Effect of Fertilizers on Diseases and Yield of Sugar Beets Planted in Depleted Soil[1]

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The investigation was planned to study the effect on seedling disease and yield of sugar beets of different fertilizer treatments when applied to depleted soil. Data were also secured on stands and top-to-root ratios of sugar beets in different plots.

These experiments were conducted at the Huntley Branch Station, Huntley, Montana, on land which had been alternately cropped for a number of years with barley and sugar beets, and was so depleted of its fertility that in 1940, only 6.06 tons of beets per acre were produced.

The fertilizers used in this study were nitrogenous fertilizers ("N"- sodium nitrate and ammonium sulphate), phosphate ("P" treble superphosphate) and manure ("M"), applied in the eight following combinations: PNM; $P\frac{NM}{2}$ (in this treatment half of the nitrogen was applied at the time of planting and the other half as a side dressing immediately after thinning); NM; PM; PN; M; N; P and a check. Nitrogen was applied as a mixture of equal parts of sodium nitrate and ammonium sulphate at the rate of 200 pounds per acre containing 36.5 pounds of nitrogen (N). The phosphorus was applied as treble superphosphate at the rate of 175 pounds per acre containing 80.5 pounds of P_2O_5. Manure was applied on the basis of 16 tons per acre. Manure and treble superphosphate were always applied in the fall before plowing.

Nitrogen was applied in an ammoniacal and nitrate form because conditions in the early spring are not favorable for rapid nitrification of ammonia. Sugar beets in their early stages of development require a considerable amount of nitrogen; therefore, it is necessary to supply them with nitrogen, such as a nitrate which is immediately available. Later when conditions become favorable for nitrification, beets can use nitrogen supplied in the form of ammonium sulphate.

Soil treatments were used in 3 randomized replications, so that, altogether, there were 27 individual plots, each consisting of 8 rows of beets 125 feet long.

All plots were treated as outlined during 1941 to 1944, inclusive. By the end of 1944 the effect of each treatment was well stabilized as far as yield, stand, seedling diseases, and top-to-root ratio of beets was con-

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cerned. For the 1945 crop, the whole field was uniformly treated with complete fertilization (treatments PNM or $\frac{PNM}{2}$, respectively) to study its effect when superimposed over the previous treatments on sugar beets.

The land was generally plowed in the fall, double disced, harrowed and leveled in the spring and planted with U.S. 22 segmented seed.

Samples of 100 or more seedlings, in the 4- to 6-leaf stage, were taken from each plot and carefully examined for disease. During the summer, counts of the stand of beets in the four central rows of each plot were made. Only portions of the four central rows of each plot were harvested. Yield and top-to-root ratios were recorded from these samples for all plots and treatments.

Results and Discussion

The results of these studies are presented in tables 1, 2, 3, and 4.

Yield of Beets

The smallest yield of beets during the first 4 years occurred in the check plots (4.39 tons per acre) and the highest in treatment $\frac{PNM}{2}$ (16.27 tons per acre) where complete fertilization was used with divided application of nitrogen (table 1). This table also shows the proportional increase in yield of sugar beets grown on fertilized plots as compared to the check. The lowest increase in yield occurred in plots fertilized with nitrogen (2.64 tons per acre) and the greatest on plots fertilized with complete fertilization with divided application of nitrogen (11.88 tons per acre). The increase in yield due to other fertilizers occupies positions between these two extremes.

There was a considerable response of beets to the fertilizers in the years 1941-44. Apparently this soil was more depleted in available phosphorus than nitrogen, at least phosphorus fertilization alone gave better response than nitrogen. The best yield was obtained by applying complete fertilization with a divided application of nitrogen. The nitrogen apparently was utilized in this way better than when all of it was applied early in the spring.

All plots of this experiment were uniformly fertilized with complete fertilization for the crop of 1945, resulting in good and uniform yields. Beets grown on the previous check plots and the plots previously fertilized with phosphorus or nitrogen alone showed the greatest increase in yield (9.80, 4.36 and 6.60 tons of beets per acre, respectively). Yield of beets grown on plots previously fertilized with M, PN, and PM, showed only a moderate increase (2.31, 3.77 and 2.11 tons of beets per acre, respectively). Beets grown on the plots previously fertilized with the remaining treatments either showed only a slight increase or a slight decrease in the yield. This decrease probably was due to seasonal variations in the yield.

The results for all these years show that a good yield of sugar beets can be obtained even in poor, depleted soil providing adequate fertilization is applied to the soil. The sugar beet crop responds very quickly to increased fertility of soil.

Stand of Beets

The stand of beets as reported in table 2 was quite good and uniform. The lowest stand of beets during the first 4 years occurred in the check plots (88.0 percent of theoretical stand 26136) and the highest in the plots treated with complete fertilization with divided application of nitrogen (101.7 percent of theoretical stand). The stand of beets in the plots treated with the remaining fertilizers, with the exception of those treated with nitrogen alone (91.9 percent of theoretical stand), was either very close to 100.0 percent or above it.

The stand of beets planted on these plots in 1945 was, in general, very good and with the exception of that of the previous check plots and those treated with phosphorus and manure (91.5 and 91.4 percent of theoretical stand, respectively) was close to 100.0 percent or above it.

Seedling Diseases of Beets

The smallest amount of healthy beet seedlings during the first 4 years occurred in the check plots (27.8 percent) and the greatest amount occurred in the plots fertilized with a complete fertilizer with a divided application of nitrogen (75.8 percent) (table 3). Beets grown in the plots fertilized with nitrogen alone also had a low percentage of healthy seedlings (44.7 percent).

Beets grown in the remaining plots had a rather high percentage of healthy seedlings which closely approached that of treatment $\frac{PNM}{2}$.

These results emphasize the value of a complete fertilizer for the control of seedling diseases of sugar beets.

The amount of healthy seedlings in the crop of 1945, when all plots were uniformly fertilized with a complete fertilizer, was rather high. An exception was noted in those previously treated with nitrogen alone where the percentage of healthy seedlings of 1945 showed the lowest increase (5.7 percent) as compared with those for previous years. The greatest increase of healthy seedlings for 1945 occurred in the former check plots (35.4 percent). The increase of healthy beet seedlings in the plots formerly treated with the remaining fertilizers varied between 9.2 and 17.2 percent over those which occurred during the years 1941-1944.

These results show that the amount of seedling diseases of sugar beets could be materially decreased by increasing the fertility of the soil. Also it is apparent that the nitrogen present in the soil in an unbalanced condition may predispose young beets to seedling diseases. This was evident even in the crop planted in 1945 when all plots were uniformly fertilized with complete fertilizers.

Top-to-Root Ratio

Beets, during the first 4 years, had the smallest percentage of tops and the greatest percentage of roots in the plots treated with the following amendments: P, PN, PM, and PNM (table 4). The greatest percentage of tops and the smallest percentage of roots in the same years occurred in the beets in the check plots and the plots fertilized with nitrogen. The top and root proportions of beets grown with the remaining treatments occupy an intermediate position.

These top-to-root proportions show that apparently there was a slight excess of nitrogen or extreme deficiency of phosphorus or both, in soils of check plots and of those fertilized with nitrogen. These plots had an unproportionally large development of the tops in comparison with the roots.

The top-to-root proportions of beets grown in the plots fertilized with P, PN, and PM approach the ideal ratio desired at the harvest time.

Top-to-root ratios of the beets grown in all fertilized plots in 1945 showed that in general they varied less than for the years of 1941-1944. Beets grown in the plots previously fertilized with P and PN showed proportionally the highest development of roots, and those fertilized with NM and $\frac{PNM}{2}$ the highest development of tops. These results indicate that there was a residual effect of the previous fertilizers on the 1945 crop of beets.

Top-to-root ratios of sugar beets in combination with the yield data offer a good criterion for judging the total and proportional balance of nutrients available to sugar beets in any particular soil under given conditions.

It appears that the most favorable ratio of tops to roots of beets at the time of harvest is equal to 35 to 40 percent for tops and 60 to 65 percent for roots. Much variation from these percentages may be interpreted in relation to mineral nutrition or environmental conditions during the growth of the beets.

In general, an excess of nitrogen and deficiency of phosphorus usually supports a proportionally greater development of tops, while an excess of phosphorus and deficiency of nitrogen results in proportionally greater development of roots.

The actual size of the tops and the roots is limited by the amounts of available nutrients in the soil, and especially by those which are in a minimum quantity.

Summary

1. Sugar beets showed a proportional effect of the different nutrients on yield, stand, seedling diseases and top-to-root ratios when planted in depleted soil.

2. Beets fertilized with NM, PNM and $\frac{PNM}{2}$ produced the best yields in the first 4 years, and those fertilized with nitrogen alone and the

checks, the poorest. The beets grown in the remaining plots produced intermediate yields. The yields of beets grown in all these plots fertilized in 1945 with complete fertilization were uniformly good. The greatest increase in yield was shown by the previous check plots and those fertilized by phosphorus or nitrogen alone. This shows an ability of beets to respond quickly to an increase in fertility of soil.

3. Stands of beets were quite good in all years of study. They were all above 90 percent of the theoretical stand except the check plots for the first 4 years of study.

4. The percentage of healthy beet seedlings in the first 4 years of study was the highest in plots fertilized with $\frac{PNM}{2}$ and the lowest in the check plots and those fertilized with nitrogen alone. The percentages of healthy seedlings in the remaining plots were fairly good and occupy intermediate positions between the above mentioned extremes. The percentage of healthy seedlings in the crop of beets grown in 1947 was considerably higher for the corresponding plots of previous treatments. The greatest increase in the percentage of healthy seedlings as a result of complete fertilization was obtained in previous check plots and the lowest in those where nitrogen alone was previously applied. The increase in percentages of healthy seedlings in the remaining plots of the previous treatments occupy intermediate positions.

5. Beets grown in the plots treated with P, PN, PM and PNM during the first 4 years had the smallest percentages of tops and the largest percentages of roots. Beets grown in checks and in those fertilized with nitrogen had the greatest percentages of tops and lowest percentages of roots. Beets grown in the plots of the remaining treatments occupy an intermediate position. Top-to-root ratios of beets grown in all plots in 1945, when complete fertilization was applied, were more uniform for all previous treatments and checks than in 1942-44.

6. In general, these results show that the fertility of the soil has a great effect on the yield, stand, seedling disease and top-to-root ratios of sugar beets, which is in accordance with results obtained in previous years.

Table 1.—Effect of fertilizers on yield of sugar beets planted in depleted soil, 1941-1944, 1945.

Fertilizers applied	Yield of sugar beets per acre in tons					
	1941 (tons)	1942 (tons)	1943 (tons)	1944 (tons)	1941-1944 Average (tons)	1945 (tons)
Check	3.02	3.50	6.70	4.33	4.39	14.19
P	8.66	8.20	10.31	11.00	9.54	13.90
N	6.86	6.77	7.56	6.94	7.03	13.63
M	12.11	11.21	13.15	14.12	12.65	14.96
PN	9.87	8.79	12.26	12.31	10.81	14.58
PM	12.16	13.19	14.14	14.00	13.37	15.48
NM	13.46	15.67	15.11	14.69	14.73	14.86
PNM	14.45	14.98	15.22	14.99	14.91	14.40
$\frac{PNM}{2}$	15.44	18.04	15.76	15.84	16.27	15.04

Table 2.- Effect of fertilizers on stand of sugar beets planted in depleted soil, 1941-1944, 1945.

Fertilizers applied	Percent of theoretical stand (26136) of beets					
	1941 (percent)	1942 (percent)	1943 (percent)	1944 (percent)	1941-1944 Average (percent)	1945 (percent)
Check	71.9	89.1	103.6	87.4	88.0	91.5
P	90.7	114.7	108.4	89.4	100.8	95.8
N	81.9	97.6	103.2	85.0	91.9	102.9
M	82.4	111.2	103.0	81.9	94.6	96.1
PN	84.3	113.5	111.0	90.0	99.7	106.5
PM	84.7	116.2	106.7	81.7	97.3	91.4
NM	87.1	119.1	105.5	89.7	100.4	108.1
PNM	92.6	115.9	107.7	84.1	100.1	96.7
$\frac{PNM}{2}$	87.5	121.5	111.1	86.7	101.7	97.5

Table 3.—Effect of fertilizers on seedling disease of sugar beets planted in depleted soil, 1941-1944, 1945.

Fertilizers applied	Percent of healthy seedlings					
	1941 (percent)	1942 (percent)	1943 (percent)	1944 (percent)	1941-1944 Average (percent)	1945 (percent)
Check	0.6	14.0	47.5	48.9	27.8	63.2
P	5.4	64.0	81.3	86.5	59.3	72.1
N	8.1	40.7	58.1	72.0	44.7	50.4
M	16.5	81.8	90.2	86.9	68.9	86.1
PN	19.0	84.5	73.1	89.3	66.5	78.9
PM	21.4	88.1	82.3	90.2	70.5	85.9
NM	16.1	86.3	84.7	92.6	69.9	79.1
PNM	32.2	83.5	85.5	93.5	73.7	83.0
$\frac{PNM}{2}$	31.0	90.4	90.1	91.5	75.8	92.6

Table 4.—Effect of fertilizers on top-to-root ratios of sugar beets planted in depleted soil, 1942-1944, 1945.

Fertilizers applied	Top-to-root ratios of sugar beets.									
	1942		1943		1944		1942-1944 Average		1945	
	Tops %	Roots %	Tops %	Roots %	Tops %	Roots %	Tops %	Roots %	Tops %	Roots %
Check	66.7	33.3	49.0	51.0	50.5	49.5	55.4	44.6	48.8	51.2
P	43.9	56.1	37.1	62.9	35.8	64.2	38.9	61.1	45.3	54.7
N	56.0	44.0	56.3	43.7	53.5	46.5	55.3	44.7	48.9	51.1
M	42.3	57.7	47.0	53.0	48.9	51.1	46.1	53.9	50.7	49.3
PN	48.1	51.9	43.5	56.5	38.2	61.8	43.3	56.7	46.1	53.9
PM	39.7	60.3	42.2	57.8	44.3	55.7	42.1	57.9	50.9	49.1
NM	40.1	59.9	52.7	47.3	50.3	49.7	47.7	52.3	54.8	45.2
PNM	40.8	59.2	46.7	53.3	46.4	53.6	44.6	55.4	51.3	48.7
$\frac{PNM}{2}$	43.6	56.4	47.8	52.2	48.2	51.8	46.5	53.5	54.9	45.1