Effect of Method of Application of Double Superphosphate on the Yield and Phosphorus Uptake by Sugar Beets[1]

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Optimum phosphate fertilizer placement for sugar beets is probably dependent upon the number of active feeding roots at various soil depths and by the distribution of moisture in the soil during the growing season. Little is known about the quantitative distribution of sugar beet roots at the various stages of growth. However, it seems reasonable that the soil layers containing the largest number of active roots are most desirable for phosphate placement. Results from Colorado (4, 6)[3] have indicated that phosphate must be placed close to the seed for optimum early season uptake. Haddock (2) has shown that later in the season double superphosphate is more available to sugar beets when placed in moist than in drier layers. Since the distribution of roots and moisture in the soil changes during the season, it may be necessary to place phosphate at more than one depth to adequately meet plant needs at all times.

It is the purpose of this paper to report results of two experiments comparing plowing under, broadcasting followed by discing, banding and seed placement of double superphosphate on the yield and phosphorus uptake by sugar beets.

Plan of Experiments

1951 Experiment

Nine treatments including a no phosphate check, broadcasting and plowing under in the fall, broadcasting and discing in the spring, and banding two and five inches deep were used. Each placement treatment was applied at rates of 40 and 80 pounds of P_2O_5 per acre as double superphosphate. A complete listing of treatments is included with the yield results.

The nine treatments were arranged in a randomized block design and replicated five times. Each plot was eight rows wide and 50 feet long. Eighty pounds of N per acre were uniformly applied to all plots. The soil type was Manvel silty clay and contained 57 pounds per acre of sodium bicarbonate soluble P_2O_5 in the surface soil (5) .

The entire plot area near Hardin, Montana, was fall plowed and spring seedbed preparation consisted of heavy discing, floating and construction of single row beds. Sugar beets were planted April 29, 1951.

The sugar beets were thinned carefully June 13. By June 30 a striking growth difference due to phosphate placement was observed and above ground plant samples were harvested for growth comparisons and for phosphorus determinations. Soil moisture was followed throughout the season by the use of gypsum resistance blocks.

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[3] Numbers in parentheses refer to literature cited,

Yields were measured October 2 using the two center rows of each plot. Sucrose and tare determinations were made by the Holly Sugar Corporation.

1952 Experiment

A similar experiment was conducted in 1952 on a Pryor silty clay soil at the Huntley, Montana, Branch Experiment Station. The surface soil contained 16 pounds per acre of sodium bicarbonate-soluble P_2O_5 (5). Treatments were the same as those used in 1951 except that the five-inch depth banding treatment was omitted. In addition each main placement treatment and check was divided and one-half of the plot received 20 pounds of P_2O_5 placed in the row with the seed. Rates of phosphate and placement methods were randomized as the main plots and seed placement of phosphate and a check were the split plots. Each subplot was four rows wide and 35 feet long. Main plots were replicated four times. Double superphosphate was used as the source of phosphate. A complete listing of treatments is given with the yield results.

An attempt was made to compare the effectiveness of the main plot placement treatments using radioactive phosphorus. Since P^{32} has a half life of 14.3 days, it was not possible to apply tagged phosphate in the fall and measure it quantitatively the following summer. Thus, all treatments were applied as scheduled using non-active phosphate. Then, at planting time, 40 pounds of radioactive double superphosphate per acre were banded three inches deep and three inches to the side of one row of each main plot not receiving phosphate with the seed. It was assumed that the greater the availability of the non-active treatments the less the plant would draw on the active phosphate. Thus, there would be an inverse relation between the activity of the plant material and the availability of the placement method. Fried and Dean (1) have discussed this general relation. Combined leaf and petiole samples were removed from the plants at three dates choosing the latest mature leaves as described by Ulrich (7). Yields were measured by harvesting the two center rows of each subplot. The radioactive row was not used for yield determinations. The sugar beets were washed, tared, weighed and sugar determined by the Great Western Sugar Company.

Total phosphorus and P^{32} were measured on the combined leaf and petiole samples[4]. Total phosphorus was determined using the method of Koenig and Johnson (3) following ashing in an electric furnace with magnesium nitrate.

Results

1951 Experiment

The effect of rates and methods of application of phosphate on the yield, relative early growth, percent phosphorus in the foliage and the percent sucrose in the roots is given in Table 1.

The mean yield increases for 40 and 80 pounds of P_2O_5 per acre over the no phosphate check were 2.1 and 2.7 tons per acre, respectively. Increasing rates of phosphate also increased early growth and percent phosphorus in the foliage.

[4] P^{32} determinations were made by Frank S. Watanabe at Fort Collins, Colorado.

Table 1.—The Effect of Method and Rate of Application of Double Superphosphate on the Yield, Early Growth and Phosphorus Content of Sugar Beets.

Treatment No.	Treatment	Yield Tons/Acre	Relative Growth on June 30	Percent P in Foliage June 30	Sucrose (roots) %
1	Check—no phosphate	12.6	100	.396	17.8
2	40 lb. P_2O_5/A. broadcast and plowed under, fall	15.3	145	.459	17.4
3	80 lb. P_2O_5/A. broadcast and plowed under, fall	15.8	185	.475	17.7
4	40 lb. P_2O_5/A. broadcast and disced in the spring on fall plowed land	15.8	196	.443	17.4
5	80 lb. P_2O_5/A. broadcast and disced in the spring on fall plowed land	15.6	226	.461	17.6
6	40 lb. P_2O_5/A. banded 2" deep and 2" to the side of the seed at planting time	14.2	134	.386	17.7
7	80 lb. P_2O_5/A. banded 2" deep and 2" to the side of the seed at planting time	14.9	151	.418	17.9
8	40 lb. P_2O_5/A. banded 5" deep and 2" to the side of the seed at planting time	13.6	158	.411	17.8
9	80 lb. P_2O_5/A. banded 5" deep and 2" to the side of the seed at planting time	15.0	160	.454	17.4

Rates of phosphate were significantly different at the 1 percent level for yields, relative growth and percent phosphorus in the foliage.

Methods of phosphate were significantly different at the 1 percent level for yields, relative growth and percent phosphorus in the foliage.

No treatment significantly affected the percent sucrose in the roots.

Plowed under and disced in phosphate produced significantly higher yields than did banding at two- or five-inch depths. For example, yields for plowed under phosphate were 1.1. tons per acre greater than the mean of the two banding treatments. There was no difference in yield between plowed under or disced in phosphate, however. Plowed under and disced in phosphate also produced greater early growth and percent phosphorus in the foliage than did the banding treatments. There was no interaction between rates and methods of application.

The percent sucrose in the roots was not affected by any treatment.

1952 Experiment

The relative growth at thinning time, stand, yield and sucrose content of sugar beets as influenced by rate and method of application are presented in Table 2.

The mean sugar beet yield increase from plowed under phosphate over banded or disced in phosphate was 2.6 and 2.2 tons per acre, respectively. Phosphate placed with the seed in addition to the regular rate and placement treatments produced a marked response in sugar beet growth at thinning time but had no effect on final yields.

Forty and 80 pounds of P_2O_5 per acre produced a 7.4 and 9.0 tons per acre increase in yields over the no phosphate check. A 20-pound per acre

Table 2.—Effect of Method and Rate of Application of Double Superphosphate on the Early Growth, Stand, Yield and Sucrose Content of Sugar Beets.

Treatment No.	Pounds P_2O_5 Per Acre	Method of Application	Yield Tons Per Acre	Relative Growth at Thinning Time (5/27)	Stand %	Sucrose (roots) %
1a	0	Check	11.3	100	73	17.4
1b	20	Applied with the seed[1]	15.3	220	86	17.6
2a	40	Applied broadcast and plowed under in fall	20.0	138	89	17.4
2b	60	Same as 2a plus with the seed	20.2	260	90	17.3
3a	80	Same as 2a	22.4	188	89	17.4
3b	100	Same as 2a plus with the seed	21.9	327	95	17.4
4a	40	Applied broadcast in spring, disced on fall plowed land	18.8	198	91	17.3
4b	60	Same as 4a plus with the seed	19.3	214	95	17.0
5a	80	Same as 4a	19.0	178	92	17.4
5b	100	Same as 4a plus with the seed	18.3	199	86	16.9
6a	40	Banded 3" deep and 2" to the side of seed at planting time	17.3	118	81	17.6
6b	60	Same as 6a plus with the seed	18.4	288	87	17.4
7a	80	Same as 6a	19.5	153	81	17.6
7b	100	Same as 6a plus with the seed	19.1	256	86	17.4

[1] Phosphate applied with the seed at the rate of 20 pounds of P2O5 per acre.

Rates of phosphate were significantly different at the 1 percent level for relative growth and yield.

Methods of phosphate application were significantly different at the 1 percent level for relative growth and yield and at the 5 percent level for stand.

Phosphate applied with the seed produced significant increases at the 1 percent level for relative growth, and increased stand and yield at the l percent level only when applied with no other phosphate.

No treatment significantly affected the percent sucrose in the roots.

application of P_2O_5 with the seed produced a 4.0 ton per acre increase over the check. Increasing rates o£ phosphate increased the early growth. There was no rate times method interaction.

Stand of sugar beets at harvest time was increased by all phophate applications. The banding treatment had fewer sugar beet plants than did either o£ the other two application methods. This was not due to disturbance by the banding equipment since all plots were treated the same except for the rate of application. Presumably the lowered stand was due to loss from disease after thinning since a heavy stand of beets was present just prior to thinning.

No rate or method of application had any effect on the percent sucrose in the root at harvest time.

The percent of the total phosphorus in the foliage and the percent of the total phosphorus in the foliage derived from the radioactive fertilizer at three sampling dates as influenced by rate and method of application are given in Table 3. Sugar beets grown on plowed under phosphate contained much greater quantities of phosphorus at all sampling dates than did those grown on other treatments. Eighty pounds of P_2O_5 produced consistently higher amounts of phosphorus in the foliage when plowed under than did 40 pounds, but this amount was not consistently better on spring disced or banded phosphate.

Table 3.—The Effect of Method and Rate of Application of Double Superphosphate on the Percent of Total Phosphorus and the Percent of the Total Phosphorus Derived from Radioactive Fertilizer in Sugar Beet Foliage.

Treatment No.[1]	Percent Total Phosphorus in Foliage			Percent of Total Phosphorus in Foliage Derived from Radioactive Fertilizer		
	June 26	Aug. 1	Aug. 28	June 26	Aug. 1	Aug. 28
1a	0.251	0.164	0.138	87.1	45.5	38.7
2a	0.334	0.181	0.173	11.5	21.4	20.0
3a	0.378	0.231	0.209	5.3	9.6	11.2
4a	0.213	0.188	0.170	23.4	32.2	27.6
5a	0.237	0.192	0.164	26.0	27.2	20.2
6a	0.245	0.196	0.169	25.6	24.5	22.2
7a	0.238	0.210	0.196	22.6	20.8	16.0
L.S.D. (.05)	0.032	0.030	0.025	9.4	5.1	5.4
L.S.D. (.01)	0.043	0.041	0.034	12.8	6.8	7.2

[1] Treatment numbers refer to treatments listed in Table 2.

Because the radioactive phosphorus was applied in addition to the regular treatments, the amounts found in the plant would be expected to be inversely related to the availability of the original treatment. Thus, plants from the higher yielding plowed under phosphate contained much smaller quantities of phosphorus from the radioactive fertilizer than did the other treatments. The increase during the season in the quantities of phosphorus in the plant from the radioactive fertilizer on the plowed under treatments indicates a relative decrease in availability as the season progressed. Banded phosphate appeared to become more available as the season progressed whereas the disced phosphate was not much affected.

Discussion

The data available indicate that an ideal method of application may be a shallow placement close to the seed for early stimulation together with a deep placement where moisture conditions are more favorable later in the season. Plowing under phosphate appears to be an easy, practical way to effect such a placement. The stimulation due to phosphate placed with the seed indicates that it must be in close proximity to the seed for seedling vigor. This indication is in agreement with other work (4, 6) . On the other hand, Haddock's data (2) show that deep banded phosphate is desirable late in the season and particularly under dry conditions.

The placement effected by broadcasting fertilizer, plowing and lightly discing the soil was determined. To establish this, ammonium nitrate of a particle size similar to commercial double superphosphate was broadcast and the soil plowed and lightly disced. The soil was sampled immediately, dried and analyzed for nitrate. The experiment was conducted adjacent to the 1952 experiment and plowing conditions were similar. Fourteen, 47 and 39 percent of the fertilizer was found in the 0-2, 2-5 and 5-7 inch layers, respectively. In addition, a banding effect was present between the plow slices. It is realized that many factors such as soil, moisture and type of plowing could affect fertilizer placement. However, this experiment probably represents good plowing conditions on a fine textured soil.

In the experiments reported herein yields and phosphorus uptake demonstrated the superiority of fall broadcasting and plowing under phosphate over the banding treatments. It is believed that the favorable comparison between disced in and plowed under phosphate in 1951 resulted from a deep incorporation caused by heavy discing and followed by ridging each row prior to planting. In contrast, the inferiority of disced in phosphate in 1952 was due to shallow incorporation by light discing and without construction of beds or ridges. Banded phosphate may have been too far distant from the seedling roots to compare favorably with plowed under phosphate.

Soil moisture records from the two experiments as indicated by gypsum resistance blocks are not reported herein. However, they do show that the experiments were irrigated as often as has been found necessary for maximum yields at this location.

On some soils plowed under phosphate may be subject to large amounts of fixation because most of it is in intimate contact with soil. However, fixation was not serious on the two soils studied since considerably more time elapsed between application and planting on the higher yielding fall plowed under phosphate than for other treatments. Spring plowed under phosphate would be expected to be as good or better than fall plowed phosphate.

Summary

Two experiments compared the effect of plowing under, broadcasting, banding and seed placement of double superphosphate at various rates of application on the yield, phosphorus uptake, stand, early growth and percent sucrose of sugar beets.

In a 1951 experiment fall plowed under phosphate and spring disced phosphate produced higher yields, better early growth and greater phosphorus concentrations in the foliage than did banding at either 2- or 5-inch depths. The mean yield increase for 40 and 80 pounds of P_2O_5 per acre strategically placed was 3.0 and 3.1 tons per acre, respectively.

In 1952, 40 and 80 pounds of P_2O_5 per acre increased yields by 8.7 and 11.1 tons per acre respectively, when fall plowed under. Mean yields for plowed under phosphate were greater than disced or banded phosphate by 2.2 and 2.3 tons per acre respectively. The superiority of plowed under phosphate was also demonstrated by better early growth and greater phosphorus concentrations. An indirect method of determining the relative effectiveness of phosphate placements and using radioactive phosphorus also demonstrated the superiority of a plowed under treatment. Phosphate applied with the seed produced early growth stimulation but had no effect on yield when applied in combination with other phosphate treatments.

An experiment to determine the placement effected by broadcasting and plowing under fertilizer on a fine textured soil showed that 14, 49 and 37 percent was placed at 0-2, 2-5 and 5-7 inch depths respectively. In addition, a banding effect was apparent between the plow slices.

It is believed that, in the two experiments reported, the superiority of plowing under phosphate was due to a small amount being near the surface and thus accessible to the young seedling and at the same time a large amount was placed deep where moisture is more favorable later in the season.

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