These meetings were especially well attended which was most gratifying because the main object of these trials was to interest and instruct 1 he producers in livestock feeding.

The place, economy, and efficiency in a ration for fattening steers and lambs on the various forms of sugar-beet pulp when compounded with locally produced alfalfa hay and barley were definitely shown.

Valuable information was developed which demonstrated that it is possible and feasible to market home-grown feeds through livestock and by so doing to produce large quantities of manure so vital to the maintenance of soil fertility.

—0—

Beet-Sugar Production as Influenced By Climate[1]

Albert Ulrich et al

The cultivation of sugar beets in the United States and Europe has been limiled by trial and error to definite areas. These areas, as shown by the annual production records, may vary considerably in productivity not only from district to district but from year to year within a district. The cause for these variations is not entirely clear. Some of the differences in yields may be attributed to diseases or to differences in rainfall or cultivation practices and undoubtedly to soil fertility. Superimposed upon these variables is the effect of climate, which in itself varies from year to year.

That climate is an important factor in sugar production was shown for sugarcane by Borden (1986) when two soils taken from high and low-production areas with similar temperatures gave yields which were related primarily to the sunlight of the localities rather than to soil differences. Clements (1940) in comparable field experiments at two locations correlated the lower yield of cane sugar with a lower light intensity. Kruger and Wimmer (1936), with sugar beets grown in pots receiving direct and diffused sunlight,

[3] conducted by the Division of Plant Nutrition. University of California, in cooperation with the Spreckels Sugar Company.

Assistance was furnished by the personnel of the Works Projects Administration, Official Project No. 65-1-08-91-B-10

Assistance in the preparation and maintenance of the light cells was received from Dr. P. K. Stout and Leo Kline. The temperature data were tabulated by James B. Carleton.

Junior Soil Chemist, Division of Plant Nutrition, University of California, Berkeley. California.

Field Superintendent and Assistant Field Superintendent, respectively. Spreckels Sugar Company, Woodland. California.

found that yields were limited by light under their conditions rather than by the nutrient deficiencies which restricted growth in direct sunlight. Borden (1940), in another study with sugarcane grown in pots, showed that shaded plants produced less sugar than unshaded plants regardless of the potash or nitrogen treatments used by him. These and other considerations already mentioned have indicated that climatic variations in California, particularly along the coast in contrast with the interior, may limit beet-sugar production.

Procedure.—For the purposes of the present investigation, two soils were collected from beet-growing areas. One soil, Metz silty clay loam, was obtained from a coastal area in the vicinity of King City which is approximately 150 miles southeast of San Francisco. The other soil, Yolo silty clay loam, was taken from a field near Woodland in the hot Sacramento Valley.

Each lot of soil was thoroughly mixed before it was placed in a series of 33-gallon pots at Woodland and at Berkeley. The pots were protected from overheating by placing soil between them which was moistened from time to time. The drainage water was caught in a pan below each pot and then returned just prior to the next watering. The composition of the tap water used to irrigate the beets, while different at each location, was believed not to influence the beet yields. All cultural practices at the two locations were similar throughout the experiment.

The fertilizer treatments given in table 1 were applied at the time of planting the U. S. No. 15 sugar-beet seed. Since Metz silty clay loam was known to be amply supplied with all nutrients except nitrogen, only ammonium sulfate was added at the 2N and 4N levels (N=-27.8 grams). In the case of the Yolo silty clay loam, adequate amounts of phosphorus and potassium were added with the nitrogen.

When the experiments were repeated in 1941 a new lot of Yolo silty clay loam was obtained within a few feet of the first lot and then prepared as in 1940. The Metz silty clay loam used in 1941 was taken from the same reserve pile as in 1940 and therefore was identical for the 2 years.

The sugar beets were planted on April 9, 1940, at Woodland and at Berkeley on the following day. In 1941 the beets were planted at the two locations on April 17. In 1940 the beets were harvested on October 4 at Berkeley and October 5 at Woodland, while in 1941 the harvest dates were October 7 and 8 respectively.

Analytical Methods.—The yields were obtained by weighing soil-free beets topped according to the methods prescribed by the beet-sugar companies. The sugar percentages were determined by the Sachs-Le Docte method as given by Browne (1912) and modified by Bachler (1934), while the purities were determined by Bachler's refractometer method (1937). All of the analyses were made by the Spreckels Sugar Company at their Woodland refinery.

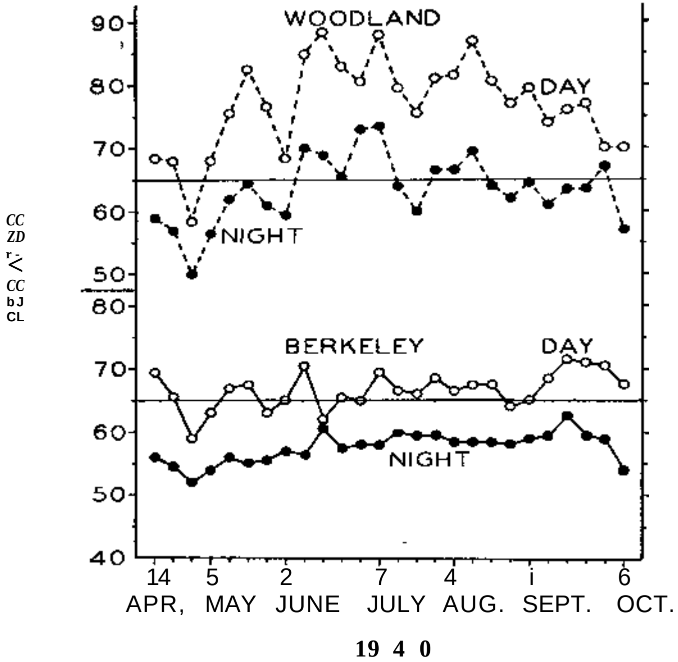
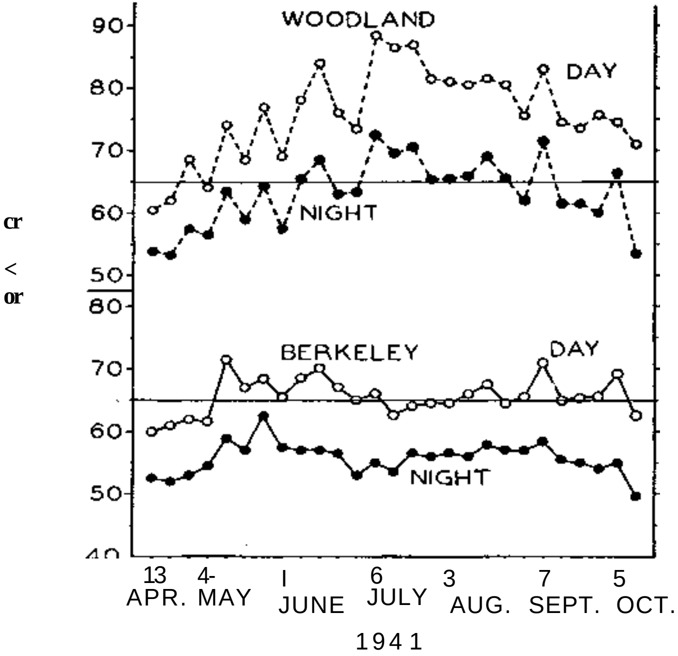


Figure 1.—Day and night temperatures at Berkeley and Woodland, California, during the 1040 and 1941 seasons. Each point is an average daily (6:01 a. m. to

The air temperatures at Berkeley and Woodland were determined with a hygro-thermograph (Julien P. Fries No. 207W) at each location. The points plotted in the graphs (figure 1) are the average weekly day or night temperatures averaged for 2-hour intervals.

The light readings are given as average milliequivalents of oxalate decomposed each day for the week. The calibrated test tubes (18 x 150 mm.) containing the uranium oxalate solution (12.605 grams $(COOH)_2.2H,0$ + 5.023 gm. $U0_2(N0_3)_2.6H_20$ per liter) are set normal to the sun by a special calibrated holder. Each test tube, except for an 8 mm. annular ring approximately 2 cm. from the base of the tube, was painted with black asphaltum varnish and then with



6:00 p. m.) and nightly (6:01 p. m. to 6:00 a. in.) temperature (averaged for every 2-hour period) for the week ending on the date given.

a coat of aluminum paint. The unpainted strip around the tube permitted the entry of sunlight for the photochemical decomposition of oxalate ions to CO and $C0_2$ (Anderson and Robinson, 1925). The decomposition of oxalate is effected by ultra violet light and the blue of the visible spectrum. Since the ultra violet light cannot penetrate readily the pyrex glass of the test tubes, the blue light of the shorter wave lengths is mainly effective in the oxalate decomposition; 10 ml. of the uranium oxalate solution has been found satisfactory for even the longest days at either Woodland or Berkeley. In 1941 the test tubes at Berkeley were modified by fusing a small flask on the end of the test tube. The capacity of the larger cells was *66* ml., which was adequate for a week's exposure to sunlight.

Results.—A comparison of the average day and night temperatures at Berkeley and Woodland for 1940 and 1941 (figure 1) shows that the day and night temperatures at Woodland are much higher than those at Berkeley. In fact the night temperatures at Woodland are approximately equal to the day temperatures at Berkeley, It is to be noted that there is no outstanding difference in temperature at each location for the two seasons except at Woodland where the degree-hours above 85°, 90°, 95°, or 100°F. (table 2) are greater in 1940 than in 1941, a point which will be discussed later.

The light intensities (figure 2) as measured by the milliequivalents of oxalate decomposed for the 1940 and 1941 seasons are 20 to 25 percent greater at Woodland than at Berkeley. There is no marked difference in the total light available for the two seasons at each location, but there is a difference in the timing of the periods of high and low light which might affect the rate of growth favorable or adversely, depending upon the physiological state of development of the plants.

The beet and sugar yields, sugar percentages, and the purities of the beets from the two soils treated with different levels of nitrogen at Berkeley and Woodland are summarized in table 1. The results are primarily of interest because of the changes in sugar percentages of the beets for the 2 years at the two locations. In 1940 the sugar percentages at Berkeley were higher than those at Woodland. The converse was true in 1941 when the sugar percentages at Berkeley were not only slightly lower than those in 1940 but were now definitely lower than those at Woodland which had increased considerably during 1941.

The yields from the two soils differed in many respects within each year and between the 2 years. In 1940 the yields at Berkeley for the comparable treatments of the two soils were not significantly different, while at Woodland the yields for the 2N treatment of the Metz silty clay loam were higher than for the 2N treatment of the Yolo silty clay loam. The significantly lower yield at Woodland for the untreated Metz silty clay loam in comparison to the Yolo silty clay loam may have been caused by the addition of a small amount of soil to the pots shortly after thinning the beets. The yields for the 2N and 4N treatments of the Metz silty clay loam at Woodland were higher than those at Berkeley, while there was no significant difference for the untreated soil at the two locations. The yields for the untreated Yolo silty clay loam were higher at Woodland than at Berkeley but there was no difference for the 2N treatment. The net effect of the higher yields and lower sugar percentages at Woodland was a similar sugar production at the two locations.

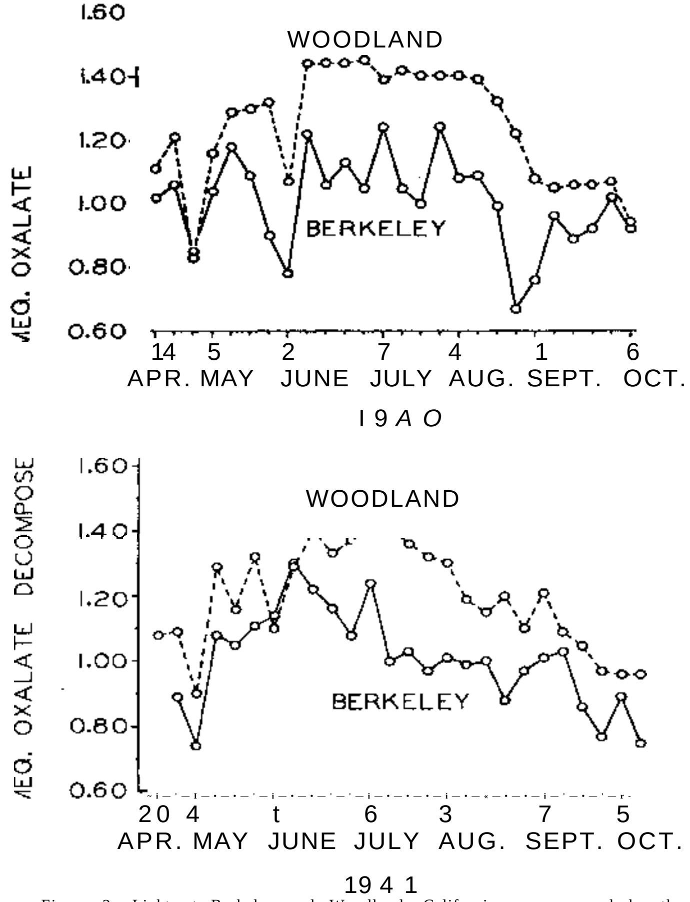


Figure 2.—Light at Berkeley and Woodland, California, as measured by the milliequivalents of oxalate decomposed during the 1940 and 1941 seasons. Each point is an average daily value for the week ending on the date given.

Table 1,—Summary of results for Berkeley and Woodland—1940 and 1941.

Location	Determination[1]	Meta silty clay loam			Yolo silty clay loam[2]			Significant difference at 5-percent point (19 to 1 odds)
		None	2N	4N	None	2N	4N[3]	
				1940				
Berkeley	Yield (gm.)	1,688	3,345	4,351	1,652	3,288	— —	331
Woodland	Yield (gm.)	1,571	4,057	4,891	2,338	3,294	— —	516
Berkeley	Percentage sugar	16.3	16.8	17.4	16.8	18.2	— —	0.7
Woodland	Percentage sugar	12.8	15.3	15.8	15.0	16.9	— —	1.0
Berkeley	Sugar (gm.)	275	562	757	328	609	— —	61
Woodland	Sugar (gm.)	201	578	763	351	558	— —	91
Berkeley	Purity	88.0	88.3	87.0	88.1	88.4	— —	0.8
Woodland	Purity	83.9	86.0	87.0	87.6	88.4	— —	1.1
				1941				
Berkeley	Yield (gm.)	2,187	4,237	4,190	1,914	3,330	4,008	492
Woodland	Yield (gm.)	3,191	4,840	4,602	1,914	3,526	3,275	575
Berkeley	Percentage sugar	16.5	16.5	16.6	16.2	16.4	16.2	0.8
Woodland	Percentage sugar	17.6	18.9	18.4	17.3	18.0	17.9	1.6
Berkeley	Sugar (gm.)	361	699	813	310	548	649	91
Woodland	Sugar (gm.)	564	876	846	332	633	590	126
Berkeley	Purity	86.8	86.4	86.4	86.7	86.3	85.6	n.s.
Woodland	Purity	87.3	87.8	86.0	87.3	87.6	86.1	n.s.

[1]Replicated 6 times.
[2]PK added to all pots in the Yolo series.
[3]2N equals 55.6 and 4N equals 111.2 grams of ammonium sulfate per pot.
n.s.=not significant.

The yields for Metz silty clay loam at Berkeley and Woodland are higher in 1941 than in 1940 in five out of six treatments while for the Yolo silty clay loam they are approximately the same for the 2 years. At Berkeley and at Woodland the Metz silty clay loam produced higher yields than the corresponding treatment for the Yolo silty clay loam. The untreated Metz silty clay loam produced a much higher yield at Woodland than at Berkeley, while in the untreated Yolo soil there was no difference between the two locations. At Woodland the maximum yields were obtained with the 2N treatment for both soils and not with the 4N treatment as at Berkeley. This difference resulted in a significant increase in yield for the 4N treatment of the Yolo series at Berkeley over the corresponding treatment at Woodland. The net effect of the higher sugar percentages at Woodland was a higher sugar production in every case except in the 4N treatment of the Yolo series. In the latter instance the higher sugar percentage did not overcome the relatively low yields occurring in this treatment at Woodland.

The purity coefficients in 1940 failed to follow any set pattern, although the lowest value was given by the 4N treatment for the Metz silty clay loam at Berkeley, while at Woodland the untreated soil in this same series gave the lowest purity value. The highest purity at Woodland was given by the 2N treatment for the Yolo series. Other differences were not statistically significant. In 1941 there were no statistically significant differences (according to the F values, Snedecor, 1938) for any of the treatments at the two locations, although it is of interest to note that the lowest values were given by the 4N treatment at Woodland for both soils and for the 4N treatment of the Yolo series at Berkeley.

Discussion of Results.—Some of the results obtained during the 2-year study with the Yolo and Metz silty clay loam soils at Berkeley and Woodland are difficult to explain. Ordinarily it is to be expected that beets grown at a higher temperature such as at Woodland would give lower yields and lower sugar percentages than the cooler climate of Berkeley. During the first year the yields were in many instances actually higher at Woodland than at Berkeley, although the sugar percentages were definitely lower at Woodland. The net effect was a similar sugar production at the two locations. In the following year all of the sugar percentages and some of the yields were distinctly higher at Woodland than at Berkeley. Perhaps these unexpected differences in sugar production could be explained on the basis of the higher light intensity at Woodland than at Berkeley. The additional light at Woodland amounting to 20 to 25 percent may have been more than enough to offset the greater respiration and thus result in the higher yields in 1940 and the higher yields and sugar concentrations in 1941. But this would leave unexplained the higher sugar production at Woodland in 1941 over 1940. The temperatures and light intensities are apparently similar for the 2 years and yet the sugar yields are different. Either the differences for the 2 years are caused by a difference in the number of degree hours above 85° F. (table 2), or to a difference in timing of the temperature or light factors, or to some condition as yet unknown. The increases in the degree hours above 85, 90, 95 and 100° F. during 1940 over 1941 favor the temperature hypothesis. Such increases in temperature with their resultant effects on respiration may have been enough to depress the sugar content of the beets during 1940.

Table 2.—Comparison of *degree* hours in 1940 to 1941 at Woodland and Berkeley.[1]

Location	Year	Day (6:01 a. m.-6:00 p. m.) Degree hours above				Night (6:01 p. m.-6:00 a. m.) Degree hours above		
		85° F.	90° F.	95° F.	100° F.	85° F.	90° F.	95° F.
Woodland	1940	4,944	2,334	928	260	498	202	42
Woodland	1941	3,992	1,948	784	216	400	180	22
Increase over 1941—In Percentages		23.8	19.8	31.2	20.4	24.6	66.4	91.0
Berkeley	1940	26	0	0	0	2	0	0
Berkeley	1941	86	4	0	0	0	0	0
Increase over 1940—In Percentages		223	......	......	......	......	......	......

[1]With an 85°F. base 1 hour at 86°F. equals 1 degree-hour and 2 hours at 91°F. equals 12 degree-hours, etc.

The higher yields from the untreated Metz silty clay loam at Woodland in 1941 may be associated with a greater bacterial activity at the higher temperature, and this would result in a more rapid decomposition of the organic matter present in the soil. The yields for the 2N and 4N treatments for this soil in 1940 are higher at Woodland than at Berkeley and this also applies to the 2N treatment in 1941. The additional nitrogen which may have been derived from the bacterial activity in the 4N treatment in 1941 was not effective in increasing the yield. In the Yolo silty clay loam there was no significant increase in yield at Woodland, and therefore it may be assumed that no additional nitrates were formed from the organic matter.

A point which requires further study is the failure during 1941 of the 4N treatment to increase the yield over the 2N treatment for both soils at Woodland. The leaves in all instances failed to give a positive nitrate test with diphenylamine at harvest time, thus indicating the utilization of the available nitrates by the plants. The appearance of the plants at harvest time supported the negative nitrate test, since the outer leaves were yellow, and only a few green leaves remained in the center of the plants. The question to be solved is the location of the nitrogen in the 4N treatments. Part of it was used in the greater top growth of the 4N treatment, but this may not account for all of it. Another part may have been trapped in the yellow leaves which became non-functional at a time when there was still a high-nitrate concentration in the plant and therefore the nitrates were not translocated to the regions of growth. From the practical standpoint split applications may be more effective than one single heavy application in the spring.

Summary

Sugar beets were grown in pots by the same technique in the different climates of Berkeley (cool and cloudy) and Woodland (hot and sunny). Two soils were obtained for the study, one (Metz silty clay loam) from the coastal area near King City and the other (Yolo silty clay loam) from the interior of California near Woodland.

In spite of marked differences in temperature and light intensities at the two locations during any one season, the differences in sugar production were not nearly so great as occurred at Woodland between two successive seasons.

Sugar beets receiving twice as much nitrogen as a comparable series produced the same yield of beets even though the available nitrates had been utilized by the plants.

Literature Cited

Anderson, W. T. and F. W. Robinson. 1925, The oxalic acid-uranyl sulfate ultra violet radiometer. J. Am. Chem. Soe. 47 :718-725.

Borden, R. J. 1936. Cane growth studies: The dominating effect of climate. The Hawaiian Planters' Record. 40:143-156.

Borden, R. J. 1940. Nitrogen-potash-sunlight relationships. The Hawaiian Planters' Record. 44:237-241.

Bachler, F. R. 1934. The Sachs-Lie Docte method: Its application to the determinations of sugar in beets under conditions in Southern California. Facts a. Sugar. 29:191-194.

Bachler, F. R. 1937. A new method for determining purity in sugar beets. Facts a. Sugar. 32:327-328.

Browne, C. A. 1912. A handbook of sugar analysis. Sachs-Le Docte method. John Wiley and Sons, New York. 242-244.

Clements Harry F. 1940. Integration of climatic and physiologic factors with reference to the production of sugar cane. The Hawaiian Planters' Record. 44:201-233.

Krliger, W. and G. Wimmer. 1936. Der Einfluss des Litches auf die Entwicklung, Zuckerbildung und Nahrstoffaufnahme bei der Zuckerriibe. Ztsehr. Wirtschaftsgruppe Zuckerind. (Techn. T.) 86 :271-288.

Snedecor, G. W. 1938. Statistical methods. Collegiate Press, Inc. Ames, Iowa.