Growth and Development of Open-pollinated, Hybrid and Inbred Sugar Beet Varieties in Controlled Climates[1]

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Agronomists and geneticists are often interested in improving crops by selecting better varieties from those already existing or from those being developed by plant breeding. Ordinarily, measurements of variety performance are obtained by conducting field trials for one or more years in a single locality or in widely separated areas. If the investigator is fortunate enough to draw a representative sample of climates for the area during the trials, a valid conclusion regarding the merits of each variety can be drawn. However, the desired climates with the proper sequences of light, temperature and rainfall do not occur in nature upon command, and consequently the advantages or disadvantages of certain varieties may not be discovered until the variety has been used in commercial plantings for some time.

The logical solution to the problem is to grow the varieties in preselected controlled climates (10)[3] in which moisture supply and nutrient level can be predetermined and controlled. The results of such an experiment, performed as part of a uniformity trial with eight sugar beet varieties in six climates, are reported in the present paper.

Procedure

The eight sugar beet varieties and the six climates used, as well as the procedure followed *in* these experiments, except for leaf counts, blade weights and plant heights, have been reported in a previous paper (9). Leaf counts and blade weights (Tables 6 and 7) were obtained by counting and weighing all immature leaf blades larger than $^1/_2$ inch in width, all mature blades and all the old leaves having blades with 50 percent or more green tissue. Leaf blades with less than 50 percent green tissue were counted as dead leaves, added to the residue material, and weighed as part of the total dry matter of the tops. The heights of the sugar beet plants were determined by measuring the length of the tallest leaf on each plant in a pot, and the results were averaged for the two plants of the pot.

Results

Sucrose weights

The sucrose weights of the beet plants differed greatly for each variety grown in the different climates and between the varieties grown within a climate (Table 1). The major increases, regardless of the variety used, occurred in the climates with the long days. Increasing the photoperiod from eight hours to natural day length (10.6 to 14.3 hours) approximately trebled the sucrose produced by most of the varieties studied (Treatment 1 versus 2 and Treatment 4 versus 5), while an increase in the day tempera-

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[3] Numbers in parentheses refer to literature cited.

ture from 20° C. to 26° C., keeping the night temperature at 20° C. (Treatments 3 and 5), resulted in no significant change in sucrose production. Maintaining the day temperatures at 20° C. (Treatment 3) or 26° C. (Treatment 6) and lowering the night temperatures to 14° C. (Treatment 2) and 20° C. (Treatment 5), also failed to change the average amount of sucrose produced by the eight varieties in eight hours of sunlight. Only by lowering the day and night temperatures simultaneously, as in Treatment 2, were the sucrose yields increased; this may be seen by comparing Treatments 2 and 6 (Table 1). These observations, made primarily at day and night temperatures favorable to beet growth, agree closely with those made in earlier experiments (8).

Table 1.—Sucrose in Grams per Pot (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	U.S. 22/3	G.W. 304	9148	6148	H148	CT9 Inbred	U.S. 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	54.4	76.8	33.4	58.1	69.6	15.6	60.1	39.9	48.5
20° C	14° C (Dark)	19.4	31.9	10.3	11.9	25.2	5.6	28.6	15.8	18.6
20° C	20° C (Dark)	19.9	34.1	12.4	10.7	14.6	5.7	12.5	14.1	15.7
26° C	20° C (NL)[2]	58.5	72.9	31.6	48.2	62.3	11.7	64.1	34.3	48.0
26° C	20° C (Dark)	16.9	31.1	8.9	14.8	15.9	5.6	12.6	12.1	14.7
26° C	26° C (Dark)	13.3	18.2	7.5	13.5	6.5	3.9	18.3	12.4	11.7
Observed F-value[3]		5.56	15.99	11.62	16.99	27.13	8.06	20.12	12.18	96.88
Significant difference[4]		21.4	18.2	10.3	15.3	15.3	4.8	15.6	10.5	4.9
Mean (24 pots)[5]		27.3	44.2	17.4	26.2	32.4	8.0	32.7	21.5	....
Mean as % of maximum		62	100	39	59	73	18	74	49	....
Rank		4	1	7	5	3	8	2	6	..

[1] NL = natural day length at Pasadena, California, which increased gradually from 10.6 hours at the time of planting on February 2 to 11.9 hours when the plants were placed in the different climates on March 15 to 14.3 hours when the plants were harvested on June 5, 1951.
[2] Required F-values at the 5 percent and 1 percent levels are 2.77 and 4.25, respectively, for a given variety and 2.28 and 3.15, respectively, for the eight varieties (mean effect of climate).
[3] At the 5 percent level.
[4] A difference of 7.5 grams is necessary for significance between variety means at the 5 percent level.

[1] NL = natural day length at Pasadena, California, which increased gradually from 10.6 hours at the time of planting on February 2 to 11.9 hours when the plants were placed in the different climates on March 13 to 14.3 hours when the plants were harvested on June 5, 1951.
[2] Required F-values at the 5 percent and 1 percent levels are 2.77 and 4.25, respectively, for a given variety and 2-28 and 3.15, respectively, for the eight varieties (mean effect of climate).
[3] At the 5 percent level.
[4] A difference of 7.5 grams is necessary for significance between variety means at the 5 percent level.

In comparing the sucrose productions of the eight varieties of beets, the open-pollinated and hybrid varieties, as expected, produced more sucrose than the inbred varieties. Within each varietal group there were further interesting differences, as for example between the two commercial varieties, U. S. 22/3 and G. W. 304. At a day temperature of 20° C, natural day length (treatment 1), the G. W. 304 variety produced more than twice as much sucrose as the U. S. 22/3 variety while, at a day temperature of 26° C, natural day length (treatment 4), the difference between the two varieties was less, although more sucrose was still produced by G. W. 304. In an 8-hour day, the G. W. 304 variety at all day or night temperatures again produced more sucrose than the U. S. 22/3 variety. Using the mean value of the 24 pots of the G. W. 304 variety *in* the six climates as 100 percent, the U. S. 22/3 variety has a relative sucrose yield of only 62 percent. Thus, the G. W. 304 variety has a wider climatic range and a higher overall sucrose production than the U. S. *22/3* variety and therefore should be the preferable variety to use from two inbred varieties like 9148 and U. S. 35 MS x CT9 should produce a field

the same amount of sucrose in all six climates, except in the 8-hour photoperiod and constant day and night temperature of 26° C. Under these conditions HI48 produced about $^1/_3$ of the sucrose of the U. S. 35 MS x CT9 hybrid.

A statistical analysis of the sucrose produced by the eight varieties in the six climates showed that the effects of climate and the differences between the varieties were highly significant (Table 10). The interaction between varieties and climates was also highly significant, indicating that some or all varieties did not respond equally to each climate. This was especially true in the comparison of the U. S. 22/3 to G. W. 304 (Table 1), in which there were significant decreases in sucrose production in U. S. 22/3 in Treatment 1 compared to Treatment 4, but not in G. W. 304. However, separate statistical analyses of the varieties in which the variety-climate interaction

Table 2.—Beet Root Weights in Grams of Fresh Material (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Hol. land Inbred	Mean effect of climate
20° C	14° C (NL)[1]	394	742	375	616	768	159	572	356	498
20° C	14° C (Dark)	205	345	155	148	330	61	289	149	210
20° C	20° C (Dark)	236	431	172	162	204	68	141	145	195
26° C	20° C (NL)[1]	590	700	357	480	645	117	635	315	480
26° C	20° C (Dark)	208	379	129	208	223	64	151	133	187
26° C	26° C (Dark)	201	214	103	161	99	49	234	138	150
Observed F-value[2]		6.68	12.11	9.17	20.46	33.65	7.00	18.30	11.98	96.23
Significant difference[3]		181	178	117	132	137	48	148	87	45
Mean (24 pots)[1]		306	468	215	296	378	87	337	206	....
Mean as % of maximum		65	100	46	63	81	19	72	44	....
Rank		4	1	6	5	2	8	3	7	....

[1] [2] For explanation, see Table 1.
[3] A difference of 52 grams is necessary for significance between variety means at the 5 percent level.

aappeared the largest (Table 1, U. S. 22/3 versus G. W. 304 and male parent 148 versus HI48) failed to disclose a significant interaction of variety and climate. A reasonable explanation for the lack of significance of the interactions of several of the paired comparisons seems to be that the larger F-value required for significance masked the interactions that actually existed between the paired varieties in two climates.

Of the four inbred varieties (Table 1), the male parent of HI48 produced the most sucrose in all six climates, but this was still only 59 percent of that produced by G. W. 304. Next is the Holland Inbred variety with a relative value of 49 percent, third is the female parent of HI48 with a relative value of 39 percent, and a poor fourth is CT9 Inbred with a relative value of 18 percent. Within the four inbred varieties it is interesting that the relative differences in sucrose production were maintained in all six climates except for minor deviations by some inbred, indicating that there is no pronounced interaction between variety and climate as indicated by the G. W. 304 and U. S. 22/3 varieties.

Beet root weights

The beet root weights of the eight varieties in the six climates are given in Table 2. In general, the results of the beet root weights parallel those of the sucrose weights even so far as to place each variety in the same rank, except for a few minor changes. Again, a pooled analysis of variance of the eight varieties in the six climates showed a highly significant variety-climate interaction (Table 10). Separate statistical analyses of paired varieties, particularly U. S. 22/3 and G. W. 304, again failed to show a significant variety-climate interaction even though the beet root weight in U. S. 22/3, but not in G. W. 304, was significantly less in Treatment 1 than in Treatment 4 (Table 2). Similarly, the H148 variety in Treatment 6 weighed significantly less than in Treatment 5, but this was not true

Table 3.—Sucrose as Percent of Fresh Root Weight (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 55 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL.)[1]	8.6	10.4	8.9	9.2	9.0	9.7	10.5	11.2	9.71
20° C	14° C (Dark)	9.3	9.2	6.7	8.0	7.7	8.7	10.9	10.4	8.77
20° C	20° C (Dark)	8.9	7.9	6.5	6.6	7.0	8.1	8.7	9.7	7.92
26° C	20° C (NL.)[1]	9.7	10.4	8.9	10.0	9.5	9.9	10.0	10.9	9.93
26° C	20° C (Dark)	7.9	7.9	6.9	8.0	6.9	8.6	8.0	9.1	7.95
26° C	26° C (Dark)	6.8	8.5	7.3	8.4	6.6	7.6	7.9	9.0	7.78
Observed F-value[2]		8.80	6.06	7.90	6.68	8.97	2.95	6.70	6.92	36.31
Significant difference[3]		1.57	1.36	1.15	1.36	1.21	1.54	1.29	1.03	0.44
Mean (24 pots)[4]		8.5	9.1	7.6	8.4	7.8	8.8	9.2	10.0	
Mean as % of maximum		85	91	76	84	78	88	92	100	.....
Rank		5	3	8	6	7	4	2	1	...

[1] [2] [3] For explanation, see Table 1.

[4] A difference of 16 percent is necessary for significance between variety means at the 5 percent level.

for the U. S. 22/3 variety, where the weights were about the same. Thus, as far as beet root weights are concerned, H148 produces larger storage roots than U. S. 22/3 (Treatment 1) when grown in cool climates with a long day, while in warm climates with a short day (Treatment 6) U. S. 22/3 does better than H148.

Regardless of the variety used, the largest change in beet root weight, just as in the sucrose weights, was produced by an increase in day length. Increasing the day temperature from 20° C. to 26° C. (Treatments 3 and 5) had no significant effect on beet root weight, which is contrary to an earlier report (8). The failure to show a significant change in beet root weight with day temperature change is most likely due to the shorter growth period of these plants, 123 days compared to 180 days in the earlier experiments (8). Apparently, longer periods of growth are necessary to show significant differences in root weight for small differences *in* temperature.

Sucrose percentages

The average sucrose concentration of each variety in each climate is given in Table 3. These values differ considerably between varieties and to a lesser extent between climates in any given variety. The highest average

sucrose concentration, 10.0 percent, was found in the Holland Inbred variety, and the lowest value, 7.6 percent, in the female parent of HI48. Arranging the varieties according to sucrose concentration and comparing this order to that found for beet root and sucrose weights brings out a relationship often observed in sugar beets; namely, high beet root weights —low sucrose concentration, and low beet root weights—high sucrose concentration. An apparent exception to this rule is G. W. 304, which ranks first in beet root and sucrose weights and almost second in sucrose concentration.

The effects of climate on the sucrose concentration of beet roots of the eight varieties (Table 3) agree closely with those reported earlier (8). In every instance but one the sucrose concentration of the beet roots is

Table 4.—Tops of Fresh Weight in Grams Per Pot at Harvest, June 5, 1951 (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	1085	1277	1178	932	1382	444	1156	1096	1062
20° C	14° C (Dark)	726	1077	786	624	886	254	864	545	719
20° C	20° C (Dark)	820	1016	1015	848	1065	298	653	699	801
26° C	20° C (NL)[1]	881	1079	897	947	895	286	985	763	841
26° C	20° C (Dark)	605	875	667	716	846	253	520	604	636
26° C	26° C (Dark)	543	559	561	597	458	156	540	419	479
Observed F-value[2]		5.11	4.40	3.64	3.12	8.39	5.90	11.89	9.43	38.52
Significant difference[3]		260	345	352	258	294	115	222	225	89
Mean (24 pots)[4]		775	980	850	777	915	281	786	688	..
Mean as % of maximum		79	100	87	79	93	29	80	70	.
Rank		6	1	3	5	2	8	4	7	....

[1] [2] [3] For explanation, see Table 1.
[4] A difference of 103 grams is necessary for significance between variety means at the 5 percent level.

higher in plants grown at a natural day length than in only eight hours of sunlight (Treatments 1 and 2 and Treatments 4 and 5). For plants at 20° C. during the day and 14° C. during the night (Treatments 1 and 2), the longer day in Treatment 1 increased the average sucrose concentration of the roots by one percentage unit and in comparable plants at 26° C. during the day and 20° C. at night (Treatments 4 and 5) the average increase was two percentage units. Apparently at 26° C. (Treatments 4 and 5) the longer day was more effective in increasing sucrose concentration than at the lower temperature (Treatments 1 and 2).

In natural day length (Treatments 1 and 4) the effect of temperature on sucrose concentration in these experiments was not significant. Of the plants grown in eight-hour photoperiods, the ones in the higher temperatures had lower sucrose concentrations in all eight varieties in Treatments 3 and 2, and five out of eight varieties in Treatments 6 and 5 (Table 3). On the average this caused a significant decrease of 0.85 percentage units in Treatment 3 compared to two, and a nonsignificant decrease of 0.17 percentage units in Treatment 6 compared to five. Apparently in shorter days, when less sucrose is synthesized, relatively small temperature changes may have at times a greater effect on sucrose concentration than

in natural day periods (comparing Treatments 2, 3, 5 and 6 with Treatments 1 and 4).

Fresh weight of tops

The fresh weight of the tops of each variety in the six climates at the time of harvest on June 5, 1951, is given in Table 4. Again, the plants which were grown in natural day lengths made the largest top growth. As a rule, the relative increases in top growth in the longer day periods were about the same as the sucrose percentages (Table 3) but not nearly as great as the gains in beet root weights (Table 2) or in sucrose stored in the roots (Table 1). Apparently, top growth is influenced less by day length than beet root growth or sucrose storage. This agrees with observations reported earlier (8).

Table 5.—Tops as Dry Weight in Grams Per Pot of All Leaves Produced (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	GT9 Inbred	US 35 MS x GT9	Hal-land Inbred	Mean effect of climate
20° C	14° C (NL)[1]	115	159	132	135	166	49	124	130	126.2
20° C	14° C (Dark)	80	121	83	69	106	30	92	71	81.4
20° C	20° C (Dark)	99	131	109	94	101	34	73	87	91.1
26° C	20° C (NL)[1]	123	171	125	148	156	38	138	117	127.1
26° C	20° C (Dark)	88	126	85	107	119	31	68	91	89.4
26° C	26° C (Dark)	72	102	79	88	87	23	76	71	74.9
Observed F-value[2]		8.79	4.72	2.98	13.51	10.10	5.05	10.84	7.57	43.51
Significant difference[3]		30	35	40	24	30	12	26	36	9.6
Mean (24 pots)[4]		96	135	102	107	122	34	95	95	....
Mean as % of maximum		71	100	76	79	90	25	70	70	....
Rank		5	1	4	3	2	8	6	7	.....

[1] [2] [3] For explanation, see Table 1.

[4] A difference of 11 grams is necessary for significance between variety means at the 5 percent level.

The temperature at which the beet plants are grown is also important for top growth. Generally, top growth is less at very high and very low temperatures (8). In these experiments the deleterious effects of high temperatures are particularly noticeable in the plants grown in natural day lengths at day temperatures 26° C. compared to 20° C. (Treatments 1 and 4) and for plants in 8 hours of sunlight at a constant temperature of 26° C. (Treatment 6) compared to 20° C. (Treatment 3).

The fresh weight of the tops (Table 4) of the different varieties agrees rather closely with the amounts of beet root (Table 2) and of sucrose (Table 3) produced by each variety. Particularly interesting is the decrease in range in the tops compared to the roots. The lowest value of the tops, when expressed as percent of the maximum, is 29 percent, and for beet roots the comparable value is 19 percent. The major change in the rank of the varieties was made by U. S. 22/3, which dropped from fourth position in beet root weight to sixth position in fresh weight of the tops. In spite of this decrease in rank U. S. 22/3 still produced 79 percent of the

maximum top growth produced by variety G. W. 304, while in beet root weight U. S. 22/3 ranked fourth but produced only 65 percent of the maximum root weight produced by G. W. 304. Usually there is a direct relationship between top growth and beet root growth; namely, large tops indicate large storage roots. However, large tops do not always produce large roots, as shown by the fact that in the seven highest yields from the eight varieties the range in top weight is only 70 percent to 100 percent of the maximum, while in the seven highest beet root yields the comparable range is 44 percent to 100 percent, showing that there is no simple relationship between top growth and amount of root developed.

Dry weight of tops

The total dry matter produced by the tops during the entire growth period of the plants (Table 5) agrees with their fresh weight, so the interpretation of the results is the same as given for the fresh weight of the tops.

Table 6.—Fresh Weight of Living Blades in Grams Per Pot (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	313	485	370	350	431	123	303	281	332
20° C	14° C (Dark)	227	359	251	194	312	78	231	165	227
20° C	20° C (Dark)	248	356	345	276	328	96	172	209	254
26° C	20° C (NL)[1]	286	359	324	354	342	89	284	219	282
26° C	20° C (Dark)	184	305	247	257	281	80	138	160	207
26° C	26° C (Dark)	163	224	233	240	182	58	175	131	176
Observed F-value[2]		2.71	4.65	2.72	9.23	6.18	2.88	11.53	5.84	30.29
Significant difference[3]		105	118	105	62	97	38	58	66	28.4
Mean (24 pots)[4]		237	348	295	279	313	88	217	194	.....
Mean as % of maximum		68	100	85	80	90	25	62	56	.....
Rank		5	1	3	4	2	8	6	7	.....

[1 2 3] For explanation, see Table 1.
[4] A difference of 33 grams is necessary for significance between variety means at the 5 percent level.

Fresh weight of the living blades

The fresh weights of the living blades (Table 6) produced by each variety in each of the six climates agrees closely with the fresh and dry weights of the tops, but these values are again related only in a general way to the beet root weights. Perhaps an integrated value of the living blade material produced during the entire growth period of the sugar beet plants, instead of the final fresh weight of the blades, may be more closely related to the beet root weights. The testing of this idea, however, must wait for future studies.

Number of living blades

The number of living blades at the time of harvest (Table 7) was influenced by the climate in which the plants were grown. The greatest number of living leaves was found in plants which grew in a cool climate with natural day length. Significant decreases in leaf counts were observed in plants in 8 hours of sunlight, particularly in the plants kept at a temperature of 26° C.

Of the eight varieties studied the Holland Inbred, which ranked seventh in fresh weight of the tops and beet root weight, had the greatest number of living leaves. In contrast to this, the G. W. 304 variety, which ranked first in top and root weight, was fifth in the number of leaves living at the time the beets were harvested. At first glance this may indicate an inverse relationship between the number of leaves found and top growth, but this idea is contradicted by the HI48 variety, which ranks second in the number of living leaves, beet root weight and fresh weight of the tops.

Total number of leaves produced

The total number of leaves produced by the sugar beet plants, surprisingly enough, was about the same in all climates (Table 8). The lowest number of leaves was produced in the warmest climate (Treatment 6), which was an average of 92.2 leaves in all varieties. In the other climates the averages, which fell between 99.2 and 104.1, were not significantly different from each other.

The total numbers of leaves produced by the varieties, while significantly different in some instances, did not differ greatly from each other. The CT9 Inbred variety produced the lowest number of leaves, 76.2, and the HI48 variety the highest number of leaves, 111.5, showing that the total

Table 7.—Number of Living Blades Per Pot at Harvest, June 5, 1951 (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	HI48	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	72	73	73	69	83	55	76	88	73.6
20° C	14° C (Dark)	68	65	57	58	69	49	63	77	64.4
20° C	20° C (Dark)	62	58	60	60	69	39	54	65	58.3
26° C	20° C (NL)[1]	71	65	68	56	68	39	55	71	61.5
26° C	20° C (Dark)	56	59	54	54	55	40	47	57	52.6
26° C	25° C (Dark)	45	39	45	41	41	27	33	44	39.6
Observed F-value[2]		4.88	2.72	3.44	8.94	12.22	6.89	20.50	12.60	50.00
Significant difference[3]		13.6	20.7	16.9	8.9	12.1	10.8	9.2	13.0	4.6
Mean (24 pots)[4]		62	60	61	56	64	41	55	67	....
Mean as % of maximum		93	90	91	84	96	61	82	100	....
Rank		3	5	4	6	2	8	7	1	....

[1 2 3] For explanation, see Table 1.

[4] A difference of 5.3 leaves is necessary for significance between variety means at the 5 percent level.

number of leaves produced by a beet plant is not by itself a good indicator of the relative growth of the plants. However, the difference between the total number of leaves produced and those living when the plants are harvested is a measure of the life expectancy of an individual leaf of a given variety in a specific climate. From this viewpoint the average life expectancy is considerably greater for leaves of plants grown in cool climates with long days, while the shortest life span is of leaves in the warmest climate in an 8-hour day.

Height of plants

The heights of the sugar beet plants at the time of harvest June 5, 1951, are given in Table 9. The results of these measurements show that the average height of the plants in any given variety of beets was not altered greatly by growing the plants in the controlled climates. The F-values (Table 9), when calculated from an analysis of variance of each variety of beets in the six climates, was significant for only the CT9 Inbred and Holland Inbred, even though the mean effect of climate on the plant heights was highly significant (Tables 9 and 10). A further inspection of the mean effect of climate on heights of the plants shows that long days were conducive to tall leaves (Table 9). The plants with the shortest leaves were those grown with 8 hours of sunlight at a temperature of 20° C. during the day and 14° C. during the night (Treatment 2). The next shortest plants were those grown in 8 hours of sunlight at a constant temperature of 26° C. (Treatment 6). Just what factors are involved in determining leaf heights in the controlled climates is not clear at present and must be left to future experiments.

In a review of the plant heights of the different beet varieties the shortest plants were the CT9 Inbred, while the tallest plants were the G. W. 304 variety. This agrees with the relative growth of the two varieties (Tables 1, 2, 4, 5, 6). A further review of the heights of the other varieties

Table 8.—Total Number of Leaves Produced, Old Plus Living, Larger Than 1/2 Inch in Width (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 M5 x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	101	100	102	104	117	84	104	117	103.4
20° C	14° C (Dark)	103	99	98	95	109	81	95	116	99.2
20° C	20° C (Dark)	110	104	97	106	112	69	90	105	99.2
26° C	20° C (NL)[1]	113	106	106	101	119	76	98	115	104.1
26° C	20° C (Dark)	107	112	94	110	107	78	93	108	100.8
26° C	26° C (Dark)	98	92	96	85	105	69	86	96	92.2
Observed F-value[2]		1.63	0.59	0.49	1.82	1.29	1.04	1.98	2.83	4.46
Significant difference[3]		(13)	(27)	(19)	(41)	(15)	(13)	(13)	14	5.7
Mean (24 pots)[4]		106	102	98	102	112	76	94	109	...
Mean as % of maximum		95	92	88	92	100	69	85	98	...
Rank		3	4	6	5	1	8	7	2	....

[1] [2] For explanation, see Table 1.

[3] At the 5 percent level. Figures in parentheses indicate that the F-values are not significant.

[4] A difference of 6.6 leaves is necessary for significance between variety means at the 5 percent level.

clearly indicates, however, that there are many exceptions to this observation, so height measurements alone are not very reliable for measuring the relative growth of a given variety of beets in different climates or for comparing the performance of different varieties of beet plants within one or more climates.

Discussion

The growth of the eight sugar beet varieties in the six climates is interesting in regard to the relative performances of the varieties in the different climates, particularly the U. S. 22/3 and G. W. 304 varieties. The results for the U. S. 22/3 and G. W. 304 varieties indicate that the G. W. 304 variety produces on the average much more sucrose and beet root growth than the U. S. 22/3. A further inspection of the results shows that the best performance of the G. W. 304 variety in the six climates is mainly in the cool climate, natural day length (Tables 1 and 2, Treatment 1). When the plants were grown in a warm climate, natural day length, the performance of U. S. 22/3 improved but did not quite equal the G. W. 304 variety (Tables 1 and 2, Treatment 4). When the plants were grown in 8 hours of sunlight at 26° C. the G. W. 304 variety grew relatively less than the U. S. 22/3 variety. Under these conditions U. S. 22/3 is about equal to G. W. 304 (Table 2, Treatment 6). From the practical standpoint, variety trials conducted in cool climates would undoubtedly favor the G. W. 304 variety while similar variety trials in warm climates would show no preference for either variety. Susceptibility to diseases and pests, which, of course, would favor U. S. 22/3 in California because of its resistance to curly top, and G. W. 304 in the mountain states, has not been considered in this discussion.

Table 9.—Height of Plants in CM. (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	HI48	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	53	58	51	51	53	47	57	56	53.1
20° C	14° C (Dark)	48	54	44	44	46	36	53	48	45.8
20° C	20° C (Dark)	55	61	51	50	50	42	52	57	52.5
26° C	20° C (NL)[1]	52	62	47	57	48	44	62	62	54.0
26° C	20° C (Dark)	52	63	50	55	55	42	55	60	53.4
26° C	26° C (Dark)	48	51	47	54	45	38	59	56	50.8
Observed F-value[2]		1.09	1.08	0.69	1.00	1.89	2.91	1.38	6.48	7.95
Significant difference[3]		(8)	(9)	(10)	(13)	(8)	7	(9)	8	3.0
Mean (24 pots)[4]		51.0	59.6	48.2	51.4	49.4	41.2	56.5	55.6	....
Mean as % of maximum		86	100	81	86	83	69	95	93	....
Rank		5	1	7	4	6	8	2	3	....

[1] [2] For explanation, see Table 1.

[3] At the 5 percent level. Figures in parentheses indicate that the F-values are not significant.

[4] A difference of 3.5 cm. is necessary for significance between variety means at the 5 per-

Another interesting point is the relationship of the inbred parents to their hybrid progeny when grown in the different climates. For example, the beet root weight of HI48 in the cool climates was greater than either of its inbred parents (Table 2, Treatments 1, 2, 3), but in the warm climates the superiority of the hybrid was manifested only in the plants grown at natural day length (Treatment 4), while in an 8-hour day at 26° C. (night at 20° C., Treatment 5) the difference decreased until, for plants maintained continuously at 26° C. (Treatment 6), the hybrid produced

less than the parents. Thus, the relative performances of the inbreds and the hybrids produced from them would be altered, depending upon the climate in which the comparison was made. If the growing season were predominantly cool hybrid vigor would be observed, but if the comparison were made in a warm climate hybrid vigor would not be evident.

The sucrose concentrations of the inbreds and their hybrids are also interesting (Table 3). Generally, a hybrid beet root has a sucrose concentration intermediate between those of its parents (1, 2, 3, 4, 5, 6, 7). Again, in the warmer climates this intermediate sucrose concentration of the hybrid declines so far that at a photoperiod of 8 hours and a constant temperature of 26° C. (Table 3, Treatment 6) the hybrid contains less sucrose than either of its parents. Regarding the amount of sucrose produced by the hybrids and inbreds, the results vary according to the relative performances of these varieties with respect to sucrose concentration and the amount of beet root formed. Thus, hybrid vigor is again manifested in all climates studied except when the plants are grown in a warm climate for a photoperiod of 8 hours (Table 1, Treatment 6); under these conditions the hybrid produced less sucrose than either of its parents.

Table 10.—Analysis of Variance.

		Mean squares								
		Beet roots			Tops		Living blades		Total leaves	Height
Source of variation	DF	gm/pot	Sucrose %	gm/pot	Fresh gm/pot	Dry gm/pot	Fresh gm/pot	number	number	cm
Total	191	.....	.....	.....	.....	.....	.....	.....	.....	.....
Climates	5	798,113[2]	29.05[2]	9,476.65[2]	1,250,929[2]	16,447[2]	99,894[2]	4,240.0[2]	591.6[1]	302.8[2]
Varieties	7	328,430[2]	15.56[2]	2,857.90[2]	1,081,515[2]	21,039[2]	161,243[2]	1,499.0[2]	2,937.6[2]	783.9[2]
Var x Cl	35	30,204[1]	1.18	313.22[1]	11,054	500	4,237	57.8	91.5	32.5
Error	144	8,294	0.80	97.81	32,645	378	3,298	84.8	132.7	38.1

[1] At the 1 percent level.
[2] At the 0.1 percent level.

Summary

Eight sugar beet varieties, two open-pollinated, four inbred and two hybrid varieties, were grown at a high level of nutrition in six controlled climates. The climates had either a natural day length of 10.6 to 14.3 hours or an 8-hour day. The temperatures, which were approximately optimum for beet growth, were 20° C. or 26° C. from 8 a. m. to 4 p. m. and 14° C, 20°. or 26° C. from 4 p. m. to 8 a. m. The sucrose produced by most of the varieties studied was nearly trebled by increasing the photoperiod from 8 hours to natural day length. As expected, the beets grown within the narrow range of temperatures used did not differ greatly in sucrose production. Only by decreasing the day and night temperatures simultaneously for the 8-hour day were the sucrose yields of the plants increased. The beet root weights, sucrose percentages, top weights, weights of living blades and numbers of living blades generally paralleled the sucrose weights; namely, increases were observed in the climates with long days over the short days and at the lower temperatures of the 8-hour days. Surprisingly enough, the

total numbers of leaves produced in each climate, except the warmest, were the same. Thus, the life expectancy of leaves of plants grown in climates with long days or with cool days or nights is much greater than in warm climates with short days.

The relative performance of each variety was not the same in each climate, as for example the better performance of G. W. 304 compared to U. S. 22/3 occurred mainly in the cool climates. Similarly, hybrid vigor was observed only in the cool but not in the warm climates. In fact, the hybrid H148 produced less sucrose than either of its parents when grown at 26° C. for an 8-hour day.

The importance of growing plants in controlled climates by agronomists and geneticists in order to improve crops is clearly indicated by the results of these experiments.

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