Cold Resistance in Sugar Beets

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The use of controlled low temperatures as a means of selection is not new to plant breeders; it is relatively new, however, in its application to the sugar beet.

In 1931 the junior writers[2], working in the U. S. Department of Agriculture at Fort Collins, Colorado, using outside temperatures during the winter months, found very striking differences in cold resistance between individual plants within a variety and also between inbred lines. (See Figure 1.)

Portable Refrigeration Equipment

Two alternates are available when one considers the manipulation and physical problem of handling plant material to be subjected to low temperature exposure: (a) the plants can be transported from their place of growth to a permanently constructed low temperature chamber, and (b) portable equipment may be devised which can be transported to the plants where they are growing. The writers chose the latter method as being more versatile and probably somewhat more adapted to the requirements to be met *in* working with the sugar beet crop. The portable type described below is more economical of construction than the permanent chamber: and while this particular model would not be adapted for use with a mature corn plant, it would be usable for treatment of all kinds of plants in the seedling stage and many kinds of plants in mature stages.

The refrigeration unit employed uses a 1/2 horsepower electric motor, air condenser, single phase compressor with seven-foot air gravity type cooling coils inside the refrigerator box. Power required is 110-volt alternating current; this requirement is met in the field by use of a portable gasoline-operated generator. About the only innovation from a standard refrigeration design is the introduction of a solenoid valve into the liquid coolant line between compressor and regular expansion valve. This additional valve is controlled by a remote bulb-type thermostat, the bulb of the thermostat being placed in a central location within the box. By means of this additional valve and thermostat combination we are able to control the temperature within a much narrower range than would otherwise be possible if we were to depend solely upon the expansion valve regulator. Temperatures are controllable within ± 3 degrees Fahrenheit at any temperature down to 0 degrees Fahrenheit. The rated capacity is in excess of 3,500 B.T.U. per hour with an outside temperature of 80° F. and box temperature 20° F. Insulation of the box consists of a three-inch layer of Fiberglas with a one-half inch layer of Celotex.

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[2] Brewbaker, H. E. Unpublished data, U. S. Department of Agriculture, 1932, 1933.

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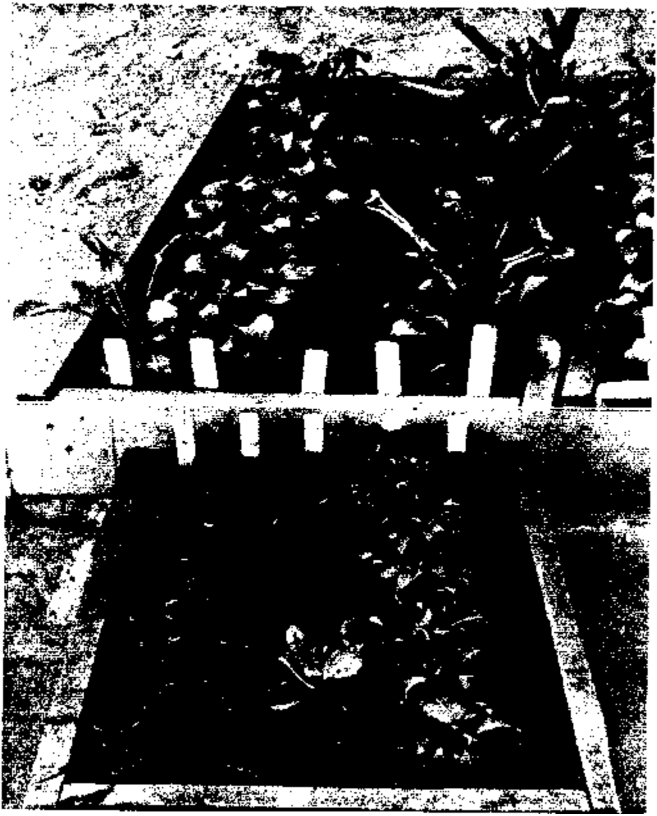

Figure 1. A (above). Seedlings in a flat before exposure to freezing temperature. B (below). Seedlings shown in A after freezing. Position of flat is the reverse of that shown in A.
(Experiments at Fort Collins by H. E. Brewbaker and H. L. Bush in 1931.)
Photo by U.S.D.A.

It is essential to have some movement of air within the box, otherwise local temperature fluctuations will occur. This is accomplished by use of an ordinary small squirrel-cage type of electric blower of 120 cubic feet per minute capacity. The introduction into the box of the small amount of heat from the fan motor is apparently advantageous in that it serves as a buffer to the more violent temperature fluctuation which would otherwise occur when the solenoid valve opens abruptly to admit refrigerant to the cooling coils. The rate at which temperature within the box can be reduced is dependent upon several factors: mass of material in the box, kind of material upon which the box rests (wet or dry soil, boards, cement or other) , each of which have a different rate of heat exchange, etc. Access to the box is gained by hoisting one end, material in flats or other containers is placed in position underneath, and the box is lowered. In the field the box is simply lowered over the material to be frozen. Inspection of material during freezing is limited to one port approximately 7 inches square. A port is also provided for insertion of instrument bulbs, fan cords, etc., and has a reasonably tight-closing rubber gasket.

Transportation in the field is accomplished by raising one end at a time and putting thereon an axle and wheels; by use of such a wheel arrangement and a small chain hoist jack, movement of the machine is accomplished rapidly and easily.

With the above equipment it is possible, on dry soil and with a normal load of eight flats, to reduce the temperature from 80° F. to 0° F in less than 4 hours and maintain it at that level. With flats precooled in the hardening room the desired low temperature is attained easily in 1 hour or less. For seedling studies, the clear space inside the refrigerator box, without the collar, will accommodate eight greenhouse flats at a time, the usual size of greenhouse fiats being about 15 by 20 inches. From our limited experience it appears to be important to hold down the plant population within the flat, thereby enhancing air circulation around each plant and preventing the formation of local areas in which the bunching of plants provides some protection to those within the clump. For studies of mature beet plants having much larger leaves, a "collar" or wall, insulated in the same manner as the box, will first be placed around the plants, then the refrigerator box placed thereon; the collar thus prevents mechanical injury to any of the leaves by raising the refrigerator unit above them.

Cold Resistance and Sucrose Content

Surviving plants from overwinter plantings at Windsor and Keenesburg, Colo., where winter killing was in excess of 99 percent, were grown to seed in 1937. Progeny testing from this selection was begun in 1940. One additional selection at Windsor on the basis of winter survival, and selection at Sterling under leafspot *(Cercospora beticola)* exposure, was given this material. It became evident in variety tests conducted in the years 1940 to 1943 that sugar content for the resulting selections GW201 and GW72 had been improved when compared with the parental variety GW25, the yielding ability remaining unchanged.

In order to obtain a comparative performance of GW25 with the two selections, GW201 and its sister line GW72, over a longer period, it is necessary to compare through a standard variety since the parent was discontinued in test after 1943. For this purpose, the long-time standard GW18 was chosen and a comparison of its sugar content and yield with that of GW25 over a three-year period is given in Table 1.

Table 1.—Comparison of Variety GW25 with Standard GWI8, Longmont, Colo., Scottsbluff, Nebr., and Lovell, Wyo.—1939, 1940, and 1943.

	1943			1940	1939	
Variety	Longmont	Scottsbluff	Lovell	Longmont	Longmont	Mean
Tons Beets per Acre						
GW25	18.04	20.55	17.67	26.26	18.04	20.11
GW18	17.93	21.67	17.88	25.82	17.53	20.17
LSD 5% pt.	1.31	1.97	1.90	.56	1.11	.66
% Sugar						
GW25	16.18	13.85	17.63	11.94	14.84	14.89
GW18	16.45	13.90	17.33	12.15	14.74	14.91
LSD 5% pt.	.50	.67	.70	.34	.62	.26

With such a close record of performance over a three-state area, it appears quite certain that GW18 is essentially equivalent in performance to GW25. The comparison of sugar content of varieties GW201 and GW72 with standard GW18 is given as the result of 20 varietal evaluation tests over the seven-year period 1940-46, inclusive, and represents data from beet-growing areas in Montana, Wyoming, Colorado, and Nebraska under widely diverse environmental conditions. The data are presented in Table 2.

Table 2.—Comparison of percent sucrose of GW72 and GW201 with GW18 (Standard)

Variety	1940	1941	1942	1943	1944	1945	1946
GW72			14.84	16.89	17.43	15.73	14.25
GW18			14.26	16.31	16.74	15.09	13.83
LSD 5% pr.			.31	.28	.36	.27	.34
GW201	14.48	15.27	14.18	15.58	17.24	15.45	14.31
GW18	13.88	14.79	13.72	15.06	16.73	15-09	13.83
LSD 5% pt.	.12	.29	.35	.35	.36	.27	.34

The increase in sugar content in GW201 and GW72 over GW18 is equally apparent at high levels of fertility and production as at average or low levels; likewise does this hold true for high and low levels of sugar content. It has long been recognized that beets growing at higher altitudes and in more northerly latitudes are generally richer in sugar. Notable in the evidence given in Table 2 was the fact that at Hysham, Mont., and Lovell, Wyo., where higher sugar content is customary, the superiority in sugar content of GW72 over GW18 is still significant.

While the evidence for increased sugar content in GW201 and GW72 as a result of mere selection for winter hardiness is rather convincing, there is some contradiction in a similar mass selection made from GW59. Some 80 non-injured stecklings were transplanted in the spring of 1943 from a fall-planted field of this variety. C233, which resulted from a direct increase of this selection, showed no improvement in either yield or sugar content as compared with the original variety. Results are presented in Table 3.

Table 3.—Comparison of Variety C233 with Parent GW59

	Tons Beets		Percent Sugar	
	Longmont	Ft. Morgan	Longmont	Ft. Morgan
C233	21.69	26.82	12.13	13.13
GW59	21.49	27.46	12.42	13.09
LSD 5% pt.			.89	.95

The experience of Lund[3] in Denmark corroborates the evidence given above for GW201 and GW72. The possibility of employing cold resistance as a means of obtaining an increased sugar content without loss of yield would, however, appear to have definite limitations, or at least require further demonstration, as indicated by the results obtained with GW59.

Selection for Cold Resistance

The survival of a few plants under conditions of severe winter injury indicates selection for cold resistance within varieties. Lund[4] found considerable variation between plants in cold resistance in the material with which he was working; however, his principal objective is to increase cold resistance in order to reduce winter killing in overwinter planting for seed. He reports some survival, after proper conditioning, down to temperatures of 12 degrees to 14 degrees Fahrenheit. In northern Colorado and elsewhere it is known that plantings for production of seed by the overwinter method may survive outside temperatures considerably below zero with very moderate losses.

The possibilities for selection were explored in a cooperative study at the University of Wyoming at Laramie in March, 1949, using low temperature equipment located at that institution. Twelve varieties with 3 replicates each, hardened off with a series of cold shocks and subjected to a temperature of approximately 12 to 14° F., showed a variation in percentage killed over a range of 43 percent to 72 percent of the total population. This preliminary work helped materially in the development of techniques necessary to the proper use of low temperatures for selection work.

Frost Resistance in Mature Beets

No actual data from planned experiments on frost resistance of mature beets is yet available; however, a sudden drop in temperature in the fall of 1948 was sufficient to show differences in varietal reaction in variety tests planted at Fort Morgan, Colo., and Gering, Nebr. This drop in temperature at Fort Morgan was to a low of 24° F. on October 7 followed by 5 days of minimum temperatures ranging from 25° to 31° F. At Gering the minimum temperature on October 10 was 26° F.; on October 11, 19° F.; and again on October 12, 19° F. In both cases there was very little possibility of hardening off. Categorical ratings of foliage injury on a basis of 0 — none to 10 = destroyed were made at each of the above locations. The averages of these readings on 9 replicates of each of 36 varieties at Gering ranged from 2.9 for variety B389 to 7.9 for variety GW64; at Fort Morgan from 3.3 for variety C381 to 7.0 for variety GW159. In general the varieties showed a very similar

[3] Lund, Viggo. Private communication.
[4] See footnote 3.

reaction to frost at each of the two locations. The correlation coefficient (r) between percent sugar and frost injury at Fort Morgan was —.79 and at Gering it was —.80, both values being highly significant.

Inasmuch as many of the varieties in the above two tests had a previous history of selection for resistance to leafspot *(Cercospora beticola)* it is pertinent to compare the reaction to leafspot with reaction to frost. Categorical ratings of leafspot were taken as 0 = none to 10 = destroyed. Where these leafspot readings were correlated with those of frost injury, the r value at Fort Morgan was .77 and when leafspot at Fort Morgan was correlated with frost injury at Gering (no leafspot encountered at Gering), the *r* value was .59, both values very significant. In both tests there was evidence of adequate variation within most varieties to permit good selection for cold resistance in mature plants. The period just prior to harvest is generally the period of most rapid accumulation of sugar, and continued effective metabolism at this stage is extremely profitable.

Germination of Beet Seed at Low Temperatures

Resistance to frost injury in the seedling stage poses the question of how early seed might be planted in the spring with the expectation of getting safe germination and emergence. Preliminary studies of 16 varieties germinated at temperatures of 35 degrees to 37 degrees gave germination percentages from .7 percent to as much as 38 percent, demonstrating that there exist rather broad differences between varieties with respect to ability to germinate at low temperatures.

Summary

Preliminary evidence has been accumulated which indicates that (a) sufficient genetic variability exists between and within lines of sugar beets to permit selection for the character of cold resistance in both seedling and mature plants; (b) results presented are suggestive of sufficient genetic relationship between frost resistance and sugar content to enable one to make improvement for both characters by selection for cold resistance alone; and (c) differences exist between varieties with respect to ability of their seed to germinate at low temperatures.