GRANULATED VERSUS NONGRANULATED FERTILIZERS: EFFECT UPON YIELD AND UPTAKE OF PHOSPHORUS BY SEVERAL CROPS

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Royce Cochran Williams

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GRANULATED VERSUS NONGRANULATED FERTILIZERS: EFFECT UPON YIELD AND UPTAKE OF PHOSPHORUS BY SEVERAL CROPS

By

BOYCE COCHRAN WILLIAMS

A THESIS

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ABSTRACT

Two greenhouse experiments and three field experiments were conducted to ascertain the effect of granulation, placement, and rate of application of fertilizers upon the yield, phosphorus content, fertilizer phosphorus uptake, and utilization of fertilizer phosphorus by wheat, beans, and sugar beets.

Fourteen different soils were used in this series of studies. The soils ranged in texture from loamy sands to clay loams, in pH from 5.1 to 7.6, and in available phosphorus from 4.8 to 125 pounds per acre.

The fertilizer materials used were ordinary superphosphate, 0-20-20, 3-12-12, 4-16-16, and 10-10-10 in both granular and nongranular forms. Formulations of 8-16-8, slurry process, ammoniated, and nonammoniated, in nongranular form were used in the 1953 greenhouse experiment.

Uptake of fertilizer phosphorus in all crops was increased by fertilizer application. Increasing the rate of application of phosphorus tended to increase the amount of total phosphorus taken up by the three crops. Banded placement of fertilizers tended to produce plants

Approved: R. L. Cook

higher in fertilizer phosphorus than did similar amounts of broadcast material. These effects were not so evident for the total phosphorus content of the three crops.

Banded placement of fertilizers generally resulted in a higher utilization of applied phosphorus than did broadcast placement. Increasing the rate of application of fertilizers tended to decrease the percentage of fertilizer phosphorus utilized though it increased the actual amount taken up by the three crops.

Yields tended to be increased by the banded placement and by the increasing of the rate of application of fertilizers.

Granulation of the fertilizers had no consistent effect upon yield, phosphorus content, fertilizer phosphorus uptake, or utilization of applied phosphorus by the three crops grown. In those cases where granulated fertilizer had more effect on the above factors than did nongranular material, the broadcast placement was involved.

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INTRODUCTION

Granulation of fertilizers started in Germany about 1925 and has been practiced extensively since that time throughout Europe, especially for nitrogenous fertilizers and some mixed materials (3). It was not until the late thirties, however, that granulation of superphosphates and other phosphatic fertilizers was investigated to any extent.

The purpose of granulation was to make the fertilizers easier to store, handle, and distribute in the field by changing the physical structure of the fertilizer materials. After this was accomplished there developed the theory that, for phosphates, granulation might increase their availability to plants. The reason postulated for this was that reduction of the fertilizer surface in contact with the soil should reduce fixation. Similar reasoning led to the banding of fertilizers in soil applications. In both cases the result is believed to be an environment with a higher quantity of phosphorus in a state of greater availability to the plants.

Because of the interest in better physical condition of granulated fertilizers and the possibility of their greater phosphate availability to plants, the granulation of fertilizer materials gained much attention, especially in the last ten years.

The theory concerning the availability of phosphorus from a granule has not been investigated thoroughly enough to have sufficient data to either prove or disprove it.

In view of the contradictory reports on the availability of phosphorus from granules and the importance of a reduction of phosphorus fixation by the soils, or higher utilization of applied phosphorus fertilizers, a series of experiments was designed to compare granular with nongranular fertilizer materials.

These studies were undertaken to: (1) evaluate yield response of several crops to granular versus nongranular materials, (2) evaluate fertilizer phosphorus uptake by the crops, and (3) evaluate utilization of fertilizer phosphorus from the two sources.

REVIEW OF LITERATURE

In the past ten years the idea has developed that granulation, theoretically at least, should improve the efficiency of a plant to obtain phosphorus from a fertilizer. This should be especially true for a fertilizer containing a high percentage of water-soluble phosphorus by reducing the degree to which the phosphorus is fixed. This should make possible better fertilizer phosphorus utilization and increase the possibility of yield response to added phosphorus.

This postulation has been under sporadic investigation since the 1930's with inconclusive results based mostly on yield data. In 1950, Sherman and Hardesty (16) presented a review of the literature pertaining to granulation studies. This review was concerned with some fifty-two experiments conducted in seven European countries, Canada, Hawaii, and in fifteen states of the United States. A further condensation of this review was made by Starostka (20).

In these reviews it is to be noted that in twenty-three placement experiments localized placement of fertilizer resulted in greater yields than mixed placement for about 50 percent of the tests. For the remainder of the experiments, no differences in crop yields were noted for placement.

Size of fertilizer particles was studied in forty-seven experiments where the localized placement was used. In about 50 percent of the experiments no significant differences in yield due to particle size were noted. The use of briquets or particles larger than 10 mesh in size caused increased yields in about 25 percent of the experiments. These experiments were mostly on podzolic, lateritic, or other soils of low available phosphorus content. The use of very fine granules or powder gave rise to increased yields in some 15 percent of the experiments, mostly on sandy loam soils or in pot tests.

Mixed placement studies were made in some twenty-two experiments on podzolic soils or in pot experiments. In 65 percent of these tests size of fertilizer particle had no effect upon yield.

Sauchelli (13) has reviewed the work of Franck in Sweden, some work from Hamburg, Germany, and some Russian work which gives evidence of large yield increases caused by granulation of phosphate fertilizers.

The work of Franck covered a five-year period and his results showed large increases in yield of oats and barley in favor of granulated over nongranulated superphosphate.

The results from Hamburg, Germany, using granular materials from Sweden, showed that coarsely granular superphosphate gave greater yields of rye and red clover than did the finely granular superphosphate. They further showed evidence that for the less-soluble phosphates better yields were obtained by use of materials where particle size was small.

Vomocil (23) used fertilizers labeled with P^{32} for beans and wheat on Conover loam and Miami sandy clay loam soils. He found that yields were not affected by granulation. He further found no statistical difference between banded and mixed placement of fertilizer, although the mixed placement tended to give slightly higher yields. Banding the fertilizer resulted in higher percentages of phosphorus in the plant than did mixing it with the soil. Granulation did not give any consistent results in the uptake of phosphorus by the plants.

Lawton, Erickson, and Lemon (5), and Rogers (12) have shown that, as the concentration of available soil phosphorus increases, the utilization of added fertilizer phosphorus decreases.

Lawton, Erickson, and Robertson (6) found that in placement studies on sugar beets on a Brookston clay loam soil the utilization of fertilizer phosphorus, during the first two months, was greatest from the banded placement. As lateral growth of roots increased, in July and August, it was found that the utilization was greatest from the drilled fertilizer. Also, sidedressed fertilizer was found to be readily absorbed when applied two months after planting. Applied phosphorus caused increases in yields with all methods of placement.

Penner (10, 11), using ammonium phosphate in liquid form and in granules, found that localized placement increased the fertilizer phosphorus uptake by wheat. No consistent results were found for granulation.

Rogers (12) found that 12- to 50-mesh granules of nitraphosphates were best, as measured by yields of corn, oats, wheat, cotton, and hay.

Stanberry and Fuller (18), working with granular dicalcium phosphate on Superstition loamy sand, found it to be superior to double superphosphate and phosphoric acid in supplying phosphorus for alfalfa. In this experiment, fine granules were more effective than coarse particles. In 1953 (19), the same two authors found similar results with the exception that the finer granulation of dicalcium phosphate was not superior to the coarser granulation.

These authors further noted that because of its less-soluble nature the dicalcium phosphate must be thoroughly mixed with the soil to make it accessible to alfalfa roots.

Lawton, Tesar, and Kawin (8) worked with different rates and methods of application of superphosphate to legume hay. They found that increasing the rate of fertilizer application increased both yields and amount of phosphorus found in the crop. Also the amount of fertilizer phosphorus in the plant increased with the increase in rate of fertilizer added. They also showed that, as the depth of placement increased from surface application to 36 inches, the amount of phosphorus absorbed by the plant decreased.

Whittaker, Coe, Bartholomew, Volk, and Radar (25), working with placement of nongranular sources of phosphorus, found superphosphate to be most effective where it was localized.

Starostka, Caro, and Hill (21) used granular superphosphate and dicalcium phosphate in an experiment to ascertain the availability of phosphorus in granulated fertilizers. The plant used was winter wheat which was grown in the greenhouse using two methods of application, banding and mixing. All phosphorus treatments caused growth responses on both soils, Evesboro and Davidson, at the thinning sampling. The apparent optimum size of superphosphate granule was 14- to 20-mesh in the banded placement and 8- to 10-mesh in the mixed placement. Dry weight yields at final harvest indicated that a growth response to superphosphate occurred on the Evesboro soil but not on the Davidson soil. Banded placement produced significantly higher yields than mixed placement. The uptake of phosphorus from superphosphate was also higher for banded placement than for mixed placement at both samplings. In this report, 14- to 20-mesh granule size was somewhat superior to other granule sizes.

Lawton, Owens, and Apostolakis (7) worked with mixed fertilizers of varying water-soluble phosphorus content and mesh size, using the mixed method of application. They used beans, wheat, and corn as indicator crops. At the end of one week they found very little fertilizer phosphorus in the seedlings gown on soil containing granular materials having less than 40 percent water-soluble phosphorus. At the end of four weeks, the wheat plants had absorbed much greater quantities of fertilizer phosphorus from granules of greater than 20 percent water-soluble phosphorus than from the similar nongranular materials.

In another experiment on a Hillsdale soil, these authors found that 4- to 6-mesh granules resulted in greater uptake of fertilizer phosphorus from materials having high amounts of water-soluble phosphorus.

It is also advisable to review two dissolution studies: one by Sayre and Clark (14) and the other by Lawton and Vomocil (9). Sayre and Clark used two mixed goods, 5-10-5 and 5-20-5, in granulated and powdered forms. They calculated the percentage of available phosphorus remaining in the granules under field conditions after periods ranging up to one year. The values for available phosphorus in the granules appear to be high. However, they report no attempt to calculate these values on the original granule weights.

Lawton and Vomocil found that there was a rapid dissolution of the water-soluble phosphorus from the granules of superphosphate. They found that the dissolution of the granules was greater as the moisture increased in the soils. The percent of original phosphorus that moved out of granules placed in soils at field capacity ranged from 50 to 80 percent in 24 hours. Where soil moisture contents were as low as 2 to 4 percent, phosphorus dissolution amounted to 20 to 50 percent in 24 hours.

A possible reason for the difference in dissolution rates reported by the two groups of authors may be that of difference in initial water-soluble phosphorus contents of the fertilizer materials used. Also, as noted before, the basis of calculation of available phosphorus remaining in the fertilizer was not the same.

Fruhstorfer (3) has reviewed much of the European work on granulation of phosphates. He reported the results of Franck and those from Hamburg, Germany, which have been previously noted. In addition, his review of Russian data showed that numerous experiments have resulted in appreciable increases in yield when granular superphosphate was worked into the row.

Also he has noted that in pot experiments, conducted in Halle by Schmallfuss and in Jena by Michael, no benefit from granulation was found on soils rich in lime and poor in phosphorus.

Fruhstorfer (3) stated in regard to his own work that when granular products were sown broadcast they were superior to the powdered form and when top-dressed they were inferior. When the materials were banded the results were variable but on the whole the granular and nongranular materials were equal. These results were especially true for limed soils. Fruhstorfer further stated that granulation of less-soluble materials reduced their effect upon yield and uptake of total phosphorus.

In the case of compound fertilizers, there has been little work. In 1952, Poll, according to Fruhstorfer, showed a decrease when granular Nitrophosphate was compared with granular superphosphate. However, Stewart, in 1953, did not obtain similar results.

Fruhstorfer (3) sums up the experiments by stating:

> It is possible to see the effect of the size of the granules on plant growth from the curve representing the unlimed plot. Experiments showed that the optimum effect of the granule size lies in between a diameter of 3 and 5 mm but when compared with the smaller sizes down to 1 mm, the advantage of this size of granule is not considerable. In contradistinction to this, finely ground superphosphate shows a considerable decrease in yield on this soil. Hence the conclusion that the size of these granules should be 1 - 5 mm appears to be confirmed.

On the other hand, Stewart (22) makes the following statement:

> Granulation of fertilizers is a spreading practice. It has not been shown conclusively that there is any general agronomic value to granulation of superphosphate, although claims of crop responses to granulation have been noted.

EXPERIMENTAL MATERIALS AND METHODS

Soils

The soils chosen for this series of experiments were all typical agricultural soils of the areas in which they were found. There was a great variation in pH range and in phosphorus fertility levels, as determined by total available phosphorus.

The soil types and some of the chemical properties of the soils used are shown in Tables 1 and 2, together with the specific location of each soil within the state of Michigan.

Fertilizer Materials

The fertilizer materials used consisted of granular and nongranular superphosphates, formulations of 8-16-8, and several mixed fertilizers of both granular and nongranular forms.

The granular and nongranular superphosphates and formulations of 8-16-8 were tagged with P^{32} and were furnished by Mr. W. L. Hill and associates of the Fertilizer and Agricultural Lime Division of the Agriculture Research Service at Beltsville, Maryland. These tagged materials were used in the greenhouse studies in 1952,

TABLE 1

SOIL TYPES AND SOME CHEMICAL CHARACTERISTICS OF MICHIGAN SOILS USED IN GREENHOUSE STUDIES IN 1952, 1953, AND 1954

Year	Soil Type	Location	pH[1]	OM[2] (pct.)	K[3] (lbs. /A.)	P[4] (lbs. /A.)
1952	Oshtemo loamy sand	Sec 27, T5N, R1W; Rose Lake Wildlife Experiment Station, Clinton County	5.3	1.0	87	102.0
	Emmet loamy sand	Sec 21, T30N, R11W; Wagbo Farm, Leelanau County	6.3	5.6	94	34.0
	Hillsdale sandy loam	Sec 20, T4N, R1W; Lawton Farm, Ingham County	5.2	2.4	112	51.0
	Fox sandy loam	Sec 4, T2S, R10W; Campbell Farm, Kalamazoo County	5.8	2.6	104	57.5
	Miami loam	Sec 21, T6N, R2W; Cook Farm, Clinton County	6.3	2.6	120	36.0
	Conover loam	Sec 21, T6N, R2W; Cook Farm, Clinton County	6.5	4.7	112	40.0
	Brookston loam	Sec 27, T12N, R2W; Bobbitt Farm, Gratiot County	7.6	5.6	172	45.0

TABLE 1 (Continued)

Year	Soil Type	Location	pH	OM (pct.)	K (lbs. /A.)	p (lbs. /A.)
1952	Wisner loam	Sec 33, T15N, R8E; Tuscola County	8.1	2.1[5]	84	4.8
	Brookston clay loam (virgin)	Sec 27, T6S, R5E; Woods Farm, Lenawee County	6.3	11.7	240	116.5
	Carlyle muck	Sec 12, T5N, R1W; MSC Muck Experimental Farm, Clinton County	6.6	92.3	76	60.0
1953	Oshtemo loamy sand	Sec 27, T5N, R1W; Rose Lake Wildlife Experiment Station, Clinton County	5.3	1.2	84	84.0
	Hillsdale sandy loam	Sec 20, T4N, R1W; Lawton Farm, Ingham County	5.1	3.0	112	45.0
	Fox sandy loam	Sec 4, T2S, R10W; Campbell Farm, Kalamazoo County	5.3	3.2	112	61.5
	Miami loam	Sec 21, T6N, R2W; Cook Farm, Clinton County	5.8	3.2	120	40.0
	Brookston loam	Sec 27, T12N, R2W; Bobbitt Farm, Gratiot County	6.1	5.2	172	45.0

TABLE 1 (Continued)

Year	Soil Type	Location	pH	OM (pct.)	K (lbs. /A.)	P (lbs. /A.)
1953	Conover loam	Sec 21, T6N, R2W; Cook Farm, Clinton County	6.9	4.8	102	36.0
	Wisner loam	Sec 33, T15N, R8E; Tuscola County	7.6	2.3[5]	76	5.0
	Brookston clay loam (virgin)	Sec 27, T6S, R5E; Woods Farm, Lenawee County	6.1	13.0	240	125.0
1954	Oshtemo loamy sand	Sec 27, T5N, R1W; Rose Lake Wildlife Experiment Station, Clinton County	5.3	0.94	84	102.0
	Brookston clay loam (virgin)	Sec 27, T6S, R5E; Woods Farm, Lenawee County	6.3	11.4	240	102.0

[1] pH determined by glass electrode on 1:1 soil-water ratio.

[2] Organic matter determined by dry combustion method (1).

[3] Potassium determined on 0.135N HCl extract according to Spurway and Lawton (17).

[4] Phosphorus determined as total available according to Bray (2), using an extracting solution which was 0.1N with respect to HCl and 0.03N with respect to NH_4F.

[5] Free carbonates present so organic matter determined by Walkley and Black method (24).

TABLE 2

SOIL TYPES AND SOME CHEMICAL CHARACTERISTICS OF MICHIGAN SOILS USED IN FIELD STUDIES IN 1952, 1953, AND 1954

Year	Soil Type	Location	pH[1]	OM[1] (pct.)	K[1] (lbs. /A.)	P[1] (lbs. /A.)
1952	Conover loam	Sec 25, T4N, R2W; MSC Experimental Farm, Ingham County	6.3	4.8	84	12.5
1953	Conover loam	Sec 4, T6N, R4W; Feneis Farm, Clinton County	5.9	1.8	97	22.5
	Wisner loam	Sec 16, T14N, R8E; Hart Farm, Tuscola County	7.4	3.5[2]	116	63.0
	Kawkawlin loam	Sec 28, T16N, R4E; Pomaville Farm, Bay County	7.6	2.3[2]	132	84.0
1954	Hillsdale sandy loam	Sec 20, T4N, R1W; Lawton Farm, Ingham County	5.1	3.2	102	45.0

[1] All values determined the same as shown in Table 1.

[2] Free carbonates present so organic matter determined by the Walkley and Black method (24).

1953, and 1954. Formulations of 8-16-8 were used only for the greenhouse studies in 1953.

The Fertilizer and Agricultural Lime Division also furnished tagged and nontagged superphosphates for field studies in 1952 and 1953.

The fertilizer materials used in the 1952 greenhouse experiment were ordinary superphosphates: (1) nongranular testing 18.5 percent P_2O_5, and (2) 4- to 8-mesh granules testing 18.3 percent P_2O_5. Both materials were tagged with P^{32} and had a specific activity of 0.2 mc per gram of P_2O_5. The pile date for the materials was March 3, 1952.

The tagged materials used in the 1952 field experiment had a specific activity of 0.2 mc per gram of P_2O_5 and a pile date of May 7, 1952. Along with the tagged materials were sent nonradioactive materials which had the same characteristics as the radioactive material except for the P^{32} present in the radioactive material. These fertilizers and their P_2O_5 contents were:

ordinary superphosphate, nongranular	18.7% P_2O_5
ordinary superphosphate, 4- to 8-mesh granules . .	18.7% P_2O_5
ordinary superphosphate, 14- to 20-mesh granules .	19.0% P_2O_5

ordinary superphosphate,
28- to 48-mesh granules . 20.6% P_2O_5

In 1953, the materials used for the greenhouse study were ordinary superphosphates of nongranular and 4- to 8-mesh granular forms and 8-16-8 formulations in nongranular form. Each of these materials was tagged with P^{32} to give a specific activity of 0.2 mc per gram of P_2O_5 and had a pile date of January 7, 1953. The fertilizers and their P_2O_5 contents were:

8-16-8 nonammoniated . . . 15.3% P_2O_5

8-16-8 ammoniated . . . . . 16.8% P_2O_5

8-16-8 slurry process . . . 17.1% P_2O_5

ordinary superphosphate,
nongranular . . . . 18.5% P_2O_5

ordinary superphosphate,
4- to 8-mesh granules . . 20.1% P_2O_5

In the 1953 field experiments, ordinary superphosphates in three different particle size ranges were used. They were radioactive and nonradioactive as in the 1952 study. The radioactive materials were tagged with P^{32} to yield a specific activity of 0.2 mc per gram of P_2O_5 and had a pile date of May 13, 1953. The nongranular material tested 21.8 percent P_2O_5; the 4- to 8-mesh granular material tested 19.9 percent P_2O_5; and the 14- to 20-mesh granular material tested 21.5 percent P_2O_5.

Mixed materials in both granular and nongranular form also were used in the 1953 and 1954 field experiments. These materials were nonradioactive. They were from the same mix and differed only in physical form. These materials were furnished by the Smith Agricultural Chemical Company of Saginaw, Michigan. The analyses of these mixed materials were: (1) 0-20-20, (2) 3-12-12, (3) 4-16-16, and (4) 10-10-10. The water-solubilities of phosphorus in the mixed materials determined according to A.O.A.C. procedure, were:

Mix	Form	Pct. Water-Soluble P
0-20-20	nongranular	86.2
0-20-20	granular	86.2
3-12-12	nongranular	7.2
3-12-12	granular	7.2
4-16-16	nongranular	46.5
4-16-16	granular	36.0
10-10-10	nongranular	14-6
10-10-10	granular	12.0

Methods and Procedures

Greenhouse. In 1952, the soils were potted in four-gallon pots, except for the Brookston clay loam and Emmet loamy sand, which were potted in three-gallon pots.

The treatments applied were:

1. Nongranular superphosphate mixed with the top four inches of the soil.

2. Granular superphosphate mixed with the top four inches of the soil.

3. Nongranular superphosphate banded one inch below and one inch to the side of the seed.

4. Granular superphosphate banded one inch below and one inch to the side of the seed.

The superphosphates were applied on a surface area basis to give 40 pounds of P_2O_5 per acre and treatments were replicated three times.

Additional treatments given to the soils consisted of the following:

1. One hundred pounds per acre of nitrogen in the form of ammonium nitrate, except for the Carlisle muck, which received 150 pounds of nitrogen per acre.

2. One hundred fifty pounds of K_2O per acre in the form of muriate of potash, except for the Carlisle muck, which received 500 pounds of K_2O per acre.

3. Twenty pounds of magnesium per acre in the form of epsom salt.

4. Forty pounds of manganese per acre in the form of manganese chloride.

5. Five pounds of copper per acre in the form of cupric sulfate, except for the Carlisle muck, which received 20 pounds of copper per acre.

All chemicals used for the additional treatments were of CP grade. The nitrogen and potassium were added to the soils in solid form and mixed in the top four inches of the soil. The copper, manganese, and magnesium were added in solution in the irrigation water. An attempt was made to keep the pots of soils at moisture equivalent by frequently bringing them back to their original weights by adding distilled water.

Henry spring wheat was planted March 27, 1952. One hundred seeds were planted per pot and on the first sampling the pots were thinned to thirty-three plants per pot. Afterward, the numbers of plants taken at each sampling were sixteen, eight, and four, respectively, leaving five plants for final harvest on June 27, 1952. Dates of samplings were April 6, 15, 22, and 29. The samples were analyzed for radioactive and total phosphorus. The plant material was sampled by pulling the entire plant and then separating the roots from the tops. The tops were kept for the analysis for radioactive and total phosphorus.

In 1953, the rate of fertilizer application was 200 pounds of P_2O_5 per acre in the form of superphosphate or mixed material 8-16-8. The planting, banding, and mixing procedures were the same as for 1952. Nitrogen and potassium were added in the forms of ammonium nitrate and muriate of potash at the rate of 100 pounds of nitrogen and K_2O per acre. On March 26, all pots received the equivalent of 20 pounds of nitrogen and K_2O per acre in liquid form and also magnesium and manganese at the rates of 20 and 40 pounds per acre, respectively, in the form of dissolved sulfates. Each treatment of phosphorus was replicated four times and check pots, identically treated except for having no phosphorus, were included to ascertain yield response to P_2O_5.

The crop again was Henry spring wheat. Planting was on January 31 and February 7, and was followed by four samplings of the plant material for radioactive and total phosphorus analysis. Dates of sampling were February 21, February 28, March 1, and March 7 for pots planted on January 31. Dates of sampling were February 28, March 7, March 14, and March 21 for pots planted on February 7. Six plants per pot were left for final harvest on April 21, 1953. All plants were harvested on this date because of the appearance of a bad infection of smut.

Field. In 1952, a field study of granulated and nongranulated superphosphate was made on the College Farm using the Rainy River variety of navy beans. The soil type and some of its chemical characteristics are reported in Table 2.

The history of the field since 1948 showed no fertilizer had been applied and a grass sod covered the soil.

Nitrogen was furnished at the rate of 40 pounds per acre in the form of ammonium nitrate and K_2O was supplied at the rate of 100 pounds per acre in the form of muriate of potash. Both of these fertilizers were drilled prior to planting.

Phosphorus treatments were applied at the rates of 50 and 100 pounds of P_2O_5 per acre as superphosphate. These materials were

both radioactive and nonradioactive. Two methods of application, banding below and to one side of the seed and broadcasting and discing into the soil prior to planting, were used. The phosphorus treatments were replicated four times, and were, namely:

1. Ordinary superphosphate, nongranular, broadcast at a rate of 50 pounds of P_2O_5 per acre.

2. Ordinary superphosphate, nongranular, drilled at a rate of 50 pounds of P_2O_5 per acre.

3. Ordinary superphosphate, nongranular, broadcast at a rate of 100 pounds of P_2O_5 per acre.

4. Ordinary superphosphate, nongranular, drilled at a rate of 100 pounds of P_2O_5 per acre.

5. Ordinary superphosphate, 4- to 8-mesh granular, broadcast at a rate of 50 pounds of P_2O_5 per acre.

6. Ordinary superphosphate, 4- to 8-mesh granular, drilled at a rate of 50 pounds of P_2O_5 per acre.

7. Ordinary superphosphate, 4- to 8-mesh granular, broadcast at a rate of 100 pounds of P_2O_5 per acre.

8. Ordinary superphosphate, 4- to 8-mesh granular, drilled at a rate of 100 pounds of P_2O_5 per acre.

9. Ordinary superphosphate, 14- to 20-mesh granular, broadcast at a rate of 50 pounds of P_2O_5 per acre.

10. Ordinary superphosphate, 14- to 20-mesh granular, drilled at a rate of 50 pounds of P_2O_5 per acre.

11. Ordinary superphosphate, 14- to 20-mesh granular, broadcast at a rate of 100 pounds of P_2O_5 per acre.

12. Ordinary superphosphate, 14- to 20-mesh granular, drilled at a rate of 100 pounds of P_2O_5 per acre.

13 No phosphate applied.

The plot size was 9-1/3 x 25 feet. Nonradioactive materials were applied to plots adjacent to the radioactive materials of the same form.

The date of planting was June 5. The two center rows of the radioactive plots were sampled on June 30, July 14, July 28, and August 11. The numbers of plants taken at each sampling were twelve for the first and eight for each of the succeeding sampling dates. These samples were oven-dried at 60°C and weighed. A portion of each of these plot samples was then analyzed for radioactive and total phosphorus.

Twenty feet of the center two rows of the nonradioactive plots were harvested for yields on September 8.

Because of the insufficient quantity of 28- to 48-mesh granules, this particular granulation was not included in the randomized block design for this experiment. The amount available permitted one plot of each rate and application method to be included on one end of the experiment for comparison with the other granule sizes.

In 1953, several studies were conducted. Two of these studies were conducted with radioactive and nonradioactive granular and nongranular superphosphate on the Feneis farm. The soil type and some chemical characteristics of the soil are shown in Table 2. In one of the experiments the crop was the Michelite variety of navy bean and in the other sugar beets were used.

The past history of the field used for these experiments and several others with mixed materials was one of very light to no fertilizer applications over the ten years previous to the experiments. Wheat had received on this field in 1951 300 pounds per acre of a 3-18-9 fertilizer. A mammoth and sweet clover mixture was seeded with the wheat in the spring and was plowed down for corn in 1952; the corn was fertilized with 300 pounds per acre of a 3-18-9 mixture. Sweet clover was seeded in 1952. However, the stand was not very good and it was plowed down before the experimental plots were planted on June 9 and 10.

The date of planting for the beans was normal but the date of planting for the sugar beets was late. Even though the date of planting of the sugar beets was late, it was thought that response to phosphate would be relatively the same and this was borne out by results obtained at the Hart location.

The design of the two radioactive experiments, plot size, and treatments were the same as those listed for the 1952 field studies. Sixty pounds of nitrogen per acre in the form of ammonium sulfate and 100 pounds of K_2O per acre in the form of muriate of potash were broadcast and disced into the soil prior to planting.

Samplings of plants were taken from the bean experiment on July 7, July 22, August 7, and August 22, and from the sugar beet experiment on July 22, August 7, and August 22. The samples were used for radioactive and total phosphorus analyses as in 1952. Twenty feet of the center two rows of the nonradioactive plots were harvested, the beans on September 8 and the sugar beets on October 16 and 17.

At this same location, other experiments were conducted with Michelite beans planted June 10 and sugar beets planted June 9. Four mixed materials, 0-20-20, 3-12-12, 4-16-16, and 10-10-10, in granular and nongranular forms, were used. Each mixture was applied at two rates, 50 and 100 pounds of P_2O_5 per acre. All fertilizers were applied in bands to the side and below the seed, and these materials were nonradioactive. Forty pounds of nitrogen per acre in the form of ammonium sulfate was sidedressed on two rows of each plot on July 17. The plot size was 9-1/3 x 25 feet with twenty feet of each two rows of the plots harvested for yields. Bean harvest was on September 8 and sugar beet harvest was on October 16 and 17.

Two other locations were used in 1953. One of these locations was on the Pomaville farm where the fertilizer mixtures listed for the Feneis farm were used with Michelite beans as the crop. The soil type and some chemical characteristics of the soil are shown in Table 2 together with those for the Hart farm where a similar study was made using sugar beets as the crop.

Previous history at the Pomaville farm showed that for the past few years the field had been well managed with a good rotation and fertilizer history.

The beans were planted on June 11, 1953, and all fertilizers were banded to the side and below the seed to give 50 and 100 pounds of P_2O_5 per acre. On July 14 two rows of the beans were sidedressed with 40 pounds of nitrogen per acre in the form of ammonium sulfate. The beans were harvested on September 11 in the same manner as were those at the Feneis farm.

The previous history of the Hart farm indicated a great effort in the last few years to get a good rotation and fertilizer program started. Sugar beets were planted on May 22, 1953, according to the same design used at the Pomaville farm. Sidedressing was carried out in the same manner as on the Pomaville farm and was done on the same day. Plot size was 9-1/3 x 40 feet at both locations. At harvest 30 feet of each two rows of the plots, sidedressed and not sidedressed, were taken for yield and sugar analyses. Manganese sulfate was sidedressed at the rate of 100 pounds per acre on the entire plot at both the Hart and Pomaville farms. The manganese was applied because of the alkaline nature of the soil at these two locations. Harvest of the sugar beets on the Hart farm was on October 23, 1953.

In 1954, one series of experiments was conducted on the Lawton farm. The field had been in quack grass sod for five years prior to the planting of the experimental plots. Once each week for a period of six weeks prior to preparation for planting the field was cultivated in order to furnish control of the quack grass. Good control of the quack grass resulted.

The fertilizers used were 0-20-20, 3-12-12, 4-16-16, and 10-10-10 in both granular and nongranular forms. A randomized block design was used for plot layout. The crop was Michelite beans and all fertilizers were applied broadcast to give rates of 50 and 100 pounds of P_2O_5 per acre. Half of the treatments were plowed down and the other half were disced into the soil prior to planting on June 15. Samples of the plant material were taken on July 17 and August 6 for total phosphorus analysis. Harvest for yields of beans was on September 15.

Laboratory. Fertilizer phosphorus in the plant was determined using the pellet method described by Vomocil (23), and a Tracerlab Auto Scaler-Mark II to measure the radiation of the pellet.

Standard pellets were prepared by using a known portion of the P^{32} materials mixed thoroughly with nonradioactive plant material. The activities of the standard pellets were compared with those of pellets of the plant material collected from field and greenhouse studies.

Total phosphorus analysis was made on the same pellet used for radioactive phosphorus analysis. After ashing the pellet in a muffle furnace at 500°C for a period of twelve hours, total phosphorus was determined on the ash by the formation of the molybdivanadophosphate complex according to Kitson and Mellon (4) and Scheffer and Pajenkamp (15). A Coleman spectrophotometer Model XIV was used to read light transmission at 4600 Angstroms.

Soil characteristics were determined by the methods indicated in the footnotes of Table 1.

DATA AND DISCUSSION

Soil Phosphorus

The level of soil phosphorus in this series of studies varied from 4.8 pounds per acre in a Wisner loam to 125 pounds per acre in a virgin Brookston clay loam. These values as shown in Tables 1 and 2 were obtained according to Bray (2).

According to Bray's system for predicting response to applied phosphorus, the Oshtemo loamy sand and the virgin Brookston clay loam soils should give no response to added phosphorus. The other soils should give responses varying from a very high response to added phosphorus on the Wisner loam to a slight response on the Fox sandy loam. The yield results presented in Tables 4 and 5 indicate a general tendency to follow the Bray system of predicting response to added phosphorus for wheat.

Greenhouse

Dry weight yields of Henry spring wheat at each sampling date and at final harvest in 1952 and 1953 are reported in Tables 3, 4, and 5.

TABLE 3

EFFECT OF GRANULATION AND PLACEMENT OF SUPERPHOSPHATE UPON YIELDS[a] OF HENRY SPRING WHEAT, 1952
(grams of oven-dried plant material per pot)

Soil Type	Nongranulated Broadcast		
	1[b]	2	3
Carlisle muck	1.26[c]	1.75	2.67
Brookston clay loam (virgin)	1.77	1.94	2.09
Brookston loam	1.15	1.27	0.97
Conover loam	1.63	1.48	1.21
Miami loam	0.98	1.39	1.18
Wisner loam	1.51	1.24	0.80
Hillsdale sandy loam	1.04	1.16	0.85
Fox sandy loam	1.22	1.23	1.00
Emmet loamy sand	1.40	1.55	1.35
Oshtemo loamy sand	1.68	1.03	0.96
	4[d]	5[e]	5[e]
Carlisle muck	2.83[f]	33.7	3.15
Brookston clay loam (virgin)	2.64	33.1	25.8
Brookston loam	0.87	20.9	13.4
Conover loam	1.17	18.1	9.9
Miami loam	0.84	19.6	11.8
Wisner loam	0.77	21.9	14.6
Hillsdale sandy loam	0.85	3.1	2.5
Fox sandy loam	0.84	2.6	2.4
Emmet loamy sand	1.15	15.8	9.6
Oshtemo loamy sand	0.94	4.3	3.1

[a] Yields show no significant differences.

[b] Numbers 1, 2, and 3 refer to sample dates April 6, 15, and 22, respectively.

[c] All values are averages of three replicates.

TABLE 3 (Continued)

Granulated Broadcast			Nongranulated Banded			Granulated Banded		
1	2	3	1	2	3	1	2	3
0.97	1.43	2.50	1.10	2.00	2.45	1.28	1.93	2.69
1.95	2.00	2.16	2.15	1.97	1.85	1.81	2.05	1.93
1.22	1.14	0.94	1.29	1.23	0.92	1.21	1.21	1.09
1.42	1.33	1.28	1.50	1.49	1.19	1.36	1.40	1.18
1.16	1.46	1.36	1.15	1.50	1.48	1.08	1.55	1.24
1.42	0.99	0.86	1.27	1.01	0.79	1.48	1.13	0.87
1.13	1.05	1.08	1.36	1.17	1.07	1.42	1.05	1.23
1.25	1.25	1.07	1.27	1.35	1.07	1.45	1.36	0.83
1.66	1.38	1.01	1.47	1.63	1.23	1.52	1.60	1.25
1.58	1.04	1.00	1.46	1.07	1.02	1.34	1.12	0.96
4	5	6	4	5	6	4	5	6
2.34	30.9	28.0	3.17	33.0	30.5	3.24	35.6	29.4
2.85	28.1	23.7	2.38	31.7	25.8	1.86	31.4	23.2
0.86	30.4	12.9	0.98	17.6	10.5	0.93	21.1	13.4
1.26	16.1	9.8	1.37	15.3	9.0	1.12	18.1	10.3
1.11	20.9	13.1	1.30	16.1	9.9	1.30	18.3	13.5
0.84	19.7	13.7	0.84	19.7	13.2	0.72	21.3	10.8
0.84	8.2	6.0	1.29	7.5	5.6	1.11	4.2	3.4
0.67	3.9	2.7	0.93	3.5	2.8	1.00	2.5	2.2
0.99	15.9	10.5	1.12	15.4	9.4	1.10	15.5	9.9
1.21	6.9	5.2	0.97	3.4	2.6	1.13	4.2	3.2

[d] Number 4 refers to sample date April 29.

[e] Numbers 5 and 6 refer to wheat head and straw weights, respectively, harvested on June 27.

[f] All values are averages of three replicates.

TABLE 4

EFFECT OF SUPERPHOSPHATE AND MIXED FERTILIZERS UPON YIELDS OF HENRY SPRING WHEAT, 1953
(grams of oven-dried plant material per pot)

Treatment	Brookston Clay Loam (virgin)		
	1[a]	2	3
No fertilizer	2.07[b]	2.94	2.66
Nongranular superphosphate, broadcast	2.91	3.19	3.10
Nongranular superphosphate, banded	2.53	3.05	3.19
Granular superphosphate, broadcast	2.69	3.12	3.18
Granular superphosphate, banded	2.71	3.17	3.34
Slurry process 8-16-8, broadcast	2.74	3.16	3.20
Slurry process 8-16-8, banded	2.86	3.01	3.63
Ammoniated 8-16-8, broadcast	3.33	3.18	3.23
Ammoniated 8-16-8, banded	2.95	3.16	3.57
Nonammoniated 8-16-8, broadcast	2.65	3.33	3.38
Nonammoniated 8-16-8, banded	3.00	2.99	3.99
L.S.D. (0.05)	ns	ns	0.46
L.S.D. (0.01)	ns	ns	0.62

Treatment	4[c]	5
No fertilizer	2.13[d]	31.9
Nongranular superphosphate, broadcast	2.42	37.5
Nongranular superphosphate, banded	2.82	35.7
Granular superphosphate, broadcast	2.50	38.0
Granular superphosphate, banded	2.45	36.7
Slurry process 8-16-8, broadcast	2.53	36.0
Slurry process 8-16-8, banded	3.05	36.2
Ammoniated 8-16-8, broadcast	2.55	36.1
Ammoniated 8-16-8, banded	2.52	35.9
Nonammoniated 8-16-8, broadcast	2.53	36.1
Nonammoniated 8-16-8, banded	2.74	25.7
L.S.D. (0.05)	ns	ns
L.S.D. (0.01)	ns	ns

[a] Numbers 1, 2, 3 refer to sample dates February 21 and 28, and March 7, respectively.

[b] All values are averages of four replicates.

TABLE 4 (Continued)

Miami Loam			Fox Sandy Loam			Oshtemo Loamy Sand		
1	2	3	1	2	3	1	2	3
1.13	1.75	2.26	1.46	1.47	1.81	1.80	1.44	1.24
1.03	1.94	3.27	1.86	2.64	3.26	2.05	2.15	2.37
0.97	2.03	2.68	1.64	2.19	2.67	1.68	1.86	2.24
0.85	2.58	2.93	1.90	2.93	2.82	1.92	1.79	2.37
1.14	2.30	2.49	1.81	2.22	3.00	1.73	1.76	2.33
1.12	1.79	2.43	1.89	2.26	3.09	1.65	2.00	1.98
1.30	2.29	2.85	1.49	1.98	2.50	1.60	1.44	1.49
1.31	2.79	2.85	1.81	2.37	3.53	2.04	2.09	2.27
1.00	2.11	3.32	1.58	2.11	2.37	1.46	1.54	1.69
1.31	2.11	2.91	1.46	2.47	3.38	1.87	2.04	2.30
1.22	2.06	2.61	1.57	2.04	2.46	1.50	1.40	1.52
ns	ns	ns	ns	0.49	0.46	0.38	0.37	0.37
ns	ns	ns	ns	0.66	0.62	0.51	0.50	0.50

Miami Loam 4	Miami Loam 5	Fox Sandy Loam 4	Fox Sandy Loam 5	Oshtemo Loamy Sand 4	Oshtemo Loamy Sand 5
1.71	31.0	1.59	26.5	0.91	19.3
2.28	34.2	2.33	26.5	1.91	25.3
2.68	30.7	2.62	28.6	1.68	24.9
2.60	32.5	2.54	26.1	1.85	25.6
2.40	32.1	2.25	28.2	1.59	23.4
2.51	34.6	2.32	25.5	1.66	28.3
2.37	33.8	1.98	27.9	1.14	25.2
2.29	31.9	2.44	25.8	1.81	26.1
2.85	32.3	2.37	28.6	1.34	27.1
2.50	33.3	2.62	26.4	1.79	26.1
2.36	36.1	2.52	28.7	1.26	24.1
ns	ns	0.48	ns	0.40	3.2
ns	ns	0.64	ns	0.54	4.3

[c] Numbers 4 and 5 refer to sample date March 14 and harvest date April 21, respectively.

[d] All values are averages of four replicates.

TABLE 5

EFFECT OF GRANULATION AND PLACEMENT OF SUPERPHOSPHATE UPON YIELDS OF HENRY SPRING WHEAT, 1953
(grams of oven-dried plant material per pot)

Treatment	Brookston Loam		
	1[a]	2	3
No fertilizer	2.23[b]	2.26	2.10
Nongranular, broadcast	2.51	3.00	3.20
Nongranular, banded	2.32	3.02	2.84
Granular, broadcast	2.53	3.08	3.13
Granular, banded	2.68	2.97	2.81
L.S.D. (0.05)	ns	0.57	0.59
L.S.D. (0.01)	ns	0.79	0.82
	4[c]	5	
No fertilizer	1.48[d]	25.9	
Nongranular, broadcast	2.72	25.4	
Nongranular, banded	2.39	28.6	
Granular, broadcast	2.42	26.5	
Granular, banded	2.29	27.3	
L.S.D. (0.05)	0.48	ns	
L.S.D. (0.01)	0.68	ns	

[a] Numbers 1, 2, and 3 refer to sample dates February 28, March 7, and March 14, respectively.

[b] All values are averages of four replicates.

[c] Numbers 4 and 5 refer to sample date March 21 and harvest date April 21, respectively.

[d] All values are averages of four replicates.

TABLE 5 (Continued)

Conover Loam			Wisner Loam			Hillsdale Sandy Loam		
1	2	3	1	2	3	1	2	3
2.56	2.19	1.63	2.50	1.96	1.41	2.34	1.69	1.29
3.14	2.93	3.08	2.69	2.79	2.59	3.17	2.85	2.79
3.11	2.41	2.50	2.45	2.08	2.04	2.74	2.63	3.04
3.40	2.98	2.93	2.81	2.38	2.17	3.26	2.89	3.10
3.14	2.41	2.92	2.42	2.33	1.97	2.70	2.28	3.06
0.50	0.53	0.53	ns	0.44	0.31	0.50	0.44	0.35
0.70	0.75	0.75	ns	0.61	0.43	0.70	0.61	0.49

Conover Loam		Wisner Loam		Hillsdale Sandy Loam	
4	5	4	5	4	5
1.10	15.1	1.24	19.0	1.08	16.1
2.80	23.4	2.16	15.8	2.38	20.5
2.35	25.2	1.64	20.5	2.15	22.1
2.57	24.0	1.76	18.4	2.22	21.2
2.53	22.6	1.76	18.6	2.11	22.3
0.38	2.9	0.50	2.1	0.53	2.6
0.54	4.0	0.70	3.0	0.74	3.6

The dry weight yield data for 1952, in Table 3, showed no significant differences in dry weight at any sampling date from either granulation or placement on any of the soils studied. It should be noted here, however, that response to added phosphorus could not be ascertained because no pots without added phosphorus were included in this study. The major difference noted during the growth season was in the growth observed on the various soils. This observation was substantiated by the yield data for the soils. At harvest time, the average of all soils shows dry weight yields of heads to be slightly in favor of granulated superphosphate. These averages are 17.3 grams for the nongranulated broadcast and 18.1 grams for the granulated broadcast. For the banded placement, the averages were 16.3 for the nongranulated and 17.2 for the granulated superphosphate. Broadcast placement of superphosphate had resulted in slightly more dry weight than had banded placement of superphosphate regardless of form. This was not true for any other sample date.

In 1953, pots with no phosphorus addition were included on eight of the soils used in the 1952 study. By doing this, it was possible to obtain some data relative to the response of the particular soil to phosphorus fertilization for wheat production. The dry weight yield data presented in Tables 4 and 5 show that a response to added phosphorus was obtained on four of the eight soils. Of the soils responding to phosphorus treatment, only the Oshtemo loamy sand was out of line with Bray's system for predicting response to phosphorus. Three of the soils not responding were not correlated with this system. No explanation was found for the variance in response, other than the possibility of interference from previous treatment about which no knowledge was available.

Prior to harvest in 1953 there were indications of response to treatment on most of the soils. Three photographs (Plates 1 to 3) are presented to illustrated response (1) to granulated and nongranulated superphosphate, (2) to formulations of 8-16-8, and (3) to show differences in wheat growth due to soil type. These photographs were taken on April 3, 1953.

The general trend of dry weight yields in the 1953 greenhouse study shows an over-all response to added phosphorus for each sample date except the first and at harvest. Final yields of heads show a trend for greater response to mixed fertilizers over nonmixed fertilizers. This latter point is borne out by the over-all averages for treatments in Tables 4 and 5: (1) no fertilizer phosphorus, 23.1 grams; (2) nongranular superphosphate, broadcast, 26.1 grams; (3)

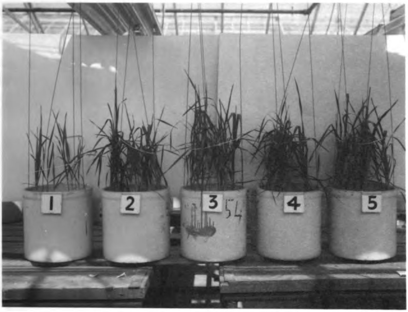

Plate I. Response of Henry spring wheat on Conover loam soil to 200 pounds per acre of P_2O_5 applied in granular and non-granular forms of superphosphate by banding near seed and mixing with soil.

1. No fertilizer phosphorus applied.
2. Nongranular superphosphate mixed with soil.
3. Nongranular superphosphate banded near seed.
4. Granular superphosphate mixed with soil.
5. Granular superphosphate banded near seed.

Plate II. Response of Henry spring wheat on Oshtemo loamy sand to 200 pounds per acre of P_2O_5 applied in nongranular form of 8-16-8 by banding near seed and mixing with soil.

1. No fertilizer applied.
2. Slurry process 8-16-8 mixed with soil.
3. Slurry process 8-16-8 banded near seed.
4. Ammoniated 8-16-8 mixed with soil.
5. Ammoniated 8-16-8 banded near seed.
6. Nonammoniated 8-16-8 mixed with soil.
7. Nonammoniated 8-16-8 banded near seed.

Plate III. Response of Henry spring wheat to soil type without fertilizer phosphorus treatment.

1. Brookston loam.
2. Wisner loam.
3. Hillsdale sandy loam.
4. Conover loam.
5. Fox sandy loam.
6. Brookston clay loam (virgin).
7. Miami loam.
8. Oshtemo loamy sand.

nongranular superphosphate, banded, 27.0 grams; (4) granular superphosphate, broadcast, 26.5 grams; (5) granular superphosphate, banded, 26.4 grams; (6) 8-16-8, slurry process, broadcast, 31.0 grams; (7) 8-16-8, slurry process, banded, 30.8 grams; (8) 8-16-8, ammoniated, broadcast, 30.0 grams; (9) 8-16-8, ammoniated, banded, 31.0 grams; (10) 8-16-8, nonammoniated, broadcast, 30.5 grams; (11) 8-16-8, nonammoniated, banded, 28.6 grams. However, these increases for the mixed over the nonmixed materials were not statistically significant. Granulation and placement of superphosphate had no apparent effect upon dry weight yields.

The phosphorus content of the dry wheat plants (Table 6) was found to be affected by fertilizer treatment only in the early stages of plant growth in 1952. All indications of significance between fertilizer treatments were not evident by the time of the fourth sampling. A trend in favor of granular superphosphate, when applied broadcast, was found in the April 15 and April 29 samplings. On April 15 the over-all averages were respectively 3.55 milligrams per gram and 3.86 milligrams per gram for the nongranular and granular broadcast treatments. On April 29 the values were 2.60 and 2.70 for the nongranular and granular broadcast treatments, respectively. In banded placement, the over-all averages showed essentially no

TABLE 6

EFFECT OF GRANULATION AND PLACEMENT OF SUPER-PHOSPHATE UPON PHOSPHORUS CONTENT OF HENRY SPRING WHEAT, 1952
(milligrams of phosphorus per gram of oven-dried plant material)

Soil Type	Nongranular Broadcast		Granular Broadcast	
	1[a]	2	1	2
Carlisle muck	6.64[b]	3.73	6.83	3.90
Brookston clay loam (virgin) . .	6.14	3.67	5.79	3.70
Brookston loam	6.10	2.72	5.65	3.20
Conover loam	4.83	4.92	4.61	5.22
Miami loam	5.48	3.50	4.95	4.83
Wisner loam	4.18	4.33	4.27	4.58
Hillsdale sandy loam	3.74	3.67	4.14	4.40
Fox sandy loam	4.10	2.72	4.14	2.27
Emmet loamy sand	4.88	2.70	5.08	2.77
Oshtemo loamy sand	4.29	3.58	4.24	3.75
	3[c]	4	3	4
Carlisle muck	3.48[d]	3.00	3.73	2.63
Brookston clay loam (virgin) . .	2.87	3.27	2.75	3.57
Brookston loam	2.10	2.73	2.33	2.67
Conover loam	2.47	2.33	2.40	2.47
Miami loam	1.87	2.47	2.45	2.23
Wisner loam	2.73	3.30	2.57	2.67
Hillsdale sandy loam	1.83	2.17	2.73	2.90
Fox sandy loam	1.73	1.90	2.13	2.00
Emmet loamy sand	2.40	2.43	2.60	3.03
Oshtemo loamy sand	2.33	2.43	2.63	2.83

[a] Numbers 1 and 2 refer to sample dates April 6 and 15, respectively.

[b] All values are averages of three replicates.

TABLE 6 (Continued)

Nongranular Banded		Granular Banded		L.S.D.			
				1		2	
1	2	1	2	0.05	0.01	0.05	0.01
9.53	3.25	8.88	4.62	ns	ns	ns	ns
6.94	4.35	7.71	4.28	0.63	0.96	ns	ns
7.25	3.75	6.83	3.65	0.76	1.15	ns	ns
5.88	5.53	6.49	4.88	1.09	1.65	ns	ns
5.63	5.68	6.11	5.98	ns	ns	1.18	1.79
4.54	4.92	4.70	4.58	ns	ns	ns	ns
5.03	5.47	4.83	4.07	ns	ns	0.69	1.05
4.74	3.17	5.43	2.58	ns	ns	ns	ns
6.03	3.50	5.43	3.72	ns	ns	ns	ns
5.20	4.20	4.39	4.28	ns	ns	0.35	0.54
3	4	3	4	3		4	
3.42	2.93	4.00	3.37	ns	ns	ns	ns
3.02	3.40	2.63	3.30	ns	ns	ns	ns
2.50	2.63	2.70	2.87	ns	ns	ns	ns
2.42	2.67	2.50	2.47	ns	ns	ns	ns
2.45	2.53	2.53	2.33	0.37	0.56	ns	ns
2.60	2.93	2.63	3.33	ns	ns	ns	ns
2.97	2.80	2.37	2.60	0.32	0.49	ns	ns
1.93	2.07	1.93	2.00	ns	ns	ns	ns
2.83	2.83	2.53	2.70	ns	ns	ns	ns
2.73	2.63	2.77	3.00	ns	ns	ns	ns

[c] Numbers 3 and 4 refer to sample dates April 22 and 29, respectively.

[d] All values are averages of three replicates.

differences as a result of granular and nongranular superphosphate so far as the phosphorus content of Henry spring wheat was concerned.

In 1953, however, significant differences in phosphorus content of the dry wheat plants due to various fertilizers persisted up to the fourth sampling, as shown in Tables 7 and 8.

Differences in phosphorus absorption for the two years may be partly explained by the increase in rate of phosphorus fertilization from 40 pounds of P_2O_5 per acre in 1952 to 200 pounds per acre in 1953. No consistent differences were noted in phosphorus absorption from granular and nongranular superphosphate in 1953. However, formulations of 8-16-8 tended to give higher values for phosphorus content when banded. In the fourth sampling this was particularly the case. Over-all averages for the fourth sampling showed that slurry processed 8-16-8 broadcast gave 3.52 milligrams of phosphorus and banded gave 3.95 milligrams of phosphorus per gram of dry plant material. For the ammoniated and nonammoniated 8-16-8, the values were, respectively, for the broadcast and banded placements, 3.52, 4.16, 3.89, and 4 52 milligrams of phosphorus per gram of dry plant material.

The uptake of fertilizer phosphorus by wheat plants, both in milligrams of fertilizer phosphorus per gram of dry plant material

TABLE 7

EFFECT OF SUPERPHOSPHATE AND MIXED FERTILIZERS UPON PHOSPHORUS CONTENT OF HENRY SPRING WHEAT, 1953
(milligrams of phosphorus per gram of oven-dried plant material)

Treatment	Brookston Clay Loam (virgin)	
	1[a]	2
No fertilizer	4.70[b]	3.71
Nongranular superphosphate, broadcast	7.50	5.06
Nongranular superphosphate, banded	6.20	4.85
Granular superphosphate, broadcast	6.91	5.42
Granular superphosphate, banded	5.98	4.70
Slurry process 8-16-8, broadcast	7.70	4.69
Slurry process 8-16-8, banded	6.97	5.30
Ammoniated 8-16-8, broadcast	7.62	5.06
Ammoniated 8-16-8, banded	6.98	4.61
Nonammoniated 8-16-8, broadcast	7.94	5.86
Nonammoniated 8-16-8, banded	7.85	4.96
L.S.D. (0.05)	0.33	0.89
L.S.D. (0.01)	0.45	1.20
	3[c]	4
No fertilizer	2.99[d]	3.10
Nongranular superphosphate, broadcast	4.27	4.04
Nongranular superphosphate, banded	3.82	4.02
Granular superphosphate, broadcast	4.27	4.25
Granular superphosphate, banded	3.87	3.92
Slurry process 8-16-8, broadcast	4.19	3.94
Slurry process 8-16-8, banded	5.23	4.55
Ammoniated 8-16-8, broadcast	4.08	3.97
Ammoniated 8-16-8, banded	4.24	3.57
Nonammoniated 8-16-8, broadcast	4.31	4.49
Nonammoniated 8-16-8, banded	5.21	4.45
L.S.D. (0.05)	0.52	0.59
L.S.D. (0.01)	0.70	0.80

[a] Numbers 1 and 2 refer to sample dates February 21 and 28, respectively.

[b] All values are averages of four replicates.

TABLE 7 (Continued)

Miami Loam		Fox Sandy Loam		Oshtemo Loamy Sand	
1	2	1	2	1	2
2.38	3.38	2.49	2.22	2.66	2.19
3.53	5.35	3.56	4.54	5.34	3.89
3.03	5.48	4.12	4.99	6.28	5.60
2.50	6.18	3.57	4.98	5.42	4.56
3.06	6.14	4.90	5.25	6.20	5.02
2.89	5.02	4.45	4.17	4.27	2.97
3.25	5.45	3.51	3.86	3.60	2.60
2.63	4.65	3.82	4.38	4.87	3.45
3.34	5.28	3.86	5.53	3.73	3.04
3.49	5.12	3.29	4.95	5.15	3.45
4.82	5.81	4.21	5.40	3.98	2.66
1.30	2.10	ns	0.47	0.53	0.53
1.75	ns	ns	0.63	0.71	0.71
3	4	3	4	3	4
2.81	2.23	2.45	3.44	1.84	2.14
4.39	3.70	4.02	3.86	3.77	3.60
4.74	4.10	4.68	4.39	4.59	3.89
4.92	4.13	3.84	3.79	4.58	3.68
4.49	4.21	4.84	4.42	5.60	3.87
4.33	3.64	3.41	3.74	3.06	2.76
4.97	4.19	3.30	4.06	2.47	3.01
4.27	3.20	3.55	3.83	3.28	3.13
5.19	4.09	4.90	5.03	3.88	3.94
4.31	3.93	4.18	4.04	3.22	3.12
5.04	5.49	4.80	5.05	3.03	3.10
0.49	0.66	0.51	0.88	0.74	0.55
0.66	0.89	0.69	1.19	0.99	0.74

[c] Numbers 3 and 4 refer to sample dates March 7 and 14, respectively.

[d] All values are averages of four replicates.

TABLE 8

EFFECT OF GRANULATION AND PLACEMENT OF SUPERPHOSPHATE UPON PHOSPHORUS CONTENT OF HENRY SPRING WHEAT, 1953
(milligrams of phosphorus per gram of oven-dried plant material)

Treatment	Brookston Loam	
	1[a]	2
No fertilizer	3.24[b]	2.43
Nongranular, broadcast	7.22	4.90
Nongranular, banded	5.61	5.04
Granular, broadcast	6.34	4.78
Granular, banded	5.61	4.44
L.S.D. (0.05)	1.94	0.44
L.S.D. (0.01)	2.72	0.61
	3[c]	4
No fertilizer	1.73[d]	1.90
Nongranular, broadcast	3.39	2.81
Nongranular, banded	4.22	3.20
Granular, broadcast	3.84	3.29
Granular, banded	4.23	3.17
L.S.D. (0.05)	0.38	0.71
L.S.D. (0.01)	0.53	0.99

[a] Numbers 1 and 2 refer to sample dates February 28 and March 7, respectively.

[b] All values are averages of four replicates.

[c] Numbers 3 and 4 refer to sample dates March 14 and 21, respectively.

[d] All values are averages of four replicates.

TABLE 8 (Continued)

Conover Loam		Wisner Loam		Hillsdale Sandy Loam	
1	2	1	2	1	2
2.51	2.07	3.13	2.23	2.12	1.89
5.46	4.52	5.92	3.65	4.30	4.13
5.33	4.35	4.25	3.07	5.00	4.60
5.74	4.41	4.57	3.45	4.48	4.24
5.15	3.81	4.17	3.24	4.90	4.74
0.77	0.84	0.34	1.18	0.27	0.60
1.08	1.18	0.48	ns	0.37	0.84
3	4	3	4	3	4
1.25	1.31	2.36	2.40	1.59	1.99
4.38	3.99	2.74	2.38	3.07	2.55
4.74	3.29	2.39	2.38	4.01	2.63
4.36	3.63	2.53	2.70	3.56	2.51
4.83	3.08	2.39	2.55	4.71	3.04
0.46	0.72	ns	ns	1.08	0.48
0.65	1.01	ns	ns	1.51	0.67

and in percent of the total phosphorus, was greatly affected by placement. The banded placement was definitely superior to the broadcast placement of fertilizer as is shown by comparisons of values in Tables 9 through 14. The data presented in Tables 9, 10, and 11 represent the content of fertilizer phosphorus in milligrams per gram of dry plant material. It should be noted that banded placement of fertilizer resulted in more than two times as much fertilizer phosphorus in dry plant tissue as did the broadcast placement. The trend for the percent of the total phosphorus derived from the fertilizer is similar as shown in Tables 12, 13, and 14. Some average values to illustrate this point may be taken from the first sampling data reported in Table 12: (1) nongranular broadcast, 2.5 percent; (2) nongranular banded, 6.7 percent; (3) granular broadcast, 2.7 percent; and (4) granular banded, 5.6 percent. However, neither the absorption of fertilizer phosphorus nor the percent of phosphorus from fertilizer were influenced by granulation. The formulations of 8-16-8 resulted in slightly higher uptake of phosphorus by wheat plants than did the nonmixed materials in the 1953 experiment especially on the virgin Brookston clay loam. The nonammoniated form was generally superior to the other forms of 8-16-8. This could be explained for the most part by the fact that ammoniation

TABLE 9

EFFECT OF GRANULATION AND PLACEMENT OF SUPER-PHOSPHATE UPON FERTILIZER PHOSPHORUS UPTAKE BY HENRY SPRING WHEAT, 1952
(milligrams of phosphorus per gram of oven-dried plant material)

Soil Type	Nongranular Broadcast		Granular Broadcast	
	1[a]	2	1	2
Carlisle muck	0.18[b]	1.56	0.16	1.87
Brookston clay loam (virgin) . .	0.12	1.18	0.09	1.28
Brookston loam	0.15	1.27	0.18	1.21
Conover loam	0.19	1.62	0.14	1.80
Miami loam	0.11	1.06	0.19	1.93
Wisner loam	0.10	3.23	0.09	2.38
Hillsdale sandy loam	0.07	2.02	0.15	2.61
Fox sandy loam	0.12	1.59	0.13	1.59
Emmet loamy sand	0.16	1.21	0.16	1.98
Oshtemo loamy sand	0.06	1.22	0.07	1.68
	3[c]	4	3	4
Carlisle muck	1.43[d]	0.98	1.61	0.97
Brookston clay loam (virgin) . .	1.21	0.80	1.17	0.78
Brookston loam	0.95	1.39	0.88	1.54
Conover loam	0.76	0.99	0.95	1.37
Miami loam	0.89	1.29	1.05	1.60
Wisner loam	1.30	1.61	0.84	1.24
Hillsdale sandy loam	0.67	0.65	1.49	1.43
Fox sandy loam	1.24	0.70	1.73	0.89
Emmet loamy sand	1.54	0.96	1.90	1.14
Oshtemo loamy sand	0.79	0.70	1.25	1.11

[a] Numbers 1 and 2 refer to sample dates April 6 and 15, respectively.

[b] All values are averages of three replicates.

TABLE 9 (Continued)

Nongranular Banded		Granular Banded		L.S.D.			
				1		2	
1	2	1	2	0.05	0.01	0.05	0.01
0.59	2.89	0.60	3.28	0.33	0.50	0.85	1.28
0.33	2.66	0.34	2.72	0.10	0.14	0.35	0.52
0.43	1.88	0.37	1.88	0.10	0.14	0.35	0.52
0.53	3.34	0.45	2.74	0.11	0.15	0.74	1.12
0.48	3.67	0.41	3.35	0.10	0.14	0.80	1.22
0.17	3.21	0.17	1.83	ns	ns	0.71	ns
0.42	3.66	0.12	2.66	0.12	0.19	ns	ns
0.38	2.33	0.40	1.94	0.08	0.12	0.37	ns
0.48	2.16	0.41	2.27	0.05	0.08	ns	ns
0.25	3.01	0.20	2.95	0.08	0.12	0.79	1.20
3	4	3	4	3		4	
1.73	1.69	2.15	1.61	ns	ns	0.29	0.44
2.10	1.13	2.09	1.11	0.30	0.46	ns	ns
1.38	1.85	1.22	1.83	0.10	0.14	ns	ns
1.18	1.42	1.34	1.60	0.26	0.39	ns	ns
1.44	1.71	1.24	1.60	0.27	0.42	ns	ns
1.12	1.15	0.91	1.10	0.15	0.23	ns	ns
1.85	1.58	1.42	1.35	0.30	0.45	0.38	0.58
1.60	1.13	1.56	1.08	0.20	0.30	0.43	ns
2.01	1.12	1.97	1.08	ns	ns	ns	ns
1.40	1.01	1.50	0.88	ns	ns	ns	ns

[c] Numbers 3 and 4 refer to sample dates April 22 and 29, respectively.

[d] All values are averages of three replicates.

TABLE 10

EFFECT OF SUPERPHOSPHATE AND MIXED FERTILIZERS UPON FERTILIZER PHOSPHORUS UPTAKE BY HENRY SPRING WHEAT, 1953
(milligrams of phosphorus per gram of oven-dried plant material)

Treatment	Brookston Clay Loam (virgin)	
	1[a]	2
Nongranular superphosphate, broadcast . . .	0.40[b]	2.10
Nongranular superphosphate, banded	0.23	3.06
Granular superphosphate, broadcast	0.37	2.67
Granular superphosphate, banded	0.28	3.21
Slurry process 8-16-8, broadcast	0.56	2.48
Slurry process 8-16-8, banded	0.67	3.63
Ammoniated 8-16-8, broadcast	0.59	2.24
Ammoniate 8-16-8, banded	0.49	3.06
Nonammoniated 8-16-8, broadcast	0.65	3.83
Nonammoniated 8-16-8, banded	0.68	3.74
L.S.D. (0.05)	0.10	0.41
L.S.D. (0.01)	0.14	0.55
	3[c]	4
Nongranular superphosphate, broadcast . . .	2.40[d]	1.79
Nongranular superhposphate, banded	2.60	1.92
Granular superphosphate, broadcast	2.27	2.13
Granular superphosphate, banded	2.68	2.01
Slurry process 8-16-8, broadcast	2.38	1.97
Slurry process 8-16-8, banded	4.15	2.20
Ammoniated 8-16-8, broadcast	2.29	1.95
Ammoniated 8-16-8, banded	2.51	1.87
Nonammoniated 8-16-8, broadcast	3.48	2.44
Nonammoniated 8-16-8, banded	4.18	2.23
L.S.D. (0.05)	1.03	ns
L.S.D. (0.01)	1.39	ns

[a] Numbers 1 and 2 refer to sample dates February 21 and 28, respectively.

[b] All values are averages of four replicates.

TABLE 10 (Continued)

Miami Loam		Fox Sandy Loam		Oshtemo Loamy Sand	
1	2	1	2	1	2
0.17	2.73	0.12	1.98	0.11	1.47
0.20	3.41	0.21	3.71	0.40	3.04
0.15	3.06	0.10	2.05	0.18	1.74
0.22	3.94	0.27	4.11	0.32	2.90
0.15	2.52	0.14	1.74	0.21	1.32
0.20	3.40	0.10	2.40	0.13	1.46
0.15	2.30	0.15	2.56	0.16	1.87
0.19	2.82	0.14	3.12	0.26	1.79
0.33	3.36	0.19	2.59	0.22	1.49
0.42	4.09	0.26	3.87	0.18	1.66
0.14	1.03	0.06	ns	0.10	0.61
ns	1.39	0.08	ns	0.14	0.83
3	4	3	4	3	4
2.74	1.80	2.16	2.12	1.60	1.31
3.10	2.40	3.24	2.95	2.53	1.87
3.10	1.95	1.83	1.74	2.49	1.75
2.89	1.92	3.49	2.79	2.97	1.89
2.54	1.80	1.39	1.69	1.72	1.44
3.15	2.01	2.17	2.51	1.83	1.84
2.32	1.60	2.11	2.11	2.00	1.65
2.89	1.97	3.11	2.73	2.76	2.49
2.72	2.02	2.16	1.92	1.78	1.51
3.28	2.65	3.23	2.94	1.77	1.71
ns	0.80	1.64	ns	0.82	ns
ns	ns	ns	ns	1.11	ns

[c] Numbers 3 and 4 refer to sample dates March 7 and 14, respectively.

[d] All values are averages of four replicates.

TABLE 11

EFFECT OF GRANULATION AND PLACEMENT OF SUPER-PHOSPHATE UPON FERTILIZER PHOSPHORUS UPTAKE BY HENRY SPRING WHEAT, 1953
(milligrams of phosphorus per gram of oven-dried plant material)

Treatment	Brookston Loam	
	1[a]	2
Nongranular, broadcast	0.38[b]	2.46
Nongranular, banded	0.31	2.84
Granular, broadcast	0.30	2.59
Granular, banded	0.35	2.33
L.S.D. (0.05)	ns	0.14
L.S.D. (0.01)	ns	0.19
	3[c]	4
Nongranular, broadcast	1.73[d]	1.64
Nongranular, banded	2.46	1.73
Granular, broadcast	1.90	2.02
Granular, banded	2.39	1.75
L.S.D. (0.05)	1.10	ns
L.S.D. (0.01)	1.14	ns

[a] Numbers 1 and 2 refer to sample dates February 28 and March 7, respectively.

[b] All values are averages of four replicates.

[c] Numbers 3 and 4 refer to sample dates March 14 and 21, respectively.

[d] All values are averages of four replicates.

TABLE 11 (Continued)

Conover Loam		Wisner Loam		Hillsdale Sandy Loam	
1	2	1	2	1	2
0.33	2.16	0.21	2.20	0.14	2.00
0.59	2.45	0.17	2.34	0.28	2.45
0.33	2.17	0.19	2.19	0.18	2.10
0.49	2.07	0.18	1.92	0.19	2.35
0.04	0.35	ns	0.41	ns	0.21
0.06	ns	ns	ns	ns	0.28
3	4	3	4	3	4
2.55	2.13	1.42	1.15	1.54	1.24
2.84	2.01	1.19	1.16	2.19	1.25
2.42	1.80	1.35	1.28	1.80	1.29
2.72	2.11	1.16	1.13	2.34	1.50
0.21	ns	ns	ns	0.08	ns
0.28	ns	ns	ns	0.11	ns

TABLE 12

TOTAL PHOSPHORUS IN HENRY SPRING WHEAT DERIVED FROM FERTILIZER, 1952
(percent of total phosphorus from fertilizer)

Soil Type	Nongranular Broadcast	
	1[a]	2
Carlisle muck	2.7[b]	41.9
Brookston clay loam (virgin)	2.0	32.2
Brookston loam	2.5	46.7
Conover loam	3.9	32.9
Wisner loam	2.4	74.6
Miami loam	2.0	30.3
Hillsdale sandy loam	1.9	55.0
Fox sandy loam	2.9	58.5
Emmet loamy sand	3.3	44.8
Oshtemo loamy sand	1.4	34.1
	3[c]	4
Carlisle muck	41.4[d]	32.7
Brookston clay loam (virgin)	42.2	24.5
Brookston loam	45.2	50.9
Conover loam	30.8	42.5
Wisner loam	47.6	48.8
Miami loam	47.6	52.2
Hillsdale sandy loam	36.6	30.0
Fox sandy loam	71.7	36.8
Emmet loamy sand	64.2	39.5
Oshtemo loamy sand	33.9	28.8

[a] Numbers 1 and 2 refer to sample dates April 6 and 15, respectively.

[b] Percentages are based upon averages of three replicates.

TABLE 12 (Continued)

Granular Broadcast		Nongranular Banded		Granular Banded	
1	2	1	2	1	2
2.3	48.0	6.2	88.9	6.7	71.0
1.5	34.6	4.8	61.1	4.4	63.5
3.2	37.8	5.9	50.2	5.4	51.5
3.0	34.5	9.0	60.4	6.9	56.2
2.1	52.0	3.7	65.2	3.6	39.9
3.8	40.0	8.5	64.6	6.7	56.0
3.6	59.4	8.4	66.9	2.5	65.4
3.1	70.0	8.0	73.5	7.4	75.2
3.2	71.5	8.0	61.7	7.5	61.0
1.7	44.8	4.8	71.7	4.6	69.0
3	4	3	4	3	4
43.2	36.9	50.3	57.7	53.7	47.8
42.5	21.8	69.6	33.3	79.5	33.6
37.8	57.6	55.2	70.3	45.2	63.8
39.6	55.5	48.8	53.1	53.6	64.8
32.7	46.5	43.1	39.3	34.6	33.0
42.9	71.8	58.8	67.5	49.0	68.7
54.6	49.3	62.3	56.5	60.0	51.9
81.2	44.5	82.9	54.6	80.8	54.0
73.1	37.6	71.0	39.6	77.9	40.0
47.5	39.2	51.3	38.4	54.2	29.3

[c] Numbers 3 and 4 refer to sample dates April 22 and 29, respectively.

[d] Percentages are based upon averages of three replicates.

TABLE 13

TOTAL PHOSPHORUS IN HENRY SPRING WHEAT DERIVED FROM SUPERPHOSPHATE AND MIXED FERTILIZERS, 1953
(percent of total phosphorus from fertilizer)

Treatment	Brookston Clay Loam (virgin)	
	1[a]	2
Nongranular superphosphate, broadcast . . .	5.3[b]	41.5
Nongranular superphosphate, banded	3.7	63.0
Granular superphosphate, broadcast	5.3	49.2
Granular superphosphate, banded	4.7	68.1
Slurry process 8-16-8, broadcast	7.3	53.0
Slurry process 8-16-8, banded	9.6	68.5
Ammoniated 8-16-8, broadcast	7.7	44.3
Ammoniated 8-16-8, banded	7.0	66.4
Nonammoniated 8-16-8, broadcast	8.2	65.4
Nonammoniated 8-16-8, banded	8.7	75.4
	3[c]	4
Nongranular superphosphate, broadcast . . .	56.4[d]	44.2
Nongranular superphosphate, banded	68.0	47.6
Granular superphosphate, broadcast	53.2	50.1
Granular superphosphate, banded	69.1	51.3
Slurry process 8-16-8, broadcast	57.0	50.1
Slurry process 8-16-8, banded	79.5	48.3
Ammoniated 8-16-8, broadcast	56.2	49.1
Ammoniated 8-16-8, banded	59.3	52.3
Nonammoniated 8-16-8, broadcast	80.7	54.5
Nonammoniated 8-16-8, banded	80.1	50.0

[a] Numbers 1 and 2 refer to sample dates February 21 and 28, respectively.

[b] Percentages are based upon averages of four replicates.

TABLE 13 (Continued)

Miami Loam		Fox Sandy Loam		Oshtemo Loamy Sand	
1	2	1	2	1	2
4.8	51.0	3.3	43.6	2.1	37.8
6.5	62.2	5.1	74.3	6.3	54.3
6.2	49.5	2.8	41.2	3.4	38.1
7.3	64.3	5.6	78.3	5.2	57.8
5.2	50.1	3.2	41.7	4.7	44.3
6.1	62.4	2.9	62.4	3.6	56.2
5.7	49.5	4.0	58.5	3.4	54.3
5.6	53.4	3.6	56.5	7.1	58.6
9.4	65.7	5.7	52.3	4.3	43.2
8.8	70.3	6.1	71.6	4.6	62.4
3	4	3	4	3	4
62.3	48.5	53.6	55.0	42.5	36.3
65.4	58.6	69.3	67.2	55.1	48.1
63.0	47.2	47.6	46.0	54.3	47.6
64.5	45.5	72.1	63.2	53.1	48.9
58.6	49.5	40.7	45.4	56.4	52.1
63.5	48.0	65.8	61.7	74.3	61.1
54.3	50.0	59.3	55.1	61.0	52.7
55.6	48.3	63.5	54.3	71.2	63.2
63.2	51.5	51.7	47.5	56.3	48.4
65.1	48.4	67.4	58.4	58.3	55.4

[c] Numbers 3 and 4 refer to sample dates March 7 and 14, respectively.

[d] Percentages are based upon averages of four replicates.

TABLE 14

TOTAL PHOSPHORUS IN HENRY SPRING WHEAT DERIVED FROM SUPERPHOSPHATE, 1953
(percent of total phosphorus from fertilizer)

Treatment	Brookston Loam	
	1[a]	2
Nongranular, broadcast	5.2[b]	50.1
Nongranular, banded	5.5	56.4
Granular, broadcast	4.7	54.2
Granular, banded	6.3	52.4
	3[c]	4
Nongranular, broadcast	51.0[d]	58.3
Nongranular, banded	58.3	54.2
Granular, broadcast	49.4	61.5
Granular, banded	56.5	55.1

[a] Numbers 1 and 2 refer to sample dates February 28 and March 7, respectively.

[b] Percentages are based upon averages of four replicates.

[c] Numbers 3 and 4 refer to sample dates March 14 and 21, respectively.

[d] Percentages are based upon averages of four replicates.

TABLE 14 (Continued)

Conover Loam		Wisner Loam		Hillsdale Sandy Loam	
1	2	1	2	1	2
6.0	47.8	3.5	60.3	3.2	48.5
11.0	56.3	4.1	64.2	5.6	53.2
5.7	49.1	4.1	63.4	4.1	49.6
9.6	54.2	4.3	59.1	3.9	49.7
3	4	3	4	3	4
58.2	53.4	51.7	48.3	50.3	48.6
60.1	61.2	49.8	48.7	54.5	47.5
55.6	49.7	53.1	47.4	50.7	51.4
56.4	68.3	48.6	44.3	49.8	49.3

of fertilizers reduces the water-solubilities of the phosphorus in the mix, thus making it less available for plant absorption. As a result the nonammoniated form should contain more water-soluble phosphorus and be more available to the plants. The fact that as the season progressed to the fourth sampling the difference was narrowed between the nonammoniated and the other forms would tend to indicate this was true. By that time the phosphorus which had been available in the nonammoniated form became less available because of fixation in the soil.

The low values reported for the first sampling in Table 12 are not out of line with those reported for first sampling in Table 13 when the ages of the plants are considered. The plant sample in Table 12 was from plants which had been planted only ten days, and that from Table 13 was from plants which had been planted twenty-two days.

Field

Rainfall data (Table 15) from April to September are reported for the East Lansing Experimental Farm weather station for the years 1952 and 1954, for the St. Johns 4N weather station for 1953, and for the Sebewaing 3E weather station for 1953. These stations were those closest to the experimental plots in the field, or those whose records most nearly approximated known conditions at the particular location.

The data from the test with Rainy River beans on Conover loam are reported in Tables 16 to 20. The data reported for 28- to 48-mesh granules were not included in the statistical analyses of the experiment as there was only enough of the material to plant one plot of each placement and rate treatment.

The dry weights of plant material (Table 16) showed significant differences for both fertilizer placement and rate of fertilizer phosphorus application in the early samplings. This significance tended to disappear in the last preharvest sampling and had completely disappeared by final harvest. Granulation of superphosphate appeared to give slightly higher dry weights and yields than the corresponding nongranular treatment but these were not significant. The lack of significant differences in 1952 was attributed to the reversal of yield trends in one replicate. No explanation for this reversal can be offered so the data are reported on the basis of all four replicates. It is emphasized, however, that when three replicates were used statistical differences were found for placement and rate of fertilizer applied but not for granular versus nongranular. It should also be noted that throughout the sampling period and at

TABLE 15

RAINFALL DATA FOR FIELD LOCATIONS, 1952, 1953, AND 1954 (inches of rainfall)

Month	Weather Station[1]				
	East Lansing Experimental Farm			St. Johns 4N	Sebewaing 3E
	1952	1953	1954	1953	1953
April	3.18	2.71	1.79	2.62	2.58
May	4.71	2.39	1.52	1.58	5.19
June	1.30	4.09	4.89	2.75	1.73
July	2.28	2.39	2.26	1.68	3.23
August	3.51	3.22	1.73	2.06	6.33
September	1.84	0.90	2.32	1.61	2.99

[1] Data taken from Climatological Data, U. S. Department of Commerce.

TABLE 16

EFFECT OF SUPERPHOSPHATE UPON DRY WEIGHTS AND YIELD OF RAINY RIVER BEANS ON CONOVER LOAM SOIL, 1952

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs./A.)	Sampling Date: June 30 (gm./plot)	July 14 (gm./plot)	July 28 (gm./plot)	Aug. 11 (gm./plot)	Harvested Sept. 8 (bu./A.)
Nongranular	Broadcast	50	7.9[a]	23.9	62.2	102.2	30.9
Nongranular	Banded	50	10.9	31.4	109.5	170.1	37.9
Nongranular	Broadcast	100	9.5	27.9	68.2	116.1	31.2
Nongranular	Banded	100	11.1	32.0	83.1	153.8	34.9
4-8 mesh	Broadcast	50	7.9	24.1	79.7	115.7	31.0
4-8 mesh	Banded	50	13.9	37.4	95.1	174.2	38.0
4-8 mesh	Broadcast	100	8.2	23.9	66.8	99.9	35.6
4-8 mesh	Banded	100	12.2	32.6	74.6	131.4	34.5
14-20 mesh	Broadcast	50	7.7	27.0	69.2	108.8	27.0
14-20 mesh	Banded	50	13.2	31.8	77.4	143.6	33.1
14-20 mesh	Broadcast	100	8.6	26.2	75.5	134.7	34.3
14-20 mesh	Banded	100	10.4	34.5	75.3	152.6	33.6
No phosphorus			6.2	17.8	59.9	130.1	29.3
L.S.D. (0.05)			2.5	7.9	23.0	47.0	ns
L.S.D. (0.01)			3.3	10.6	30.8	ns	ns
28-48 mesh	Broadcast	50	6.8	22.0	84.7	70.0	46.1
28-48 mesh	Banded	50	11.3	33.1	132.5	145.0	47.0
28-48 mesh	Broadcast	100	9.2	21.8	88.0	120.7	38.3
28-48 mesh	Banded	100	8.9	31.3	76.2	139.1	37.0

[a] All values are averages of four replicates.

final harvest granular materials tended to give higher dry weights and yields than did the corresponding nongranular treatments; however, these increases were not significant.

The phosphorus content of Rainy River beans, reported in Table 17, showed trends very similar to those reported for yields. The placement and rate of phosphorus gave significant increases in the phosphorus content of the bean plants on June 30, July 14, and July 28, but these differences were not significant at the August 11 sampling. Granular materials resulted in slightly higher phosphorus content of bean plants in some cases than did nongranular materials, but the increases were eratic and of no significance. Variation in granular size of superphosphate did not give consistent difference for either yields or phosphorus contents of bean plants.

In Table 18, the effect of superphosphate upon the fertilizer phosphorus content of Rainy River beans is reported. Here, there are significant differences for placement and rate of fertilizer at all preharvest samplings, but again, even though granulation tended to increase the amount of fertilizer phosphorus in the plants, no significant differences for particle size were noted. A similar trend was noted for percent of plant phosphorus derived from the applied phosphorus (Table 19). The low values for July 28 may be

TABLE 17

EFFECT OF SUPERPHOSPHATE UPON PHOSPHORUS CONTENT OF RAINY RIVER BEANS ON CONOVER LOAM SOIL, 1952
(milligrams of phosphorus per gram of oven-dried plant material)

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs./A.)	Sampling Date			
			June 30	July 14	July 28	Aug. 11
Nongranular	Broadcast	50	5.38[a]	5.90	4.85	2.52
Nongranular	Banded	50	9.90	6.46	5.18	2.56
Nongranular	Broadcast	100	6.54	6.13	5.39	2.65
Nongranular	Banded	100	9.70	7.05	6.16	2.57
4-8 mesh	Broadcast	50	6.15	5.76	4.45	2.35
4-8 mesh	Banded	50	9.02	5.86	5.14	2.53
4-8 mesh	Broadcast	100	5.79	5.14	4.79	2.22
4-8 mesh	Banded	100	10.08	6.40	5.53	2.83
14-20 mesh	Broadcast	50	5.71	6.01	5.10	2.90
14-20 mesh	Banded	50	8.47	6.24	5.24	2.14
14-20 mesh	Broadcast	100	6.35	5.46	4.90	2.58
14-20 mesh	Banded	100	10.46	7.34	6.09	2.54
No phosphorus			2.46	2.29	1.96	1.71
L.S.D. (0.05)			1.43	0.94	0.82	ns
L.S.D. (0.01)			1.91	1.26	1.10	ns
28-48 mesh	Broadcast	50	4.45	5.90	4.95	2.50
28-48 mesh	Banded	50	10.00	7.60	5.55	2.61
28-48 mesh	Broadcast	100	6.10	6.10	4.85	2.60
28-48 mesh	Banded	100	10.15	6.65	5.90	2.78

[a] All values are averages of four replicates.

TABLE 18

EFFECT OF SUPERPHOSPHATE UPON FERTILIZER PHOSPHORUS CONTENT OF RAINY RIVER BEANS ON CONOVER LOAM SOIL, 1952
(milligrams of phosphorus per gram of oven-dried plant material)

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs./A.)	Sampling Date June 30	Sampling Date July 14	Sampling Date July 28	Sampling Date Aug. 11
Nongranular	Broadcast	50	0.91[a]	0.88	0.51	0.54
Nongranular	Banded	50	5.87	2.92	1.89	1.45
Nongranular	Broadcast	100	1.57	0.81	0.67	0.66
Nongranular	Banded	100	5.06	3.86	2.67	1.72
4-8 mesh	Broadcast	50	1.37	1.16	0.58	0.68
4-8 mesh	Banded	50	6.31	4.10	2.43	1.76
4-8 mesh	Broadcast	100	1.86	1.80	0.85	0.92
4-8 mesh	Banded	100	7.95	3.74	2.73	2.03
14-20 mesh	Broadcast	50	0.90	0.75	0.35	0.36
14-20 mesh	Banded	50	5.10	3.03	1.72	1.37
14-20 mesh	Broadcast	100	2.12	1.30	0.91	0.78
14-20 mesh	Banded	100	5.88	3.24	2.18	1.82
L.S.D. (0.05)			1.33	0.69	0.54	0.47
L.S.D. (0.01)			1.79	0.93	0.72	0.63
28-48 mesh	Broadcast	50	0.57	0.35	0.36	0.27
28-48 mesh	Banded	50	5.91	3.27	2.10	1.66
28-48 mesh	Broadcast	100	1.86	1.32	0.80	0.95
28-48 mesh	Banded	100	6.28	3.47	2.06	1.50

[a] All values are averages of four replicates.

TABLE 19

TOTAL PHOSPHORUS IN RAINY RIVER BEANS DERIVED FROM FERTILIZER, 1952
(percent of total phosphorus from fertilizer)

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs./A.)	Sampling Date June 30	July 14	July 28	Aug. 11
Nongranular	Broadcast	50	16.9[a]	14.9	10.5	21.4
Nongranular	Banded	50	59.3	45.2	36.5	56.6
Nongranular	Broadcast	100	24.0	13.2	12.4	24.9
Nongranular	Banded	100	52.2	54.7	43.3	66.9
4-8 mesh	Broadcast	50	22.3	20.1	13.0	28.9
4-8 mesh	Banded	50	70.0	70.0	47.3	69.5
4-8 mesh	Broadcast	100	32.2	35.1	17.8	41.4
4-8 mesh	Banded	100	78.9	58.5	49.4	71.7
14-20 mesh	Broadcast	50	15.7	12.5	6.9	12.4
14-20 mesh	Banded	50	60.2	48.6	32.9	64.0
14-20 mesh	Broadcast	100	33.4	23.8	18.6	30.2
14-20 mesh	Banded	100	56.2	44.2	35.8	71.6
28-48 mesh	Broadcast	50	12.8	5.9	7.3	10.8
28-48 mesh	Banded	50	59.1	43.0	37.9	63.6
28-48 mesh	Broadcast	100	30.5	21.6	16.5	36.5
28-48 mesh	Banded	100	61.8	52.2	34.9	54.0

[a] All percentages based on averages of four replicates.

explained by the fact that a local dry spell had caused the surface of the soil to become quite dry down to about three inches. This may have inhibited the uptake of surface-applied phosphates.

In Table 20, the percent utilization of applied phosphorus by Rainy River beans showed a trend similar to those previously discussed for dry weights, yield, phosphorus content, and percent phosphorus in the plant derived from the fertilizer. Further, it is worthy of note that the beans showed a tendency to increase their fertilizer phosphorus uptake as the season progressed to the July 28 sampling and to decrease at the August 11 sampling. Also, the increase in rate of applied phosphorus tended to decrease the percent of fertilizer phosphorus utilized by the plant. This latter tendency is reasonable when one considers the fact that increase in rate did not double the rate of uptake of fertilizer phosphorus and therefore the percent would necessarily be decreased.

In 1953, Michelite beans and sugar beets were studied on a Conover loam soil at the Feneis Farm. The data from the bean study are reported in Tables 21 to 25.

The dry weights and yield of Michelite beans as given in Table 21 showed a trend very similar to that reported for beans in Table 16. Again, placement and rate of fertilizer phosphorus

TABLE 20

FERTILIZER PHOSPHORUS UTILIZED BY RAINY RIVER BEANS FROM JUNE 5 TO SEPTEMBER 8, 1952
(percent phosphorus utilized of that applied)

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs./A.)	Sampling Date				Total
			June 30	July 14	July 28	Aug. 11	
Nongranular	Broadcast	50	1.1[a]	5.1	11.0	9.4	26.6
Nongranular	Banded	50	2.7	7.4	20.7	15.9	46.7
Nongranular	Broadcast	100	0.8	3.1	6.7	5.6	16.2
Nongranular	Banded	100	1.4	4.1	9.4	7.2	22.1
4-8 mesh	Broadcast	50	1.2	4.9	12.9	9.9	28.9
4-8 mesh	Banded	50	3.2	8.0	17.8	16.1	45.1
4-8 mesh	Broadcast	100	0.6	2.2	5.8	4.0	12.6
4-8 mesh	Banded	100	1.6	3.8	7.5	6.8	19.7
14-20 mesh	Broadcast	50	1.1	5.9	12.9	11.5	31.4
14-20 mesh	Banded	50	2.8	7.2	14.8	11.2	36.0
14-20 mesh	Broadcast	100	0.7	2.6	6.8	6.3	16.4
14-20 mesh	Banded	100	1.4	4.6	8.4	7.1	21.5
28-40 mesh	Broadcast	50	0.7	4.7	15.3	6.4	27.1
28-40 mesh	Banded	50	2.9	9.2	23.9	13.2	49.2
28-40 mesh	Broadcast	100	0.7	2.4	7.8	5.7	16.6
28-40 mesh	Banded	100	1.1	3.8	8.2	7.1	20.2

[a] All percentages based on averages of four replicates.

TABLE 21

EFFECT OF SUPERPHOSPHATE UPON DRY WEIGHTS AND YIELD OF MICHELITE BEANS ON CONOVER LOAM SOIL, 1953

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs. /A.)	Sampling Date: July 7 (gm. per plot)	July 22 (gm. per plot)	Aug. 7 (gm. per plot)	Aug. 22 (gm. per plot)	Harvested Sept. 8 (bu. /A.)
Nongranular	Broadcast	50	27.0[a]	53.9	136.7	133.5	15.8
Nongranular	Banded	50	32.7	61.3	130.1	165.9	12.9
Nongranular	Broadcast	100	28.6	50.8	105.2	126.8	9.8
Nongranular	Banded	100	34.7	71.5	153.1	153.9	17.0
4-8 mesh	Broadcast	50	30.3	52.6	116.1	159.1	11.9
4-8 mesh	Banded	50	33.0	69.8	145.1	153.7	21.0
4-8 mesh	Broadcast	100	28.9	55.0	120.3	139.8	11.5
4-8 mesh	Banded	100	33.0	65.8	135.0	165.6	14.6
14-20 mesh	Broadcast	50	28.1	54.3	108.8	123.0	12.9
14-20 mesh	Banded	50	32.0	53.1	116.1	149.3	16.1
14-20 mesh	Broadcast	100	28.6	54.5	120.0	116.2	15.3
14-20 mesh	Banded	100	34.0	67.4	141.5	142.5	14.7
No phosphorus			23.2	52.3	104.5	123.6	10.1
L.S.D. (0.05)			3.9	11.7	28.6	ns	ns
L.S.D. (0.01)			5.2	15.7	38.4	ns	ns

[a] All values are averages of four replicates.

were consistent in increasing dry weights of plant material in the early samplings but the significance disappeared by the last pre-harvest sample and was not evident at harvest time. Granulation effects were inconsistent, regardless of mesh size of particles.

It can be noted that the phosphorus content of beans in 1953, shown in Table 22, was much lower than that reported in 1952 in Table 17. This may be explained in part by the difference in variety of beans used and in part by the difference in rainfall for the two years. The growing season in 1953 was drier than in 1952 and since available moisture would affect phosphorus movement in soils as noted by Lawton and Vomocil (9), a lower uptake of phosphorus might be expected. Only the August 7 sampling of beans showed any significant differences in phosphorus content of the bean plants due to fertilizer treatment. The trend was similar to that reported for 1952 with banded placement and increases in rate of phosphorus applied tending to give increases in dry weight.

As shown in Table 23, the fertilizer phosphorus content of beans was increased by banded placement. Increasing the rate of phosphorus increased the fertilizer phosphorus content of the beans for the 4- to 8-mesh and the 14- to 20-mesh granules but not for the nongranular material. This fact might possibly be explained by

TABLE 22

EFFECT OF SUPERPHOSPHATE UPON PHOSPHORUS CONTENT OF MICHELITE BEANS ON CONOVER LOAM SOIL, 1953
(milligrams of phosphorus per gram of oven-dried plant material)

Form of Phosphate	Method of Appli- cation	Rate of P_2O_5 (lbs. /A.)	Sampling Date			
			July 7	July 22	Aug. 7	Aug. 22
Nongranular	Broadcast	50	2.90[a]	2.65	2.15	1.75
Nongranular	Banded	50	2.85	2.77	2.33	2.03
Nongranular	Broadcast	100	2.79	2.46	2.08	1.81
Nongranular	Banded	100	2.91	2.78	2.32	1.91
4-8 mesh	Broadcast	50	3.03	2.52	2.13	2.05
4-8 mesh	Banded	50	3.19	2.38	2.31	2.14
4-8 mesh	Broadcast	100	3.12	2.23	2.23	1.92
4-8 mesh	Banded	100	3.17	2.72	2.33	1.94
14-20 mesh	Broadcast	50	3.20	2.46	2.06	1.84
14-20 mesh	Banded	50	3.07	2.70	2.30	2.18
14-20 mesh	Broadcast	100	2.99	2.31	2.13	1.98
14-20 mesh	Banded	100	2.95	2.76	2.60	2.09
No phosphorus			2.71	2.24	2.08	1.65
L.S.D. (0.05)			ns	ns	0.20	ns
L.S.D. (0.01)			ns	ns	0.27	ns

[a] All values are averages of four replicates.

TABLE 23

EFFECT OF SUPERPHOSPHATE UPON FERTILIZER PHOSPHORUS CONTENT OF MICHELITE BEANS ON CONOVER LOAM SOIL, 1953
(milligrams of phosphorus per gram of oven-dried plant material)

Form of Phosphate	Method of Appli-cation	Rate of P_2O_5 (lbs./A.)	Sampling Date			
			July 7	July 22	Aug. 7	Aug. 22
Nongranular	Broadcast	50	0.32[a]	0.40	0.36	0.39
Nongranular	Banded	50	1.30	1.28	0.96	0.72
Nongranular	Broadcast	100	0.39	0.25	0.15	0.25
Nongranular	Banded	100	1.22	1.23	0.87	0.81
4-8 mesh	Broadcast	50	0.61	0.44	0.33	0.38
4-8 mesh	Banded	50	1.70	1.21	1.12	1.02
4-8 mesh	Broadcast	100	0.97	0.77	0.64	0.62
4-8 mesh	Banded	100	1.82	1.34	1.25	0.96
14-20 mesh	Broadcast	50	0.48	0.32	0.29	0.27
14-20 mesh	Banded	50	1.51	1.15	0.89	1.08
14-20 mesh	Broadcast	100	0.82	0.49	0.40	0.49
14-20 mesh	Banded	100	1.57	1.23	1.05	0.98
L.S.D. (0.05)			0.41	0.61	0.20	0.81
L.S.D. (0.01)			0.55	0.82	0.27	ns

[a] All values are averages of four replicates.

the fact that in this instance granulation of superphosphate maintained the applied phosphorus in a state more available to beans than did the nongranulated form. Also, in the July 7 sampling, 4- to 8-mesh and 14- to 20-mesh fertilizer granules gave slightly significant increases in phosphorus content at the 100-pound rate of broadcast P_2O_5 when compared with nongranular material. In general, however, no important differences in phosphorus absorption were evident when granular and nongranular materials were compared.

The percentages of total phosphorus derived from the fertilizer, listed in Table 24, were similar to those reported in Table 19 for 1952. At all sampling dates, large differences in plant phosphorus from fertilizer were noted between broadcast and banded fertilizer applications. It should further be noted that at the 100-pound rate of P_2O_5 applied broadcast, 4- to 8-mesh and 14- to 20-mesh granules of superphosphate resulted in percentages of phosphorus from fertilizer two to three times as large as those from the nongranular material. This would indicate that a much greater amount of the applied fertilizer was available to the plant when applied in the granular form.

The percentage of fertilizer phosphorus utilized by Michelite beans in 1953 is reported in Table 25. The values shown are much

TABLE 24

TOTAL PHOSPHORUS IN MICHELITE BEANS DERIVED FROM FERTILIZER, 1953
(percent of total phosphorus from fertilizer)

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs./A.)	Sampling Date July 7	July 22	Aug. 7	Aug. 22
Nongranular	Broadcast	50	11.2[a]	15.0	16.9	22.1
Nongranular	Banded	50	45.6	46.4	41.2	35.6
Nongranular	Broadcast	100	14.3	10.2	7.4	14.3
Nongranular	Banded	100	42.0	44.3	37.3	42.6
4-8 mesh	Broadcast	50	20.0	17.3	14.4	18.4
4-8 mesh	Banded	50	55.0	50.6	48.3	47.5
4-8 mesh	Broadcast	100	31.1	34.4	28.7	32.5
4-8 mesh	Banded	100	57.5	49.1	53.5	49.6
14-20 mesh	Broadcast	50	15.1	13.2	14.2	14.9
14-20 mesh	Banded	50	49.3	42.6	38.7	49.3
14-20 mesh	Broadcast	100	27.5	21.4	18.6	24.6
14-20 mesh	Banded	100	53.2	44.7	40.3	46.8

[a] Percentages are based upon averages of four replicates.

TABLE 25

FERTILIZER PHOSPHORUS UTILIZED BY MICHELITE BEANS FROM JUNE 10 TO AUGUST 22, 1953
(percent phosphorus utilized of that applied)

Form of Phosphate	Method of Appli-cation	Rate of P_2O_5 (lbs. /A.)	Sampling Date				Total
			July 7	July 22	Aug. 7	Aug. 22	
Nongranular	Broadcast	50	0.6[a]	1.8	4.1	4.3	10.8
Nongranular	Banded	50	2.9	6.6	10.0	10.0	29.5
Nongranular	Broadcast	100	0.4	0.5	0.7	1.3	2.9
Nongranular	Banded	100	1.4	3.7	5.6	5.2	15.9
4-8 mesh	Broadcast	50	1.3	1.9	3.2	5.1	11.5
4-8 mesh	Banded	50	3.8	7.1	13.6	13.1	37.6
4-8 mesh	Broadcast	100	1.0	1.8	3.2	3.6	9.6
4-8 mesh	Banded	100	2.1	3.7	7.1	6.6	19.5
14-20 mesh	Broadcast	50	0.9	1.5	2.9	2.8	8.1
14-20 mesh	Banded	50	3.3	5.1	8.7	13.5	30.6
14-20 mesh	Broadcast	100	0.8	1.1	2.0	2.4	6.3
14-20 mesh	Banded	100	1.8	3.5	6.2	5.8	17.3

[a] Percentages are based upon averages of four replicates.

smaller than the values reported for 1952. This may be attributed mostly to moisture conditions during this experiment. It should be noted, however, that the drier condition accentuated the differences between methods of placement and actually decreased uptake at the higher rates of application. Here again, the effect of granules is to increase the percentage of fertilizer phosphorus utilized by plants at the 100-pound rate applied broadcast when compared to the same rate of nongranular material applied broadcast. This would further emphasize that more phosphorus was apparently available to the plant from the granules at this rate and method of application.

At this same location, as previously mentioned, a study using sugar beets was conducted using granular and nongranular superphosphate. Various data are reported in Tables 26 to 30.

A very definite response to phosphorus application in terms of dry weight and yield of sugar beets was obtained as indicated in Table 26. The trends are similar to those reported for beans in 1952 and 1953. The lateness of planting together with dryness of the season prevented larger yields. No significant differences were found between banded and broadcast placement, granular and nongranular forms, or between 50- and 100-pound rates of P_2O_5 application.

TABLE 26

EFFECT OF SUPERPHOSPHATE UPON DRY WEIGHTS AND YIELD OF SUGAR BEETS ON CONOVER LOAM SOIL, 1953

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs. /A.)	Sampling Date: July 22 (gm. per plot)	Sampling Date: Aug. 7 (gm. per plot)	Sampling Date: Aug. 22 (gm. per plot)	Harvested Sept. 16-17 (tons /A.)
Nongranular	Broadcast	50	28.9[a]	52.3	88.4	7.2
Nongranular	Banded	50	29.4	58.5	100.4	7.6
Nongranular	Broadcast	100	32.9	61.8	80.7	7.0
Nongranular	Banded	100	34.3	63.7	112.7	9.6
4-8 mesh	Broadcast	50	26.8	55.8	78.3	6.1
4-8 mesh	Banded	50	35.4	70.9	116.0	8.6
4-8 mesh	Broadcast	100	29.9	58.8	106.4	6.9
4-8 mesh	Banded	100	33.0	56.5	98.2	8.2
14-20 mesh	Broadcast	50	30.0	48.5	99.6	7.0
14-20 mesh	Banded	50	34.2	58.2	92.3	7.6
14-20 mesh	Broadcast	100	31.5	73.2	121.0	7.8
14-20 mesh	Banded	100	41.6	48.2	103.8	7.7
No phosphorus			15.3	25.0	44.5	3.3
L.S.D. (0.05)			9.6	19.1	32.7	2.4
L.S.D. (0.01)			12.9	25.6	43.9	3.2

[a] All values are averages of four replicates.

The very high L.S.D.'s shown in Table 26 are due in part to stand of sugar beets obtained because of dryness at planting date and in part to the eratic growth which occurred subsequent to germination. These two factors made sampling in a truly randomized manner very difficult, especially the latter factor at the two August samplings.

Both total phosphorus content, and fertilizer phosphorus content of sugar beets as listed in Table 27 and Table 28 showed significant increases from banded placement of fertilizer phosphorus. Granular materials tended to produce sugar-beet tops which were higher in total and fertilizer phosphorus than were plants receiving nongranular superphosphate, but the increases were not significant. Increased rate of P_2O_5 application gave significant increases of the total phosphorus and the fertilizer phosphorus contents of sugar-beet tops. In addition, banding the superphosphate resulted in significantly higher phosphorus absorption than when broadcast placement was used.

The percent of total phosphorus derived from fertilizer, Table 29, showed effect of placement and rate. As the rate of applied P_2O_5 increased the percent of fertilizer phosphorus in the sugar-beet tops also increased. As was true for experiments with field beans, the banded placement of superphosphate resulted in higher plant contents

TABLE 27

EFFECT OF SUPERPHOSPHATE UPON PHOSPHORUS CONTENT OF SUGAR-BEET TOPS ON CONOVER LOAM SOIL, 1953
(milligrams of phosphorus per gram of oven-dried plant material)

Form of Phosphate	Method of Appli- cation	Rate of P_2O_5 (lbs. /A.)	Sampling Date		
			July 22	Aug. 7	Aug. 22
Nongranular	Broadcast	50	1.35[a]	2.03	1.73
Nongranular	Banded	50	2.32	2.77	2.09
Nongranular	Broadcast	100	1.75	2.17	1.70
Nongranular	Banded	100	3.00	2.88	2.64
4-8 mesh	Broadcast	50	1.65	1.84	1.45
4-8 mesh	Banded	50	2.50	2.94	2.06
4-8 mesh	Broadcast	100	1.69	2.29	1.65
4-8 mesh	Banded	100	3.13	3.21	2.62
14-20 mesh	Broadcast	50	1.45	1.92	1.54
14-20 mesh	Banded	50	2.71	3.02	2.25
14-20 mesh	Broadcast	100	1.95	2.26	1.90
14-20 mesh	Banded	100	3.27	3.27	2.79
No phosphorus			1.43	1.40	1.28
L.S.D. (0.05)			0.48	0.42	0.52
L.S.D. (0.01)			0.64	0.57	0.69

[a] All values are averages of four replicates.

TABLE 28

EFFECT OF SUPERPHOSPHATE UPON FERTILIZER PHOSPHORUS CONTENT OF SUGAR-BEET TOPS ON CONOVER LOAM SOIL, 1953
(milligrams of phosphorus per gram of oven-dried plant material)

Form of Phosphate	Method of Appli-cation	Rate of P_2O_5 (lbs./A.)	Sampling Date		
			July 22	Aug. 7	Aug. 22
Nongranular	Broadcast	50	0.38[a]	0.83	0.90
Nongranular	Banded	50	1.10	1.34	0.90
Nongranular	Broadcast	100	0.90	1.16	1.01
Nongranular	Banded	100	1.69	1.23	0.93
4-8 mesh	Broadcast	50	0.39	0.67	0.66
4-8 mesh	Banded	50	1.11	1.43	0.78
4-8 mesh	Broadcast	100	0.77	1.21	0.68
4-8 mesh	Banded	100	1.95	1.90	1.69
14-20 mesh	Broadcast	50	0.44	0.80	0.58
14-20 mesh	Banded	50	1.31	1.38	0.86
14-20 mesh	Broadcast	100	0.96	1.04	1.04
14-20 mesh	Banded	100	1.94	1.88	1.35
L.S.D. (0.05)			0.41	0.30	0.39
L.S.D. (0.01)			0.55	0.41	0.52

[a] All values are averages of four replicates.

TABLE 29

TOTAL PHOSPHORUS IN SUGAR-BEET TOPS DERIVED FROM FERTILIZER, 1953
(percent of total phosphorus from fertilizer)

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs./A.)	Sampling Date		
			July 22	Aug. 7	Aug. 22
Nongranular	Broadcast	50	28.5[a]	42.1	52.3
Nongranular	Banded	50	47.6	48.3	43.2
Nongranular	Broadcast	100	51.4	53.4	59.6
Nongranular	Banded	100	56.2	42.7	35.3
4-8 mesh	Broadcast	50	23.8	36.2	45.7
4-8 mesh	Banded	50	44.3	48.8	38.4
4-8 mesh	Broadcast	100	45.4	52.7	41.9
4-8 mesh	Banded	100	62.1	59.3	64.5
14-20 mesh	Broadcast	50	30.7	41.5	37.6
14-20 mesh	Banded	50	48.5	45.6	38.2
14-20 mesh	Broadcast	100	49.4	46.1	54.7
14-20 mesh	Banded	100	59.3	57.6	48.4

[a] Percentages are based upon averages of four replicates.

of fertilizer phosphorus than did broadcast placement at the early sampling dates. Granule size did not appear to have any consistent effect upon percent of plant phosphorus derived from the applied fertilizer.

In Table 30, utilization percentages are given for sugar beets sampled on June 9, August 7, and August 22, 1953. The percentages of phosphorus utilized from the superphosphate were greater for superphosphate placed in bands than when broadcast. Increasing the rate of application of P_2O_5 again decreased the utilization of applied phosphorus. Granule size had no apparent effect upon percent of applied phosphorus utilized by sugar beets.

The experiments on the effects of granulation of superphosphate were further expanded in 1953 to include mixed fertilizers in field studies. At the Feneis Farm on Conover loam soil two tests were conducted on granular and nongranular mixed materials using sugar beets and Michelite beans as indicator crops. The results of these tests are reported in Table 31.

No significant differences in yields of either sugar beets or beans were obtained at this location between fertilizers of different grades or granule size. The fact that all fertilizers were applied in bands may account in part for lack of possible differences,

TABLE 30

FERTILIZER PHOSPHORUS UTILIZED BY SUGAR BEETS FROM JUNE 9 TO AUGUST 22, 1953
(percent phosphorus utilized of that applied)

Form of Phosphate	Method of Application	Rate of P_2O_5 (lbs./A.)	Sampling Date			Total
			July 22	Aug. 7	Aug. 22	
Nongranular	Broadcast	50	0.7[a]	3.6	6.6	10.9
Nongranular	Banded	50	2.2	6.6	7.6	16.4
Nongranular	Broadcast	100	1.0	3.0	3.4	7.4
Nongranular	Banded	100	2.0	3.3	4.4	9.7
4-8 mesh	Broadcast	50	0.7	3.1	4.3	8.1
4-8 mesh	Banded	50	2.7	8.5	7.5	18.7
4-8 mesh	Broadcast	100	0.8	1.5	3.0	5.3
4-8 mesh	Banded	100	2.2	4.5	6.9	13.6
14-20 mesh	Broadcast	50	0.9	3.2	4.8	8.9
14-20 mesh	Banded	50	3.1	6.7	6.6	16.4
14-20 mesh	Broadcast	100	1.0	3.2	5.3	9.5
14-20 mesh	Banded	100	2.8	3.8	5.9	12.5

[a] Percentates are based upon averages of four replicates.

TABLE 31

THE EFFECT OF NONGRANULAR AND GRANULAR FERTILIZERS, FOUR GRADES, ON THE YIELDS OF SUGAR BEETS AND FIELD BEANS ON CONOVER LOAM SOIL, 1953

Form of Fertilizer	Grade of Fertil-izer	Rate of P_2O_5 (lbs./A.)	Beets (tons/A.)		Beans (bu./A.)	
			40 lbs. N/A. Side-dressed	Not Side-dressed	40 lbs. N/A. Side-dressed	Not Side-dressed
Check			5.2[a]	5.1	10.8	13.0
Nongranular	0-20-20	50	8.3	8.3	18.6	18.7
Nongranular	0-20-20	100	7.3	7.9	19.3	16.9
Granular	0-20-20	50	5.3	6.5	14.9	16.8
Granular	0-20-20	100	7.4	7.3	17.5	16.7
Nongranular	3-12-12	50	6.8	7.0	17.0	17.5
Nongranular	3-12-12	100	8.0	8.3	12.2	13.2
Granular	3-12-12	50	7.1	7.6	18.8	19.1
Granular	3-12-2	100	6.1	6.4	12.3	11.5
Nongranular	4-16-16	50	6.7	6.8	15.8	16.4
Nongranular	4-16-16	100	7.1	7.5	10.7	13.5
Granular	4-16-16	50	6.2	6.7	12.5	11.3
Granular	4-16-16	100	7.1	8.1	15.0	17.0
Nongranular	10-10-10	50	5.7	6.3	16.3	15.4
Nongranular	10-10-10	100	4.8	6.8	16.0	12.6
Granular	10-10-10	50	6.3	5.3	12.4	14.5
Granular	10-10-10	100	5.8	5.9	8.5	10.8
L.S.D.			ns	ns	ns	ns

[a] All values are averages of four plots.

together with a low supply of soil moisture during much of the growing season. Nitrogen sidedressed on two rows of each plot on July 17 did not result in increases in either the yields of beans or sugar beets.

In Table 32, data from a sugar-beet experiment on the Hart Farm and from a bean experiment on the Pomaville Farm are presented.

The beans showed no yield response from any of the fertilizers applied at the Pomaville Farm. This situation may be partially explained by the fact that on August 5 flooding rains caused the complete loss of one replicate and beat many of the beans off the remaining vines. The water remained on the field for about 36 hours. It was noted that germination on this experiment and on the similar bean experiment at the Feneis Farm was retarded by the higher rates of application of all the fertilizers containing nitrogen.

At the Hart Farm, yields of sugar beets were found to be increased by all fertilizer treatments. Increasing the rate of application raised the beet yield but these increases were not significant. No apparent effect upon yield of beets resulted from granulation of any of the fertilizers studied. Sidedressed nitrogen had no effect upon yield of sugar beets at this location.

TABLE 32

THE EFFECT OF FOUR GRADES OF NONGRANULAR AND GRANULAR FERTILIZERS ON THE YIELD OF FIELD BEANS, AND ON THE YIELD AND SUGAR CONTENT OF SUGAR BEETS, 1953

Form of Fertilizer	Grade of Fertilizer	Rate of P_2O_5 (lbs./A.)	Pomaville Farm (Kawkawlin Loam) Yield of Beans (bu./A.)		Hart Farm (Wisner Loam)			
					Yield of Beets (tons/A.)		Pct. Sugar Content of Beets	
			40 lbs. N/A. Side-dr.	Not Side-dr.	40 lbs. N/A. Side-dr.	Not Side-dr.	40 lbs. N/A. Side-dr.	Not Side-dr.
Check			24.5[a]	21.4	9.8[b]	10.0	19.5	19.3
Nongranular	0-20-20	50	19.0	18.4	12.2	11.6	20.1	20.1
Nongranular	0-20-20	100	30.0	22.8	13.0	12.6	20.0	19.8
Granular	0-20-20	50	25.8	22.1	11.4	11.3	20.4	20.4
Granular	0-20-20	100	24.9	18.9	12.0	12.5	19.8	19.9
Nongranular	3-12-12	50	29.2	27.0	11.8	12.1	19.8	19.7
Nongranular	3-12-12	100	23.2	21.2	14.0	13.6	19.7	20.1
Granular	3-12-12	50	23.6	25.8	11.8	12.1	19.8	20.2
Granular	3-12-12	100	25.7	23.4	14.1	14.6	19.8	20.2
Nongranular	4-16-16	50	22.0	24.2	11.9	11.0	19.6	20.0
Nongranular	4-16-16	100	22.6	20.1	12.3	13.4	20.3	20.2
Granular	4-16-16	50	26.1	20.3	13.2	12.1	20.1	20.2
Granular	4-16-16	100	26.2	23.9	13.6	13.5	19.5	19.9
Nongranular	10-10-10	50	27.0	24.6	12.9	12.2	20.4	19.9
Nongranular	10-10-10	100	22.7	20.5	14.4	14.2	19.6	19.9
Granular	10-10-10	50	22.1	18.9	13.1	12.2	20.3	20.1
Granular	10-10-10	100	11.3	18.9	14.2	13.5	20.7	20.2
L.S.D. (0.05)			ns	ns	2.0	2.0	ns	ns
L.S.D. (0.01)			ns	ns	2.7	2.7	ns	ns

[a] Values are averages of three replicates at this location. One replicate lost because of heavy rains on August 5.

[b] Values at this location are averages of four replicates.

The percent sugar in sugar beets was not affected by either granulation, rate of application, or nitrogen sidedressing. In addition, no differences in sugar content were found when comparing the beets from unfertilized and fertilized plots.

Since the mixed fertilizers had differing nitrogen contents and there was a possibility that this might obscure granulation effects, the data were broken down into individual grades of fertilizers and analyzed statistically. The results of these statistical analyses showed no greater differences than those reported in Tables 31 and 32.

In 1954, another field experiment with four grades of fertilizers was conducted with Michelite beans on a Hillsdale sandy loam soil at the Lawton Farm. As shown in Table 33, no significant yield differences were obtained at harvest between granular and non-granular materials, between grades of fertilizer, nor between plow down and broadcast methods of application of fertilizer. Neither was there a yield response to any fertilizer application. The lack of response is mostly believed to be attributed to the difficulty experienced at harvest in obtaining a complete threshing of beans due to early fall rains. A definite dry weight response to fertilizer application was noted at the July 17 sampling.

TABLE 33

EFFECT OF MIXED FERTILIZERS, FOUR GRADES, UPON DRY WEIGHTS AND YIELD OF FIELD BEANS, 1954

Form of Fertilizer	Grade of Fertilizer	Rate of P_2O_5 (lbs./A.)	Method of Application	Sampling Date: July 17 (gm. per plot)	Sampling Date: Aug. 6 (gm. per plot)	Harvested Sept. 15 (bu./A.)
	None			18.4[a]	148.8	17.8
Nongranular	3-12-12	50	Plow down	23.7	141.8	17.6
Granular	3-12-12	50	Plow down	23.1	137.2	22.7
Nongranular	3-12-12	50	Broadcast	23.0	133.0	19.1
Granular	3-12-12	50	Broadcast	25.3	153.6	18.2
Nongranular	3-12-12	100	Plow down	24.8	151.2	21.1
Granular	3-12-12	100	Plow down	27.3	158.3	16.3
Nongranular	3-12-12	100	Broadcast	31.3	143.5	15.3
Granular	3-12-12	100	Broadcast	29.6	152.0	17.5
Nongranular	4-16-16	50	Plow down	23.4	156.2	14.4
Granular	4-16-16	50	Plow down	24.5	156.6	17.0
Nongranular	4-16-16	50	Broadcast	26.9	127.5	18.1
Granular	4-16-16	50	Broadcast	24.4	144.0	14.9
Nongranular	4-16-16	100	Plow down	25.8	178.2	15.2
Granular	4-16-16	100	Plow down	25.6	152.5	17.3
Nongranular	4-16-16	100	Broadcast	29.7	149.1	14.2
Granular	4-16-16	100	Broadcast	34.0	163.4	18.5
Nongranular	0-20-20	50	Plow down	23.1	146.0	18.7
Granular	0-20-20	50	Plow down	21.9	144.2	17.0
Nongranular	0-20-20	50	Broadcast	25.9	150.1	16.2
Granular	0-20-20	50	Broadcast	28.0	144.7	14.5
Nongranular	0-20-20	100	Plow down	25.4	142.8	13.9
Granular	0-20-20	100	Plow down	25.5	152.2	17.2
Nongranular	0-20-20	100	Broadcast	28.6	162.5	16.9
Granular	0-20-20	100	Broadcast	30.8	148.0	16.9

TABLE 33 (Continued)

Form of Fertilizer	Grade of Fertil-izer	Rate of P_2O_5 (lbs. /A.)	Method of Appli-cation	Sampling Date July 17 (gm. per plot)	Sampling Date Aug. 6 (gm. per plot)	Har-vested Sept. 15 (bu. /A.)
Nongranular	10-10-10	50	Plow down	20.4	143.8	17.8
Granular	10-10-10	50	Plow down	20.0	140.9	15.8
Nongranular	10-10-10	50	Broadcast	26.3	132.2	15.4
Granular	10-10-10	50	Broadcast	25.9	139.1	17.3
Nongranular	10-10-10	100	Plow down	26.7	157.6	14.3
Granular	10-10-10	100	Plow down	24.3	138.5	14.8
Nongranular	10-10-10	100	Broadcast	31.9	145.5	17.8
Granular	10-10-10	100	Broadcast	29.2	147.5	18.9
L.S.D. (0.05)				6.1	ns	ns
L.S.D. (0.01)				8.1	ns	ns

[a] All values are averages of four replicates.

The phosphorus content of bean plants in 1954 was not significantly affected by fertilizer application as shown in Table 34. Although substantial differences in percent phosphorus due to treatment are evident, they are not consistently related to either form or analysis of fertilizer or method of application.

TABLE 34

EFFECT OF MIXED FERTILIZERS, FOUR GRADES, UPON PHOSPHORUS CONTENT OF FIELD BEANS, 1954
(milligrams of phosphorus per gram of oven-dried plant material)

Form of Fertilizer	Grade of Fertil-izer	Rate of P_2O_5 (lbs./A.)	Method of Appli-cation	Sampling Date	
				July 17	Aug. 6
	None			2.72[a]	2.12
Nongranular	3-12-12	50	Plow down	2.49	2.08
Granular	3-12-12	50	Plow down	3.29	2.03
Nongranular	3-12-12	50	Broadcast	2.89	1.95
Granular	3-12-12	50	Broadcast	2.21	2.06
Nongranular	3-12-12	100	Plow down	3.40	2.08
Granular	3-12-12	100	Plow down	2.66	2.20
Nongranular	3-12-12	100	Broadcast	2.76	1.80
Granular	3-12-12	100	Broadcast	2.74	2.06
Nongranular	4-16-16	50	Plow down	2.74	2.14
Granular	4-16-16	50	Plow down	2.43	2.14
Nongranular	4-16-16	50	Broadcast	2.34	2.10
Granular	4-16-16	50	Broadcast	3.07	2.07
Nongranular	4-16-16	100	Plow down	2.59	2.02
Granular	4-16-16	100	Plow down	3.21	2.20
Nongranular	4-16-16	100	Broadcast	3.08	2.08
Granular	4-16-16	100	Broadcast	2.99	2.14
Nongranular	0-20-20	50	Plow down	3.06	2.18
Granular	0-20-20	50	Plow down	3.19	2.08
Nongranular	0-20-20	50	Broadcast	2.40	2.17
Granular	0-20-20	50	Broadcast	2.70	2.05
Nongranular	0-20-20	100	Plow down	3.26	2.14
Granular	0-20-20	100	Plow down	3.24	2.11
Nongranular	0-20-20	100	Broadcast	2.90	2.13
Granular	0-20-20	100	Broadcast	2.71	2.12

[a] All values are averages of four replicates.

TABLE 34 (Continued)

Form of Fertilizer	Grade of Fertil-izer	Rate of P_2O_5 (lbs./A.)	Method of Appli-cation	Sampling Date July 17	Aug. 6
Nongranular	10-10-10	50	Plow down	2.92	1.84
Granular	10-10-10	50	Plow down	2.89	2.30
Nongranular	10-10-10	50	Broadcast	2.63	1.97
Granular	10-10-10	50	Broadcast	2.41	2.13
Nongranular	10-10-10	100	Plow down	2.74	1.89
Granular	10-10-10	100	Plow down	2.57	2.29
Nongranular	10-10-10	100	Broadcast	2.89	1.98
Granular	10-10-10	100	Broadcast	3.35	2.11
L.S.D. (0.05)				ns	ns
L.S.D. (0.01)				ns	ns

SUMMARY AND CONCLUSIONS

Greenhouse and field studies were conducted in 1952 and 1953 using ordinary superphosphate, tagged with P^{32}, in granular and nongranular form. Formulations of nongranular 8-16-8, tagged with P^{32}, were included in the 1953 greenhouse study. Mixed fertilizers of four different grades, in both granular and nongranular form, were included in the 1953 and the 1954 field studies. In both greenhouse and field experiments every fertilizer was applied in banded and broadcast placement.

Henry spring wheat was grown in the greenhouse during both years. Rainy River beans were used in the 1952 field study. Michelite beans were used as one of the crops in the field studies of 1953, and the other crop was sugar beets. In 1954, Michelite beans were used in the field study.

The soils used in the greenhouse studies in 1952 and 1953 were virgin Brookston clay loam, Brookston loam, Conover loam, Miami loam, Wisner loam, Fox sandy loam, Hillsdale sandy loam, and Oshtemo loamy sand. A Carlisle muck and an Emmet loamy sand were also used in the greenhouse in 1952. The soils ranged from pH 5.1 to pH 7.6. They varied in available phosphorus, by the Bray procedure, from 4.8 to 125 pounds per acre.

The soils used in the field studies were Conover loam in 1952, Conover loam, Wisner loam, and Kawkawlin loam in 1953, and Hillsdale sandy loam in 1954. These soils ranged from pH 5.1 to pH 7.6. They varied in available phosphorus, according to the Bray method, from 12.5 to 84 pounds per acre.

In the greenhouse studies phosphorus was mixed in and applied in bands near the seed at two rates, 40 pounds of P_2O_5 per acre in the 1952 study and 200 pounds of P_2O_5 per acre in the 1953 study. Other nutrient levels were adjusted by additions of CP grade chemicals either mixed with the soil in solid form or applied in liquid form in the irrigation water.

Dry weight yields, phosphorus content, and fertilizer phosphorus content of Henry spring wheat were not affected consistently by granulation. These same criteria did reflect a definite trend in which banded placement of fertilizer phosphorus resulted in higher values when compared with those of the mixed placement. Granular materials did give some increases which, although not significant, did indicate the possibility of some beneficial effect upon dry weight yields, phosphorus content, and fertilizer phosphorus uptake by plants.

The nonammoniated formulation of 8-16-8 tended to be somewhat superior to the slurry processed, and ammoniated formulations of 8-16-8, in terms of dry weight yields and phosphorus absorption. It is believed that, since ammoniation of fertilizers decreases the water-solubility of the phosphorus in the mix, the availability of phosphate ions to wheat was reduced.

In the 1952 and 1953 field studies with granular and nongranular tagged ordinary superphosphate, the phosphorus was applied at the rates of 50 and 100 pounds of P_2O_5 per acre by two methods, broadcast and banded near the seed. Nitrogen and K_2O were applied at the rates of 40 and 100 pounds per acre, respectively, in 1952, and 60 and 100 pounds per acre, respectively, in 1953.

Yields, phosphorus content, and fertilizer phosphorus content of Rainy River beans, 1952, and Michelite beans, 1953, indicated little effect resulted from varying the granule size. There was a definite dry weight yield response to fertilizer phosphorus at two experimental locations early in the season, but significant differences due to treatment disappeared by harvest time. Banded placement tended to be more effective than the broadcast placement of ordinary superphosphate in increasing yield and was of greater benefit also in increasing phosphorus content and phosphorus uptake from fertilizer. Similar results were obtained with sugar beets in 1953. The sugar beets showed a significant response in yield to phosphorus application, but as in all greenhouse and field experiments there was little to no effect from granulation of superphosphate. The utilization of fertilizer phosphorus by both field beans and sugar beets was affected by placement with higher values generally resulting from banding the superphosphate. Granulation had no effect on the percent of phosphorus absorbed from applied fertilizer.

Comparison of mixed fertilizers in granular and nongranular form on sugar beets and Michelite beans on Conover loam and Michelite beans on Kawkawlin loam in 1953 resulted in no increases in yield that could be attributed to granulation. Since all materials were applied banded near the seed at the rates of 50 and 100 pounds of P_2O_5 per acre, these results are what might be expected of the availability of phosphates in row application.

Use of mixed fertilizers in granular and nongranular form on sugar beets on Wisner loam gave increases in yield for all treatments. However, there were no significant increases in yield of beets that could be attributed to granulation. All fertilizers were banded near the seed at the rates of 50 and 100 pounds of P_2O_5 per acre. Sidedressing of nitrogen had no effect upon yield or sugar content of the sugar beets.

In 1954, four grades of mixed fertilizers were applied plow down and broadcast at the rates of 50 and 100 pounds of P_2O_5 per acre for Michelite beans on a Hillsdale sandy loam soil. No significant differences in yield of beans were noted. There was a tendency for the granular material to result in slightly higher yields than the nongranular material.

These data presented here can best be generally summarized by the following statement made by Stewart (22): "It has not been shown conclusively that there is any general agronomic value to granulation of superphosphate. . . ."

On the basis of the data presented here, it can be concluded that:

1. Banded placement of fertilizers in contrast to broadcast or mixed placement tended to increase yields, phosphorus content, and fertilizer phosphorus utilization of sugar beets and field beans.

2. Granulation of superphosphate and mixed fertilizers resulted in no consistent effects upon yields, phosphorus content, and fertilizer phosphorus utilization by sugar beets, field beans, and wheat.

3. Increase in rate of application of superphosphate tended to increase the total and fertilizer phosphorus content of sugar beets,

field beans, and wheat, and to decrease the percent utilization of that applied.

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