EFFECT OF FERTILIZERS ON SUGAR BEETS GROWN AFTER ALFALFA

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Alfalfa and sugar beets are often grown in the same crop rotation in the eastern sugar beet area and in many instances sugar beets is the first crop following the breaking of the alfalfa. The results of this sequence have not always been satisfactory to the beet grower. Many reports have been received to the effect that the stand of sugar beets obtained and maintained following alfalfa has been unsatisfactory.

The general effect of alfalfa in a well-managed rotation is to improve the yield of the following crops. This has been noted regularly in the case of corn, field beans, and potatoes. With sugar beets, however, the situation is complicated by the fact that organisms causing the black-root of sugar beets are intensified in number by the growing of alfalfa on infested soils. Hence, under conditions favorable to black-root organisms, the stand of sugar beets may be adversely affected, if alfalfa is the immediate forerunner.

Not infrequently sugar beets yield better when grown immediately following alfalfa than they do where an intervening crop is grown, despite the less favorable stands which are often reported. This was the case in trials reported by Cook, Millar, and Robertson[2] in Saginaw County which show that beets following alfalfa outyielded beets following corn after alfalfa by 0.51 ton per year for a five year average in spite of an average of 3414[3] fewer beets per acre.

Experimental work was started at the Michigan Agricultural Experiment Station at East Lansing in 1941 to determine whether the management of the alfalfa might in some way be modified so as to favorably affect the stand and yield of the following sugar beets. The results of the first year's work, obtained in 1942, which included breaking the alfalfa at different dates and the application of nitrogenous and phosphatic fertilizers, have already been published.[4]

2/ Cook, R.L., Millar, C.E., and Robertson, L.S. Sugar Beets in Seven Michigan Systems of Crop Rotation. Proceedings American Society of Sugar Beet Technologists, 1945.

3/ Figures indicating the number of beets obtained from the original records.

4/ Lill, J.G., and Rather, H.C. Sugar Beets after Alfalfa. Michigan Agricultural Experiment Station Quarterly Bulletin, Vol. 26, No. 2, Nov. 1943. pp 129-33.

The experimental work, under a modified plan, was continued during the seasons of 1943, 1944, 1945, and 1946. In 1943 the crop on three-fourths of the experimental area was destroyed by the excessive rainfall received during the growing season. In 1944 the lack of rainfall prevented crop growth and no records were taken. In 1945 the entire experimental crop with exception of the plants on a few small areas, was lost by thinning time. The cause of this loss could not be definitely ascertained. Black-root was very definitely present throughout the area but the complete loss could not be attributed entirely to the presence of black-root. During the season of 1946 the experimental work was carried through the season and the results obtained are presented herewith.

With exception of the first year, the results of which have already been published, the experimental plan has been as follows: Alfalfa has been grown on the experimental area for two years in advance of the experimental crop of sugar beets. Late in the summer of the second year but prior to the breaking of the alfalfa, the area has been divided into 32 large plots on which mineral fertilizers have been applied. These mineral fertilizers have been turned under with the alfalfa. In the following spring, the area has been prepared for the crop of sugar beets. At the time of planting the experimental crop, mineral fertilizers have again been applied. The spring applications have been close to but not in direct contact with the seed.

The fertilizers applied both in the fall and the spring consisted of mineral carriers of nitrogen, phosphoric acid, and potash. The nitrogen carrier in the fall was sulphate of ammonia and in the spring, nitrate of soda. The rate of application in the fall was 40 pounds of nitrogen furnished by 200 pounds of a 20 per cent material, 120 pounds of phosphoric acid from 600 pounds of 0-20-0, and 40 pounds of potash from 80 pounds of 50 per cent material. The application rate in the spring has been just one half of the fall rate. These fertilizing materials were applied alone and in every possible combination both in the fall and in the spring. In the spring the treatments were made in such a manner that each spring treatment crossed each fall fertilizer plot. Thus, in the fall there were eight different treatments, seven different fertilizer treatments plus the check, upon which the same eight different treatments were super-imposed, at one half the rate, in the spring or there were a total of 64 combinations of fall and spring treatments. The work was replicated four times or there were a total of 256 experimental plots.

The soil in the area where the 1946 experimental work was carried out was not uniform. The texture ranged from a fine sand to a loam and the type from Hillsdale through Conover to Brookston. It is believed that the larger part of the area would be classified as a fine sandy loam of the Conover type. The productivity of the soil, judging by the yields of crops previously grown upon it, was sufficiently high for satisfactory yields to have been obtained with only a moderate fertilizing program.

The area had been planted to sugar beets in 1942, to corn in 1943, to oats seeded to alfalfa in 1944 and remained in alfalfa in 1945. The alfalfa was broken in the fall of 1945 in preparation for the experimental crop. During the season of 1945, the alfalfa crop was clipped but not removed from the area.

For the experimental crop of sugar beets in 1946, the fall fertilizers were broadcast on the various plots September 7, 8, and 11, 1945. The area was plowed between the 12th and 15th of September and the soil was allowed to lie undisturbed throughout the winter. Following the preparation of the seed bed in the spring of 1946, the spring fertilizer applications were made on May 2 by drilling the fertilizer in deeply with the beet drill. The beets were planted to the desired depth in the same rows on May 3 by driving the drill in the same wheel tracks. The project was harvested during the week of October 13 to 20. The latter part of the season was deficient in rainfall and the development of the crop was considerably handicapped by this factor.

Segmented seed at the rate of four pounds per acre was planted for the 1946 experimental crop. The germination of the seed and the emergence of the seedlings was entirely satisfactory. However, within a few days after emergence, the appearance of many seedlings throughout the area and particularly upon many of the plots, became distinctly unsatisfactory and the death rate high. These seedlings became a light yellowish green in color and growth stopped. Individual seedlings might continue to live for days and even weeks before dying. The appearance of these seedlings and the growth stoppage was very similar to the appearance of the seedlings of the previous years experimental crop which had been entirely lost.

The data taken during the harvest of the project in 1946 consisted of the number and weight of the marketable roots on each of the 256 plots. No record was made of the number of unmarketable roots. In addition to the number and weight of the marketable roots, a sample of the roots was taken from each plot and submitted to the laboratory for a determination of the sucrose content of the beet roots and the apparent purity coefficient of the beet juice. Summaries of the data obtained in 1946 are given in table 1.

Table 1. Summary of the 1946 season's data.

Spring treatment	Fall treatments: Check	N	P	K	NP	NK	PK	NPK	Spring treatment average
	MARKETABLE ROOTS. NUMBERS OBTAINED PER ACRE.								
Check	6008*	7370	13331	7088	12252	10538	12885	9271	9843**
N	3990	4788	9693	5070	11758	12838	11571	6877	8323
P	15772	15302	15631	14176	14716	16570	15420	13566	15144
K	5985	7111	11970	7815	11007	9435	14082	10937	9793
NP	10960	12462	13120	10632	12064	14997	11735	12486	12307
NK	7628	6032	12322	9388	10937	9764	12627	11289	9998
PK	15631	16171	17392	15091	16218	16617	17438	14903	16184
NPK	13143	15208	15818	13730	16265	15044	15185	14786	14898
Fall treatment average	9890**	10556	13660	10374	13152	13225	13868	11764	12061***
	YIELD. TONS PER ACRE.								
Check	1.830*	2.582	5.997	2.535	5.903	4.671	6.489	4.272	4.285**
N	1.467	1.725	4.800	1.854	5.632	6.208	7.041	3.743	4.059
P	7.370	7.698	8.895	7.534	7.991	9.552	8.320	7.886	8.156
K	1.608	2.347	5.269	2.582	5.081	3.603	6.314	4.424	3.903
NP	5.762	6.220	6.795	6.102	6.466	8.484	7.182	7.252	6.783
NK	2.535	2.206	6.161	3.532	5.328	4.201	6.841	5.539	4.543
PK	7.745	7.334	8.977	8.284	8.367	8.954	8.672	9.153	8.436
NPK	6.348	7.194	7.792	6.431	8.097	8.308	8.168	8.308	7.581
Fall treatment ave.	4.333**	4.663	6.836	4.857	6.608	6.748	7.378	6.322	5.968***

Table 1. Continued.

Spring treatments	Fall treatments								Spring treatment average
	Check	N	P	K	NP	NK	PK	NPK	
	SUCROSE CONTENT. PER CENT.								
Check	18.18*	18.78	20.95	19.12	20.20	18.90	19.60	18.92	19.33**
N	18.72	17.52	18.88	18.48	19.38	18.80	19.85	18.15	18.72
P	18.92	19.20	19.12	18.90	19.98	19.38	20.00	18.78	19.28
K	18.48	18.15	21.12	19.75	21.18	18.78	20.80	19.80	19.76
NP	19.55	19.48	19.85	18.85	20.40	19.68	19.65	19.05	19.56
NK	18.02	17.62	18.48	18.32	20.85	18.60	19.90	19.45	18.91
PK	19.70	19.48	20.45	19.68	20.20	19.82	20.72	20.18	20.03
NPK	18.90	19.88	20.42	19.15	21.22	19.80	21.02	19.25	19.96
Fall treatment ave.	18.81**	18.76	19.91	19.03	20.42	19.22	20.19	19.20	19.44***
	APPARENT PURITY COEFFICIENT. IN PER CENT.								
Check	83.69*	84.81	87.00	84.70	86.92	84.87	86.78	84.92	85.46**
N	84.17	83.58	85.78	82.88	86.17	86.73	87.06	86.42	85.35
P	87.90	87.37	87.84	87.45	87.68	88.75	88.80	87.55	87.92
K	85.68	85.55	87.27	85.54	86.26	83.47	87.22	85.74	85.72
NP	86.88	87.09	86.82	86.32	86.22	88.30	85.88	86.03	86.69
NK	85.08	85.01	86.54	83.67	88.10	85.14	87.48	87.40	86.05
PK	87.58	86.48	86.62	86.53	86.64	86.66	88.43	88.36	87.16
NPK	86.64	87.20	86.54	86.56	86.58	87.38	88.24	86.32	86.93
Fall treatment ave.	85.83**	85.89	86.80	85.46	86.82	86.41	87.49	86.59	86.41***

Table 1. Continued.

Spring treatments	Fall treatments: Check	N	P	K	NP	NK	PK	NPK	Spring treatment average
	CALCULATED GROSS SUGAR PRODUCTION PER ACRE. IN POUNDS.								
Check	666*	975	2538	1006	2461	1782	2561	1654	1705**
N	564	602	1842	705	2266	2390	2886	1364	1577
P	2793	2919	3396	2856	3191	3686	3267	2957	3133
K	604	847	2258	1109	2256	1331	2576	1808	1598
NP	2279	2415	2702	2337	2646	3329	2860	2762	2666
NK	900	750	2307	1440	2251	1638	2659	2239	1773
PK	3058	2851	3660	3263	3333	3538	3584	3659	3368
NPK	2406	2861	3182	2514	3473	3303	3409	3230	3047
Fall treatment ave.	1659**	1778	2735	1904	2735	2625	2975	2459	2359***
	INDICATED AVAILABLE SUGAR PRODUCTION PER ACRE. IN POUNDS.								
Check	554*	834	2208	854	2135	1502	2238	1414	1467**
N	479	504	1586	584	1957	2067	2547	1176	1362
P	2454	2554	2982	2495	2797	3266	2901	2591	2755
K	505	727	1968	947	1929	1113	2246	1552	1373
NP	1985	2103	2343	2012	2293	2943	2455	2372	2313
NK	763	652	2004	1220	1980	1404	2328	1967	1540
PK	2676	2459	3165	2826	2891	3062	3172	3234	2936
NPK	2083	2500	2756	2080	3007	2887	3008	2787	2639
Fall treatment ave.	1437**	1572	2376	1627	2374	2281	2612	2137	2048***

* Figures in body of table are average of four plots.
** Figures in last column and bottom line of each section are average of 32 plots.
*** General average based upon 256 plots.

Table 2. F Values with indicated reliability as determined through the Analysis of Variance of the data obtained in this project.

Factor considered	For each of the following crop characteristics. Marketable roots	Yield per acre	Sucrose content	Apparent purity coefficient	Calculated production of sugar per acre in pounds Gross	Indicated available
Fall treatments	5.30**	4.29**	4.04**	5.07**	4.39**	4.64**
Spring treatments	18.23**	36.22**	1.35	7.96**	37.73**	36.86**
Interaction:						
Fall X spring treatments	2.18**	2.06**	0.91	1.52*	2.01**	2.06**

* Exceeds the 5% point of statistical significance.
** Exceeds the 1% point of statistical significance.

The evaluation of the data by the Analysis of Variance indicated that the differences found to exist as a result of the fertilizer treatments applied to the sugar beets were significant to the 1% point, table 2, in all cases with the exception of the effect of spring treatments upon sucrose content which did not reach the 5% point of statistical significance.

In order to determine which of the eight fertilizer treatments were most largely responsible for the significant F-values, table 2, in the primary analysis, the data were evaluated by the factorial method. The main effects of the seven fertilizers applied in the fall and the main effects of the seven applied in the spring are given in table 3.

Table 3. Main and interaction effects of the three mineral plant food elements applied to the sugar beet crop grown following alfalfa.

Effect of:	Crop characteristic. Marketable roots	Yield per acre	Sucrose content	Apparent purity coefficient	Calculated sugar production per acre. Indicated available
	number	tons	per cent	per cent	pounds
	FALL TREATMENTS ONLY WITHOUT REGARD TO SPRING TREATMENTS. MAIN EFFECTS				
N	113	0.117	-0.043	0.018	35
P	1050**	0.818**	0.488**	0.515**	326**
K	247	0.358	0.033	0.076	116
	FIRST ORDER INTERACTIONS				
NP	-766**	-0.438*	-0.078	-0.237*	-154*
NK	74	0.092	-0.160	-0.002	10
PK	-542	-0.294	-0.203	0.038	-116
	SECOND ORDER INTERACTION				
NPK	-473	-0.299	-0.218	-0.226*	-128
	SPRING TREATMENTS ONLY WITHOUT REGARD TO FALL TREATMENTS. MAIN EFFECTS.				
N	-680*	-0.227	-0.157	-0.154	- 85*
P	2572**	1.771**	0.264	0.766**	612**
K	657*	0.148	0.218	0.056	74
	FIRST ORDER INTERACTIONS				
NP	-351	-0.330**	0.208	-0.210	-100*
NK	410	0.173	-0.074	0.180	52
PK	250	0.122	0.066	-0.184	53
	SECOND ORDER INTERACTION				
NPK	- 22	-0.043	0.014	0.068	- 16

* Exceeds the 5% point of statistical significance.
** Exceeds the 1% point of statistical significance.

MAIN EFFECT OF ELEMENTS.

The factorial method of evaluating the main effect of any plant food element when applied to the soil for the crop, balances the results obtained from all plots receiving a certain plant food element against the results obtained from all plots which did not receive that certain plant food element. Thus, the results presented in table 3 under main effects for nitrogen, phosphoric acid and potash, show the differences in the results obtained between the 128 plots that received the certain plant food element and the 128 plots which did not receive that certain plant food element.

It will be noted from these results that the application of phosphoric acid either in the fall or the spring resulted in very highly significant increases in the number of marketable roots, the acre-yield, the apparent purity coefficient, and the pounds of indicated available sugar per acre; that the increases resulting from the spring application of phosphoric acid, which was only one half of the fall application, were much greater than the increases resulting from the fall application in all cases with the exception of the sucrose content which had been significantly increased by the fall application but not by the spring treatment.

On the other hand, it will be noted that neither the nitrogen nor the potash when applied in the fall had an effect of statistical significance. The spring application of nitrogen caused a decrease of the 5% degree of significance in the numbers of marketable roots and the pounds of indicated available sugar while the spring application of potash caused an increase, of the 5% order of significance, in only the number of marketable roots. Thus, it has been shown that the application of phosphoric acid resulted in large and consistent benefits as compared with the results obtained following the application of either nitrogen or potash.

MAIN INTERACTION EFFECTS OF ELEMENTS

In the evaluation by the factorial method of the interaction effect of the plant food elements when applied together, all those plots which received neither and those which received both of the plant food elements are balanced against those plots which received either one or the other but not both of the two elements being considered. Thus, again the results are based upon the entire number of plots, 128 having received either none or both of the elements and the other 128 having received either one or the other. If the plots which received neither or both of the plant food elements total to the same figure as the plots which received either one or the other of the elements, there is a zero interaction. If the plots receiving neither or both of the elements total to more than the plots which received either one or the other, there is a positive interaction -- the two elements together have given greater results than when applied singly. If the plots receiving neither or both of the plant food elements total to less than the plots which received either one or the other of the elements, then there is a negative interaction or the two elements applied together have given results less than when applied separately.

It will be noted from table 3 under first order interactions that the fall nitrogen-phosphoric acid (NP) application resulted in a negative interaction effect upon all characteristics of the crop while the spring application of nitrogen-phosphoric acid (NP) resulted in a negative interaction for all crop characteristics except the sucrose content. It would be concluded from this, as far as the results of this one year's experimental work are concerned, that the application of nitrogen with the phosphoric acid either in the fall or in the spring reduced the benefits to be derived from the application of phosphoric acid to sugar beets when grown following alfalfa.

The application of potash with phosphoric acid (PK) likewise resulted in negative interaction effects except with the apparent purity coefficient, when the fall application is considered and slight beneficial effects, except with the apparent purity coefficient, when the application was made in the spring.

The three factor or second order interaction effect, as determined by the factorial analysis is obtained by balancing all those plots which received each of the different elements alone or all three together against all those plots which received none or any two of the plant food elements. According to the results presented in table 3 the triple interaction effect of nitrogen, phosphoric acid, and potash (NPK) when applied together in the fall was negative for all characteristics of the beet crop but such effect did not reach the 5% point of statistical significance. With the spring application of the three elements (NPK) the triple interaction effect was negative for the marketable roots, acre-yield, and pounds of indicated available sugar but positive for the sucrose content and the apparent purity coefficient. Like the fall application effect, the spring effect was also of very low statistical significance.

Thus, it has been shown by the results presented in table 3 that the application of phosphoric acid either in the fall or the spring resulted in very considerable benefit to the crop; that the application of either nitrogen or potash with the phosphoric acid either in the fall or the spring resulted in negative effects, some of which reached statistical significance, or relatively slight benefits; that the application of all three plant food elements together resulted in further negative effects or at most non-significant benefits.

INTERACTION EFFECT OF FALL AND SPRING APPLICATIONS.

The evaluation of the data by the Analysis of Variance indicated an interaction of a statistical degree of significance, between the fall and spring treatments, table 2, when the numbers of marketable roots, acre-yields, and pounds of indicated available sugar were considered. The factorial method of analysis was again used to determine the location and extent of the interaction indicated. The effects determined are shown in table 4.

Table 4. Interaction effects between the fall and spring treatments together with the determined reliability of such effect.

The spring: treatment: was	N	P	K	NP	NK	PK	NPK
	NUMBER OF MARKETABLE ROOTS PER ACRE						
N	230	- 23	123	72	92	-167	- 52
P	90	-886**	-356**	142	71	294*	244
K	-223	181	44	220	-125	208	253
NP	129	190	- 41	- 42	- 44	58	208
NK	-152	- 2	-135	171	- 14	39	146
PK	132	116	-125	-165	-143	-193	-177
NPK	110	- 9	33	- 49	-110	- 15	-162
	Tons of roots per acre.						
N	0.073	0.012	0.100	-0.028	0.024	0.023	-0.089
P	0.098	-0.537**	-0.060	0.143	0.144	0.093	0.176*
K	-0.080	0.097	-0.017	0.158*	-0.024	0.099	0.154*
NP	0.071	0.032	-0.051	-0.012	-0.059	0.050	0.042
NK	-0.025	0.040	-0.087	0.012	-0.003	0.002	0.068
PK	0.071	0.055	-0.005	-0.029	-0.021	-0.042	-0.105
NPK	0.071	-0.008	-0.016	-0.089	-0.042	-0.008	-0.096
	INDICATED AVAILABLE SUGAR, POUNDS PER ACRE.						
N	39	- 5	35	- 12	2	10	- 45
P	39	-190**	- 21	30	54*	39	46
K	- 22	51	2	60*	- 11	36	59*
NP	23	20	- 38	- 12	- 22	3	20
NK	7	17	- 32	3	- 8	- 7	21
PK	15	28	- 2	- 26	- 8	- 5	- 40
NPK	21	3	- 8	- 38	- 26	- 3	- 43

* Exceeds the 5% point of statistical significance.
** Exceeds the 1% point of statistical significance.

As is shown in table 4, statistical significance can be attached to but few of the interaction effects between the fall and spring fertilizer treatments. Those between the fall and spring applications of phosphoric acid were all negative, were highly significant, and were of appreciable magnitude. This negative interaction effect between the fall and spring applications of phosphoric acid, decreased the benefits derived from the combined applications as is shown in table 5.

Table 5. Combined effect of fall and spring applications of phosphoric acid.

Time of application	Effect on the crop characteristic: Marketable roots	Acre-yield	Indicated available sugar
	number	tons	pounds
Fall	1050	0.818	326
Spring	2572	1.771	612
Total	3622	2.589	938
Fall X spring interaction	- 886	-0.537	-190
Combined effect	2736	2.052	748

CONCLUSIONS.

The yields obtained from the other crops that had been grown upon this area of soil prior to the experimental crop of sugar beets, indicated that the soil held reserves of the plant food elements which, together with the amounts supplied by a moderate fertilizing program, were sufficient to produce fairly normal and satisfactory yields. However, the behavior of the sugar beet crop grown following the alfalfa and its response to the various fertilizer treatments applied to the soil, indicated that the alfalfa crop through its accumulation of nitrogen and its consumption of or its depletion of the phosphorus reserve, had set up an unbalance of the mineral plant food elements in the soil to which the sugar beet plant seemed to be particularly sensitive. This effect of the alfalfa crop upon the plant food balance in a soil would depend to a very large extent upon the amount of plant food reserves present. In soils where the plant food reserves were ample, the amount of nitrogen added and the amount of phosphorus used would be insufficient to upset the balance of the plant food elements to any serious extent, but with a soil where the plant food reserves were low, the amount of nitrogen added by the alfalfa and the amount of phosphorus removed might be very large proportionally and the effect of the alfalfa would be to produce a very definite unbalance of the plant food elements.

This unbalance of the plant food elements in the soil, resulting in a malnutrition of the sugar beet seedlings and plants, rendered them unable to withstand the attacks of the black-root organisms. Hence large numbers of seedlings were lost by reason of black-root while many others, though living through the season, handicapped by the unbalance of the plant food elements and the attacks of the black-root organisms, were unable to make normal or satisfactory growth.

As has been described earlier, the color of the distressed seedlings became a yellowish green within a few days after emergence and growth stopped. This yellowish green color is not ordinarily associated with an abundance of available nitrogen but even on those plots which received applications of readily available nitrogen only, the color of the seedlings became yellowish green and, if the accumulated data are to be believed, the application of nitrogen only added to the distress of the seedlings for the number of marketable roots upon those plots at harvest was even less than where nothing had been applied. But when the proper balance of the plant food elements in the soil had been approximated by the application of phosphoric acid, the sugar beet seedlings responded by being better able to withstand the attacks of the black-root organisms and the sugar beet plant responded by making a more normal growth throughout the season. This is evidenced by the higher numbers of marketable roots and the higher yields obtained from those plots where phosphoric acid had been applied.

The deficiency of rainfall during the crop season of 1946 may have had some very definite effect upon the quantity of the response of the sugar beet crop to the various fertilizer treatments. Sufficient moisture was in the soil to insure the germination of the seed. Sufficient moisture was received during the first few weeks following planting to give the sugar beet seedlings every opportunity to live. That they did not is in no way due to a deficiency in the moisture supply during the earlier part of the season but the fact that those that did live through the season were unable to make a more vigorous growth was very definitely due to the marked deficiency of moisture during the latter part of the growing season.

On the basis of the information obtained from this one year's results of this experimental project, the following conclusions seem to be warranted:

1. The growth of the alfalfa crop upon this soil apparently had a tendency to upset the balance of the plant food elements in the soil by increasing the amount of nitrogen and reducing the amount of phosphorus.

2. The sugar beet plant seems to be particularly sensitive to the unbalance in the plant food elements in the soil especially when the amount of available nitrogen is increased and the amount of available phosphorus decreased.

3. The unbalancing effect of the alfalfa crop upon the mineral plant food elements may be corrected to such an extent by the application of phosphoric acid to the soil that the sugar beet seedlingand plant can resist the attacks of the blackroot organisms and make a normal growth.

4. The spring applications of the phosphoric acid were much more effective per pound of material applied than the fall applications.

5. Nitrogen, when applied to the soil with the phosphoric acid either in the fall or in the spring, operated to reduce the benefits to be derived from the phosphoric acid application.