The Influence of Antecedent Climates Upon the Subsequent Growth and Development of the Sugar Beet Plant

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The main factors that are known to influence the growth and development of the sugar beet plant are its genetic composition, climatic environment, nutritional status, and the prevalence of diseases and pests. Of these, the effect of climate upon the beet plant has been the least studied. This deficiency in our knowledge of the specific effects of climate upon the growth of the sugar beet plant has evolved from a lack of suitable facilities for growing plants in simulated climates. Most of our information concerning sugar beets has been obtained through chance observations under field conditions, in which good growth was correlated with favorable temperatures and light conditions, and by relating poor growth with frosts and excessively high temperatures, cloudy weather, high wind velocities or low rainfall.

When the Phytotron at the California Institute of Technology, Pasadena, California, was completed in 1949 under the direction of F. W. Went (5)[2], experiments pertaining to the effects of light, day length, night and day temperatures became readily possible. The results of these experiments have been reported earlier (3, 4). Since then, other studies have been completed in the Pasadena facilities. One of these has been a comparison of the effects of climatic sequences upon the beet plant, such as a "cold spring" followed by a "mild" or a "hot summer," as contrasted with a "mild" or even "hot spring" followed by a "mild" or "cold summer." The results of these and other climatic sequences, as they affect top and beet root growth and the sucrose content of the beet root, are reported in this paper.

Methods and Materials

On May 14, 1952, seeds of the sugar beet variety U.S. 22/3, treated with Phygon XL (1 gram per 100 grams of seed), were planted at the rate of 10 seedballs per pot into vermiculite No. 2 at a depth of ¾ inch. A modified Hoagland nutrient solution (2) was added immediately after planting and at daily intervals thereafter for the duration of the experiment. The pots used were standard metal containers 10 inches in diameter and 12 inches deep having a sanitary lacquer lining on the inside and painted with aluminum on the outside. Drainage was provided by means of four small holes at the bottom of the containers. All 108 pots were filled by adding, in rotation, small amounts of vermiculite. When the pots were filled, they were watered, tamped lightly by dropping the pots vertically on the floor, refilled and tamped again until no further settling took place.

The pots were distributed to a total of 27 trucks, with 4 pots per truck. The trucks were divided into 3 groups with 9 trucks per group. Each group was placed prior to planting into its initial climatic condition. These conditions were:

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[2] Numbers in parentheses refer to literature cited.

	"Day temperature" 8:00 a.m. to 4:00 p.m.	"Night temperature" 4:00 p.m. to 8:00 a.m.
Cold	17° C. (63° F.)	12° C. (54° F.)
Mild	23° C. (73° F.)	17° C. (63° F.)
Hot	30° C. (86° F.)	22° C. (72° F.)

All plants were subjected to natural daylight and natural day lengths under greenhouse conditions of the Phytotron, California Institute of Technology, Pasadena, California.

The seedlings emerged on May 19, in the mild and hot climates, and on the following day in the cold climate. On May 29 the plants in the mild and hot climates were in the 2-3 leaf stage. These were thinned to one seedling per seedball. Two weeks later, on June 12, the mild and hot climate plants (6-7 leaf stage) were thinned to four seedlings per pot. On this date the plants in the cold climate were in the 4-leaf stage and were thinned to one seedling per seedball. The final thinning to two plants per pot for the mild and hot climate plants (12-leaf stage) was done on June 24. The cold climate plants (9-leaf stage) were thinned on this day to four plants per pot and on the following day to two plants per pot.

In order to equalize the effects of position on plant growth within a climate, the trucks were re-randomized at weekly intervals. Also, at weekly intervals, old leaf and new leaf counts were made. The plants were allowed to grow in their initial climate for a period of 56 days, May 14 to July 9, 1952. On July 9, the plants were placed into their final climatic conditions. Of the 9 trucks originally in a given initial climate, 3 trucks were allowed to remain in the initial climate and the other 6 trucks were divided into 2 groups of 3 trucks each, and then placed into the two remaining climates. Thus, in any one final climate, there were 3 trucks which were there originally and 3 trucks from each of the other two initial climates.

The plants were subjected to the final climatic condition until September 22, 1952 (75 days), at which time the plants were harvested. During the harvest, each plant was separated as follows: (a) Blades of recently matured leaves; (b) other living blades more than one inch wide; (c) petioles of recently matured leaves; (d) unclassified material (petioles, immature leaves and tip of stem); and (e) root. The tops were cut off at the point of the oldest remaining living leaf. The beet roots were trimmed slightly to remove the remaining dead petiole tissue.

Sucrose samples consisting of 26.0 grams of beet pulp were taken from the combined storage roots for each pot and placed in glass jars, then immediately frozen with dry ice. Sucrose was determined in duplicate, using a saccharimeter and the hot extraction method of Browne and Zerban (1).

The temperatures of the three rooms were recorded automatically by a 16 point Brown temperature recorder.

Results

Beet root weights: The beet root weights were influenced greatly by the cold, mild and hot climates of the initial and final growth periods (Tables 1 and 2). The effects of the initial climate were noticeable even

Table 1.—Summary of F-values and Error Variances of Beet Plants in Relation to Initial (I) and Final (F) Climates.

Source of Variation	D.F.	Required F-values		Observed F-values Relative to Error *a*								
				Beet Roots			Tops			Living leaves		
				Fresh	Sucrose		Fresh	Dry	Old leaves dry wt.		Blades fresh	Blades as % of
		5%	1%	gm	%	gm	gm	gm	gm	Number	gm	total tops
Treatments	8	2.51	3.71	6.73	40.53	7.97	17.83	21.42	7.70	13.13	20.25	10.65
Climate (I)	(2)	3.55	6.01	7.26	1.41	7.86	13.60	7.20	2.57	1.87	3.84	10.73
Climate (F)	(2)	3.55	6.01	19.51	158.60	22.92	52.74	71.84	27.60	49.54	75.41	22.70
I x F	(4)	2.93	4.58	0.08	1.06	0.25	2.50	3.32	0.32	0.57	0.87	1.58
Error *a*[1]	18			12,991	0.866	127.29	18,110	172.29	58.95	99	1601	25.75
Error *b*[2]	81	2.00	2.71	31,786	0.568	333.84	31,820	324.39	136.85	95	3889	17.95

[1] Error *a* is the variance between trucks of the same treatment.

[2] Error *b* is the variance between pots within a truck. Error *b* significance is relative to error *a*.

Table 2.—Beet Root Weights in Grams per Pot.[1]

Initial Climate May 14-July 9 (56 Days)	Final Climate July 9-Sept. 22 (75 Days) Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	Initial Climate Mean
Cold	300	432	274	335
Mild	395	522	388	435
Hot	356	510	347	404
Final climate mean	350	488	337	

[1] Significant differences within climates are 98 and 134, and between climates 56 and 77, at the 5% and 1% levels, respectively.

though the initial growth period of 56 days was followed by a final period of 75 days in another climate. The observed F-value for the final 75-day period, as expected, was much larger than the F-value for the initial period of 56 days (Table 1). The low F-value observed for the interaction of the two growth periods implies that the climatic effects were strictly additive and were not dependent upon the climate that preceded or followed a given climate. Whether there would have been a significant interaction had the temperatures been lower so as to induce flowering, or higher initially or finally so as to alter still more the metabolism of the plant, is a point worthy of further study.

The effects of the initial climate on storage root growth may be observed from the storage root weights of the plants initially in the cold, mild or hot climate, regardless of the final climate (Table 2). The plants initially in the cold climate averaged 335 grams and this is significantly less than the 435 and 404 grams for the plants originally in the mild and hot climates. The average root weights for the final climates, regardless of initial climate, were 350, 488, and 337 grams per pot for the cold, mild, and hot climates, respectively (Table 2). Since these weights differ much more than those for the initial climates, this accounts for the F-value being larger for the final than for the initial climate (Table 1).

The results presented in Table 2 also indicate that the cold climate plants made very poor root growth when the plants were retained in the cold climate (300 grams) or when comparable plants were transferred to a hot climate (274 grams). When the cold climate plants were moved to the mild climate, a distinct improvement in growth took place (432 grams). The best root growth, however, was made by the plants continuously in the mild climate. These roots weighed 522 grams per pot. When comparable plants of the mild climate were moved to the cold or hot climates, the root weights were 395 grams and 388 grams per pot, respectively. Plants continuously in the hot climate had roots that weighed 347 grams, but when moved to the mild or cold climates these weighed 510 and 356 grams per pot, respectively. Thus, root growth was favored whenever the plants were kept continuously or even partly in a mild climate.

Sucrose concentration: The sucrose concentrations of the roots were not influenced by the initial climate under which the plants had been grown. This is shown by the lack of significance of the initial climate F-values, Table 1, and by the uniformity of the initial climate means presented in Table 3. There was, however, a tremendous effect of the final climate upon

Table 3.—Percent Sucrose[1]

Initial Climate	Final Climate July 9-Sept. 22 (75 Days)			Initial Climate Mean
May 14-July 9 (56 Days)	Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	
Cold	11.45	8.72	7.49	9.22
Mild	12.00	8.70	7.98	9.56
Hot	11.40	9.08	8.07	9.52
Final climate mean	11.62	8.84	7.85	

[1] Significant differences within climates are 0.80 and 1.09 and between climates 0.46 and 0.63 at the 5% and 1% levels, respectively.

the sucrose concentration of the beet roots. The plants in the cold climate had an average sucrose concentration of 11.62%, in the mild climate 8.84%, and in the hot climate 7.85%. These findings are in accord with those reported earlier, that is, low temperatures are conducive to sucrose accumulation and high temperatures tend to depress the sucrose concentration of the storage root (3, 4). Again the interaction of initial and final climate was not significant (Table 1).

The finding that the sucrose concentration of the root is independent of the antecedent climate has a practical implication, especially if the time required to effect a change during the final growth period is rather brief. Thus, if it is found that it takes only two weeks to change the sucrose concentration of beets from 7.85% in a hot climate to that of 11.62% in a cold climate, then the proper climatic measurements made prior to harvest may offer a clue as to the trends that are to take place in the sucrose concentrations of the beets as the season progresses. An integrated value of the climatic measurements could then serve as a guide to the harvesting of sugar beets, assuming some leeway as to the time of harvesting the crop in a given district.

Sucrose stored: An inspection of the results presented in Tables 1 and 4 indicates rather clearly that the initial period of 56 days had a pronounced effect upon the sucrose stored in the root. The effect of the final period of 75 days was even greater than that of the initial growth period. The F-value for interaction was again not significant and this indicates that the initial and final climate effects were additive and not dependent upon each other. The largest amounts of sugar were stored in the plants that

Table 4.—Sucrose in Grams per Pot.[1]

Initial Cimate	Final Climate July 9-Sept. 22 (75 Days)			Initial Climate Mean
May 14-July 9 (56 Days)	Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	
Cold	34.4	38.2	20.5	31.0
Mild	47.3	46.0	31.6	41.6
Hot	41.4	46.2	28.4	38.7
Final climate mean	41.0	43.5	26.8	

[1] Significant differences within the table at the 5% and 1% levels are equal to 9.7 and 13.3 and between climate means 5.6 and 7.7, respectively.

had been grown in the cold and mild climates during the final 75 day growth period (Table 4). The plants that ended their growth period in the hot climate were exceedingly low in sugar stored. This was the result of the combined effects of low sucrose concentrations (Table 3) and smaller beet root sizes (Table 2). The small amount of sugar stored in the plants kept continuously in the cold climate (34.4 grams per pot) was primarily a matter of slower root growth and not of lower sucrose concentration. Of special interest is the observation that the plants initially in the hot climate and then transferred either to a cold or intermediate climate were not materially altered in sugar stored (Table 4). Apparently early hot weather is not nearly so detrimental as hot weather late in the season.

Table 5.—Fresh Weight of Tops in Grams per Pot[1]

Initial Climate	Final Climate July 9-Sept. 22 (75 Days)			Initial Climate Mean
May 14-July 9 (56 Days)	Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	
Cold	752	656	356	588
Mild	594	642	329	522
Hot	456	531	284	424
Final climate mean	600	610	323	

[1] Significant differences within climates are 115 and 158, and between climates 67 and 91 at the 5% and 1% levels, respectively.

Fresh weight of tops: The results presented in Tables 1 and 5 indicate that there was not only a large effect of the final climate on top growth, but that the initial climate influenced the top weights greatly. The largest effect of the initial climate on top weight may be seen in the plants which were transferred from the hot to the cold climate. Here the top weights increased from 284 grams per pot to 456 grams, as compared to 752 grams per pot for plants continuously in the cold climate (Table 5). The largest effect of the final climate may be seen for the cold climate plants moved to a hot climate. These plants decreased in top weight from 752 grams to 356 grams per pot, a value which is only slightly better than the 284 grams per pot for plants continuously in the hot climate. During cold weather the tops remain green and the leaves tend to accumulate without dying, whereas hot weather occurring either early or late in the growing season is obviously detrimental to top growth.

Table 6.—Dry Weight of Tops in Grams per Pot.[1]

Initial Climate	Final Climate July 9-Sept. 22 (75 Days)			Initial Climate Mean
May 14-July 9 (56 Days)	Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	
Cold	78.4	51.5	29.4	53.1
Mild	65.6	52.9	28.6	49.0
Hot	51.1	46.9	26.7	41.6
Final climate mean	65.1	50.4	28.2	

[1] Significant differences within climates are 11.3 and 15.4, and between climates 6.5 and 8.9, at the 5% and 1% levels, respectively.

Dry weight of the tops: The dry weights of the tops (Table 6) are quite similar to the corresponding fresh weights (Table 5). The effects of both the initial and final climates are highly significant. The F-value for the interaction of the initial and final climate exceeds the 5% level of significance, instead of being somewhat short of significance as observed for the fresh weights of the tops (Table 1). A careful inspection of the dry weights of the tops (Table 6) indicates that this interaction has arisen primarily because the plants initially in the hot climate failed to recover fully when placed in the cold climate. The tops of these plants weighed only 51.1 grams in comparison to the 78.4 grams for the plants continuously in the cold climate. At the same time the plants initially in the cold climate, when placed in the hot climate, weighed only 29.4 grams. This compares with the 26.7 grams for the plants continuously in the hot climate. Thus, by moving the plants from the hot to the cold climate the tops nearly doubled in weight, whereas by moving the plants from the cold climate to the hot climate, the tops weighed only one-third of those in the cold climate. Apparently, the recovery of plants from the effects of a hot climate takes place more slowly than injury to tops when the plants are moved from a cold to a hot climate.

Table 7.—Fresh Weight of Blades in Grams per Pot.[1]

Initial Climate	Final Climate July 9-Sept. 22 (75 Days)			Initial Climate Mean
May 14-July 9 (56 Days)	Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	
Cold	222	189	105	172
Mild	230	177	97	168
Hot	188	159	95	147
Final climate mean	213	175	99	

[1] Significant differences within the table at the 5% and 1% levels are equal to 34.3 and 47.0 and between climate means, 19.8 and 27.1, respectively.

Fresh weight of blades: The fresh weight of the blades is also closely related to the fresh weight of the tops, except that the initial climate had a very much smaller effect upon the blades (Tables 1 and 7) than upon the fresh or dry weights of the tops (Tables 1 and 5). This indicates that, if one is seeking an attribute of the beet plant which is closely associated with climate, weighing leaf blades would be a better measure of the effect than weighing the entire tops of the plants.

Table 8.—Blades as Percent of Total Weight of Top (Fresh Basis).[1]

Initial Climate	Final Climate July 9-Sept. 22 (75 Days)			Initial Climate Mean
May 14-July 9 (56 Days)	Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	
Cold	30.0	29.1	29.4	29.5
Mild	38.6	27.7	29.4	31.9
Hot	41.4	30.0	33.7	35.0
Final climate mean	36.7	28.9	30.9	

[1] Significant differences within climates are 4.4 and 6.0, and between climates 2.5 and 3.4 at the 5% and 1% levels, respectively.

Blades as percent of total tops: The values for the fresh weight of the blades expressed as percent of the total fresh weight of the tops are presented in Tables 1 and 8. The F-values reported in Table 1 indicate that the interaction of the effects of initial and final climates is highly significant, as are the main effects of the initial and final climates. The main effects, however, may be the result of the interaction rather than due to the specific effects of climate upon this percentage. This may be seen in Table 8 where the largest increase in the percentage of blades to total tops took place in the plants in the cold climate from July 9 to September 22, 1952. These percentages increased gradually from 30.0 for the plants continuously in the cold climate to 38.6 and 41.4 for the plants initially in the mild and hot climates, respectively. All other percentages are approximately the same as for the plants continuously in the cold climate, namely, 30.0 percent. Other than this effect of cold climate on the blade to top ratio there seems to be no consistent pattern of this ratio to growth or to sucrose concentration.

Dry weight of old leaves: The F-values tabulated in Table 1 indicate that the dying of old leaves is more closely associated with the final climate than with the initial climate. Interesting too, is the fact that the highest weight of old leaves is to be found for the plants in a hot climate (Table 9), which is just the converse of that found for the fresh tops (Table 5), or for the dry tops exclusive of the old leaves (Table 6). The increase in old leaf formation is another indication that the sugar beet plant grows better in a mild climate, or even in a relatively cold climate, than in a hot climate.

Table 9.—Dry Weight of Old Leaves in Grams per Pot.[1]

Initial Climate	Final Climate July 9-Sept. 22 (75 Days)			Initial Climate Mean
May 14-July 9 (56 Days)	Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	
Cold	25.6	36.4	39.6	33.9
Mild	29.0	40.7	41.3	37.0
Hot	31.2	38.8	43.1	37.7
Final climate mean	28.6	38.6	41.3	

[1] Significant differences within climates are 6.6 and 9.0, and between climates 3.8 and 5.2, at the 5% and 1% levels, respectively.

Kind and number of leaves formed: The sugar beet plants that were grown in the cold, mild, and hot climates differed tremendously in outward appearance. Both the blade and petiole tissues of the leaves of plants in the cold climate were a dark green color. The blades were generally broad and rounded in shape and the petioles relatively short and thick in structure. In sharp contrast to this sturdy appearance of the leaves of the beet plants in the cold climate, the blades of the plants in the hot climate were pale green and the petioles a pale yellow color to almost white. The blades of these leaves were long and narrow with the outer edges of many curled upward. The corresponding petioles were long, brittle, and narrow in structure. Intermediate to the leaves in the cold and hot climates were those of the plants in the mild climate. The leaves of these plants were similar to those found in many sugar beet areas during midseason and were characterized as being exceedingly vigorous by all observers familiar with the culture of the sugar beet plant.

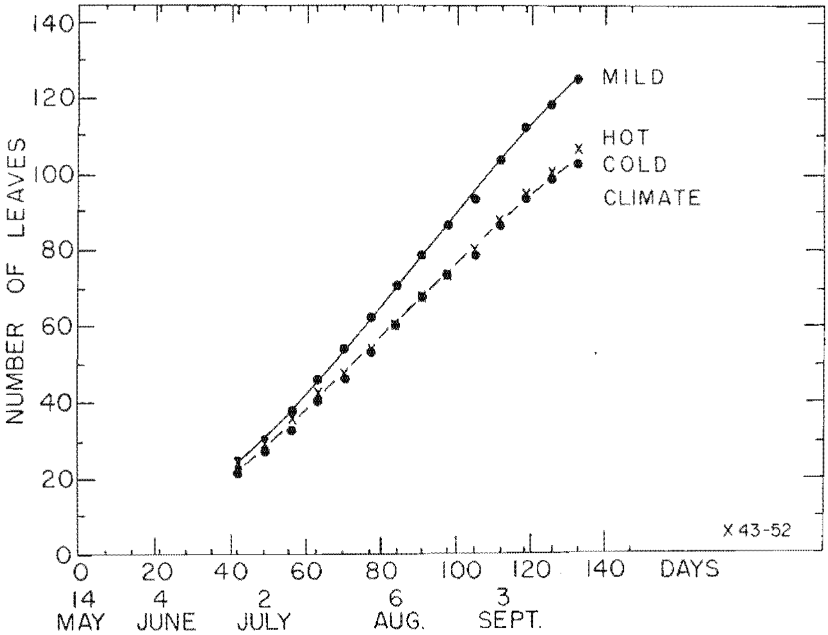

Figure 1.—Total number of leaves produced in relation to time by sugar beet plants continuously in a cold, mild (temperate) or hot climate. The leaf counts are on a pot basis of two plants per pot, using 12 pots per climate.

Table 10.—Number of Living Leaves per Pot at Harvest.[1]

Initial Climate May 14-July 9 (56 Days)	Final Climate July 9-Sept. 22 (75 Days) Cold 63-54° F.	Mild 73-63° F.	Hot 86-72° F.	Initial Climate Mean
Cold	67.8	64.8	43.5	58.7
Mild	67.4	71.1	50.8	63.1
Hot	65.9	67.1	47.1	60.0
Final climate mean	67.1	67.6	47.1	

[1] Significant differences within climates are 8.5 and 11.7, and between climates 4.9 and 6.7 at the 5% and 1% levels, respectively.

Even though there were tremendous differences in the kind of leaf developed by the beet plants in the cold, mild, and hot climates, there was very little difference in the total number of leaves formed by the beet plants in these climates (Figure 1). There was also no effect of the initial climate upon the number of living leaves present at time of harvest (Table 1) nor was there any interaction of the initial and final climates on the number of living leaves for these plants. Even though the differences in the number of living leaves relative to the final climate were highly significant statistically, the differences in actual numbers were not large at the time of harvest (Table 10), nor during the growing periods of the plants in the different climates (Figures 2, 3, 4). A study of these figures reveals that the number of living leaves in the cold climate (Figure 2) tends to increase gradually, whereas those in the mild climate (Figure 3) may or may not reach a plateau, depending most likely upon the amount of light prevailing during growth. The number of living leaves for the plants in the hot climate reached a definite plateau by August 20, 1952 (Figure 4). In all climates there was a decrease in the number of living leaves starting August 20 (Figures 2, 3, and 4), but this decrease was relatively minor for the plants in the cold and hot climates (Figures 2 and 4). Three weeks later, the number of living leaves for the plants in the mild climate increased again (Figure 3), whereas those in the hot climate remained constant (Figure 4). As would be expected there was an increase in the number of old leaves removed from the plants during this period, but three weeks later the rate returned to normal for all climates (Figures 2, 3, 4). Since the same individual counted and removed the leaves during the entire experiment, this would suggest that an external factor, such as a decrease in light intensity (temperature, nutrition and watering were constant) must account for the increased death rate of the leaves. Unfortunately light measurements were not made at the time and this possibility cannot be confirmed or disproved. The plants were entirely free of diseases and insects, and therefore these factors cannot account for the increased death rate of the leaves in all three climates. Leaf formation, it is interesting to note, was not affected (Figure 1).

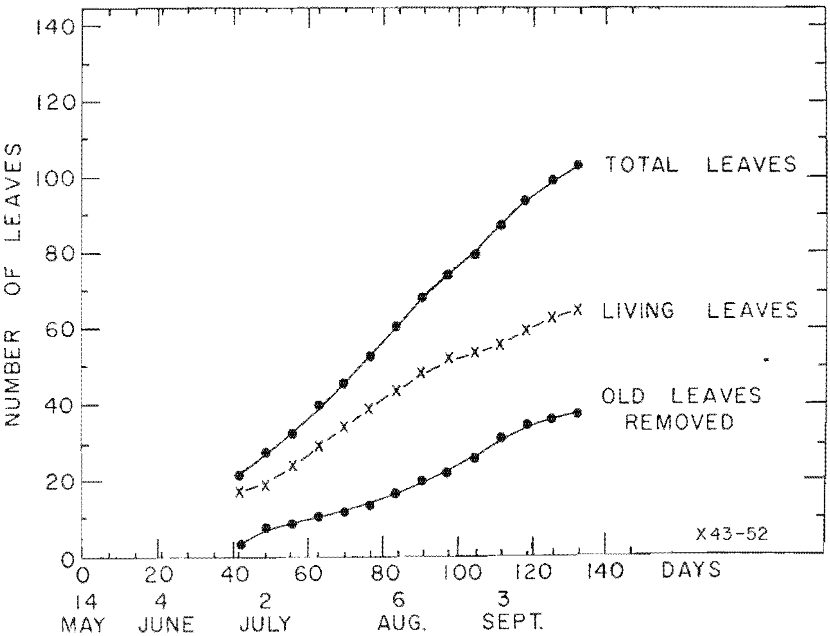

Figure 2.—Relation of time to the total number of leaves formed, the number of leaves living, and the number of old leaves removed from sugar beet plants in a "cold climate" (63° F., 8 a.m. to 4 p.m. and 54° F., 4 p.m. to 8 a.m.). The leaf counts are for two plants per pot, using 12 pots per climate.

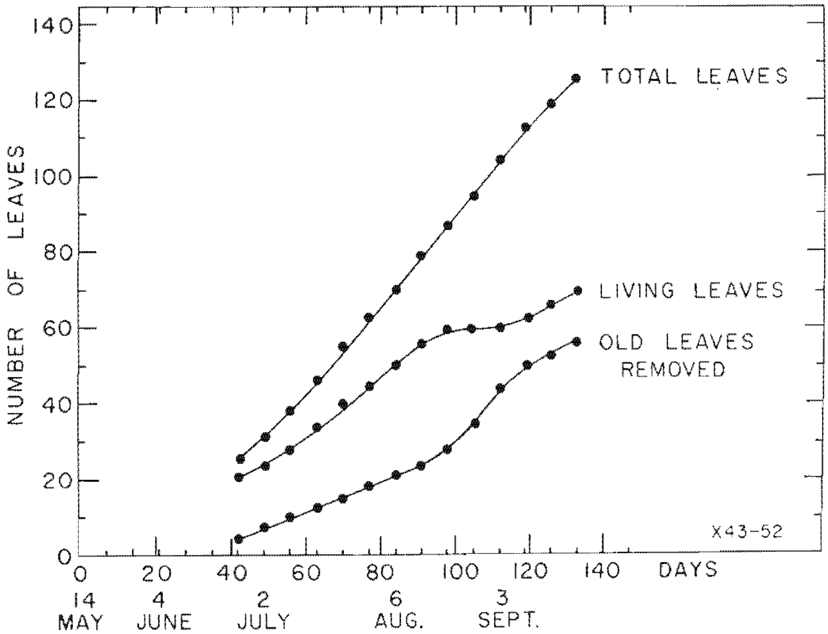

Figure 3.—Relation of time to the total number of leaves formed, the number of leaves living, and the number of old leaves removed from sugar beet plants in a "mild climate" (73° F., 8 a.m. to 4 p.m. and 63° F., 4 p.m. to 8 a.m.). The leaf counts are for two plants per pot, using 12 pots per climate.

Life expectancy of sugar beet leaves: The life expectancy of a sugar beet leaf can be estimated graphically by drawing a line parallel to the abscissa from the old leaf curve to that of the curve for the total leaves formed (Figures 2, 3, and 4). By dropping a line perpendicular to the abscissa from the points of intersection of the two curves, the distance as measured between the two perpendicular lines is the average age of the leaf at the time of death (removal from the plant). When the plants were 126 days old (next to the last point on the curve for the "old leaves removed"), the average age of the leaves before death was 67 days for the plants in the "cold climate," 58 days for the plants in the "mild climate," and only 44 days for the plants in the "hot climate." Thus, while plants grow more slowly in the cold climate, the leaves live much longer and remain functional for a longer time than the leaves in the "mild" or "hot" climates. The shorter life expectancy, and therefore the much smaller tops of the plants in the "hot climate," may be another reason for the smaller beet root growth and the lower sugar concentrations of the beet plants in the "hot climate" in comparison to the plants in the "mild climate." Low temperatures, in contrast to moderate temperatures, retard growth (Table 2) but in terms of sugar produced (Table 4), the smaller beet root size at low temperatures is only partly compensated for by the higher sucrose concentrations of the "cold climate" beet roots (Table 3).

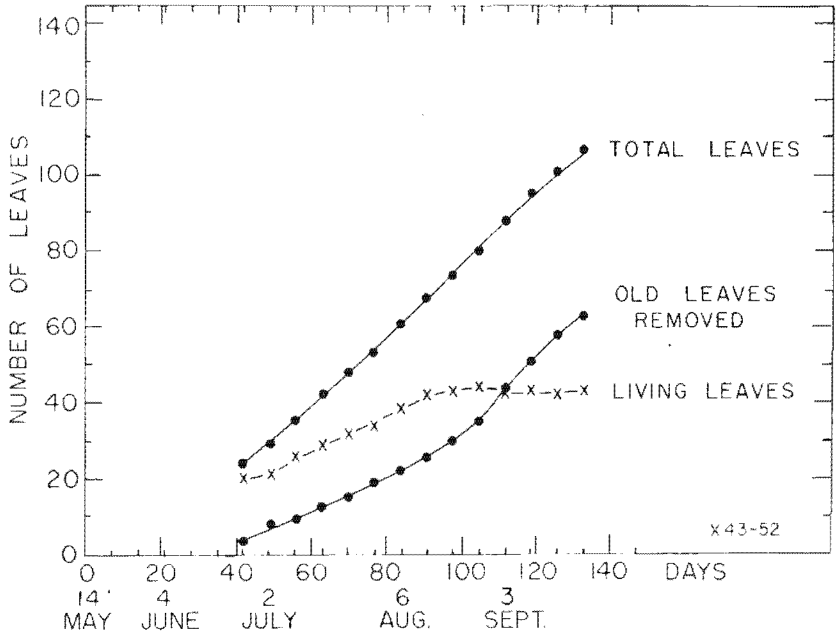

Figure 4.—Relation of time to the total number of leaves formed, the number of leaves living, and the number of old leaves removed from sugar beet plants in a "hot climate" (86° F., 8 a.m. to 4 p.m. and 72° F., 4 p.m. to 8 a.m.). The leaf counts are for two plants per pot, using 12 pots per climate.

Summary

Sugar beet plants of the variety U. S. 22/3 were grown by the open pot culture technique, using vermiculite as the solid medium, and a complete nutrient solution added daily in excess as the liquid medium. Nine sets of plants (three per climate) were germinated and grown in vermiculite for the first 56 days in a controlled temperature greenhouse simulating either a cold, mild or hot climate. After 56 days, one set of the three was retained in the original climate and the two sets remaining were exchanged for plants in the other two climates. These plants were then grown for another period of 75 days.

The climatic sequences produced the following effects:

(a) Beet root growth was influenced by the initial climate and still more by the final climate. A mild (temperate) climate was conducive to root growth whether this occurred early or late in the growing season. A hot or a cold climate, occurring at either time, reduced growth.

(b) Sucrose concentrations were influenced primarily by the final climate. No initial climate effects were detectable. Climatic measurements (temperature, light) made prior to harvest should anticipate the sucrose concentration of the crop. A cold climate was found conducive to high sucrose concentrations and a hot climate to low sucrose concentrations.

(c) The sucrose stored by the beet root reflected the combined effects of climate on root size and sucrose concentration. Temperate weather was conducive to sucrose storage, whether this occurred early or late in the growing season. Cold weather was conducive to sugar storage, providing it was associated with temperate weather. Early hot weather was not nearly so detrimental as hot weather late in the season.

(d) The tops of the sugar beet plants remained green and tended to increase in size during cold weather. During hot weather the tops decreased in size, whether the hot weather occurred early or late in the growing season. Blade weights, however, were affected primarily by the final climate. Hot weather during the final growth period was found to be detrimental to blade growth. Old leaf formation (dead leaves) was in accord with these findings.

(e) The ratio of blades to total top weight, on the fresh weight basis, was the highest for plants transferred to the cold climate from either the mild or hot climates. No other combinations of climate differed significantly.

(f) The leaves of sugar beet plants in a cold climate were characterized by a dark green color and by short, stocky petioles and by broad, thick blades. The blades of plants in a hot climate were a pale green color and were long and narrow in shape, with the outer edges of the blades curled upward. The petioles of these leaves were a pale yellow to almost white in color and were long, narrow, and brittle in structure. A change in climate was followed by a change in kind of leaf formed. The new leaves formed assumed the appearance characteristic of the new climate regardless of the original climate.

(g) The rate of new leaf formation was not affected by climate nearly as much as leaf appearance or the number of living leaves present at any one time. In a cold climate, the living leaves gradually increased in number so that they exceeded greatly the number of living leaves of plants in a hot climate. The life span of a sugar beet leaf in a cold, mild or hot climate was approximately 67, 58 or 44 days, respectively.

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