by the three suppliers—Owens, Kohls and Deming. Kohls has an ample supply. Roots were saved of all lines at Longmont and Sheridan. Some but not all of these will be increased as reported by Brewbaker and Peterson. Seed could be made available from these increases to others

Further Testing

Locations for field tests in 1952 were agreed on as follows:

- 1. Longmont, Colorado, Great Western Sugar Company
- 2. Sheridan, Wyoming, Holly Sugar Corporation 3. Idaho Falls, Idaho, Utah-Idaho Sugar Company



Figure 1.

Rocky Ford was not included for the 1952 tests because of rather great danger of leaf spot there, and the desire to have one test west of the Rockies. For other characters:

Bolting, Spreckels Sugar Company Rust, Spreckels Sugar Company Downey mildew, Spreckels Sugar Company Seedling damping-off, Colorado A & M College, N. Gerhold Seedling damping-off, Montana Experiment Station, M. M. Afanasiev Aphanomyces resistance, American Crystal Sugar Company Cold resistance—germination and seedling stage, Great Western Sugar Co. Curly top resistance, U.S.D.A., F. V. Owen Leaf spot resistance, U.S.D.A., J. Gaskill Male sterility indexing, supplier of inbred Sugar beet nematode, Henk Rietberg

For the 1952 tests, 53 inbred lines are available. Deming (U.S.D.A.) will supply 26, Kohls (Mich. State Exp. Sta.) 14, Great Western Sugar Co. 5, McFarlane (U.S.D.A.) 1, and Owen (U.S.D.A.) 7.

Policy Regarding Ownership of Inbreds and Basis for Interchange

Dr. Wadleigh (U.S.D.A.) proposed each contributor retain ownership, and that interchange be on the basis of mutual and individual agreement. Also, for inbred lines contributed from organizations supported by public funds, it was proposed that full credit be given in all publications. Credit for use of inbred lines contributed by companies shall be given in all scientific publications and in company publications, at the discretion of the company. This basis of agreement was generally acceptable.

Discussion-Various Characters

In answer to the question of whether all lines should be indexed for each character, Dr. Rietberg stated that they should be because some other-

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wise undesirable line may be outstanding for some other valuable character. Mrs. Savitsky stated that degree of self-fertility should be determined in

Mrs. Savitsky stated that degree of self-fertility should be determined in an area not conducive to pseudo-self fertility. Dr. Downie suggested finding locations conducive to pseudo-self fertility for bagging operations so that the S^f gene would not be necessary.

Male sterility indexing.—Dr. Owen suggests planting male steriles in increase plots to index for xxzz. Mr. Kohls felt that four or five roots were insufficient for this test.

Weight of tops.—Dr. Doxtator wants tops actually weighed, rather than a categorical estimate of "top vigor." Mr. Kohls was not interested in top weights.

Records

There was some discussion of the form which permanent indexing records should take. A difference of opinion exists re—actual versus categorical ratings for various characters. Both ratings were provided at the meeting which may continue to be desirable if after careful consideration this difference of opinion continues to exist.

In the meantime, some convenient and workable system of recording needs to be worked out so that all of the data (actual or categorical) can be briefly summarized for each line for efficient use by breeders. Can it take the form of ordinary file card (one per line), I.B.M. cards with a maximum of ease for sorting, "Visible" system equipment, ordinary summary pages, etc.? Here is an opportunity for some filing ingenuity, for such records can become extensive and unwieldly if, the system set up is inadequate for large numbers.

Such a recording system should provide space for a photograph, at least 2i/4 inches x 3i/4 inches in size, taken in the field to show eight to ten beets in front of an unharvested portion of each plot as, for example Figure 1.

Dr. H. E. Brewbaker was elected chairman for the 1952 season with Dr. C. W. Doxtator to be chairman pro-tem in absence of the chairman.

Yield, sugar percentage and chemical analysis summaries for the 1951 tests are available upon request from the Great Western Sugar Company, Agricultural Experiment Station, Longmont, Colorado.

Literature Cited

- CRABB, R. A. 1947. The Hybrid Corn Makers, Rutgers University Press, New Brunwick.
- FISHER, R. A. 1949. Theory of Inbreeding, Oliver & Boyd, London.
- (3) Report of Committee to Formulate a Cooperative Program of Corn Improvement under the Purnell Act. 1926. Jour. Amer. Soc. Agron. 18:823-829.