Harvest Results of Inorganic Fertilizer Tests on Sugar Beets Conducted in Four States, 1947[1]

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FERTILIZER TRIALS on farmers' fields have a definite part in the determination of soil nutrient deficiencies and the response obtained from fertilizer treatment. The number of such trials that can be made are generally limited by economic and physical factors. To be sure, if one were to exhaust the treatments, fields, and crops that could enter into a study of this type, the number of plots required would be innumerable. Even then one would arrive at only certain deductible conclusions that would have limited application unless other factors were observed and correlated with the tests. To observe and study the many aspects of several fertilizer trials from the selection of fields to condensing and reporting the data is an immense job. It was felt this could best be attacked, as has been the case in so many other problems, through cooperative effort.

The data presented here is limited to the first year's harvest results. The study of cropping history, past fertilizer practices, soil classification and analysis, tissue analysis and other factors under observation have not been assimilated or completed at this time.

The reader will note that there is a certain amount of standardization in the conduct of these tests carried out in sections of four states. Nevertheless, due to the variation in the number of tests and the variation between tests within the states the writers have chosen to present the results of each state in a somewhat different manner.

In this paper identity of the results for each state is maintained; however, in presentation, especially of materials and methods, generalizations covering the four states are made wherever possible.

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[1]Investigations of the Department of Agronomy of the State Agricultural Experiment Stations and the Extension Service of the State Agricultural Colleges of Colorado, Nebraska, Wyoming and Montana in cooperation with The Tennessee Valley Authority and the Great Western Sugar Company.

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Materials and Methods

Initially there were selected in each fieldman's district of the Great Western Sugar Company two or more fields to be planted to sugar beets in 1947. From this array of fields one field per fieldman's district was selected on the basis of uniformity of soil, cropping and yield history, and desirability of location for demonstrational purposes. Generally fields of low, medium, and high productivity were selected within a factory district.

Six or eight row plots the length of the field were used. The experimental design was that of a randomized complete block including nine treatments and two or three replications. The treatments are presented in tabular form in table 1 for tests conducted in Colorado, Wyoming and Montana.

Table 1.- Kind, amount in pounds per acre, time and manner of application of fertilizers used for each treatment in tests conducted in Colorado, Wyoming and Montana (treatments applicable to Nebraska tests exclusive of treatments 7 and 8).

Treatment		Planting				Thinning	
		In row with seed	Side-dressed			Side-dressed	
No.	Symbol	P_2O_5	P_2O_5	N	K_2O	N	Minor elements
		(pounds)	(pounds)	(pounds)	(pounds)	(pounds)	(pounds)
1	P	23	92	--	--	--	--
2	N	--	--	--	--	64	--
3[1]	2(N/2) (split application)	--	--	32	--	32	--
4	NP	23	92	--	--	64	
5	NPK	23	92	--	60	64	
6	2(NPK)	23	184	--	120	128	--
7	NPK+ (minor elements)	23	92	--	60	64	100
8	Check 1	Undisturbed check					
9	Check 2	Equipment pulled through field at each date of side-dressing					

P_2O_5 from superphosphate, approximately 46 percent P_2O_5.
N from ammonium nitrate, 32 percent N, except for Montana and Lovell, Wyoming, districts where ammonium sulfate, 20.5 percent N, was used.
K_2O from muriate of potash, 60 percent K_2O.
Minor elements from a mixture of 22.2 pounds $MnSO_4$, 22.2 pounds $ZnSO_4$, 22.2 pounds $Na_2B_4O_7 \cdot 10H_2O$, 22.2 pounds $FeSO_4$ and 11.1 pounds $CuSO_4$.

[1]For Wyoming, treatment 3 includes application of superphosphate as in treatment 4.

The treatments used in Nebraska are identical with those listed in table 1, except for treatments 7 and 8. The minor elements which characterized treatment 7 for the other states were not used, and neither was the undisturbed check. In Nebraska, treatment 7 was similar to treatment 4 except that N was applied at planting time instead of after thinning. Treatment 8 was made to differ from treatments 4 and 7 in that 32 pounds N was side-dressed at planting time and 32 pounds side-dressed at thinning time.

Generally, beet drills with fertilizer attachments were used in making the fertilizer applications. The standard equipment was in many cases modified to fit the need. Tractor-mounted fertilizer side-dressing equipment was also used in some areas. In Montana, the side-dressing at planting time was conducted so that the fertilizer was placed about 2 inches to the side of the row and at the depth of the seed. Side-dressing applications in the other states were made somewhat deeper and further from the row as was also the case for the Montana tests side-dressed at thinning time.

The harvest results were obtained by hand-sampling 32 ten-foot lengths of row taken at intervals from the four center rows of each plot. All these beets were carefully topped, washed, counted and weighed. One-fourth of this quantity was then used in the determination of sugar content. The sampling was completed the week prior to the opening of the beet-receiving stations. These harvesting rules were not followed without exception as in a very few cases the entire plots were harvested individually by the farmer, and tare and sugar samples taken from each load.

Results for Colorado

The mean effects of nine fertilizer treatments on the yield of beets, gross sugar, and percentage sugar for the Colorado tests are given in table 2. The data are averages of the results from 37 farms participating in the experiment. The summarized results in table 2 have a threefold purpose, (1) they show the comparative effects of the different treatments as a whole, (2) they provide an estimate of the significance of the average results and (3) they serve as a basis for estimating the yield increase which might be expected from any of these treatments if applied to all the sugar beets in northeastern Colorado territory.

Table 2.—Mean increase in yield per acre over check 2 and difference in percentage sugar due to treatment.

	Treatment									
	1 P	2 N	3 2(N/2)	4 NP	5 NPK	6 2(NPK)	7 NPK+	8 Ck_1	9[1] Ck_2	LSD[2] 5-percent point
Tons beets	0.56	1.22	1.22	1.75	1.75	2.14	1.54	0.25	17.16	.522
Percent sugar	.01	-.47	-.53	.51	-.45	-1.12	-.54	.05	14.15	.262
Pounds sugar	148	195	165	318	338	175	216	50	4919	155

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1).

The summary presented in table 2 does not constitute a reliable basis for predicting response from the treatments on individual farms nor for predicting response from any one of the other possible rates or combinations of fertilizers which might be used but which were not included in this experiment. It does, however, bring out the following significant facts:

1. Nitrogen and phosphorus alone or in combination resulted in increased average yields.

2. Nitrogen alone gave about twice as much average increase in yield of beets as phosphate alone and slightly greater increase of total sugar.

3. The average increases in beet yield from nitrogen and phosphate were approximately additive when the two were applied in combination.

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Table 2.—Mean increase in yield per acre over check 2 and difference in percentage sugar due to treatment.

	Treatment									LSD[2] 5-percent point
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Tons beets	0.56	1.22	1.22	1.75	1.75	2.14	1.54	0.25	17.16	.522
Percent sugar	.01	–.47	–.53	.51	–.45	–1.12	–.54	.05	14.15	.262
Pounds sugar	148	195	165	318	338	175	216	50	4919	155

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[2]Least significant difference at 5-percent point (odds 19:1).

The summary presented in table 2 does not constitute a reliable basis for predicting response from the treatments on individual farms nor for predicting response from any one of the other possible rates or combinations of fertilizers which might be used but which were not included in this experiment. It does, however, bring out the following significant facts:

1. Nitrogen and phosphorus alone or in combination resulted in increased average yields.

2. Nitrogen alone gave about twice as much average increase in yield of beets as phosphate alone and slightly greater increase of total sugar.

3. The average increases in beet yield from nitrogen and phosphate were approximately additive when the two were applied in combination.

4. No significant increase was obtained from the addition of potash or minor elements. A possible decrease due to minor elements is indicated.

5. Percentage sugar was decreased approximately one-half of 1 percent by the application of nitrogen at the rate of 200 pounds of NH_4NO_3 per acre, and 1 percent when twice this rate was added. It should be noted, however, that the beets in this experiment were harvested in advance of the regular harvest and it is quite possible, if not probable, that the differences in sugar percentage would have been less pronounced later in the season.

Statistical Behavior of the Data.—Before making the comparisons of the effects of the various treatments the data were tested for homogeneity to determine if a generalized standard error could be used as a basis of estimating significance of differences between treatments. For the combined data including all the separate experiments it was found that the data were homogeneous with respect to treatments but not with respect to farms. The data were not homogeneous with respect to treatments in the individual experiments. Comparison of the differences of the means of the treatments in the combined experiment on the basis of the generalized standard error of the difference is, therefore, justifiable but similar comparisons cannot be made between different treatments in the individual experiments.

Results of Individual Experiments.—Wide variability between soils and between other factors affecting response to fertilizers on different tracts of land limit the breadth of generalizations which can be drawn from a single experiment or groups of experiments. Before generalizations from an experiment on one tract of land can be applied to other tracts, some ideas of the variability between tracts is necessary. The percentage response data in table 3 and the frequency distribution curves in figures 1 and 2 show wide differences in response to the fertilizer treatments on different farms. The variability includes differences due to experimental error in addition to the actual differences due to response to treatment but in either case the generalizations which can be made are affected. It is probable that a large part of the negative response can be attributed to error, but since nitrogen significantly reduced sugar percentages it is logical to assume that some actual decrease due to nitrogen may have occurred in the yield of sugar and under some conditions actual decreased yields of beets may have resulted from fertilizer application.

Table 3.—Response of individual farms to P, N, NP and NPK.

Treatment	Beet Yield		Sugar Yield	
	Positive	Negative	Positive	Negative
	(percent)	(percent)	(percent)	(percent)
1 P	70.3	29.7	70.3	29.7
2 N	67.6	32.4	48.6	51.4
4 NP	83.8	16.2	67.6	32.4
5 NPK	81.1	18.9	70.3	29.7

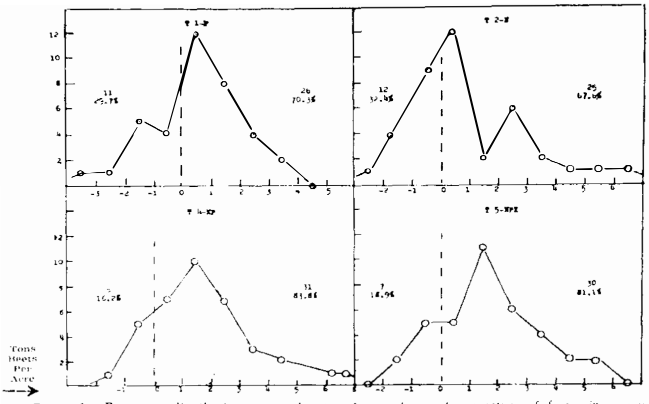

Figure 1.—Frequency distribution curves showing the number and percentage of farms in various beet yield increase groups for treatments 1, 2, 4 and 5 compared with check 2.

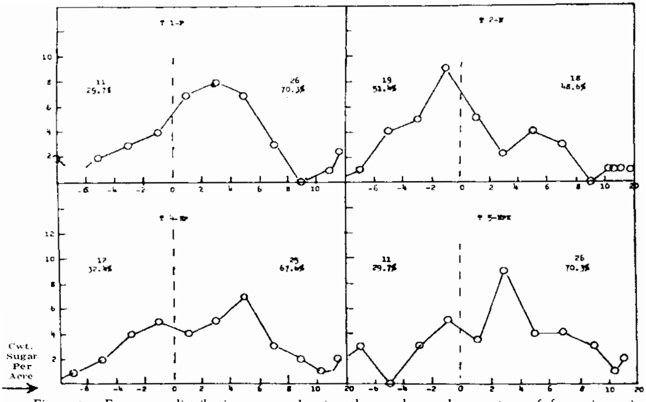

Figure 2.—Frequency distribution curves showing the number and percentage of farms in various sugar yield increase groups for treatments 1, 2, 4 and 5 compared with check 2.

The number and percentage of farms which gave significant response to fertilizers is shown in table 4. Only about 30 percent of the farms gave significant F values for treatments but since the treatments were made only in duplicate, the number responding to treatment is comparatively large. Well-replicated experiments probably would show a much higher percentage.

Table 4.—Number of separate experiments with significant F values for treatment and replication.

Results studied	Treatment	Replication
Yield beets	12	14
Percent sugar	11	11
Yield sugar	11	10

The question frequently has been raised regarding the comparative response to fertilizers of high- and low-yielding fields. Correlation coefficients between yields of the untreated plots (check 2) and the increase in yields due to N, P, and NP were determined. The correlations between yield of the check and N or P were not significant but between the increase of yield due to NP and the yield of the untreated plots, a significant negative correlation of —.386 was found, indicating a tendency for lower response on the high-fertility fields.

Conclusions.—On the basis of this experiment there appears to be a large potential source of increased crop yields in northeastern Colorado which might be obtained by the use of fertilizers. This experiment has shown the response from a few of many possible fertilizer combinations on sample farms of the areas, but further research is necessary to provide a means of determining the best fertilizer practices to meet the highly variable needs of the many different farms and the different crops.

Results for Nebraska

Fourteen fertilizer experiments were conducted in Nebraska. The mean yields of sugar beet, percentage sugar, and gross sugar per acre of these fourteen experiments are presented in table 5. In addition, similar data are presented for the seven fields where noticeable increases in sugar production were obtained from the use of commercial fertilizer and for the seven fields where only small increases or noticeable decreases in sugar production were obtained as a result of the use of commercial fertilizer. None of the fields in the first group of seven received an application of manure in 1947 whereas five of the seven fields in the second group received an application of manure. An attempt was made to group the experiments into two groups according to soil series but the data were not sufficiently homogeneous to warrant such a grouping. Gross sugar production by individual experiments is presented in table 6.

Table 5.—Mean increase or decrease in yield due to treatment and yield of check in tons beets, percentage sugar and gross sugar per acre, Nebraska, 1947.

	Treatment									LSD[4]
	1 P	2 N	3 2(N/2)	4 NP	5 NPK	6 2(NPK)	[1] NP	[2] 2(N/2)P	9[3] Ck.	5-percent point
					Mean 14 fields					
Tons beets	0.95	0.63	0.83	1.43	2.07	2.29	1.72	1.58	14.83	0.48
Percent sugar	0.13	—0.48	—0.54	—0.65	—0.55	—1.05	—0.30	—0.48	13.2	0.21
Pounds sugar	297	28	54	182	405	224	355	268	3877	150
			Mean 7 fields showing increased production of sugar due to fertilizers							
Tons beets	2.40	1.39	1.38	2.88	3.57	3.77	3.03	2.91	11.94	0.79
Percent sugar	0.12	—0.40	—0.16	—0.40	—0.31	—0.86	—0.34	—0.50	13.6	0.29
Pounds sugar	694	284	370	668	909	758	713	639	3207	244
			Mean 7 fields showing slight increases or noticeable decreases in sugar production due to fertilizer							
Tons beets	—0.24	0.01	0.39	0.24	0.84	1.08	0.66	0.49	17.22	0.63
Percent sugar	0.12	—0.56	—0.86	—0.88	—0.75	—1.23	—0.28	—0.47	12.9	0.29
Pounds sugar	—3	—186	—210	—223	15	—222	56	—41	4436	185

[1]Comparable with treatment 4 except N side-dressed at planting time.
[2]Comparable with treatment 4 except ½ N side-dressed at planting time and ½ N side-dressed after thinning.
[3]For description of treatments according to number see table 1.
[4]Least significant difference at 5-percent point (odds 19:1).

Nitrogen.—Based on the mean of the fourteen experiments, the application of a nitrogen fertilizer alone had no significant effect upon the production of sugar. This was due to the fact that a significant increase in yield of roots was offset by significant decrease in sugar percentage. However, the mean for the first seven fields shows a significant increase in sugar due to an application of nitrogen fertilizer alone even though the sugar percentage was decreased. On the other hand, a significant decrease in yield of sugar was obtained for the mean of the second seven experiments as a result of an application of nitrogen fertilizer. The time of application of the nitrogen fertilizer had no significant effect upon the production of sugar.

Table 6.—Increase or decrease in yield due to treatment and yield of check in pounds gross sugar per acre for individual experiments, Nebraska, 1947.

Field No.	Treatment									LSD[4]
	1 P	2 N	3 2(N/2)	4 NP	5 NPK	6 2(NPK)	[1] NP	[2] 2(N/2)P	9[3] Ck.	5-percent point
			Fields showing increased production of sugar due to fertilizer							
1	294	—258	—158	312	455	671	536	414	2111	527
2	920	439	785	1192	1459	1345	1446	1094	2402	572
3	702	—184	155	940	585	894	768	422	2887	676
4	476	60	401	570	1135	1002	516	897	2729	423
5	706	729	1335	609	1428	1283	974	860	3425	742
6	1123	800	217	717	978	267	669	735	3832	790
7	421	144	—71	319	293	93	117	6	4747	NS[5]
			Fields showing slight increases or noticeable decreases in sugar due to fertilizer							
8	—368	—22	111	32	318	63	164	106	2263	NS
9	—81	123	—234	—479	—234	—421	124	114	3843	407
10	—64	—190	—202	—508	—343	—691	—147	—145	4693	369
11	255	—442	—383	—428	—107	93	173	—77	3927	NS
12	126	—538	—558	5	258	—215	—183	—16	5151	NS
13	127	—407	—329	—36	—1	—263	307	—273	5193	NS
14	—84	—27	—2	—270	—36	—174	—153	—33	6137	NS

[1]Comparable with treatment 4 except N side-dressed at planting time.
[2]Comparable with treatment 4 except ½ N side-dressed at planting time and ½ N side-dressed after thinning.
[3]For description of treatments according to number see table 1.
[4]Least significant difference at 5-percent point (odds 19:1).
[5]Differences not significant at 5-percent point.

There was considerable variation in the results obtained from the individual experiments, only three experiments showing a significant increase in yield of sugar as the result of an application of a nitrogen fertilizer alone (table 6).

Phosphate.—An application of a phosphate fertilizer alone increased sugar production significantly based on either the mean of the fourteen fields or the mean of the first seven fields (table 5). This increased sugar production was due to a significant increase in yield of roots and a small but not significant increase in sugar percentage. The mean of the second seven fields showed no significant effect of the phosphate fertilizer upon sugar production.

The results obtained with phosphate fertilizer alone were not quite as variable in the individual experiments as those obtained with nitrogen alone. Significant increases in production of sugar were obtained in four of the individual experiments.

Nitrogen + Phosphorus.—Based on the mean of the fourteen fields or the mean of the first seven fields, a combination of nitrogen and phosphorus fertilizers increased the yield of sugar significantly over the application of a nitrogen fertilizer alone. However, the increases were not significantly greater than those obtained from the application of a phosphate fertilizer alone. On the basis of the mean of the fourteen fields or the mean of the second seven fields, the increases were significantly greater where the nitrogen was applied at planting time than where it was applied following the thinning of the beets. This latter difference was due to a smaller increase in root production as well as to a greater decrease in sugar percentage. In those fields showing a marked response to fertilizer application, there was little difference in yield due to time of application of the nitrogen fertilizer.

A combination of nitrogen and phosphorus fertilizers increased the yield of sugar significantly in five of the individual experiments whereas the yield was decreased significantly in two experiments where the nitrogen was applied following thinning. On the basis of these results and those reported for an application of a nitrogen fertilizer alone, it seems apparent that nitrogen fertilizers should not be indiscriminately applied to lands that have adequate supplies of available nitrogen.

Nitrogen + phosphorus + potassium.—On the basis of the mean of fourteen fields, the addition of a potassium fertilizer increased the yields significantly over a similar treatment without potash (table 5, treatments 4 and 5). However, the increases were not significantly greater than where phosphate alone was applied or where a combination of nitrogen and phosphorus fertilizers were applied with the nitrogen being applied at planting time. Where double the rate of fertilizer containing nitrogen, phosphorus and potassium was applied, the increases were less than where the smaller rate was applied. This was due largely to the marked decrease in percentage sugar where the large rate of fertilizer was used.

In two of the individual experiments the application of a potash fertilizer increased the yield of sugar significantly over a similar treatment without potash.

Conclusions.—On the basis of the results obtained in Nebraska during 1947, the following conclusions appear to be warranted:

1. Commercial fertilizer can have an important part in the production of sugar by sugar beets.

2. One fertilizer cannot be recommended generally for all fields. In some fields the application of a nitrogen fertilizer alone may give maximum yields, in other fields the application of a phosphate fertilizer alone may produce maximum yields, and in still other fields a combination of the two fertilizers may be necessary to produce maximum yields. Potash fertilizer may be needed in some fields in addition to nitrogen and phosphorus fertilizers.

3. Nitrogen fertilizers should not be used indiscriminately. In general, it appears to be a better practice to apply the nitrogen fertilizer at planting time, especially if the field is likely to be moderately well supplied with available nitrogen. Where marked nitrogen deficiency occurs, a late application would be satisfactory.

Results for Wyoming

The variation in treatments that existed in the Wyoming tests as compared to those used in Colorado lies in treatment 3. The basic rate of phosphate was used with the split application of nitrogen for it was thought at the time of designing the experiment that phosphate might generally be the limiting element and that one would not have proper expression in growth from the addition of nitrogen unless used with phosphate. Though ammonium sulfate was used in place of ammonium nitrate in northern Wyoming the quantity of nitrogen applied was maintained equivalent and it is felt that no difference should exist from this change in yield responses obtained.

In spite of the intended uniformity in conducting the fertilizer tests a geographical consideration divides the results into two classes. An examination of the data indicates that the location effect is indeed very marked. In view of this difference and the difference between tests within an area the results of each test are presented in tables 7 and 8.

In northern Wyoming (Lovell District) no apparent response was obtained from the use of phosphate alone or in combination with other elements. The general increases on the whole appear attributable to the application of nitrogen. While the application of part of the nitrogen at planting time might be beneficial, there is also indication of possible loss of this element (Hartman field, treatment 3, table 7) when an appreciable portion is applied early.

Table 7.—Increase or decrease in yield (from check 2) due to treatment and yield of check 2 in tons beets, percentage sugar and gross sugar per acre for two locations in the Lovell District, 1947.

	Treatment									LSD[2]	
	1 P	2 N	3 2(N/2)P	4 NP	5 NPK	6 2(NPK)	7 NPK+	8 Ck_1	9[1] Ck_2	5% point	1% point
	Hartman Farm, Basin, Wyoming										
Tons beets	0.05	3.94	2.45	3.31	3.43	5.80	5.05	1.00	15.11	1.92	2.66
Percent sugar	0.05	0.23	0.58	0.08	0.13	0.13	-0.44	0.88	17.29	.67	NS[3]
Pounds sugar	32	1450	1051	1174	1234	2060	1569	629	5225	714	987
	Kegi Farm, Powell, Wyoming										
Tons beets	1.40	0.63	1.14	0.41	0.85	0.70	0.24	—1.14	16.63	1.07	NS
Percent sugar	0.37	0.12	—0.14	0.42	—0.08	—0.61	0.03	0.03	18.30	NS	NS
Pounds sugar	400	272	367	293	283	44	77	—427	6087	NS	NS

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

Table 8.—Increase or decrease in yield (from check 2) due to treatment and yield of check 2 in tons beets, percentage sugar and gross sugar per acre for three locations in the Wheatland District, 1947.

	Treatment									LSD[2]	
	1 P	2 N	3 2(N/2)P	4 NP	5 NPK	6 2(NPK)	7 NPK+	8 Ck_1	9[1] Ck_2	5% point	1% point
	Stumpff Farm, Wheatland, Wyoming										
Tons beets	4.66	.07	8.36	8.88	7.17	8.01	7.92	1.86	5.03	2.50	3.64
Percent sugar	0.6	0.4	0.9	0.3	0.4	—0.4	-1.4	1.0	14.6	NS	NS[3]
Pounds sugar	1472	-21	2205	2514	1988	2226	1942	410	1464	793	1154
	Dinges Farm, Wheatland, Wyoming										
Tons beets	0.75	0.18	1.31	1.72	0.70	0.88	0.64	1.44	14.05	1.34	NS
Percent sugar	0.3	-0.2	0.0	0.3	0.1	—1.7	0.2	0.5	14.9	.80	1.16
Pounds sugar	312	-18	375	418	179	—245	117	584	4187	459	NS
	Raines Farm, Wheatland, Wyoming										
Tons beets	2.18	0.84	1.00	0.78	2.35	1.74	2.45	1.35	18.40	1.53	2.11
Percent sugar	0.8	—0.1	0.2	0.0	0.4	0.3	-0.2	0.8	11.2	NS	NS
Pounds sugar	817	139	301	174	692	510	465	14	4122	403	555

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

In the southeastern area of Wyoming (Wheatland District) the tests on three farms (table 8) gave very different results. The results of the single test on the Stumpff farm reveal one of the most striking examples of phosphate deficiency. While nitrogen was also deficient in this field the application of nitrogen alone gave no response, except possibly to hasten the development of phosphate deficiency symptoms, which were very evident in the beets growing on the unphosphated plots. The phosphate application alone gave an increase in yield of approximately 3 tons beets per acre and when nitrogen was added also the increase amounted to about 6.7 tons. Thus, the yield from the NP combination was nearly twice that of check 1 and more than twice that of check 2. The other two fields considered to be of medium-to-high fertility, respectively, did not respond so well to the fertilizer treatment.

Results for Montana

During 1947, eight fertilizer tests were placed on sugar beets in the Upper Yellowstone Valley of Montana. One test was abandoned because disease was prevalent in all plots, resulting in poor stands. A second test was abandoned because harvesting was interrupted by rain and yields were not comparable on the two harvesting dates. This report deals with the other six tests which consisted of randomized triplicate plots, each six rows wide and at least 500 feet long. The results are given for gross sugar, tons beets and percentage sugar in tables 9, 10 and 11, respectively.

Table 9. —Increase or decrease in yield (from check 2) due to treatment and yield of check 2 in pounds gross sugar per acre at six locations, Montana, 1947.

	Treatment									LSD[2]	
Location	1 P	2 N	3 2(N/2)P	4 NP	5 NPK	6 2(NPK)	7 NPK+	8 Ck_1	9[1] Ck_2	5% point	1% point
1	-63	81	190	-201	-23	-99	108	54	4430	NS[3]	NS
2	554	480	792	1606	1012	1086	996	376	5750	630	867
3	-243	1030	415	398	321	112	410	-104	4363	325	448
4	275	-56	-70	-301	00	99	209	311	7687	NS	NS
5	12	636	204	809	686	1070	863	-98	3892	470	647
6	14	-176	352	30	149	46	325	112	4126	NS	NS
Mean	92	333	197	390	358	386	485	90	5041	207	285

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

Table 10. Increase or decrease in yield (from check 2) due to treatment and yield of check 2 in tons beets per acre at six locations, Montana, 1947.

	Treatment									LSD[2]	
Location	1 P	2 N	3 2(N/2)P	4 NP	5 NPK	6 2(NPK)	7 NPK+	8 Ck_1	9[1] Ck_2	5% point	1% point
1	-0.06	0.64	1.25	-0.41	0.89	0.89	1.46	0.20	13.80	NS[3]	NS
2	0.88	1.82	2.49	4.69	3.07	3.38	3.17	0.49	17.36	1.84	2.54
3	0.77	3.27	1.39	1.43	1.10	0.78	1.36	0.04	12.50	1.88	2.60
4	0.05	-0.35	-0.33	-0.75	0.34	1.10	0.52	0.05	25.42	NS	NS
5	0.07	1.85	1.10	2.42	2.44	4.06	2.69	-0.42	12.58	1.44	1.92
6	0.31	-0.09	0.65	0.64	0.80	1.20	0.99	0.16	13.70	NS	NS
Mean	0	1.19	0.88	1.34	1.44	1.90	1.70	0.09	15.89	0.72	0.96

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

Table 11. Increase or decrease in percentage sugar (from check 2) due to treatment and percentage for check 2 at six locations, Montana, 1947.

	Treatment									LSD[2]	
Location	1 P	2 N	3 2(N/2)P	4 NP	5 NPK	6 2(NPK)	7 NPK+	8 Ck_1	9[1] Ck_2	5% point	1% point
1	-0.16	-0.43	-0.70	-0.26	-1.05	-1.31	-1.18	-0.42	16.05	0.83	1.15
2	0.72	-0.32	0.25	0.12	-0.01	0.08	-0.13	0.59	16.56	0.45	0.62
3	0.11	0.35	-0.25	-0.36	-0.23	-0.60	-0.23	-0.47	17.45	NS	NS[3]
4	0.51	0.10	0.06	-0.15	-0.20	-0.44	0.10	0.58	15.12	NS	NS
5	-0.04	0.22	-0.50	0.20	-0.23	-0.56	0.10	0.13	15.47	NS	NS
6	0.40	-0.55	-0.60	-0.57	-0.32	-1.06	0.09	0.23	15.06	0.78	NS
Mean	0.26	-0.22	-0.29	-0.17	-0.34	-0.68	-0.21	-0.11	15.95	0.31	0.42

[1]For description of treatments according to number see table 1.
[2]Least significant difference at 5-percent point (odds 19:1) and 1-percent point (odds 99:1), respectively.
[3]Differences not significant.

In interpreting the results, increases above check 2 have been used because it is believed this more nearly indicates the increases due to fertilizers. Table 9 shows that in four of the six tests the yield of gross sugar from the phosphated plot was higher than the check but this did not reach significance at the 5-percent level on any test. For nitrogen alone in single application, differences of significance in yields of gross sugar were obtained at only two of the six locations. At these same two locations the single application of nitrogen was also significantly better than the application of phosphorus alone. A comparison of a single application of nitrogen after thinning versus the split application of the same amount, reveals differences of significance at one location but not as averages of all locations.

A combination of nitrogen and phosphorus gave significant increase in gross sugar yields over check 2 in three cases, in three cases over phosphorus alone, in two cases over the split application of nitrogen, and one case over the single application of nitrogen.

The addition of potash to the combination of nitrogen and phosphorus discussed above, failed to give any difference in favor of potash. The application of twice the quantities of nitrogen, phosphorus and potash failed to give any significant increase in yield of sugar as compared with the basic rate at any location.

In five cases out of six, the addition of the "minor elements" (treatment 7) gave an increase in yield of sugar over treatment 5, but none of these increases were significant at the 5-percent level nor was the 127 pounds increase in the average for all locations significant.

The three tests which showed significant differences in yields of gross sugar also showed similar though not identical differences in yield of beets (tables 9 and 10). In the individual tests, 14 plots differed significantly from their checks (check 2) in gross sugar, but in yields of beets only 11 plots showed comparable differences. The average yield of all plots receiving nitrogen showed that this treatment produced yields of beets that were significantly greater than the average yields of the phosphate-treated plots or either of the checks. The split application of nitrogen showed an increase which was significant only at the 5-percent level, while all other plots receiving nitrogen gave highly significant increases. When the yield is expressed in terms of gross sugar per acre, the increase due to a split application of nitrogen did not reach significance, while all other plots receiving nitrogen gave increases which were highly significant.

The percentage sugar in the beets for the different tests varied between 14.00 and 17.56 percent. In only three tests (table 11) did one or more plots differ significantly from the checks and these do not show a definite pattern. In the averages, all plots receiving nitrogen had lower sugar contents than the checks and in two of the six cases this reached the level of significance. The average percentage sugar for the plots receiving phosphate alone showed highly significant increases over all nitrogen-treated plots.

Location 3 had a low yield and a high content of sugar while location 4 had a high yield and a low content of sugar, but location 2 was relatively high in both yield and sugar content.

While fertilizer treatments have given positive yield increases in some of the tests, the treatments used in 1947 did not always correct low yields.

General Discussion

From the tests reported here it becomes clear that the increased production obtained from the use of commercial fertilizers, and the efficient consumption of available fertilizer supplies, for any one year, lies in the proper distribution and use of that fertilizer. The farms on which fertilizer tests were made did not give 100-percent response or approach closely that percentage. It is realized that measuring yield responses in any one year is not to be taken as an absolute value contributable by the fertilizer. Assuming that the cost of fertilizers added may be paid in different increments per year for a number of years, which may well vary with field, year, and a number of other factors, it is conceivable that at some time hence each field may actually pay manyfold for the fertilizer applied. Yet, in the interests of an investment made each time fertilizers are used, and in the immediate returns that investment can rightfully be expected to give, some conclusions, even though temporary and vulnerable, should be made. These conclusions are:

1. As a side-dressing application, 1000 pounds of fertilizer, or more, as used in treatment 6 is excessive for general practice.

2. The indiscriminate use of nitrogen fertilizer with regard to fields, even at moderate rates, rapidly minimized through reduction in sugar percentage the effectiveness of certain moderate gains made in yield of roots.

3. The results indicate that with some consideration given nitrogen applications in regard to fields, increases in gross sugar production from the use of nitrogen on the sugar beet crop could be improved.

4. The response in certain fields from phosphate gave evidence that fertilizers containing this element are needed. More knowledge on when and how to use phosphate might well increase the efficiency of its use.

5. Nitrogen and phosphate, being the two most frequent deficiencies and often occurring on the same fields, make, on a probability basis, a combined application of both nitrogen and phosphate the most reliable when little or no information on the field is available.

6. The possible need for potassium was suggested in the results of two tests in Nebraska and a similar number in Colorado. This gives indication that on certain farms the supply of potassium in the soil has dropped below the critical level necessary for high yields.

7. The minor elements, Fe, Mn, Cu, Zn and B gave no beneficial response in yield or sugar percentage under the conditions of the tests

conducted in Colorado and Wyoming. A beneficial effect from at least one of the mentioned minor elements was suggested in five of the six tests conducted in Montana.

8. No general difference in response was noted between time of nitrogen application for the alternatives: all at planting time, one-half at planting time and one-half at thinning time, or all at thinning time.

9. The side-dressing equipment itself may do damage to the extent that it becomes a factor important to yield.