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SUGAR BEET acreage in Minnesota during the past decade has been relatively uniform, but there has been a shift in the distribution of the crop in different parts of the state. Between 1938 and 1942 the acreage in the Red River Valley counties was approximately 45 per cent of the total acreage of the state. Since that date the percentage for that area has increased until, at the present time, about 60 per cent of the total acreage is grown there. When new facilities for processing sugar beets are completed the acreage in the Red River Valley will be further expanded.

Sugar beets, along with potatoes, are important intertilled crops which fit well into the crop rotations used in the Red River Valley. The fertilization of the crop until recently was limited almost entirely to the use of superphosphate, which was applied along the row when the beets were planted. Preliminary experiments in 1941 indicated that there was a probability of increasing yield by including some potash in the fertilier mixture.

The study reported in this bulletin was initiated in 1942 and continued through four crop seasons. Major emphasis was placed on the study of the effect of potash, when applied with phosphate, on the yield of roots and sugar. Another phase of the study included the effect upon yield of the ratio of phosphate (P_2O_5) to potash (K_2O) in the fertilizer mixture. Some data were obtained on the effect of nitrogen when used in a mixture containing the three constituents: nitrogen, phosphate, and potash. Included also was a limited study of the form of potash best suited to the production of sugar beets.

Character of Soil

Sugar beets in the Red River Valley are grown almost exclusively on the fine-textured soils of the Fargo-Bearden soil association.[1] These soils are characterized by a relatively high level of organic matter, and a high content of

[1] McMiller, P. R. Principal soil regions of Minnesota. Minn. Agr. Expt. Sta. Bul. 392. 1947.

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silt and clay which gives them a high water-holding capacity and high retentive power for fertilizer materials. Available phosphorus in the soil has been found to be generally low but the supply of nitrogen and available potash has been assumed to be adequate. The soils are generally well supplied with lime and hence are neutral or slightly alkaline in reaction and not in need of liming.

Fertilizer Experiments

The fertilizer experiments were designed primarily to test the need for the inclusion of potash in the fertilizer. In 1942, the first year, the experiments included treatment with superphosphate and potash and with superphosphate alone. An additional treatment with potash alone was added in 1943. During the first two years the rates of application of the materials were approximately 100 pounds per acre of 43 per cent superphosphate (40 pounds of P_2O_5), applied along the row with an attachment to the planter, and 200 pounds per acre of 60 per cent muriate of potash (120 pounds of K_2O), spread broadcast immediately after the beets were planted. Since the potash was spread broadcast, the rate of application was increased above an amount which would normally have been used if applied along the row.

At the end of the second season it was evident that the inclusion of potash was proving beneficial on at least one-third of the fields. Since the initial rate of application of potash was relatively high, a second series of experiments was started in which the rate of application and the ratio of phosphate (P_2O_5) to potash (K_2O) were varied. At that time the study was further enlarged to include nitrogen in the fertilizer mixture and to determine the effect of different forms of potash: muriate, sulfate, and manure salts. These experiments were carried for two seasons, 1944 and 1945.

All the experiments were laid out on regular fields of beets in cooperation with growers in Polk and Marshall counties. Each year the experiments were shifted to new fields. It is probable that many of the fields had previously been fertilized with phosphate for the sugar beet crop. All treatments were duplicated on each field and the results shown are averages of two plots. Data obtained included the yield of roots and tops and the percentage and yield of sugar. The results of the study in so far as it applies to sugar beet tops have already been reported.[2]

Weather Conditions

Rainfall during the growing season was lower in 1942 and 1945 than in the two intervening years (table 1). The seasons of both 1942 and 1945 were characterized by rather dry springs. September was dry in 1942 but wet in 1945. The distribution of rainfall was best in 1943 when adequate amounts fell during each successive 10-day period from May through August and was followed by relatively dry weather during September. Ample amounts of rain fell in 1944 and distribution was good, but excessive amounts fell during the last 10-day period in August. This meant that the soil moisture was high as the crop matured in September.

Swift[3] has recently reported that under Montana conditions the mean annual temperature appears to influence sugar beet yields. Differences in average annual temperatures in Montana amounted to about 4.5° F. between the warmest and coldest years. Yield variations were found to be

[2] Dunn, L. E., and Rost, C. O. Yield and nutrient content of sugar beet tops. Minn. Agr. Expt. Sta. Bul. 391. 1946.

[3] Swift, Ed. Effect of weather on sugar beet yields. *Crystal-ized Facts about Sugar Beets.* Vol. 1, No. 3. September, 1947.

Table 1. Rainfall in Inches during the Growing Season, May 20 to September 20, 1942 to 1945, Inclusive

Year	Number of stations	May	June			July			August			September		Total
		21-31	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-31	1-10	11-20	
Polk County														
1942	5	0.55	0.20	0.45	0.75	0.92	1.03	0.75	1.35	0.51	3.69	0.19	0.33	10.72
1943	14	2.13	1.55	0.99	0.86	0.24	1.40	1.36	1.50	0.14	1.45	0.49	0.06	11.44
1944	11	1.29	1.61	1.19	1.44	1.11	0.59	0.20	4.93	0.53	3.35	0.29	0.15	16.68
1945	9	0.11	1.17	1.11	0.73	0.61	0.84	0.55	0.21	0.94	0.64	1.63	1.25	9.79
Marshall County														
1943	8	1.73	2.35	1.03	0.68	0.25	1.37	0.72	0.97	0.42	1.24	0.59	0.05	11.53
1944	7	1.23	2.87	1.12	1.55	1.07	0.23	0.36	4.25	0.47	2.50	0.26	0.08	16.26
1945	7	0.55	0.95	0.53	0.99	1.00	1.24	0.86	0.17	1.14	1.27	2.25	1.33	12.28

about 4½ tons per acre and lowest average yields were obtained in years when mean annual temperatures were the lowest. Over a period of 14 years a rise or fall of one degree in mean annual temperature under Montana conditions was accompanied by a rise or fall of about one ton per acre in the yield of beets.

The average yield of beets in the Red River Valley during the four-year period 1942-45 was 15.3, 16.5, 13.1, and 10.3 tons per acre respectively. The variation in mean annual temperature in Polk and Marshall counties for the same period ranged from approximately 1.8° F. above normal in 1944 to 0.5° F. below normal in 1945 (table 2). In 1943, when beet yields were highest, the mean annual temperature was about 0.1° below normal. Thus during the first three years of the period the mean annual temperatures were normal or above. In 1945, the fourth year, when beet yields were lowest, the mean annual temperature was only 0.6° F. below normal.

A closer correlation between beet yield and temperature during the growing season might be expected since temperature variations during the remainder of the year should have little effect on beet growth. The average departures from normal in Polk and Marshall counties for the growing seasons 1942-45 were −3.0° F., −1.5° F., −0.7° F., and −4.1° F. respectively. If any close relationship existed, yields of beets should have been lower in both 1942 and 1945 because of the cooler season, and about average in 1943 and 1944 when temperatures were about normal. Ample and well-distributed rainfall in 1942 was probably an important factor in the production of favorable yields. In 1943, when the distribution of rainfall was best, July and August temperatures were above normal and this, together with a favorable distribution of moisture, doubtless accounts for the generally better yields of both roots and sugar obtained in that year. On the other hand the cool season, accompanied as it was by a lower rainfall less favorably distributed, probably played an important part in lowering yields in 1945.

Table 2. Mean Monthly Temperatures during the Growing Season, 1942 to 1945, Inclusive*

Year	May	June	July	August	September	Season average	Annual
			Polk County (Crookston)				
Normal	54.5	64.4	69.5	66.6	57.2	.....	.....
Departure from normal							
1942	−3.2	−3.3	−2.2	−0.2	−4.5	−2.7	+1.4
1943	−3.8	−1.8	+3.0	+1.0	−3.2	−1.3	+0.2
1944	+2.5	−0.7	−1.7	−0.6	−1.1	−0.3	+2.0
1945	−7.2	−5.2	−2.6	0.0	−3.8	−3.8	−0.7
			Marshall County (Argyle)				
Normal	54.4	63.2	68.9	66.5	56.7	.....	.....
Departure from normal							
1942	−4.2	−3.0	−3.0	−1.9	−4.7	−3.4	+0.7
1943	−5.1	−3.1	+2.6	+0.3	−3.6	−1.8	−0.5
1944	+2.1	−1.5	−3.2	−1.9	−1.0	−1.1	+1.6
1945	−9.7	−5.0	−3.3	−0.5	−3.8	−4.5	−0.4

* Climatological Data, U. S. Department of Commerce, Weather Bureau.

Yields of Roots and Sugar

While the rates of application of phosphate and potash varied somewhat during the first and last two-year periods, the general effect of phosphate and potash used both singly and in combination may be observed from a consideration of yields for the entire four-year period.

The yields of roots in tons and of sugar in pounds per acre for each of the four years are given in tables 3 and 4, and the yields of both for the 35 fields over the entire period are summarized in table 5. Fertilizer treatment significantly increased yields of roots on all except two fields, one in 1942 and one in 1943. On the one field which in 1942 showed no significant increase in the yield of roots, fertilizer did significantly increase the yield of sugar (table 4). Both phosphate alone and the phosphate-potash mixture were effective. The latter treatment produced 680 pounds per acre more sugar than the untreated or check plots. Fertilization in this case increased the percentage of sugar from 10.8 to 14.0, and this is responsible for the increase in sugar yield. The field on which fertilization failed to cause a significant increase in yield of roots in 1943 did not show a significant increase in the yield of sugar.

Of the three years in which potash alone was used as a treatment, the most general response was obtained in 1943 when five of the 10 fields gave the largest increases in the yield of roots from that treatment. In 1945 only one field gave maximum yields of roots from applications of potash only.

It is to be noted that the increases in yields of both roots and sugar from applying potash were generally lower than those obtained on other fields from phosphate or a phosphate-potash mixture. As previously stated, the use of phosphate for the fertilization of sugar beets has been a regular practice in the Red River Valley and it is probable that some if not all of the six fields which gave the greatest increases from potash alone had grown one or several crops of sugar beets in the past and had received phosphate fertilizer for the crop. The fact that the use of potash alone on the six fields gave substantial increases in both roots and sugar is an indication that the time is at hand when potash must be included in the fertilizer mixture for the growing of sugar beets in the Red River Valley if maximum yields are to be obtained. The validity of such a conclusion is further substantiated by the maximum increases in yield from the phosphate-potash mixture on 14 other fields.

Table 5 summarizes the yields of roots and sugar for the four seasons. Considering the yields on the unfertilized plots it is seen that they were highest on the two fields which showed no increase from the use of fertilizer and were lowest on the 13 fields which responded to phosphate only. The unfertilized plots on the 14 fields which responded to the phosphate-potash mixture yielded about 1½ tons less than the two fields which were unresponsive to fertilizer. This would lead to the suggestion that fields known to produce rather low yields of sugar beets are in need of fertilization with phosphate and that the more fertile or productive fields be fertilized with phosphate-potash mixture.

The use of phosphate appears to be essential to both root and sugar production. The increase in root tonnage on the 27 fields responding to either phosphate or the phosphate-potash mixture was 3.1 tons of roots and 950 pounds of sugar per acre. Those fields responding to potash only gave increases of 2.2 tons of roots and 540 pounds of sugar. There is a strong

Table 3. Yields of Sugar Beets (Roots) with Different Fertilizer Treatments in Four Seasons, 1942 to 1946, Inclusive

Response to fertilizer	No. of fields	Per cent of total fields	Roots, tons per acre				Per cent increase from		
			Unfertilized	Increase from P*	Increase from PK	Increase from K	P	PK	K
1942—6 fields									
No response to fertilizer	1	17	16.8	0.5	0.0	.....	3.0	0.0	.....
Greatest response to P	3	50	13.0	3.2	2.3	.....	24.6	17.7	.....
Greatest response to PK	2	33	18.1	0.1	2.7	.....	0.5	14.9	.....
Greatest response to K	.....	.....	.....	.....	.....	.....	.....	.....	.....
1943—10 fields									
No response to fertilizer	1	10	16.1	0.8	0.8	0.0	4.9	4.9	0
Greatest response to P	1	10	14.5	3.4	2.1	1.9	23.4	14.5	13.1
Greatest response to PK	3	30	18.6	1.8	3.9	0.9	9.7	21.0	4.8
Greatest response to K	5	50	15.8	0.4	1.1	2.4	2.5	7.0	15.2
1944—9 fields									
No response to fertilizer	0	0	.....	.....	.....	.....	.....	.....	.....
Greatest response to P	3	33	11.9	2.2	0.7	1.3	18.5	5.9	10.9
Greatest response to PK	6	67	13.7	0.7	2.6	1.5	5.1	19.0	10.9
Greatest response to K	0	0	.....	.....	.....	.....	.....	.....	.....
1945—10 fields									
No response to fertilizer	0	0	.....	.....	.....	.....	.....	.....	.....
Greatest response to P	6	60	9.8	3.5	2.8	0.4	35.7	28.5	4.1
Greatest response to PK	3	30	11.7	2.0	3.3	0.3	17.1	28.2	2.6
Greatest response to K	1	10	8.9	0.8	0.9	1.3	9.0	10.1	14.6

Differences required for significance: 1942, .84 ton; 1943, 1.04 tons; 1944, 0.96 ton; and 1945, 1.0 ton.
* P = superphosphate; PK = superphosphate and muriate of potash; K = muriate of potash.

Table 4. Yields of Sugar with Different Fertilizer Treatments in Four Seasons, 1942 to 1946, Inclusive

Response to fertilizer	No. of fields	Per cent of total fields	Sugar, pounds per acre				Per cent increase from		
			Unfertilized	Increase from P*	Increase from PK	Increase from K	P	PK	K
			1942—6 fields						
No response to fertilizer	1	17	3,640	370	680	.....	10.2	18.7	.....
Greatest response to P	3	50	3,490	1,160	740	.....	33.2	21.2	.....
Greatest response to PK	2	33	4,100	460	1,050	.....	11.2	25.6	.....
Greatest response to K	.....	.....	.....	.....	.....	.....	.....	.....	.....
			1943—10 fields						
No response to fertilizer	1	10	5,620	220	20	200	3.9	.4	3.6
Greatest response to P	1	10	5,120	1,080	820	800	19.1	16.0	15.6
Greatest response to PK	3	30	6,560	400	1,220	160	6.1	18.6	2.4
Greatest response to K	5	50	5,480	280	200	560	5.1	3.6	10.2
			1944—9 fields						
No response to fertilizer	0	0	.....	.....	.....	.....	.....	.....	.....
Greatest response to P	3	33	3,620	850	70	90	23.5	1.9	2.5
Greatest response to PK	6	67	4,090	170	630	70	4.2	15.4	1.7
Greatest response to K	0	0	.....	.....	.....	.....	.....	.....	.....
			1945—10 fields						
No response to fertilizer	0	0	.....	.....	.....	.....	.....	.....	.....
Greatest response to P	6	60	3,000	1,060	680	0	35.3	22.7	0
Greatest response to PK	3	30	3,310	450	820	0	13.6	24.8	0
Greatest response to K	1	10	2,010	530	570	440	26.4	28.4	21.9

Differences required for significance: 1942, 617 pounds; 1943, 356 pounds; 1944, 300 pounds; 1945, 260 pounds.
* P = superphosphate; PK = superphosphate and muriate of potash; K = muriate of potash.

Table 5. Yields of Sugar Beets (Roots) and Sugar Obtained by Different Fertilizer Treatments on 35 Fields during Four Seasons, 1942 to 1945, Inclusive

Response to fertilizer	No. of fields	Per cent of total fields	Roots, tons per acre				Sugar, lbs.			
			Unfertilized	Increase from P	Increase from PK	Increase from K	Unfertilized	Increase from P	Increase from PK	Increase from K
No response to fertilizer	2	5.7	16.5	0.6	0.4	0.0*	4,630	340	355	200*
Greatest response to P	13	37.1	11.4	3.1	1.9	0.8	3,420	1,034	564	97
Greatest response to PK	14	40.0	14.9	1.1	3.1	1.1	4,450	321	857	75
Greatest response to K	6	17.2	14.7	0.2	1.1	2.2	4,900	322	262	540

* One field only.

probability that such fields will also need phosphate in the near future.

The experiments indicate that 37 per cent or approximately one-third of the fields will give profitable increases in the yields of sugar beets (roots) and sugar from the application of a fertilizer containing only phosphate (table 5). About 40 per cent of the fields can be expected to respond to a mixture of phosphate and potash. In these trials 17 per cent of the fields responded to potash alone. It is not improbable that these fields had previously been fertilized with phosphate and that they belong in the group which would require fertilization with phosphate and potash. If this assumption is valid, about 57 per cent of the fields of the Red River Valley should receive treatment with phosphate and potash for the sugar beet crop. Since only about 6 per cent of the fields do not respond to fertilizer and since the beet crop is one which gives a relatively high acre return it would appear that fertilizers can be used profitably for the crop.

Effect of Varying Fertilizer Rates and Ratios

The ratio of phosphate (P_2O_5) to potash (K_2O) in commonly used phosphate-potash mixtures is 2:1, 1:1, and 1:2 as carried in 0-20-10, 0-20-20, and 0-10-20. In two seasons, 1944 and 1945, these fertilizer mixtures were used at single and double rates on 19 fields: 9 in 1944 and 10 in 1945. Included also was phosphate only at 40 and 80 pound of P_2O_5 per acre. The single rate of 40 pounds of P_2O_5 is the one most commonly used for the sugar beet crop. In these experiments the phosphate was applied as superphosphate along the row with the planter attachment and the potash was applied as muriate of potash broadcast immediately after planting.

The yields of roots and sugar are shown in table 6. Doubling the rate of application of the fertilizer mixtures did not materially increase the yield of either roots or sugar. The data indicate that a 200-pound-per-acre rate will give more economical returns than a heavier one. The average increase in the yield for 200 pounds of 0-20-20 was 3.0 tons of roots and 815 pounds of sugar per acre. It is clear that the use of the lighter rate is the more economical one at the present time. A P_2O_5:K_2O ratio of 1:1, as in 0-20-20, when applied at the 200-pound rate, gave better returns in both roots and sugar than did the 2:1 or 1:2 ratios (0-20-10 or 0-10-20).

Inclusion of Nitrogen in the Fertilizer Mixture

A considerable number of sugar beet growers in the Red River Valley are using complete fertilizers for the crop. These fertilizers contain all three of the major plant nutrients; namely, nitrogen, phosphate, and potash. The fertilizers so employed include such grades as 4-24-12, 3-12-12, 4-16-16, and 3-18-9. It has been commonly observed that these fertilizers increase the growth of the crop early in the season when the weather is cool and the soil somewhat wet. These conditions retard nitrification in the soil and the nitrogen in the fertilizer hastens the early growth. Because of this, growers have been inclined to believe that this early effect tends to carry through the entire season. Regardless of whether nitrogen in the fertilizer mixture affects the yield of roots or sugar, its use may be justified by this effect alone—that when the spring season is cool and backward the inclusion of nitrogen is almost sure to have this "starter" effect.

Table 6. Effect of Varying the Fertilizer Rate and Ratio on the Yield of Sugar Beets and Sugar in the Red River Valley

Fertilizer	Ratio	Rate, lbs. per acre	Plant food in lbs. per acre	1944 average, 9 fields				1945 average, 10 fields				Average gain	
			N P_2O_5 K_2O	Roots, tons per acre	Gain, tons	Sugar, lbs. per acre	Gain, lbs.	Roots, tons per acre	Gain, tons	Sugar, lbs. per acre	Gain, lbs.	Roots, tons	Sugar, lbs.
Single rate of phosphate with increasing potash													
None		0	0— 0— 0	13.1	.....	3,940	.....	9.8	.....	2,900	.....	.....	.....
0—20— 0		200	0—40— 0	14.3	1.2	4,340	400	12.9	3.1	3,790	890	2.15	645
0—20—10	0—2—1	200	0—40—20	.....	.....	.....	.....	13.2	3.4	4,000	1,100	.....	.....
0—20—20	0—1—1	200	0—40—40	15.2	2.1	4,440	500	13.7	3.9	4,030	1,130	3.00	815
0—10—20	0—1—2	400	0—40—80	15.1	2.0	4,380	440	12.8	3.0	3,640	740	2.50	590
Double rate of phosphate with increasing potash													
None		0	0— 0— 0	13.1	.....	3,940	.....	9.8	.....	2,900	.....	.....	.....
0—20— 0		400	0—80— 0	14.5	1.4	4,500	560	13.1	3.3	3,930	1,030	2.35	790
0—20—10	0—2—1	400	0—80—40	15.5	2.4	4,520	580	13.8	4.0	4,080	1,180	3.20	895
0—20—20	0—1—1	400	0—80—80	15.7	2.6	4,420	480	13.2	3.4	3,690	790	3.00	635
Significant difference at 5 per cent level	.....	.....	.....	.....	1.0	.....	300	.....	0.96	.....	260	.....	.....

The two seasons during which experiments with nitrogen fertilizers were conducted, 1944 and 1945, were both below normal in temperature (table 2) although May, 1944, was warmer than normal and May, 1945, much cooler than normal. Under the conditions prevailing in May and June nitrogen was somewhat more effective, though it should have been much more effective in 1945.

The data given in table 7 show that the inclusion of nitrogen in the fertilizer mixture produced no significant increase in either roots or sugar for either year but that there was a slight tendency toward higher yields, especially in 1945 when the season was abnormally cool. Doubling the rate of application of the fertilizers containing nitrogen tended to increase the yield of roots but did not produce a proportional increase in the yield of sugar. The data would indicate that if nitrogen is included in the fertilizer mixture for sugar beets in the Red River Valley the amount should be limited to a percentage which will be useful chiefly as a starter for the young plants during the early part of the season.

Effect of Different Forms of Potash

Three forms of potash fertilizer: muriate of potash, sulfate of potash, and manure salts, were tested for the sugar beet crop. The muriate or chloride of potash is the most common form of potash employed in compounding the mixed fertilizers used in Minnesota. It is well known that the chloride ion tends to increase the moisture and consequently decrease the dry matter in some root crops. The magnitude of the effect is related to the amount of fertilizer used. Moderate or light applications of fertilizers containing the chloride (muriate) of potash generally do not cause excessive increases in moisture or decreases in dry matter. Heavy applications, on the other hand, may lower crop quality by producing a high moisture and a lower dry-matter content with high percentage of ash. These conditions tend to interfere with the crystallization of sugar in the refining process.

Because of the effects of the chloride ion, the use of sulfate of potash has been recommended, thus eliminating the application of the objectionable chlorine ion. The investigation re-

Table 7. Effect of the Inclusion of Nitrogen in Fertilizers for Sugar Beets

Fertilizer	Rate, lbs. per acre	Plant food, lbs. per acre	Roots, tons per acre	Gain	Sugar, lbs. per acre	Gain
		N P_2O_5 K_2O				
1944 average, 9 fields						
None	0	0— 0— 0	13.1	.....	3,940	.....
0—10—20	200	0—20—40	15.1	2.0	4,380	440
10—10—20	200	20—20—40	15.3	2.2	4,500	560
Significant difference at 5 per cent level				0.96		280
1945 average, 10 fields						
Single rate						
None	0	0— 0— 0	9.8	.....	2,905	.....
0—20—10	200	0—40—20	13.2	3.4	4,000	995
4—24—12	175	7—40—20	12.8	3.0	3,760	855
Double rate						
0—20—10	400	0—80—40	13.8	4.0	4,080	1,175
4—24—12	350	14—80—40	14.4	4.6	4,110	1,205
Significant difference at 5 per cent level				0.96	.....	260

ported here dealt only with the effect of three forms of potash on the yield of roots and sugar. Another study, which will be reported later, concerned itself with the effect of the three forms on the composition and quality of the crop.

The effect of the three forms of potash is reported in table 8. In 1944 the yield of roots was definitely lower when the potash was applied in the form of sulfate. On the other hand there was no significant difference on three fields in 1942. When the yields of sugar are considered, there is no significant difference between the three forms. The results obtained with manure salts are essentially the same as those obtained with muriate of potash.

In so far as the yield of roots and sugar are concerned it would appear that forms of potash containing chlorine (muriate of potash and manure salts) are as effective or slightly more effective than the sulfate of potash. It will be shown in a subsequent publication that when muriate of potash is used in moderate amounts no serious lowering of quality occurred. Heavy applications of potash in the form of muriate or manure salts will reduce quality. As soon as sulfate of potash is available in quantity it should be substituted for the muriate in fertilizer mixtures for both sugar beets and potatoes.

Fertilizer Recommendations for Sugar Beets in the Red River Valley

1. Since the study reported in this bulletin showed that only two, or 6 per cent, of the 35 fields used in the experiments failed to responde to fertilizer it is recommended that the crop in the Red River Valley be universally fertilized.

2. About one-third of the fields gave maximum yields when only superphosphate was used. When only phosphate is used, an application of approximately 100 pounds per acre of 43-47 per cent or 200 pounds of 20 per cent superphosphate applied along the row is recommended.

3. Approximately 57 per cent of the sugar beet fields of the Red River Valley gave maximum yields from a fertilizer containing only potash or a mixture of phosphate and potash. These fields produced relatively high tonnages. On such fields an application of 200 pounds per acre of 0-20-20 or 0-20-10 along the row at planting time is recommended. Any fertilizer mixture with an 0-1-1 or an 0-2-1 ratio may be used and the rate adjusted to supply 40 pounds of P_2O_5 and either 40 or 20 pounds of K_2O per acre.

4. While the inclusion of nitrogen in the fertilizer mixture did not significantly increase the yield of roots or sugar some growers may wish to

Table 8. Effect of Different Forms of Potash on the Yield of Sugar Beet Roots and Sugar in the Red River Valley

Form of potash	Roots, tons per acre			Sugar, lbs. per acre		
	1942, 3 fields	1943, 10 fields	1944, 9 fields	1942, 3 fields	1943, 10 fields	1944, 9 fields
	Without phosphate					
Muriate	.....	18.1	14.5	.....	6,180	4,000
Manure salts	.....	17.5	14.4	.....	6,020	4,100
Sulfate	.....	.....	13.5	.....	.....	3,940
	With phosphate					
Muriate	16.4	18.4	15.1	4,420	6,360	4,380
Manure salts	15.9	19.0	14.5	3,900	6,520	4,180
Sulfate	16.2	.....	14.2	3,840	.....	4,260
Significant difference	0.84	1.04	0.96	617	356	300

use a complete fertilizer for the starter effect obtained by including nitrogen. In such cases the following formulas and rates per acre applied along the row are recommended:

3-12-12	350
4-16-16	250
5-20-20	200
3-18- 9	200
4-24-12	175

Summary

The results of four years of trials with commercial fertilizers for sugar beets in the Red River Valley are reported. Sugar beets were grown on one soil association, the Fargo-Bearden, upon which the crop is most generally grown. Fertilizer treatments included superphosphate alone, superphosphate and potash, and potash alone. In two seasons, 1944 and 1945, nitrogen fertilizer was included.

Only 6 per cent of the fields failed to respond to some fertilizer or fertilizer combination. Thirty-seven per cent responded to phosphate alone. These fields when unfertilized were the ones which produced the lowest tonnages of roots. Approximately 57 per cent of the fields gave maximum yields when a mixture of phosphate and potash or straight potash was applied. All of these will require phosphate and potash for continuous high yields. Fields which responded to potash only had probably been treated with phosphate for some previous crop.

The inclusion of nitrogen in the fertilizer mixture did not significantly affect the yield either of roots or of sugar. It was pointed out that nitrogen in the fertilizer could serve as a "starter" early in the growing season and hasten the growth of the young plants, thus permitting earlier cultivation.

Three forms of potash: muriate, manure salts, and sulfate, were tested. The first two tended to produce higher yields of roots but there was no significant difference in the yield of sugar. It was pointed out that fertilizers containing chlorine tend to reduce the quality of sugar beets. When used in moderate amounts, it is probable that such fertilizers do not seriously affect quality under the conditions which prevail in the Red River Valley.