Resume of Commercial Fertilizer Studies With Sugar Beets[1]

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Commercial-fertilizer studios with sugar beets have been in progress in the Arkansas Valley in Colorado since 1909. During the period 1909 to 1920 inclusive, various fertilizer constituents and soil amendments were used in numerous trials conducted on the company properties near Rocky Ford. For the greater part, fertilizer response was not sufficiently great to be profitable. On the other hand, factory-waste lime applied as a soil amendment in irrigation water over a large acreage to refractory soil types resulted in definite improvement in soil structure and tilth. This practice has been limited to acreages immediately adjacent to the factory.

In 1921, and continuing through 1928. a comprehensive study of commercial-fertilizer response was undertaken cooperatively with the Tinted States Department of Agriculture. Division of Soil Fertility Investigations.[3] During this period, 31 experiments with commercial fertilizers were made on various soil types, irrigation conditions, and fertility levels, and the effects of various fertilizer combinations, sources of plant food in the fertilizer mixture and rates of application were studied. The soils on which these fertilizer studies were conducted ranged from neutral to highly alkaline reactions. During the first 4 years of study, 21 different fertilizer combinations of nitrogen, phosphoric acid, and potash Avere used in varying proportionate amounts in each test to determine trends, and to ascertain in which portion of the fertilizer triangle the response from fertilizer application was most pronounced.[4]

From this exploratory work it was determined which fertilizer constituent was productive of better results, and the rate of application most likely to produce profitable returns. Therefore, in the tests conducted during the years 1923 to 1928 inclusive, only those fertilizer constituents, or fertilizer combinations found most promising in the earlier studies were used. In general, fertilizer response was correlated with soil type and certain cropping practices. For example, on the lighter-textured sandy loam soils, a 4-16-0 and 4-12-4 fertilizer mixture produced the better results. Soils intermediate in texture, such as the silt loam and loam types, responded best to 0-16-4

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[3]Hurst, L. A. and Skuderna, A. W. Fertilizer Studios with Sugar Beets in The Arkansas Valley Area, Colo., 1921-1928. U.S.D.A. Circ. 319. Bureau Chemistry and Soils, and Bureau Plant Industry ; 20 pp. illus. 1934.

[4]Schreiner. O. and Skinner, J. J., The Triangle System for Fertilizer Experiments. Jour. Am. Soe. Agr. 10: 225-246, illus. 1918.

and 4-16-4 mixtures. For the heavier-textured clay loam and clay types, the 0-16-4 and 0-20-0 fertilizers were the best. As a rule, beets following alfalfa, responded to an application of superphosphate, and especially so. when this was made in conjunction with manure. In this connection, it is worthy of note to record that large scale fertilizer usage, principally treble superphosphate, was commercially adopted in this Valley in 1926.

Fertilizer-placement studies were also made during this period. With the amounts of fertilizer applied—25 to 50 pounds plant food per acre—the greater response was obtained from a direct application of fertilizer in the row with the seed, and promptly furrow irrigating the planted field. This practice is an extensive one in this Valley, although occasionally some damage is caused to the germinating stand where prompt irrigation is not resorted to. In general, heavier applications of commercial fertilizer, beyond the 50 pounds plant food per acre were not profitable, unless the field was in a high state of fertility, which condition will be discussed later in this paper.

It is interesting to observe the source of the various fertilizer constituents used, either singly or in combination, in these fertilizer mixtures. The nitrogen was derived principally from three sources, although in some mixtures as many as four sources were used. Generally, sodium nitrate, ammonium sulfate, and either cottonseed meal or tankage or dried blood were used, one-third each as nitrogen carriers. The organic nitrogen gave the best results on the lighter-textured soils, and the inorganic nitrogen was best on the heavier soils. Sodium nitrate produced consistently better results than ammonium sulfate, although the differences were small. Another inorganic source of nitrogen was cyanamid. This did not produce the response obtained from either sodium nitrate or ammonium sulfate. Further, its use in the fertilizer mixture in excess of 80 pounds per ton is not generally recommended, since it especially reacts with superphosphate.

It was early observed that the percentage of inorganic nitrogen in the fertilizer formula could be quickly overdone with detriment to the germinating stand. In general, when fertilizer is applied with ihe seed, not more than 4 percent of the total plant food used in a complete fertilizer mixture should be nitrogen, and the balance primarily phosphoric acid.

Since a high percentage of phosphoric acid in the fertilizer used produced the best results, the sources of phosphoric acid in the fertilizer mixture received considerable attention in these experiments. Superphosphate containing 16 percent P_2O_5 and treble superphosphate containing 44 to 45 percent P_2O_5 were compared in 20 tests made in a number of locations and on various soil types during 1923-

1027. Due to the injurious effects upon stands of beets resulting' from the excess free acidity of the treble superphosphate as manufactured at that time, the superphosphate consistently outyielded the treble superphosphate in practically every test. An attempt was made to neutralize this excess free acidity by the addition of factory-waste Lime, so as to make a mixture equivalent to the 16 percent superphosphate. This worked very satisfactorily, resulting in significant sugar-per-acre increases.

This suggests the possible use of lime as a filler in the treble-superphosphate fertilizer instead of gypsum. On soils highly charged with sodium salts, which is a condition frequently met with in many irrigated soils in the Arkansas Valley and undoubtedly elsewhere, there is a possibility that 1 he phosphoric acid in the fertilizer may be affected adversely b\ the accumulation of salt. This suggests also the advantageous use of lime as a light top dressing on such soils, and for which purpose existing supplies of factory-waste lime might be beneficially drawn upon.

Potash as potassium sulfate was primarily used in these tests, although some applications were made with potassium chloride. While its moderate use favorably influenced purity values and to some extent the storing quality of heels, the yields were not materially greater. Therefore, during this period of fertilizer tests, it was concluded that potash was not essential to successful sugar-beet growing in the Arkansas Valley.

In addition to these fertilizers, special mixtures as ammo-phos A and potassium ammonium phosphate were used, the latter with especially favorable results. In 1926, Steffens molasses was added to the superphosphate-lime mixture at the rate of $2^{1/2}$ percent of the total mixture. After drying and grinding, the mixture was applied with the seed at the rate of 40 pounds P_2O_5 per acre. An increase of 500 pounds of sugar per acre was obtained from the use of this mixture compared to the superphosphate-lime treatment alone. During this period various minor elements were used singly and in combination with the 1hree essential plant-food elements used in the body of these tests. The results for the greater part were inconclusive. Similarly, this was found true for such soil amendments as sulfur. iron sulfate, and gypsum.

As a result of these tests, in the Arkansas Valley area in Colorado, it was concluded that phosphoric acid is the plant-food element most needed by the sugar beet, all soil types considered. Nitrogen in addition to phosphoric acid is also needed for best results when beets are grown on the lighter-textured soils. The use of potash in small amounts appeared to be beneficial but not essential.

It was further observed, that the efficiency of a commercial fertilizer is increased materially by an abundance of organic matter in the soil, either in the form of animal manures or crop residues resulting from good cropping practices. The studies indicated quite definitely that larger quantities of plant food could be applied with profit in fields of higher fertility than in fields low in fertility.

The conclusions reached were, that for more fertile fields, a reasonable increase could be expected in most cases from commercial-fertilizer application if needed, at the rate of 60 to 80 pounds of plant-food per acre. For soils of average fertility a 40-pound plant-food application was found most profitable. The most outstanding results were obtained from well-farmed and properly rotated fields where a combined use of treble-superphosphate fertilizer and manure was made. This was particularly true, where part of the treble-superphosphate fertilizer was applied to an 8-tons-per-acre application of well-rotted manure made in the fall immediately prior to plowing, and the remainder applied with the seed at planting time.

During the period 1909 to 1928 inclusive, a wide range in annual precipitation was experienced, and with it the inevitable fluctuations in quantity and quality of irrigation water. This is especially true in this area where almost entire dependence is placed upon the direct flow from the river for irrigation requirements.

Of interest to the farmer is the quality of the irrigation water by months, during the irrigation season. For example, in years of copious rainfall, it might be well to pass up an irrigation run in the event water is not of suitable quality for building up the soil-moisture supply. Obviously, such procedure is out of question in years of water scarcity, when poor-quality water must be applied, regardless of its effect upon soil structure, fixation of certain plant foods, nitrification, and the inevitable increase in soluble alkali salts in the soil surface.

From studies conducted by the writer on accumulated alkali salt residues per acre during the 7-year period 1919 to 1925), this amounted to .25 ton annually. It is evident that in irrigated areas the problem of maintaining a high organic-matter content in the soil as a buffer against excessive alkali salt-accumulation is of extreme importance.

As a general premise, commercial-fertilizer response is greater in years of more abundant rainfall than when a deficiency in moisture exists. Due to the general distribution of precipitation, the winter and early spring months are generally *dry* and soil nitrification is at its lowest ebb at beet-planting time. This condition makes it profitable to apply at planting time on lighter-textured soils, a suitable commercial fertilizer containing some nitrogen.

The period 1929 to 1956 was one during which efforts were directed primarily at consolidating gains made in commercial-fertilizer usage, principally treble superphosphate, rather than instituting new work. However, a cycle of abnormally dry years prevented obtaining full benefits from the fertilizer applied, and reduced rather than increased The number of growers using commercial fertilizer.

With the advent of rapid methods of soil testing for N-P-K and other essential plant-food deficiencies, an extensive soil-testing program was undertaken in 1937 in cooperation with the Anaconda Company and also with the American Potash Institute. Using Morgans' Rapid Chemical Method, a large number of soil samples procured from fields located in various parts of the Valley were tested. In general, it was found that 78 percent of them were deficient in phosphoric acid, 38 percent showed nitrogen deficiency, and 29 percent were deficient in potash. Prom previous experience in the field, the results in phosphoric acid and nitrogen deficiency were expected. However, the large increase in soil samples showing some potassium deficiency was apparently a new development.

Accordingly, this phase of study was investigated further, and. samples to a depth of 7 to 12 and 13 to 24 inches were obtained from 139 fields selected at random from sugar-beet-producing areas in this Valley. The La Motte Rapid Chemical Method for Potassium was used. Of the number of samples tested, 58 percent showed some deficiency in potassium.

To confirm these results, a number of fertilizer tesls were conducted in 1938 in the field on fertile soils, using- treble superphosphate, a 4-16-4 complete mixture, and a 4-16-0 fertilizer. In these treatments, the amounts of plant food applied per acre were the same. While all three fertilizers outyielded the unfertilized check by more than 25 percent in pounds of sugar per acre, there was no appreciable difference in yield produced by either of these three treatments. However, the results again demonstrated the importance of organic matter in the soil in increasing the benefits accruing from commercial-fertilizer application.

To check further on the need of some organic matter in the soil in increasing the efficiency of commercial-fertilizer application, a comparison test was conducted in 1939 with an organic base (packing-house waste product). Both the treble-superphosphate fertilizer and the 4-16-4 fertilizer mixture received organic waste as a filler, and each applied with the seed at rate of 40 pounds of mineral plant food per acre. In a field of low fertility, the results were greatly in favor of both fertilizers receiving the organic-base filler. In the field of higher fertility, there were no significant differences in yields produced by these treatments.

In 1940, 12 different fertilizer treatments were used in a field of average fertility. Again, the outstanding treatments were the complete fertilizer mixture 4-24-4, and treble superphosphate, to both of which organic-base fertilizer had been added as a filler. Another promising treatment was Soil Aid, a treated coal product, reinforced with phosphoric acid and nitrogen.

From the results obtained during 1938 to 1940 on soils of various levels of fertility, rather definite conclusions can be drawn: (1) That the importance of organic matter in our irrigated soils cannot be overstressed, and (2) that the more fertile soils generally respond more favorably to commercial fertilizer than soils low in fertility. The results of earlier work done during 1921 to 1928 are thereby confirmed.

This still left the question of potash fertilization open for further work. A study of this phase of the problem was therefore undertaken, and the plan of experiment modified somewhat. Three fields of varying levels of fertility (as adjudged from previous crop results) were selected. All were of silt-loam type and similar cropping practice. The treble-superphosphate fertilizer was used at rate of 45 pounds P_2O_5 with the seed for tests 1 and 2. Side dressings were made immediately after beet thinning, with the kind of fertilizer as outlined in the plan of treatment. The application was 4 inches away from beet row, and about 3 inches deep. The results follow:

Table 1.—High-fertility field—Manzanola, Colorado, 1941

Treatment with seed	Pounds commercial fertilizer per A.	Tons beets per acre	Percentage sucrose	Coeff. app. purity	Sugar per A. yield Gross	Sugar per A. yield Ind. Avail.
0-0-0		18.63	11.54	64.0	4200	2751
0-45-0	150	20.48	11.34	64.9	4634	3007
0-45-0, 20-0-0 } 1-4-0	235	21.17	11.71	65.0	4959	3223
0-45-0, 20-0-0, 0-0-48 } 1-4-2	307	21.72	12.48	66.4	5421	3600
Mean		20.45	11.77	65.1	4828	3145
Req. for sig. diff.		2.25	.71		485	

In this test the complete fertilizer treatment (1-4-2) produced significantly higher results than obtained from the other fertilizers under test. More effective utilization of commercial fertilizer, as conditioned by the fertility level of the field, is evident in this test. It is unfortunate that in this test as in the other two to be presented, hail damage was such as to defoliate completely the plants and abnormally depress sucrose and purity values. Further, record-breaking rains occurring in September and October tended to prevent normal recovery in sucrose.

The results of a test conducted on an intermediate level of fertility are shown in table 2.

In this test, the 0-30-15 and 15-30-0 fertilizer treatments were the most efficient in their response, from the standpoint of unit of fertilizer plant food applied. A trend is seen in increases in sugar-

Table 2.—Intermediate-fertility field—Rocky Ford, Colorado, 1941

Treatment with seed	Side dressing (pounds)	Tons beets per acre	Percentage sucrose	Coeff. app. purity	Pounds sugar per A. Gross	Ind. avail.
0-0-0		12.78	12.60	69.3	3220	2231
0-45-0		13.56	12.47	70.2	3332	2339
0-45-0	40 K_2O	14.58	12.84	73.6	3744	2756
0-45-0	80 K_2O	16.06	12.81	74.8	4116	3079
0-45-0	120 K_2O	17.44	12.40	74.4	4324	3217
0-30-15		16.54	12.84	73.9	4248	3139
15-30-0		16.56	13.61	74.6	4208	3244
Mean		15.33	12.72	73.3	3899	2858
Req. for sig. diff.		2.16	.37		512	

per-acre yields resulting: from additions of potash in the side-dressed applications of 40, 80, and 120 pounds K_20 respectively. It would appear from these results that lesser amounts of K_20 in the commercial-fertilizer mixture, if needed, are sufficient for present crop needs.

A third test was located in a field of lower-fertility level. In this test, 45 pounds of plant food, all from treble superphosphate, was applied per acre with the seed. One side-dressed application of 100 pounds K_20 was made to treatment 4 immediately following beet thinning. The results are shown in table 3.

Table 3.—Low-fertility field—Rocky Ford, Colorado, 1941

No.	Treatment with seed	Rate plant food per A.	Tons beets per acre	Percentage sucrose	Coeff. app. purity	Sugar per acre yield Gross	Ind. avail.
1	0-0-0	None	10.95	12.07	56.60	2669	1513
2	0-45-0	90 lb.	12.76	12.21	57.80	3128	1808
3	0-45-0 } 0-0-40 }	95 lb.	12.25	12.30	57.56	3014	1735
4	0-45-0 } *0-0-40 }	100 lb.	12.53	11.85	56.56	2985	1687
Mean			12.12	12.10	57.14	2949	1680
Req. for sig. diff.			1.92	.67		373	

*100 lb. side dressed.

It is of interest to note that in the side-dressed treatment which received a total of 190 pounds of plant food, no significant yield difference was demonstrated. For that matter, none of the treatments produced yield differences sufficiently large to be profitable.

Conclusions

Despite an apparent increase in the alkali salt residue left in the soil as a result of irrigation-water use over a 50-year period, it appears that the changes which have occurred in the soil under normal cropping conditions are as yet not sufficient to cause widespread mineral plant-food deficiencies. The greatest single need in the building up and maintaining; of fertility in irrigated soils is organic matter.

Second in importance is the increasing need for phosphoric acid. As indicated in this resume, 78 percent of the fields tested showed need of phosphate fertilization. Even so. the symptoms are not as sharply pronounced, as in some other sugar-beet growing areas where blaekheart, a phosphate-deficiency disease, may become so severe as to completely kill the plant.

From the point of view of most efficient application of treble superphosphate, it would appear that applying it in conjunction with barnyard manure at time of fall plowing, and a light application with the seed at time of planting deserves increased consideration. For alfalfa fields showing phosphate deficiency, broadcasting the fertilizer, and either disking it in or working it into the soil with a renovator have proved successful.

In connection with phosphate application to sugar beets, certain varieties have shown selective preference for this plant food compared to others. It would, therefore, appear that in borderline cases of phosphate deficiency, variety tests in conjunction with fertilizer tests will need to be conducted to determine the best practice to follow. Side dressings with treble superphosphate after thinning have not generally shown large returns for the fertilizer dollar expended. There is reason to believe, however, that this practice may develop into sizeable proportions, when the right conditions are provided.

Addition of nitrogen to the fertilizer mixture has been shown to be a profitable practice on light-textured soils, and especially so in years of deficient rainfall in the spring, resulting in decreased nitrification in the soil. Experience in the Arkansas Valley indicates that the percentage of nitrogen in the fertilizer mixture must be kept fairly low if injury to germinating stand is to be avoided. Side dressings with nitrogen after beet thinning have not been found profitable as a general rule.

The application of potash in the fertilizer mixture is as yet in the experimental stage. Results obtained thus far indicate that for the heavier-textured soils well supplied with organic matter, the general use of this element is not yet required. However, on the lighter-textured soils, its use in a complete fertilizer mixture such as 4-16-4, or 4-24-4, or eventually even in a 4-36-4, may be frequently justified. Even where tangible increases in sugar per acre yield have not been shown, the effect upon the keeping quality of the beet in storage has been demonstrable.

In these immature soils of the irrigated West, the use of certain soil amendments may well be considered. Sulfur as a soil corrective is receiving increasing attention, and under the load of increased accumulation of mixed alkali salts in the soil it may have to be given a more prominent place in our fertilizer practice. Agricultural practice in Arizona and in part of New Mexico is already aware of the potential possibilities of sulfur on highly alkaline soils, as witnessed by a rapidly spreading usage of this plant-food element.

Another plant-food element that has shown surprisingly good results, and especially so on highly alkaline soils, has been lime. Not only has it been proved a good flocculating agent under such conditions, but yields have been measureably increased. This suggests the need of further study in determining areas where it is needed, and possible use as a filler for certain fertilizer mixtures where danger of reaction in the mixture is not too great. In this connection, symptoms of overliming as evidenced by boron deficiency are quite generally lacking in this Valley.

The use of minor- elements such as copper, manganese, zinc, boron, and others, either singly or in a fertilizer carrying these rare elements, has not as yet been productive of outstanding results. Possibly there are areas in the irrigated areas where the reverse holds true. From studies conducted on use of copper-lime sprays in control of leafspots, there are indications at times that copper may be utilized by the plant as evidenced by increased sugar-per-acre yield under non-leafspot conditions. Also, certain varieties apparently show a selective preference for this element.

Finally, there is need for more critical testing of newer fertilizers that are on the market. Some of these have decided merit, while others have nothing to recommend them except the claims of the manufacturer or sales agent. With a rapidly maturing soil and with a heavy production load as evidenced by the large yields of crops grown per acre under irrigation, the conclusion is, that increased attention will not only have to be given to proper cropping sequence, crop rotations, and maintenance of high organic reserves in the soil, but to intelligent and efficient use of commercial fertilizers as well.