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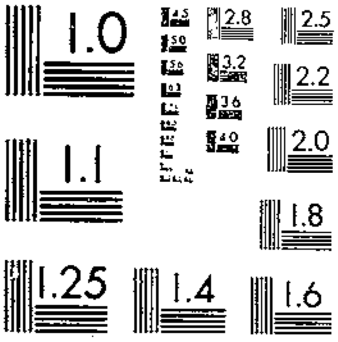

MICROCOPY RESOLUTION TEST CHART
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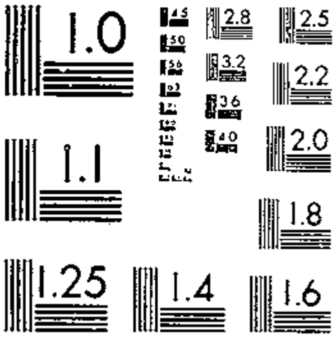

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Sugar-Beet Seed Production in Southern Utah, with Special Reference to Factors Affecting Yield and Reproductive Development[1]

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CONTENTS

INTRODUCTION

Sugar-beet seed is produced in southern Utah by the method of overwintering plants in the field (*2*).[3] This method has been used in all the commercial sugar-beet seed-production areas developed in the United States in recent years.

Results with the sugar-beet seed crop in various areas have indicated that soils of more than average fertility are desirable. In addition to the use of barnyard and green manures, commercial fertilizers are commonly used. In New Mexico, nitrogen fertilizers applied as side dressings in early spring have given increased yields (*3*). In western Oregon both nitrogen and sulfur are limiting factors in production, and about 500 pounds of ammonium sulfate per acre are applied to the growing crop (*9*). In much of the Oregon sugar-beet seed-producing

[1] Submitted for publication October 1942.
[2] The studies were conducted in cooperation with the Utah-Idaho Sugar Co. Acknowledgment is made to G. H. Coons, principal pathologist, Eubanks Carsner, senior pathologist, and F. V. Owen, geneticist, of this Division, for helpful suggestions during the course of the work and in the preparation of the manuscript.
[3] Italic numbers in parentheses refer to Literature Cited, p. 35.

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area, boron has also proved to be deficient (*8*), and remedial applications are necessary.

In southern Utah, both phosphate and nitrogen were shown to be limiting factors in sugar-beet seed production.[4] Nitrogen has been found to be a determining factor conditioning the utilization of carbohydrate reserves stored in the root of the beet. An adequate supply of this fertilizer element during the entire fruiting period was necessary to produce maximum yields (*6*).

In addition to the economic importance of maximum seed yields, complete reproduction within a mass-selected sugar-beet variety is of vital concern, since it has been shown that where some component types within a variety fail to enter into seed production objectionable deterioration of the variety has resulted (*4*). Initiation of seedstalks and flowering in biennial beets is brought about mainly by the cumulative effects of prolonged exposure to low temperature, followed or accompanied by the effects of long photoperiods. This process, including both thermal induction and photoperiodic induction, has been termed "photothermal induction" (*5*).

It has been shown that the range of temperature within which thermal induction takes place is rather narrow (*7*, *7a*).[5] Beet-crown temperatures above 10° to 12° C. are unfavorable for thermal induction, and there may be reversal of the thermal-induction process at temperatures of 15° to 18°. It has also been shown that thermal induction takes place only under conditions where physiological processes are possible. At 0° physiological processes are so retarded that little, if any, thermal induction occurs (*7*, *7a*).[5] In a seed-growing area, it is impossible to control air temperatures during the overwintering period, but it is possible to modify soil temperatures and, in a measure, to control the thermal environment of the beet crowns.

The tests reported in this bulletin are a continuation of the earlier work in the southern Utah sugar-beet seed districts; they deal with practices that affect not only seed yield but also the reproductive development of the sugar beet.

HISTORY OF SUGAR-BEET SEED GROWING IN SOUTHERN UTAH

Irrigated districts around the towns of St. George and Hurricane, in southern Utah, were among the first to become established in the production of domestic sugar-beet seed. Several small fall plantings of sugar beets for seed were made in Washington County, in southern Utah, prior to 1930, by D. A. Pack, of the Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering. These test plantings were continued in 1930 and subsequent years by F. V. Owen, of the same Division. Beginning in 1930, interest was stimulated in these plantings by the fact that a sugar-beet variety (U. S. 1) resistant to curly top had been developed by the Division of Sugar Plant Investigations, and an immediate need arose for production of seed of this variety on a commercial scale. In the fall of 1931, the Utah-Idaho Sugar Co. gave support to the program and 5 acres of U. S. 1 (*1*) were planted. The following year

[4] Unpublished data from tests conducted in 1933 and 1934 by J. O. Culbertson, associate agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering.

[5] Also in unpublished data from tests conducted by Myron Stout, assistant physiologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering.

241 acres of seed were produced, and 3 years later the plantings had increased to more than 700 acres. Since these early experiences with U. S. 1, several other varieties, improved with respect to curly top resistance, have also been grown. These, in the order of their release for commercial use, are U. S. 33, U. S. 34 (*10*), A-600, U. S. 12 (*4*), and U. S. 22 (table 1).

TABLE 1.—*Acreage and production of sugar-beet seed in the St. George, Utah, district for the years 1932–42* [1]

Year of harvest	Growers	Acreage planted to variety No.—							Total	Seed produced	
		U. S. 1	U. S. 12	U. S. 22	U. S. 33	U. S. 34	A-600	Other		Total	Per acre
	Number	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Pounds*	*Pounds*
1932	3	5							5	8,324	1,665
1933	84	241							241	341,308	1,416
1934	105	387				11			398	938,040	2,357
1935	94				27	427	5		459	921,794	2,008
1936	157		13		108	460	145		726	1,590,613	2,199
1937	159		432		180	27	103		751	1,361,546	1,813
1938	155		430		275			51	756	1,531,923	2,026
1939	141		413	52	201			27	693	1,241,616	1,792
1940	110			373	136				509	1,209,835	2,377
1941	125			610					610	1,288,334	2,110
1942	122			458					458	933,157	2,037
Total or average		633	1,268	1,493	936	925	253	78	5,609	11,372,490	2,029

[1] Data assembled by the Utah-Idaho Sugar Co.

During the early years of sugar-beet seed production near St. George, Utah, it became obvious that nutritional deficiencies were seriously checking plant growth and development. In nearly all fields, the majority of plants turned yellow and were stunted in growth, and the yield of seed was low. However, around the entire edge of the fields was a narrow fringe of plants that were much greener in color and grew much more rapidly in both the fall and the subsequent spring and summer. This extreme border effect gave the fields a "picture frame" appearance. In the fall of 1933, in preparation for the 1934 seed crop, a preliminary recommendation on nitrogen and phosphate fertilization was worked out between representatives of the Utah-Idaho Sugar Co. and the Division of Sugar Plant Investigations. This schedule has been modified as more complete information has become available.

SOILS AND CLIMATIC CONDITIONS

In the Virgin River Valley (*13*) the farm lands where beet seed is grown are principally near the towns of Hurricane and St. George, Utah. Here the soils are alluvial in origin and, in general, are deep, friable, and fine in texture. All cultivated crops must be grown under irrigation, and the irrigable lands occupy the comparatively level valley areas. A general feature of the irrigated soils in this area is the presence on the surface of a layer of silt deposited by the irrigation water. This layer of silt is generally 12 to 18 inches deep, but, in extreme cases, may be as deep as 3 to 4 feet. The silt is usually fine in texture, varying in type from silty clay loam to heavy clay. The higher, steeper lands are lighter in texture, and the upper end of many fields grades off into fine, sandy loams. The underlying subsoils are generally highly calcareous and of medium texture. Most of the soils are red or have a reddish tinge and are low in organic matter, nitrogen, and available phosphorus (*11*). The soils are generally rich in soluble salts of the alkaline earth group. Calcium carbonate and gypsum are very plentiful. Sugar-beet seed is grown principally in rotation with grain and alfalfa and occupies some of the best agricultural lands in the valley. It is also grown to some extent on new lands broken out of saltgrass and associated salt-tolerant shrubs, such as *Atriplex canescens* James. Although too high in soluble salts to support growth of grains or legumes, some of this land produces fair crops of sugar-beet seed.

All of the experimental plots were located on soil of the silted phase of the Redfield silty clay loam series. This series represents the better agricultural lands of the Virgin River Valley (*13*).

The climate in southern Utah is relatively dry. The average annual precipitation at St. George is about 8.6 inches, and even at Leeds, nearer the Pine Valley Mountains, the average rainfall is only 13 inches. The climate is characterized by rather large daily variations in temperature. The summer period is long and hot; the winters are short and generally mild. The average frost-free season is listed by the United States Weather Bureau as 197 days. However, the sugar beet is relatively hardy and makes some growth even in the coldest months. The sugar-beet seed crop, which is normally planted during the last week of August and the first 15 days of September, usually grows rapidly until the latter part of November and resumes rapid growth again in the latter part of February. Consequently, there is generally not more than a 3-month period during the winter when growth is almost completely stopped. During this period, the average monthly mean temperature ranges from about 38° to 42° F.

AGRONOMIC EXPERIMENTS

Plan and Procedure

Agronomic experiments with sugar beets grown for seed were conducted during the years 1936, 1937, 1938, and 1939. These tests followed the same general pattern but varied as to amounts of nitrogen and phosphate applied, dates of application, and related factors affecting fertilizer response, such as planting date, plowing date, and variety. In general, the experimental designs used consisted of a split-plot arrangement (*12*). There were four replications of all fertilizer treatments. Appropriate errors were obtained for each main-plot and subplot comparison and for the interaction effects of the various treatments.

All nitrogen applications were made as side dressings to the growing crop as were also the spring applications of phosphate. Phosphate applied in the fall was broadcast and worked into the soil during the final operations of seedbed preparation. The source of the nitrogen was ammonium sulfate (20 percent N) and the phosphate was applied as Treble Superphosphate (46 percent P_2O_5).

The plots were planted between August 25 and September 22 each fall. Where planting date constituted a variable in an experiment, at least 2 weeks elapsed between planting dates. The seed was usually planted in comparatively dry soil and irrigated up. Irrigation furrows were made either prior to drilling or when the seed was planted. Water was supplied as needed throughout the growing season. The plots were harvested during the last week of June or the first week of July, depending on the season. Buffer rows were discarded to avoid border effects.

Effects of Treatments on Vegetative Growth, Reproductive Development, and Seed Yields

The sugar beet is a biennial, and both thermal induction and photoperiodic induction are necessary to bring about complete reproductive development. The amount of photothermal induction required to bring about complete reproductive development in a beet is controlled by the genetic factors that determine bolting tendency. Beets of "easy bolting" tendency are those whose photothermal requirements are easily satisfied. In contrast to easy-bolting types, beets of "nonbolting" tendency require prolonged exposure to conditions that induce flowering. In this sense, "nonbolting" is a relative term.

There is a direct relation between fall growth and the induction process. Because the induction process is an indispensable factor in seed production, no amount of care in the spring can compensate for the inadequate photothermal induction that may result from insufficient fall growth. Consequently, any factor that depresses fall growth may be critical in seed production by the overwintering method. A knowledge of the factors that influence induction of the reproductive process is, therefore, of importance. Planting date, time and method of seedbed preparation, and phosphate and nitrogen fertilization greatly affected fall growth and subsequent reproductive development. In all of the experimental plots, sugar-beet plants in the check plots were noticeably different in both fall and spring growth from those of plots receiving nitrogen and phosphorus. Sugar beets in plots receiving nitrogen and phosphorus grew vigorously, as indicated by dark-green, vigorous foliage, in contrast to the yellow, dwarfed foliage of the check plots. Examination in late fall showed that root development was indicated rather accurately by top development. Plants of the check plots often had roots less than one-quarter of an inch in diameter, whereas in the plots receiving nitrogen and phosphate the roots were three-quarters to 1 inch in diameter. Late planting or late seedbed preparation also influenced the fall growth of plants; when either or both of these factors accompanied lack of fall fertilization, the effects were additive and extreme depression of fall growth resulted.

When growth was resumed in the spring, the effects of nitrogen and phosphate deficiencies became even more pronounced. Seedstalk development began in late March and early April. On some of the check plots where growth had been extremely poor in the fall because of late planting, late seedbed preparation, and phosphorus deficiency, as high as 66 percent of the plants remained vegetative and 90 percent of the total plant population did not enter into seed production (fig. 1).

During the flowering period, beginning about May 15, and until harvest time, further symptoms of phosphorus deficiency became evident. These symptoms were first noticeable as a necrosis of portions of the leaf blade (fig. 2) and, as the deficiency increased, most of the

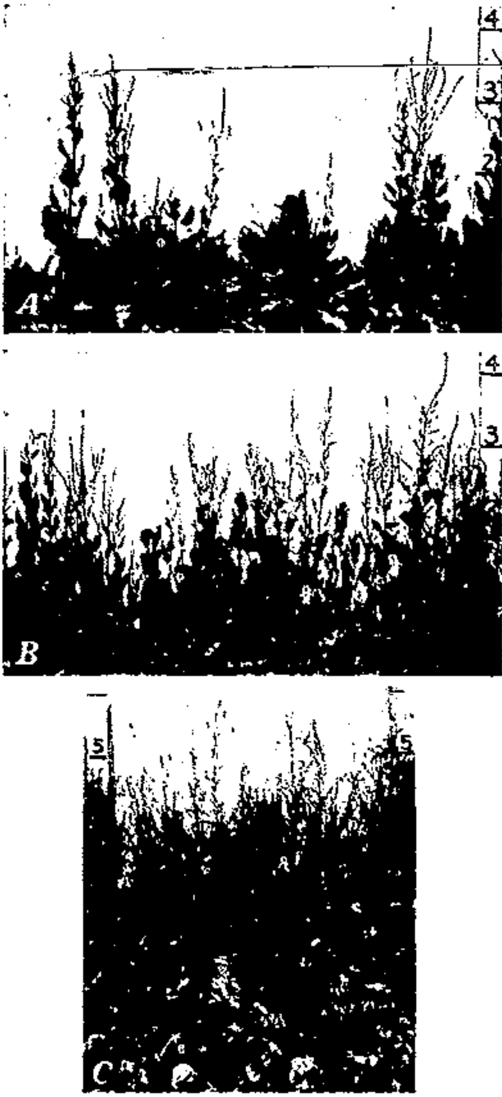

FIGURE 1.—Reproductive development of sugar beets as influenced by planting date, time of seedbed preparation, and phosphate application. *A*, Late planting, late seedbed preparation, 400 pounds of Treble Superphosphate per acre applied February 24, 1939; result, 34 percent of plants with seedstalks and 10 percent seed producers. *B*, Early planting, late seedbed preparation, and no phosphate fertilizer application; result, 66 percent of plants with seedstalks and 46 percent seed producers. *C*, Late planting, early seedbed preparation, 400 pounds of Treble Superphosphate per acre applied February 24, 1939; result, 93 percent of plants with seedstalks and 70 percent seed producers. (Photographed May 26, 1939.)

leaves died and turned brown. During the latter part of June many of the roots began to die and the whole plant, including the maturing seed, took on a rusty-red color. By harvest time, the blocks that had not received phosphate were strikingly evident (fig. 3).

It was also evident that nitrogen applications did not increase growth where phosphate was deficient. In fact, it often did more harm than good and generally brought on the visible symptons of phosphorus deficiency at an earlier date. On the plots where phosphate was applied, the seed matured evenly and the effect of nitrogen on yield was strikingly evident (fig. 4). Further details of the relation of the various factors affecting reproductive development and seed yield are given in connection with the data from each of the experimental plots conducted from 1936 to 1939.

TESTS HARVESTED IN 1937

The experimental plots planted in the fall of 1936 included two dates of planting, four varieties, and three rates of nitrogen application. The entire experimental plot received Treble Superphosphate at the rate of 290 pounds per acre. The rate and time of nitrogen applications are shewn in table 2. The first planting was made on August 24 and the second planting on September 12. The four varieties, U. S. 12, A-600, S. L. C. 550, and U. S. 14, included in the test, differed widely in bolting tendency. Preliminary tests near St. George in 1936 had shown U. S. 12 to be an easy-bolting and early-flowering variety. A-600 was definitely slower in seedstalk development and later in flowering, but finally reproductive development was practically as complete in A-600 as in U. S. 12. In the same test, U. S. 14 and S. L. C. 550 were not only definitely slower than either U. S. 12 or A-600 in the development of seedstalks but there was also a larger percentage of plants that remained vegetative. U. S. 14 was not so uniform in bolting tendency as S. L. C. 550. It had a rather wide range in this respect and included some extremely nonbolting types. Inclusion of these four varieties at two planting dates provided plants with a wide range in induction requirement and made possible an evaluation of the relation of time and rate of nitrogen application to the induction process.

A count of plants developing seedstalks was made on June 19, 1937, by pulling 100 plants from each plot and classifying them in two groups, those with seedstalks and those that had remained vegeta-

FIGURE 2.—Symptoms of phosphorus deficiency on sugar beets grown for seed. Leaves show browning caused by necrosis of the leaf blades; this symptom was generally followed by root injury and killing of the entire plant before time for harvest. Browning of the leaves and stalks of phosphorus-deficient plants gave a dark color to the blocks to which no phosphate had been applied. (See fig. 3.) (Photographed June 2, 1938.)

FIGURE 3.—Combined phosphorus and nitrogen deficiencies and their effects on sugar-beet seed production. The three height stakes give a comparison of the results from application of nitrogen alone (*a*), phosphate alone (*b*), and nitrogen plus phosphate (*c*). The complete treatments and yield of clean seed per acre were as follows: *a*, No phosphate, 600 pounds of ammonium sulfate per acre; result, acre yield of clean seed, 1,440 pounds; *b*, 300 pounds of Treble Superphosphate per acre, no nitrogen; result, acre yield of clean seed, 2,496 pounds; *c*, 300 pounds of Treble Superphosphate per acre, 600 pounds of ammonium sulfate per acre; result, acre yield of clean seed, 3,084 pounds. (Photographed June 1, 1938.)

FIGURE 4.—Nitrogen and phosphate effects on growth and yield of sugar-beet seed and the nitrogen-phosphate interaction relationship. The three height stakes mark three different nitrogen treatments on one of the blocks that received 400 pounds of Treble Superphosphate per acre. Note the lack of contrast between the nitrogen treatments, where these treatments run across a no-phosphate block in the extreme background. The nitrogen treatments and resulting yields of seed were as follows: *a*, 600 pounds of ammonium sulfate per acre in the spring of 1939; result, acre yield of clean seed, 2,818 pounds; *b*, no-nitrogen fertilizer; result, acre yield of clean seed, 1,826 pounds; *c*, 600 pounds of ammonium sulfate per acre in the fall of 1938; result, acre yield of clean seed, 3,057 pounds. (Photographed July 2, 1939.)

TABLE 2.—*Schedule of the nitrogen treatments on the experimental plots at St. George, Utah, 1936–37*

Dates of application on—		Ammonium sulfate per acre applied in treatment No.—		
Aug. 24 planting	Sept. 12 planting	1	2	3
1936	*1936*	*Pounds*	*Pounds*	*Pounds*
Aug. 24	Sept. 12	80	80	80
Sept. 28	Oct. 8		175	175
1937	*1937*			
Mar. 1	Mar. 4	40	40	40
Mar. 25	Mar. 25		175	175
Apr. 10	Apr. 10		...	175
Total		120	470	645

tive. The group with seedstalks was then classified as seed producers and nonseed producers. The result of this classification is shown in table 3. There was no significant difference between the August 24 and September 12 plantings in the number of plants developing seedstalks. However, there were significantly fewer plants classed as seed producers on the late planting. Nitrogen treatment alone did not significantly influence the number of plants developing seedstalks, but the number of plants producing seed was significantly less on the low-nitrogen treatment. The effect of low nitrogen on the percentage of plants producing seed was especially apparent on the nonbolting variety U. S. 14. Only 46 percent of the plants of U. S. 14 produced seed on the low-nitrogen and late-planted plots. The differential response of varieties to nitrogen treatment is apparent from the fact that U. S. 14 increased 23 percent in the number of plants producing seed on the high-nitrogen treatment, whereas the other varieties increased only 5 to 8 percent.

TABLE 3.—*Influence of planting date, variety, and nitrogen level on the photothermal induction of sugar beets grown for seed, as indicated by the number of beets developing seedstalks and also by the number of beets entering into seed production*

[Classification made June 10, 1937]

Variety	Ammonium sulfate applied per acre	Plants developing seedstalks			Plants entering into seed production		
		Aug. 24 planting [1]	Sept. 12 planting [1]	Mean [2]	Aug. 24 planting [3]	Sept. 12 planting [3]	Mean [4]
	Pounds	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
U. S. 12 (618)	120	96	98	97	82	84	83
	470	100	98	99	92	84	88
	645	98	98	98	94	88	91
A-600 (5639)	120	97	99	98	78	80	79
	470	98	98	98	82	73	79
	645	99	99	99	90	84	87
S. L. C. 750	120	96	96	96	78	70	74
	470	97	97	97	84	68	76
	645	99	99	99	86	72	79
U. S. 14 (617)	120	92	88	90	60	46	53
	470	97	93	95	72	66	69
	645	98	96	97	84	68	76

[1] Least significant difference, 6 percent.
[2] Least significant difference, 4 percent.
[3] Least significant difference, 10 percent.
[4] Least significant difference, 7 percent.

The development and maintenance in the fall of an extensive growth of leaves to shade the soil and thereby reduce soil temperatures has proved to be an important factor in the complete thermal induction of nonbolting varieties and component types within varieties having a wide range in bolting tendency. Increased nitrogen in the fall evidently forced greater fall growth, which resulted in more complete induction. Effects of this nature would be most apparent on a variety such as U. S. 14, which contained some extremely vegetative types.

Subsequent tests indicated that September 12, the date of the second planting, is not to be classed as a late date for planting. Plantings made by this date, if given good cultural care, make sufficient growth to create favorable conditions for satisfactory induction of flowering of varieties with an easy-bolting tendency. This test does indicate that complete reproduction of extreme nonbolting varieties would be difficult in the St. George area, and that with nonbolting varieties special care should be taken to obtain a maximum of fall growth.

The yield data furnished striking confirmation of the visible growth effects and their relation to reproductive development. Significant differences in yield were obtained between nitrogen quantities and also between varieties. There was also a variety × nitrogen interaction relationship. All varieties increased in yield as the rate of nitrogen application was increased, but U. S. 14 and U. S. 12 increased proportionately more than did the other two varieties (table 4).

TABLE 4.—*Acre yield of clean seed in a replicated test including 4 varieties and 3 levels of nitrogen, when all plots received a uniform application of 200 pounds of Treble Superphosphate per acre* [1]

Variety	Acre yield of seed in plot receiving indicated amount (pounds) of ammonium sulfate per acre			
	120	470	645	Mean
	Pounds	*Pounds*	*Pounds*	*Pounds*
U. S. 12 (618)	1,615	2,420	2,698	2,251
A-600 (5899)	1,701	2,009	2,200	1,970
S. L. C. 550	1,426	1,756	2,108	1,763
U. S. 14 (617)	1,258	1,939	2,212	1,803
Mean	1,500	2,031	2,305	...

[1] Difference for significance between 12 subplot comparisons, 250 pounds. Difference for significance between 4 varietal means, 141 pounds. Difference for significance between 3 nitrogen-treatment means, 167 pounds.

Increasing the ammonium sulfate application from 120 to 645 pounds per acre gave an average increase of a little less than 800 pounds of seed per acre. It is also evident that the 645-pound application of ammonium sulfate gave significant increase in yield over the 470-pound application. Further work was therefore necessary to determine the most economical rate of nitrogen application.

During the 1937 season, some tests were made also in the Moapa Valley in southern Nevada. These tests included three levels of both nitrogen and phosphate in all the possible combinations. Neither nitrogen nor phosphate had a marked influence on seed yield. There was, however, striking evidence of the effect of phosphate on seed maturity, especially at the high-nitrogen level. On the plots where 1,000 pounds of ammonium sulfate was applied per acre in the absence of a phosphate treatment, much of the seed was immature and the plants continued to send out new growth after the first seed had started to ripen. However, when 300 pounds of Treble Superphosphate was applied in addition to the 1,000-pound application of ammonium sulfate, the seed matured normally (fig. 5). This relationship was borne out by the increased clean-out of small, undersized seed

FIGURE 5.—Effect of an unbalanced relationship between nitrogen and phosphate on plant growth and maturity: *A*, High nitrogen and low phosphate; *B*, a proper balance of nitrogen and phosphate.

when seed from the no-phosphate plots was run over a 3-mm. slotted screen.

TESTS HARVESTED IN 1938

In the 1937–38 tests, three relationships were thought to be of most importance: (1) Determination of the maximum economic application of nitrogen, (2) the relation of phosphate to nitrogen utilization, and (3) the relation of both these factors to the reproduction of varieties differing widely in bolting tendency. Consequently, the 1938 experiments again included U. S. 12, as representative of the easy-bolting types, and U. S. 14, as representative of those that are comparatively nonbolting. Three levels of nitrogen were employed: None, 600 pounds, and 1,000 pounds of ammonium sulfate per acre. Results of the previous tests had shown that yield increases with applications of 600 pounds of ammonium sulfate per acre were such as to warrant this quantity. The 1,000-pound application was considered adequate to explore possible advantages from additional nitrogen and also to determine the conditioning effects of phosphate when combined with heavy nitrogen treatments. In these tests, the phosphate applications were at three levels: None, 300 pounds, and 600 pounds of Treble Superphosphate per acre. Treatments in which either nitrogen or phosphate was used alone were included, so that there would be some measure of the individual responses to these elements.

The phosphate was broadcast during seedbed preparation on blocks 42 feet wide and 200 feet long. These blocks were of sufficient width to accommodate three nitrogen plots each eight rows wide, and each eight-row nitrogen plot was made up of four rows of each of the two varieties used in the test. The complete nitrogen fertilizer schedule, with rate and time of application, is shown in table 5, and the combinations of nitrogen and phosphate treatments are shown in table 6.

TABLE 5.—*Schedule of the nitrogen treatments in the experimental plots at St. George, Utah, 1937-38*

Date of application—	Ammonium sulfate per acre applied in treatment No.— 1	2	3
	Pounds	*Pounds*	*Pounds*
Oct. 1, 1937	None	200	200
Mar. 6, 1938	None	200	400
Apr. 5, 1938	None	200	400
Total	None	600	1,000

TABLE 6.—*Influence of variety and of nitrogen and phosphate levels on the photothermal induction of flowering in sugar beets, as shown by the percentage of plants developing seedstalks and entering into seed production* [1]

Variety	Ammonium sulfate per acre	Plants developing seedstalks in plots receiving indicated amount (pounds) of Treble Superphosphate per acre: None	300	600	Mean	Plants classed as seed producers in plots receiving indicated amount (pounds) of Treble Superphosphate per acre: None	300	600	Mean
	Pounds	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
U. S. 12 (618)	None	93	98	96	96	74	86	86	82
	600	94	96	98	96	84	90	90	88
	1,000	95	97	97	96	83	92	90	88
U. S. 11 (617)	None	77	92	93	87	52	71	73	65
	600	86	94	96	92	74	86	86	82
	1,000	84	93	94	90	70	85	87	81
Combined varietal response	None	85	95	95	92	63	78	79	73
	600	90	95	97	94	79	88	88	85
	1,000	89	95	96	93	77	88	88	84
Mean		88	95	96		73	85	85	

[1] Difference for significance of all subplot comparisons: Seedstalk percentages, 5 percent; seed producers, 9 percent. Difference for significance of nitrogen-treatment means: Seedstalk percentages, 3 percent; seed producers, 7 percent. Difference for significance of phosphate-treatment means: Seedstalk percentages, 4 percent; seed producers, 10 percent.

Counts to determine percentages of plants producing seedstalks and of those producing seed were made just prior to harvest. These percentages are shown in table 6. It is evident that the percentage of plants producing seedstalks, as well as the percentage entering into seed production, was influenced by variety and also by nitrogen and phosphate level. Varietal response was conditioned by applications of both nitrogen and phosphate. For example, the mean difference in the percentage of seed-producing plants between U. S. 12 and U. S. 14 on the no-nitrogen and no-phosphate plots was 22 percent, whereas the mean difference between these two varieties in the percentage of seed-producing plants on plots receiving both nitrogen and phosphate was only 3 percent. The nitrogen effect was also much greater in the presence of phosphate. The application of 1,000 pounds per acre of ammonium sulfate alone caused an increase of 14 in the percentage of plants entering into seed production. The application of 600 pounds per acre of Treble Superphosphate alone increased the percentage of seed producers by 16. The combined effect of these two substances at these rates increased the percentage of seed-producing plants by 25. The absence of either nitrogen or phosphate retarded fall growth, as reflected in both top and root development, and thereby reduced the effectiveness of induction during the fall, winter, and spring months.

The magnitude of yield differences was much greater on the plots harvested in 1938 than on those of the previous year. The importance of phosphate stood out above all other factors in the test. Nitrogen applications also increased the yield of seed. There was, however, a high interaction relationship between nitrogen and phosphate (figs. 3, 5). Without phosphate, the 1,000-pounds-per-acre application of ammonium sulfate gave an increase in yield of only 235 pounds of seed per acre. When 300 pounds of Treble Superphosphate per acre was added with this amount of nitrogen, the increase in yield was 1,226 pounds of seed per acre (table 7). It was also evident that use of phosphate alone would be a more economical practice than the use of nitrogen alone. This fact was especially evident on some of the plots where phosphorus deficiency was most pronounced. On these plots, the application of nitrogen served to increase the phosphorus-deficiency effects; mortality of plants was greatest in the plots with the highest nitrogen level.

TABLE 7.—*Acre yield of clean seed in a replicated test that included 3 levels of nitrogen and 3 levels of phosphorus employed in the 9 possible combinations*[1]

Ammonium sulfate applied (pounds per acre)	Acre yield of seed in plot receiving indicated amount (pounds) of Treble Superphosphate per acre			
	None	300	600	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*
None	1,431	2,088	2,379	1,966
600	1,677	2,625	2,760	2,354
1,000	1,666	2,657	2,877	2,400
Average	1,591	2,457	2,672	----

[1] Least significant difference between the 9 subplot comparisons, 209 pounds; least significant difference between the 3 phosphate means, 257 pounds; least significant difference between the 3 nitrogen means, 178 pounds.

There was an increase of 1,194 pounds in acre yield of seed over the checks from the plots receiving 600 pounds of ammonium sulfate and 300 pounds of Treble Superphosphate per acre. The fact that an additional 400 pounds of ammonium sulfate per acre caused an average increase of only 32 pounds of seed per acre indicated that, for general practice in commercial sugar-beet seed production, applications of 600 pounds of ammonium sulfate per acre represent a more profitable practice than the use of larger amounts. With 600 pounds of ammonium sulfate per acre the addition of 300 pounds of Treble Superphosphate caused a further increase in yield of almost 1,000 pounds of seed per acre. The average increase in yield from the plots receiving the 600-pound application of phosphate fertilizer over those receiving the 300-pound application was 215 pounds of clean seed per acre. Adjoining tests, which included an application of Treble Superphosphate at the rate of 400 pounds per acre, indicated that the 400-pound application was as effective as was the 600-pound application. For soils of the type on which these tests were located, the most profitable application of Treble Superphosphate would be 300 to 400 pounds per acre.

TESTS HARVESTED IN 1939

From experimental data of previous seasons and from observations in numerous commercial fields, the application of 600 pounds of ammonium sulfate plus 300 to 400 pounds of Treble Superphosphate per acre seemed adequate to meet the nitrogen and phosphate demands of the sugar-beet seed crop in the southern Utah sugar-beet districts. From the previous work, it was known that planting date, as well as nitrogen and phosphate, affected the amount of fall growth. Inasmuch as practically all of the sugar-beet seed acreage follows alfalfa in the rotation, it also seemed desirable to have information regarding the effect of time and method of seedbed preparation on fertilizer requirements. Consequently, the following factors were included in the 1938–39 tests: Two dates of planting, two dates of plowing, four phosphate treatments, and four nitrogen treatments. These various factors were introduced into the experiment by utilizing a split-plot arrangement.

The relationship of the various factors in the test is evident from figure 6 and table 8.

TABLE 8.—*Schedule of treatments testing nitrogen as fall, spring, and divided applications, in contrast to no-nitrogen, in combination with 4 phosphate treatments of similar type*

Ammonium sulfate per acre and season of application	Treble Superphosphate per acre and season of application			
	P_0 (none)	P_F (400 pounds, fall)	P_S (400 pounds, spring)	P_{FS} (200 pounds, fall, +200 pounds, spring)
N_0 (none)	N_0 P_0	N_0 P_F	N_0 P_S	N_0 P_{FS}
N_F (600 pounds, fall)	N_F P_0	N_F P_F	N_F P_S	N_F P_{FS}
N_S (600 pounds, spring)	N_S P_0	N_S P_F	N_S P_S	N_S P_{FS}
N_{FS} (200 pounds, fall, +400 pounds, spring)	N_{FS} P_0	N_{FS} P_F	N_{FS} P_S	N_{FS} P_{FS}

The early-plowing date was May 28 and the late-plowing date was August 4, 1938. These two plowing dates represent the range most commonly used by commercial seed growers. At each plowing date alfalfa was plowed under when it was about 12 inches high, and the soil moisture in each case was such as to permit a good job of plowing and to hasten decomposition of the green manure.

There were check plots of both nitrogen and phosphate, and the other nitrogen and phosphorus treatments were variations in date of application rather than in amount of fertilizers applied.

The effect of treatments on fall growth was more striking than had

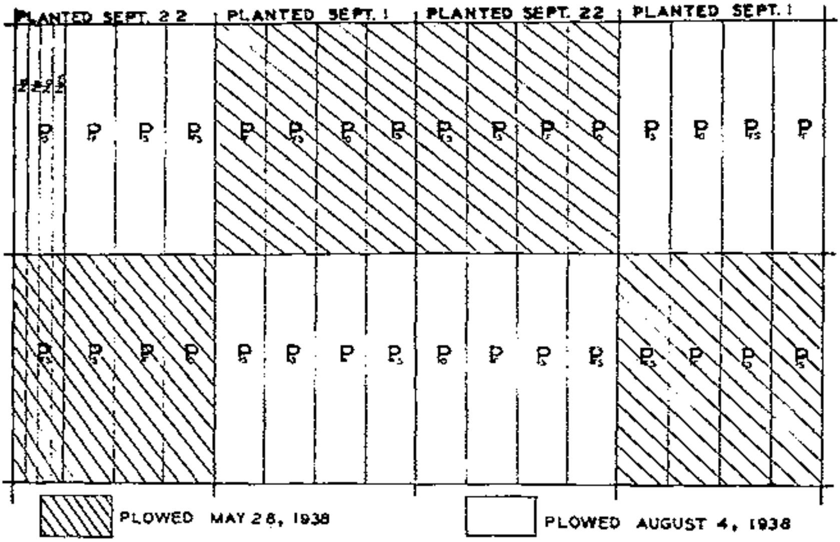

FIGURE 6.—Plan of the 1938-39 experimental plot: Two dates of planting (September 1 and September 22), two dates of plowing (May 28 and August 4), four phosphate treatments (P_0, P_F, P_S, P_{FS}), and 4 nitrogen treatments (N_S, N_F, N_0, N_{FS}). Subscript zero and letters indicate none, fall, spring, and applications divided between fall and spring, respectively. The four nitrogen treatments, as illustrated at the left, were located at random in each of the remaining 15 sections.

been observed in any previous experiment. At least two factors were responsible for this difference in response. The late planting was made on September 22, which was at least a week later than the planting date on previous plots. The effect of the resulting shorter season for fall growth was especially apparent on the plots that did not receive either nitrogen or phosphate fertilizer in the fall. The second factor responsible for the contrast between plots was plowing date. Growth was exceptionally good on the early-plowed plots and, in contrast, it was extremely poor on the late-plowed plots. Some of the effects of late plowing on fall growth were no doubt direct effects, while others may have been indirect and as yet not completely understood. Among the direct effects must be considered the fact that an additional crop of alfalfa (approximately 2 tons) was removed from the land on which the late-plowed plots were located. This further reduced the available phosphorus content of the soil. The significance of this was suggested by the fact that the growth of beets on plots plowed late but given fall applications of phosphate was equal to the growth on plots plowed early but to which no phosphate was applied in the fall. On the early-plowed plots all of the crowns and roots, as well as the green-manure crop, were completely decomposed by planting time. In contrast to this, the undecomposed roots and crowns were still much in evidence on the late-plowed plots. No attempt is made to analyze all the indirect effects on growth of contrasting seedbed conditions of this nature. It has, however, been noted many times that the addition of a small amount of organic matter to the soil in many cases greatly increases the utilization of inorganic food materials.

On plots where late planting, late and improper seed preparation, and no fall fertilization were combined the effect of each factor on growth was additive and by December 1, 1938, beets on these plots were less than one-tenth the size of those on plots where early planting, early seedbed preparation, and fall fertilization were combined. These extreme size differences in the beets during the fall, winter, and early spring made it possible to study the relation of both the size and age of the plants to photothermal induction of flowering. The results from counts made on June 1, 1939, of plants with seedstalks and the classification of these with respect to the percentage of plants producing seed are given in tables 9 and 10.

TABLE 9.—*Influence of time of planting, time of plowing, and time of application of nitrogen and phosphate on photothermal induction of flowering, as shown by the percentage of plants developing seedstalks*

Fertilizer treatment	Plants developing seedstalks in plot receiving indicated treatment							
	Early planting			Late planting			Mean of early plowing	Mean of late plowing
	Early plowing	Late plowing	Mean	Early plowing	Late plowing	Mean		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
$N_0 P_0$	88	68	78	80	40	60	84	54
$N_F P_0$	96	82	89	89	50	70	93	66
$N_S P_0$	91	66	79	83	38	61	87	52
$N_{FS} P_0$	94	78	86	80	48	64	87	63
Mean	92	74	83	83	44	64	88	59
$N_0 P_F$	93	91	92	82	85	84	88	88
$N_F P_F$	99	99	99	93	96	95	96	98
$N_S P_F$	97	96	97	84	88	86	91	92
$N_{FS} P_F$	97	97	97	94	95	95	96	96
Mean	97	96	96	88	91	90	93	94
$N_0 P_S$	79	73	76	81	27	54	80	50
$N_F P_S$	99	94	97	93	47	70	96	71
$N_S P_S$	99	89	94	87	34	61	93	62
$N_{FS} P_S$	97	82	90	88	40	64	93	61
Mean	94	85	89	87	37	62	91	61
$N_0 P_{FS}$	92	86	89	89	76	83	91	81
$N_F P_{FS}$	98	98	98	97	86	92	98	92
$N_S P_{FS}$	99	92	96	96	80	88	98	86
$N_{FS} P_{FS}$	98	94	96	96	85	91	97	90
Mean	97	93	95	95	82	89	96	88
Average	95	87	91	88	64	76	92	75

TABLE 10.—*Influence of planting date, plowing date, and time of application of nitrogen and phosphate on photothermal induction of flowering, as indicated by percentage of plants classed as seed producers*

Fertilizer treatment	Plants classed as seed producers in plot receiving indicated treatment							
	Early planting			Late planting			Mean of early plowing	Mean of late plowing
	Early plowing	Late plowing	Mean	Early plowing	Late plowing	Mean		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
N_0P_0	80	50	65	55	17	36	68	34
N_FP_0	82	56	60	76	21	49	79	39
N_SP_0	67	46	57	49	18	34	58	32
$N_{FS}P_0$	76	41	59	55	20	38	66	31
Mean	76	48	63	59	19	39	68	34
N_0P_F	79	61	70	62	55	59	71	58
N_FP_F	92	86	89	80	74	77	86	81
N_SP_F	86	83	84	67	62	65	77	73
$N_{FS}P_F$	88	89	89	75	63	69	82	76
Mean	86	80	84	71	64	67	79	72
N_0P_S	61	44	53	54	9	32	58	27
N_FP_S	91	74	83	70	18	44	81	46
N_SP_S	90	52	71	71	10	41	81	31
$N_{FS}P_S$	88	54	71	75	12	44	82	33
Mean	83	56	70	68	13	40	76	34
N_0P_{FS}	69	70	70	76	59	68	73	65
N_FP_{FS}	89	87	88	86	83	85	88	85
N_SP_{FS}	83	75	79	80	70	75	82	73
$N_{FS}P_{FS}$	86	76	81	85	71	78	86	74
Mean	82	77	80	82	71	77	82	74
Average	82	65	74	70	42	56	76	54

It is evident from the data in the tables that any factor that depressed the fall development of the beets also depressed bolting and increased the number of non-seed-producing plants. None of the combinations of spring fertilizer treatments overcame the effects of depressed fall growth (figs. 1 and 7). It is also evident that plant size was much more important to the process of photothermal induction than was plant age. There is possibly a direct relation between plant size and photoperiodic induction, inasmuch as plant size directly affects the leaf area exposed to light. The principal effect of plant size on thermal induction may not, however, be the amount of tissue exposed to thermal effects. It may rather be the influence of size of top on soil temperature and, consequently, the temperature to which the crown of the beet is exposed. Special studies on crown temperature in relation to thermal induction showed the importance of this relationship.

The yield of clean seed per acre followed rather closely the percentage of plants entering into seed production. This was to be expected where the difference in the number of seed-producing plants on the various plots was as great as it was in this test.

Where early seedbed preparation or early planting, either separately or in combination, stimulated fall growth sufficiently for satisfactory reproductive development to be initiated in the spring, the plants seemed to make good use of the spring application of both phosphate and nitrogen. However, where fall growth was not sufficient and

508106 - 43 - 3

induction was incomplete, the spring applications of nitrogen or phosphate, either alone or in combination, had little effect on seed yield, although they did stimulate rank vegetative growth (fig. 7). There were highly significant interaction effects between planting date and plowing date, planting date and time of phosphate application, plowing date and time of phosphate application, and time of nitrogen and time of phosphate application, as shown by the variance analysis and by the yield data in table 11. For example, the mean effect of the time of seedbed preparation on seed yield varied widely, depending on other related factors. When no phosphate was applied, the difference

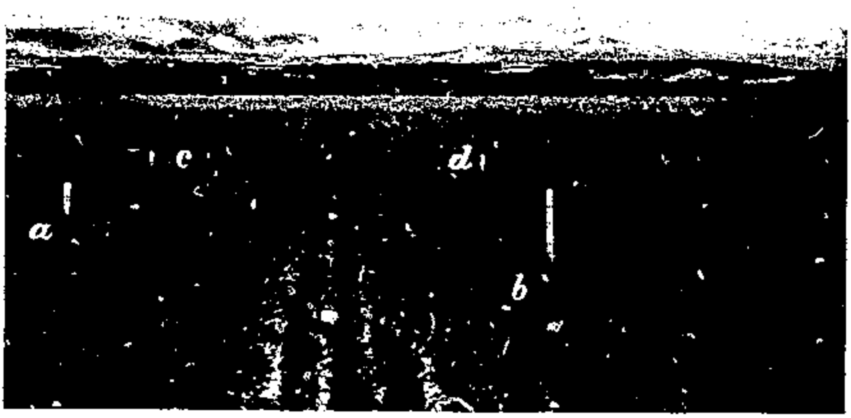

FIGURE 7.—Effect of phosphate, planting date, and plowing date on plant growth and development. The four height stakes mark four different treatments. The treatments indicated by the two height stakes in the foreground were as follows: a, Late planting, late plowing, 100 pounds of phosphate fertilizer per acre October 6, 1938; b, late planting, late plowing, 100 pounds of phosphate fertilizer per acre February 21, 1939. The two treatments in the background were as follows: c, Late planting, early plowing, 100 pounds of phosphate fertilizer per acre October 6, 1938; d, late planting, early plowing, 100 pounds of phosphate fertilizer per acre February 21, 1939. 1939 experimental plot, photographed May 26, 1939.

in yield of seed in favor of early seedbed preparation was 1,091 pounds per acre. When phosphate was added in the early spring, the difference was 1,059 pounds per acre. However, when phosphate was added in the fall, the difference between early and late seedbed preparation was reduced to 549 pounds of seed per acre.

In like manner, the difference between fall and spring application of phosphate was greatly affected by other factors that influenced fall growth. On the early planting, the increase in seed yield of the plots receiving phosphate in the fall over the plots that did not have phosphate till spring was 310 pounds per acre. On the late planting, where rapid fall growth was more vitally important, this difference increased to 1,208 pounds of seed per acre. The same relation was evident between time of phosphate application and time of seedbed preparation. Where the seedbed was prepared early (plowed May

28), the difference in seed yield between the application of phosphate in the fall and in the spring was 369 pounds per acre. When the seedbed was prepared late (plowed August 4), the difference in yield due to time of phosphate application was 1,079 pounds of seed per acre.

TABLE 11.—*Yield of clean seed per acre from a replicated test, including 2 dates of planting, 2 dates of plowing, 4 nitrogen treatments, and 4 phosphate treatments*

Fertilizer treatment	Acre yield of seed from plot receiving indicated treatment							
	Early planting			Late planting			Mean of early plowing	Mean of late plowing
	Early plowing	Late plowing	Mean	Early plowing	Late plowing	Mean		
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
N_0 P_0	[1] 1,745	[1] 952	[2] 1,349	[1] 1,537	[1] 798	[2] 1,168	[3] 1,641	[3] 875
N_F P_0	1,838	1,031	1,435	2,292	828	1,560	2,065	930
N_S P_0	2,000	844	1,422	2,256	832	1,544	2,128	838
N_{FS} P_0	1,867	805	1,336	2,190	902	1,546	2,029	854
Mean	1,863	908	[4] 1,386	2,069	840	[4] 1,455	[5] 1,966	[5] 875
N_0 P_F	[1] 2,010	[1] 1,703	[2] 1,602	[1] 2,808	[1] 1,991	[2] 2,400	[3] 2,454	[3] 1,847
N_F P_F	3,520	2,897	3,209	3,139	2,959	3,049	3,330	2,028
N_S P_F	3,054	3,129	3,092	3,042	2,946	2,994	3,048	3,038
N_{FS} P_F	3,106	2,850	2,978	3,339	2,845	3,092	3,223	2,848
Mean	2,923	2,667	[4] 2,795	3,105	2,663	[4] 2,884	[5] 3,014	[5] 2,665
N_0 P_S	[1] 1,278	[1] 1,431	[2] 1,355	[1] 2,473	[1] 831	[2] 1,652	[3] 1,876	[3] 1,131
N_F P_S	3,185	3,025	3,105	2,797	808	1,803	2,991	1,917
N_S P_S	2,936	2,552	2,744	2,776	788	1,782	2,856	1,670
N_{FS} P_S	2,850	2,372	2,616	2,849	879	1,864	2,854	1,626
Mean	2,565	2,345	[4] 2,455	2,724	827	[4] 1,776	[5] 2,645	[5] 1,586
N_0 P_{FS}	[1] 2,465	[1] 2,209	[2] 2,337	[1] 2,362	[1] 1,892	[2] 2,127	[3] 2,414	[3] 2,051
N_F P_{FS}	3,580	3,298	3,439	2,910	2,507	2,709	3,245	2,903
N_S P_{FS}	3,450	2,923	3,187	3,099	2,431	2,765	3,275	2,677
N_{FS} P_{FS}	3,551	3,223	3,387	3,090	2,493	2,792	3,320	2,858
Mean	3,262	2,913	[4] 3,088	2,865	2,331	[4] 2,598	[5] 3,064	[5] 2,622
Mean	[6] 2,653	[6] 2,208	[7] 2,431	[6] 2,691	[6] 1,665	[7] 2,178	[8] 2,673	[8] 1,937

[1] Least significant difference between 64 fertilizer × plowing date × planting date subplot comparisons=350 pounds of clean seed.
[2] Least significant difference between 32 fertilizer × plowing date mean comparisons=248 pounds of clean seed.
[3] Least significant difference between 32 fertilizer × planting date means=248 pounds of clean seed.
[4] Least significant difference between 8 time of phosphate × planting date means=301 pounds of clean seed.
[5] Least significant difference between 8 time of phosphate × plowing date means=301 pounds of clean seed.
[6] Least significant difference between 4 planting date × plowing date means=250 pounds of clean seed.
[7] Least significant difference between 2 planting date means=209 pounds of clean seed.
[8] Least significant difference between 2 plowing date means=209 pounds of clean seed.

In view of the importance of proper fall growth, it seems essential that sufficient nitrogen and phosphate fertilizer be applied to the crop in the fall to insure optimum fall growing conditions. It also seems evident that, inasmuch as beets generally follow alfalfa, care should be exercised to see that the alfalfa is plowed under far enough in advance of the planting date to allow complete decomposition to take place. The data in table 12 indicate that, even when all of the nitrogen and phosphate fertilizer was applied in the fall, the plants utilized it and very little was gained by dividing the application between fall and spring.

TABLE 12.—*Effect of time of nitrogen application, with and without variation in phosphate treatment, on production of clean seed per acre*

[Values are averages of 4 replicated plots]

Planting date, pounds ammonium sulfate per acre, and time of application	Clean seed per acre when plots received Treble Superphosphate at rates shown						
	200	None	400	400 fall	400 spring	200 fall + 200 spring	Mean
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Sept. 3, 1936:							
None (check)	2,416						
400 (fall)	[1] 3,512						
200 (fall) + (spring)	[1] 3,575						
400 (spring)	[1] 3,450						
Sept. 13, 1937:							
None (check)		1,365	2,280				1,823
200 (fall) + 400 (spring)		2,050	3,000				2,525
None (fall) + 600 (early spring)		1,960	2,920				2,440
None (fall) + 600 (late spring)		2,010	2,080				2,405
400 (fall) + 200 (spring)		2,140	3,140				2,640
600 (fall), none (spring)		1,980	2,992				2,486
Sept. 1 and Sept. 22, 1938: [2]							
None (check)		1,253		2,151	1,504	2,232	1,785
600 (fall), none (spring)		1,498		3,129	2,252	3,074	2,488
None (fall) + 600 (spring)		1,488		3,024	2,237	2,976	2,431
200 (fall) + 400 (spring)		1,412		3,036	2,240	3,090	2,452

[1] No significant differences among nitrogen treatments.
[2] Data given as averages of the two planting dates.

SPECIAL STUDIES ON THE RELATION OF TOP GROWTH TO CROWN TEMPERATURES AND INDUCTION OF FLOWERING

Special studies were started in the fall of 1937 on the relation of top growth to crown temperatures and induction of flowering. During these studies, the following factors influencing the shading effect of top growth were considered: (1) Size of plants—large as compared with small beets; (2) removal of tops by clipping—tops removed as compared with those not removed; (3) spacing—1 plant per foot as compared with 12 plants per foot; and (4) shading—soil and beet crowns shaded with horizontal shades as compared with those not shaded. The use of artificial shades was suggested by field experiments started by Carsner at Riverside, Calif., in the fall of 1936 (*5*).

FACTORS STUDIED

PLANT SIZE

Large beets were obtained by early planting and ample fall applications of phosphate. The top growth of large beets completely shaded the crowns and surrounding soil by December 1. During the winter, the tops froze down and became more or less straw-colored; however, they continued as an effective source of shade. Small beets were the result of either late planting or lack of phosphate on beets planted early or moderately early (fig. 8). Size comparisons were made between beets of the same age but of different rates of growth and between beets of the same rate of growth but of different ages. The tops of small beets generally remained dark green during the entire winter but furnished very little shade for the surrounding soil.

and temperature of the beet crowns tended to follow the rise in surrounding soil-surface temperature during the warm part of the day.

TOP REMOVAL

Unclipped beets had the benefit of the shading effect of top growth according to the amount of top growth present. The shading effect of top growth was largely dependent on plant size and the proximity of adjacent beets in the row. Removal of the tops by clipping, from either large or small beets, left the soil bare and unshaded, and crown temperatures fluctuated as rapidly as did surrounding soil-surface temperatures. This treatment possibly introduced unknown physiological effects, including such factors as a difference in photoperiodic induction between the clipped and unclipped beets.

FIGURE 8.—Plant size in relation to crown temperatures and induction of flowering, showing range of plant size obtained by controlling planting date and phosphate application in the 1938 experiment: *A*, Sugar beets planted September 3, 400 pounds of Treble Superphosphate per acre added in the fall; *B*, planted September 3, no phosphate in the fall; *C*, planted September 22, 400 pounds of Treble Superphosphate per acre added in the fall; *D*, planted September 22, no phosphate in the fall. The variation in size made it possible to study both plant size and plant age in relation to the induction process.

SPACING

Spacing was accomplished by thinning the beets to the desired distance in the row when they were about 6 weeks old. Spacing changed the habit of top growth, causing the tops to spread horizontally and leaving the crowns more directly exposed to the sunlight. This was especially true with small beets. Spacing also eliminated the shading effect of adjacent beets.

HORIZONTAL SHADES

Shading the soil and beet crowns with horizontal aluminum-painted shades, in combination with the other factors studied, made it possible to separate temperature effects from other possible physiological responses. For example, the horizontal shades reflected the light and heat away from beets where the tops had been removed by clipping and kept both soil and crown temperatures at almost the same level as the soil and crown temperatures of the large, unclipped, unshaded beets. Thus a direct comparison could be made between temperature effects and other physiological responses accompanying top removal.

The greatest contrast between different combinations of treatments was that between (1) large, unthinned beets with maximum top growth plus horizontal shades between the rows and (2) small, spaced, unshaded beets with the tops removed. The former combination of treatments furnished a maximum of shade to soil and beet crowns and helped greatly to maintain favorable temperatures for thermal induction. The latter combination of treatments left the soil and beet crowns completely exposed to sunlight, and during the warm part of the day the beets were subjected to temperatures that are known to be unfavorable for thermal induction (7).

Methods

Tests were planted in the fall of 1937, 1938, and 1939. Varieties differing widely in bolting tendency were used in each test. All variety plots were 4 rows wide and 150 feet long. These plots were of sufficient size to accommodate a complete set of associated treatments. Each top-removal and spacing plot was of sufficient size to include at least 100 plants. The shading plots were 21 feet long and included at least 100 plants, except where shades were used in combination with plants spaced 12 inches apart. There were four replicated plots of each treatment in each test. All temperature measurements were made by inserting the bulb of a mercury thermometer in a small hole made in the crown of the beet with a nail of appropriate size. At each date and time of temperature measurement, four temperature readings were taken on each plot. There was seldom a greater difference than 0.5° C. between the four temperature readings on any one plot. Prior to harvest, the plants on all plots were classified as to the percentage developing seedstalks and the percentage entering into seed production.

Experimental Results

The object of the first test was to determine the extent of the shading effect of top growth on crown temperatures and to determine further whether the increase in crown temperature that was most certain to follow top removal would significantly affect seedstalk development and the percentage of plants producing seed. The test was planted on September 13, 1937, and tops were removed on two rows of each four-row plot on December 4, 1937, and again on March 15, 1938 (fig. 9). Temperature measurements made during March and April 1938 showed that the removal of tops did increase crown temperatures and that during the warm part of the day there was a difference of as much as 12.5° C. between the crown temperatures of clipped and unclipped beets. Counts showed that this temperature increase interfered with induction and was responsible for an increase in vegetative plants and a decrease in plants entering into seed production (table 13). The reduction of seed-producing plants, due to increased crown temperatures, was much greater in the nonbolting variety U. S. 15 than in the easy-bolting variety U. S. 12.

The main object of the second test was to separate more completely temperature effects from other possible physiological responses accompanying top removal. Consequently, top-removal studies were continued in the second set of tests, planted September 22, 1938. To separate true temperature effects from other responses, aluminum-painted horizontal shades were used between the rows to shade the soil and the beet crowns. These shades were supposed to compensate for the loss in shading effect of the removed top growth and at the same time not interfere seriously with top growth on the unclipped plots (fig. 10). In addition to the use of shades in connection with

FIGURE 9. Top removal of sugar beets in relation to soil temperature and crown temperature. Tops were clipped December 1, 1937, and the regrowth was clipped March 15, 1938. Photographed December 15, 1937.

top removal, shades were also used on large and small beets to equalize the shading effect of large and small tops. The size difference was due to an increased rate of growth on the half of the experimental area that received a fall application of phosphate. Consequently, rate of growth rather than age of plant was responsible for the difference in size between the large and the small beets. One spacing treatment was included to test the shading effect of adjacent beets where beets were continuous in the row.

Temperature readings made at intervals during the fall, winter, and spring months indicated that horizontal shades were effective in minimizing crown-temperature differences between clipped and unclipped beets and between beets with large and with small tops. The data in table 14 indicate that where horizontal shades were not used crown temperatures of both clipped beets and small beets increased during the warm part of the day. Increased crown temperatures were associated with an increase in vegetative beets and a decrease in the percentage of plants producing seed.

TABLE 13.—*Relation of top removal to beet-crown temperatures and induction of flowering, as shown by the percentage of plants developing seedstalks and the percentage entering into seed production*

[1938 experiment, planted Sept. 13, 1937; averages of 4 replicated plots]

Treatments in ascending order of their effect on crown temperatures and subsequent seed-producing plants	Temperature reading at date (1938) and time of measurement shown						Seed producers					Plants developing seedstalks				
	Mar. 15			Mar. 16		Apr. 15										
	10 a. m.	12:30 p. m.	3 p. m.	8:30 a. m.	3 p. m.	3 p. m.	U. S. 12	U. S. 14	732	U. S. 15	Mean	U. S. 12	U. S. 14	732	U. S. 15	Mean
	°C.	°C.	°C.	°C.	°C.	°C.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Large unclipped tops	9.0	9.5	15.0	5.5	13.0	14.5	[1] 91	[1] 87	[1] 88	[1] 78	[2] 86	[3] 99	[3] 95	[3] 97	[3] 87	[4] 95
Tops clipped only in fall, Dec. 4, 1937	14.0	15.0	19.0	5.5	18.0	20.5	------	------	------	------	------	------	------	------	------	------
Tops clipped both fall and spring, Dec. 4, 1937, and Mar. 14, 1938	21.5	22.0	25.0	5.5	24.5	27.0	89	69	75	49	71	97	82	79	66	81

[1] Least significant difference, 7 percent.
[2] Least significant difference, 5 percent.
[3] Least significant difference, 4 percent.
[4] Least significant difference, 3 percent.

F[illegible] soil temperatures [illegible] growth temperature. As-[illegible] roots [illegible] tops removed [illegible], and normal top growth [illegible] rows from Decem-[illegible] in [illegible] December 5, 1958.

TABLE 14.—*Relation of plant size, top removal, spacing, and shading to beet-crown temperatures and induction of flowering, as shown by the percentage of plants developing seedstalks and the percentage entering into seed production: 1939 experiments, planted Sept. 22, 1938*

[Averages of 4 replicated plots]

Treatments arranged in order of their effect on crown temperature and subsequent seed-producing plants	Temperature reading at date and time of measurement shown								Seed producers					Plants developing seedstalks				
	Nov. 30, 1938	Dec. 1, 1938		Jan. 18, 1939		Mar. 9, 1939		Mar. 29, 1939										
	4 p. m.	10:30 a. m.	1 p. m.	8 a. m.	3 p. m.	8:30 a. m.	1:30 p. m.	4 p. m.	U. S. 12	815	732	U. S. 15	Mean	U. S. 12	815	732	U. S. 15	Mean
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Large beets, unthinned, unclipped, horizontal shades	8.0	7.0	10.0	−1.5	6.0	8.0	15.0	16.0	[1] 93	[1] 88	[1] 84	[1] 78	[2] 86	[3] 100	[3] 92	[3] 93	[3] 89	[4] 94
Small beets, unthinned, unclipped, horizontal shades	8.5	7.0	10.0	−1.5	7.0	7.5	16.0	17.5	89	81	80	72	81	98	89	84	81	88
Large beets, unthinned, unclipped, not shaded [5]	8.5	6.0	11.5	−1.0	6.0	7.0	16.5	17.5	92	82	79	69	81	98	86	87	80	88
Large beets, thinned, unclipped, not shaded [6]	11.5	8.5	13.5	−1.0	8.0	7.0	17.0	17.5	88	73	67	63	73	95	80	80	72	82
Large beets, unthinned, clipped, horizontal shades	10.0	7.5	12.5	−1.0	7.5	8.0	17.5	19.0	90	76	68	61	74	95	82	78	74	82
Small beets, unthinned, unclipped, not shaded [5]	13.5	7.5	12.3	−1.5	10.0	7.0	18.0	26.0	87	68	66	55	69	96	78	71	67	78
Small beets, thinned, unclipped, not shaded [6]	15.5	8.7	15.0	−1.5	12.5	7.0	22.5	24.0	86	54	51	42	58	96	72	69	61	75
Large beets, unthinned, clipped, not shaded	16.0	10.0	16.0	−1.5	15.0	7.5	23.5	26.0	88	54	46	38	56	94	70	66	56	72

[1] Least significant difference, 9 percent.
[2] Least significant difference, 6 percent.
[3] Least significant difference, 5 percent.
[4] Least significant difference, 3 percent.
[5] Conditions equivalent to those frequently found in farmers' fields.
[6] Conditions equivalent to portions of many fields where stands are irregular.

In the third set of tests, special emphasis was placed on the relation of plant size to the effect of spacing and shading on crown temperatures. In the previous experiment, spacing, especially on small beets, increased crown temperatures and decreased seedstalk development. In this test, spacing was used in combination with horizontal shades, so that other possible size effects could be separated from the effect of size of tops on crown temperatures. Differences in size of beets were obtained by making plantings on August 23, September 16, and October 3, 1939. From previous results with horizontal shades, it was thought unnecessary to include shading treatments on the extremely large beets resulting from the August 23 planting. Consequently, only spacing comparisons were made on this planting date. The treatments on the other two dates of planting consisted of thinned and unthinned and shaded and unshaded beets, both alone and in combination. Temperature measurements indicated that both plant size and spacing, especially on small beets, were factors influencing the shading effect of top growth.

Crown temperatures were definitely higher on the small beets than they were on the large, and they were also higher on the spaced beets than they were on the unthinned. The greatest increase in crown temperature occurred on small, thinned beets. Counts made on May 28, 1940, showed that thermal induction was seriously interfered with at the higher crown temperatures and that this resulted in a large percentage of non-seed-producing plants (table 15 and fig. 11).

TABLE 15.—*Relation of plant size, spacing, and shading to beet-crown temperatures and induction of flowering, as shown by the percentage of plants developing seedstalks and entering into seed production, 1940 experiments*

[Averages of 4 replicated plots]

Beet size as indicated by planting date and the spacing and shading treatments started Dec. 4, 1939	Temperature reading Feb. 28, 1940, at			Seed producers			Plants developing seedstalks		
	8:30 p.m.	1 p.m.	4 p.m.	U.S. 22	732	Mean	U.S. 22	732	Mean
	° C.	° C.	° C.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Planted Aug. 23, 1939:									
Approximately 12 beets per foot, no shades [1]	8.5	13.0	15.0	[2] 98	[2] 96	[3] 97	[4] 100	[5] 98	[4] 99
Thinned to 1 beet per foot, no shades	8.0	13.0	15.0	97	94	96	100	99	100
Planted Sept. 16, 1939: [6]									
Approximately 12 beets per foot, no shades [1]	8.0	14.0	17.0	90	76	83	94	90	92
Approximately 12 beets per foot, horizontal shades	8.0	13.0	15.0	96	90	93	99	95	97
Thinned to 1 beet per foot, no shades	8.0	16.5	20.0	76	63	70	81	75	78
Thinned to 1 beet per foot, horizontal shades	8.0	14.0	17.5	86	79	83	97	92	95
Planted Oct. 3, 1939: [6]									
Approximately 12 beets per foot, no shades [1]	8.5	20.5	23.5	52	42	47	85	72	79
Approximately 12 beets per foot, horizontal shades	8.0	15.5	17.5	79	72	76	92	86	89
Thinned to 1 beet per foot, no shades	8.5	23.5	25.0	28	12	20	66	53	60
Thinned to 1 beet per foot, horizontal shades	8.0	16.5	18.5	72	60	66	92	84	88

[1] Conditions equivalent to those frequently found in farmers' fields.
[2] Least significant difference, 10 percent.
[3] Least significant difference, 7 percent.
[4] Least significant difference, 8 percent.
[5] Least significant difference, 6 percent.
[6] In the text, comparisons between the Sept. 16 and Oct. 3 planting are given as comparisons between large and small beets inasmuch as size is the relationship being discussed.

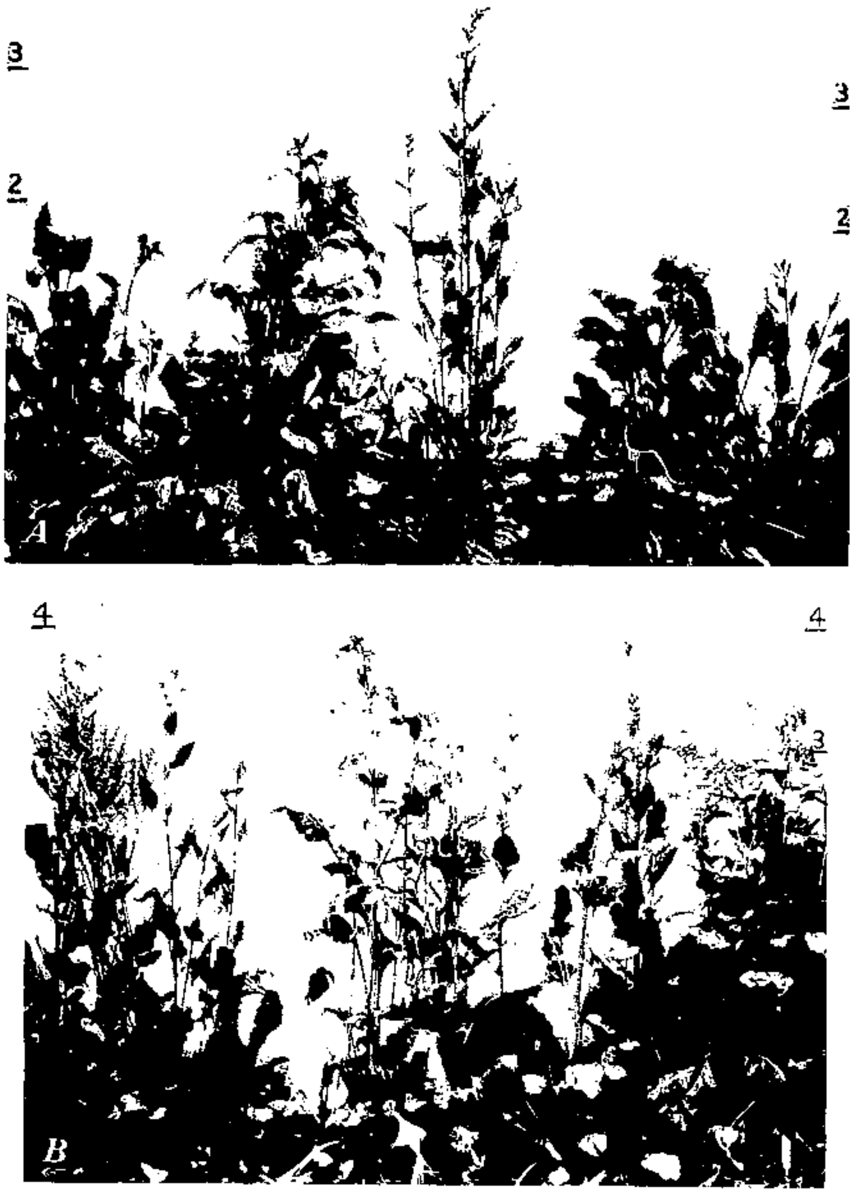

FIGURE 11.—Spacing and shading in relation to soil temperature and subsequent bolting. Beets in both plots were thinned to approximately 1 beet per foot on December 1, 1939. *A*, Beets (U. S. 22) receiving no further treatment; *B*, beets (U. S. 22) with horizontal shades between the rows from December 1, 1939, to April 10, 1940. (Photographed May 28, 1940.)

Interaction Relations of the Factors Studied

TOP REMOVAL AND SHADING EFFECTS

In both the 1938 and 1939 experiments, removal of the tops by clipping caused a temperature difference during the hot part of the day of as much as 10° C. between the crown temperature of beets on clipped and unclipped plots. Subsequently, when plants were counted to determine percentages with seedstalks, there were significantly lower percentages for the clipped plots and also a smaller number of plants entering into seed production than for the unclipped plots. The four varieties differing in bolting tendency reacted differentially to the clipping treatment. This differential variety response is considered a fair indication of the effect of top removal on the induction process. The easy-bolting variety U. S. 12 had only 2 percent fewer seed producers on the clipped than on the unclipped plots. Under the same conditions, U. S. 15, the nonbolting variety, decreased by 29 in the percentage of seed-producing plants. In the 1939 test, the beets were planted later and were smaller. In this test, U. S. 12 had 4 percent fewer seed producers on the clipped than on the unclipped plots and U. S. 15 had 31 percent less. The use of horizontal shades largely overcame the effect of top removal. The shades reduced the temperature differences between beet crowns on clipped and unclipped plots to 3°. The use of shades on clipped plots reduced the difference in percentage of seed producers between clipped and unclipped plots in U. S. 15 from 31 in the unshaded to 8 in the shaded plots.

In the 1939 treatments involving top removal, the lowest percentage of seed-producing plants was found in U. S. 15 on clipped, unshaded plots. Table 14 shows that this treatment had the greatest daily range in temperature. During the middle of the day, these temperatures were not favorable for thermal induction. The highest number of seed-producing plants in U. S. 15 was found on plots with maximum top growth plus horizontal shades. These plots had the smallest daily change in temperature.

It should be noted that shading did not completely overcome the effect of top removal. Top removal may have interfered with induction by light, which is also necessary for induction of flowering in beets.

PLANT SIZE AND SHADING EFFECTS

In both the 1939 and 1940 experiments there was a very marked difference between large and small beets (in favor of the large beets) in the percentage of plants developing seedstalks and also in the percentage classed as seed producers. In the 1939 test, this difference in variety 732 was 16 in the percentage of plants developing seedstalks and 13 in the percentage of plants producing seed. In 1940 the difference was 18 in the percentage of plants developing seedstalks and 34 in the percentage of plants producing seed. The larger difference in the 1940 test was due to a greater size contrast between the large and small beets. Where horizontal shades were used to furnish supplementary shade to the soil and to the beet crowns, the difference in the percentages of seed-producing plants between large and small beets of variety 732 was 4 in 1939 and 18 in 1940. These results indicate that the size effects are more important than age relationships and that age is chiefly important only to the extent that it influences size of the top growth. On large beets in the 1939 test, the difference in the percentage of seed producers on the shaded and unshaded plots was only 1 in U. S. 12 and 9 in U. S. 15. On small beets in the same test, the use of shades increased the percentage of seed producers by 2 in U. S. 12 and 17 in the nonbolting variety U. S. 15.

SPACING AND SHADING EFFECTS

Spacing plants 12 inches apart in the row increased crown temperatures. This increase was much greater on small than on large beets. The difference in temperature relationships between thinned and unthinned beets was sufficient to decrease both seedstalk initiation and the number of plants entering into seed production. In the 1939 experiments where small beets were involved, thinned plots of U. S. 15 decreased by 13 in the percentage of plants producing seed as compared with the unthinned plots. In the same test, large thinned beets of U. S. 15 decreased by 6 in the percentage of seed-producing plants as compared with the large unthinned beets.

The interaction effect of size and spacing gave further evidence of the effect of increased temperature. Temperature readings taken at 4 p. m. on March 29, 1939, showed a difference in crown temperature of 2.5° C. between large and small unthinned beets. At the same time, the difference in crown temperatures between large and small thinned beets was 6.5°. Counts made May 24, 1939, showed that the difference in percentage of seed producers between large and small unthinned beets in U. S. 15 was 14 and that where the plants were spaced 12 inches apart this difference was increased to 21.

The 1940 tests furnished further evidence that the difference in the percentage of seed-producing plants between large and small beets was largely due to temperature effects. By using horizontal shades between the rows, the temperature differences due to size were greatly reduced. Temperature readings taken at 1 p. m. on February 28 showed that there was a difference of 7° C. between the crown temperatures of spaced small beets and spaced large beets. This difference was reduced to 2.5° when horizontal shades were used in combination with the spacing treatment. The significance of the above temperature differences is shown by the percentage of plants classed as seed producers on each of these plots. The difference in percentage of seed-producing plants in variety 732 between large and small spaced beets was 51. In the presence of the horizontal shades, this difference was reduced to 19.

Spacing beets 12 inches apart in the row on the early planting made August 23, 1939, did not affect seedstalk initiation and did not decrease significantly the percentage of plants entering into seed production. Temperature measurements indicated that beets of this size were not dependent on adjacent beets to furnish adequate shade to maintain soil and crown temperatures at a favorable level for the induction process.

GENERAL APPLICATION

FACTORS AFFECTING YIELD OF SEED

These studies indicate that temperatures for induction of flowering in southern Utah, although adequate for easy-bolting or moderately nonbolting varieties, are not adequate for the complete reproduction of nonbolting varieties such as U. S. 15, even under the most favorable conditions of growth. During much of the overwintering period, maximum daily air temperatures are higher than the temperature most favorable for thermal induction. Under these conditions, top growth is an important factor in furnishing sufficient shade for the soil and beet crowns to prevent crown temperatures from rising so high that thermal induction is interfered with. Plant size and spacing are the two factors most frequently found affecting the crown temperature of beets in commercial fields. Within any seed-growing area there is wide variation in plant size, due to such factors as planting date, fertilizer practice, and time and method of seedbed preparation. Frequently stands are irregular and approach the condition of plants spaced by thinning. Occasionally tops are accidently or even purposely pastured off by livestock, producing a condition very similar to that resulting from the removal of tops by clipping. All of these factors that decrease shading effects and allow large daily increases in crown temperatures create conditions unfavorable to complete induction of flowering and decrease the number of plants producing seed. Under these conditions, not only are yields of seed less but also complete varietal reproduction does not take place. All of these relationships become doubly important as varieties with increased nonbolting characteristics are grown.

FACTORS AFFECTING QUALITY OF SEED

Seed quality is reflected in seed size and germination percentage. Minimum size of acceptable seed is stipulated by contract for each area, and the seed must have a germination percentage of 75 or better if full contract price is to be paid. In view of this fact, any practice that definitely influences seed quality is of importance. The influence of planting date and fertilization on the percentage of small seed has been rather consistent. Seed from late plantings tends to mature unevenly and, as a consequence, there has been a consistently larger clean-out of small seed from the late plantings. When nitrogen was applied alone, even in comparatively small quantities, the percentage of small seed was increased. However, when the nitrogen was balanced with phosphate applications the maturity was normal and there was no increase in clean-out of small seed even when as much as 1,000 pounds of ammonium sulfate per acre was applied (fig. 5).

The effect of such factors as planting date and nitrogen or phosphate application on seed germination has not been so consistent. Seed germination seems to be determined largely by other factors, such as presence or absence of injurious insects or the occurrence or nonoccurrence of high temperatures or hot drying winds during the period of early seed set.[6] In seasons when conditions were favorable to the production of seed of high germination percentage, seed from plots receiving nitrogen was generally higher in germinations than

[6] Investigations of insects affecting sugar beets grown for seed are conducted by the Bureau of Entomology and Plant Quarantine. Reference is made to the following publications, whose findings are also applicable to Utah conditions:

HILLS, ORIN A., and ROMNEY, VAN E. A PROGRESS REPORT ON INVESTIGATIONS OF INSECTS AFFECTING SUGAR BEETS GROWN FOR SEED IN ARIZONA AND NEW MEXICO. Bureau of Entomology and Plant Quarantine Mimeographed Circular E-552, 13 pp., illus. October 1941.

ROMNEY, VAN E. THE BEET LEAFHOPPER AND ITS CONTROL ON BEETS GROWN FOR SEED IN ARIZONA AND NEW MEXICO. Bureau of Entomology and Plant Quarantine Mimeographed Circular E-567, 9 pp., illus. May 1942.

was seed from the check plots. However, in years when the average germination of seed from the area tended to be low, the higher application of nitrogen depressed the germination percentages.

Factors such as heavy applications of nitrogen, late planting, and slow-maturing of varieties cause an increase in plant succulence. This condition of the plants is not only more attractive to certain insects but also lengthens the critical period when damage from both insects and unfavorable temperature can take place. Applications of phosphate proved to be effective in hastening maturity, thus helping to minimize the damage resulting from the aforesaid relationships.

DISCUSSION

Planting date, fertilizer practice, time and method of seedbed preparation, and the bolting tendency of the variety being grown are all

FIGURE 12.—One of the better fields of sugar-beet seed in southern Utah. Optimum cultural practices are necessary to produce more than 3,000 pounds of clean seed per acre. Summer-fallowed land, early planting, and the application of 500 pounds of ammonium sulfate plus 160 pounds of Treble Superphosphate per acre were all factors in producing the excellent crop shown above. Photographed in June 1936.

factors that affect the percentage of plants developing seedstalks, the rate of development of the seedstalks, the percentage of plants entering into seed production, and the yield and quality of the seed produced. These factors may act separately or in combination, and the combined effect of any two factors may be additive or one may alter the effect of the other. For example, lack of phosphate and nitrogen may be accentuated by improper seedbed preparation, or the benefit of early planting may be lost as a result of poor cultural care or failure to supply needed fertilizer. In southern Utah some of the factors, such as planting date or phosphate application, are so critical that they alone may determine whether the seed crop will be a success or failure. It is only through the integration of all factors at the optimum level that maximum yields of the highest quality seed can be produced (fig. 12).

Fall growth has at least two important aspects in sugar-beet seed production by the overwintering method. The first of these is the accumulation of carbohydrate reserves during the period of vegetative growth (*6*). The second and a very important aspect is the relationship of fall growth to the physiological process of photothermal induction of flowering, which takes place during the fall, winter, and spring. There is a definite point below which fall growth cannot be depressed without seriously affecting reproductive development. This relation of plant size to thermal induction involves not only the accumulation of substances prerequisite or essential to a reproductive response but also the indirect relation of the shading effect of the tops to crown temperatures. Field experiments with artificial shades showed that shading the soil lowered the mean temperature of the beet crown and made thermal induction more effective, as shown by an increase in the percentage of plants developing seedstalks. Carsner reported similar results with shading experiments near Riverside, Calif. (*5*).

The significance of the shading effect of an extensive growth of leaves was further demonstrated in spacing and top-removal studies. Any treatment that reduced the effectiveness of top growth in helping to maintain the most effective temperature range for thermal induction caused an increase in the percentage of vegetative beets. The relation of size of top growth to induction by light may also be important, but the evidence indicates that during the fall and winter months the light relationship is not so important as those affecting thermal induction. Factors such as planting date, time and method of seedbed preparation, and fertilizer practice affect fall growth, and it is through this relationship that they are intimately connected with reproductive development. On some plots where fall growth was especially depressed because of late planting, late seedbed preparation, and the absence of fall applications of phosphate, induction of flowering was so incomplete that 90 percent of the total plant population did not enter into seed production. No amount or kind of spring care was adequate to alter this result. Under conditions of this nature there is no chance for the utilization of stored carbohydrate reserves, but on the contrary the beets continue to grow vegetatively, and large supplies of food reserves are accumulated in the roots.

Varietal differences in bolting tendency, as this character is reflected in normal seedstalk formation, and irregularity with respect to this tendency within varieties make the relationships described above of even greater significance. When induction of flowering in all the component types within a variety does not take place, reproduction of the variety in its entirety is impossible, and undesirable changes in varietal characteristics occur (*4*). Conditions of fall growth that facilitate the process of induction are therefore of more than usual importance if nonbolting varieties or varieties with a wide range in bolting tendency are to be satisfactorily reproduced.

Some of the factors that affect fall growth are much more easily controlled than others. Time and method of seedbed preparation can be easily governed. Much of the acreage planted to sugar-beet seed is broken out of alfalfa. Land preparation should start early enough and be handled in such a manner that green manure or plant crowns and roots will have a chance to decompose completely prior to planting time. The land can also be rid of the most troublesome weeds during this period. Planting date is not so flexible and can be adjusted only within certain rather narrow limits, from about August 25 to September 20. Planting later than September 20 is too late for sufficient fall growth, regardless of other optimum growing conditions, unless the fall growing season is extended beyond the usual length. Planting earlier than the last week of August is hazardous from the standpoint of winter injury. Beets have an optimum size for greatest hardiness. Counts made on the 1936–37 plots of sugar beets planted on August 23 showed that as many as 16 percent of the plants had been killed and an additional 35 percent had received winter injury in the crown tissue, whereas no winter-injured plants were found in the September 12 planting. Fertilizing practice, the third factor affecting fall growth, can be easily controlled. In all cases, enough phosphate should be applied in the fall to insure that lack of it will not become a limiting factor in plant growth. Fall fertilization is doubly important if other factors, such as planting date and time and method of seedbed preparation, are not optimum.

Beginning with the period of seedstalk initiation large quantities of nitrogen are necessary. Pultz (*6*) showed that one of the important functions of fertilizing with nitrogen is to make the carbohydrate reserves stored in the root available for seed production. It is therefore important that an adequate supply of nitrogen be available during the entire fruiting period. There was no significant difference between the dates of applying nitrogen so long as the nitrogen was applied by March 1. This is in accord with previously reported results (*6*). Time of phosphate application was much more important. In all cases where application of phosphate was delayed until spring there was a decrease in seed yield in comparison with plots where phosphate was applied either in the fall or in an application split between fall and spring. Much greater response in plant growth and in seed yields was obtained from phosphate alone than from nitrogen alone. Phosphate had a marked influence on nitrogen utilization. In many soils phosphate was so deficient that it seemed impossible for plants to utilize the nitrogen that was naturally present in the soil. If this is true, the marked response in plant growth and seed yield following phosphate applications was due not only to the utilization by the plants of the applied phosphate but also to a more efficient utilization of soil nitrogen. Phosphate must, therefore, be available throughout the entire period of plant growth.

SUMMARY

Tests conducted during the seasons of 1936–37, 1937–38, and 1938–39 have shown that phosphatic and nitrogenous fertilizers are important factors in sugar-beet seed production in southern Utah. Applications of 300 to 400 pounds of Treble Superphosphate per acre, either in the fall or split between fall and spring, gave consistent increases of about 1,000 pounds of clean seed per acre over the check plots. Applications of 600 pounds of ammonium sulfate per acre gave additional increases of 500 to 700 pounds in yield of seed per acre. Time of nitrogen application was relatively unimportant in all the tests as long as it was applied by early March. Time of application of phosphate was much more critical, inasmuch as it proved to be a more limiting factor in plant growth. At least half of the phosphate to be applied should go on early in fall.

There was a relation between fall growth and the physiological process of photothermal induction of flowering that takes place during the fall, winter, and spring. Planting date, time and method of seedbed preparation, and fertilizing practice all affect fall growth. The development and maintenance of an extensive growth of leaves to shade the soil and help create the most effective temperature range for thermal induction proved to be beneficial. Root reserves stored during the fall vegetative period are an important factor in seed production only after there has been sufficient induction to bring about complete reproductive development.

Maximum yields of the highest quality seed can be obtained only through the integration of all factors that affect growth and reproductive development.

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