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Fertilizers for White Pea Beans

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Michigan farmers, for the period 1927-37, received an average yearly income of $13,466,000 from their bean crop. When this amount is compared with an average income of $13,582,000 from the sale of winter wheat, the importance of the crop to Michigan farmers is fully realized.

In 1937, Michigan produced 28.8 per cent of all beans and 87.0 per cent of the white pea beans that were grown in the United States. These beans were grown on 485,000 acres of land. Of this total acreage, approximately 90 per cent was in 19 counties of the central eastern part of the Lower Peninsula. The bean acreage comprises approximately 13 per cent of the total cropped area of these 19 counties. The bean plant appears to be better adapted to the soils and weather conditions of this section than to that of other parts of the state. The average yields obtained in the Saginaw Valley and Thumb area are higher than those obtained on soils of equal fertility in other sections of the bean-growing region. This is proof of the fact that climatic factors are extremely important in the successful culture of beans. The bean crop is very susceptible to injury by late spring and early fall frosts, and because it makes its growth during the summer months, it is often subjected to adverse moisture conditions. As maturity approaches, the humidity and temperature relations greatly affect the set of pods, which relationship would tend to explain the apparent regional adaptation of the crop.

The use of fertilizer for beans presents some difficult problems, owing to the extreme sensitivity of the seed and sprouts to fertilizer injury and of the crop to adverse weather conditions particularly at blossom time. Preliminary experiments and observations led to the conclusion that the application of fertilizers for beans by methods commonly employed by farmers could not be depended upon to give consistently beneficial results. Fertilizer practices which gave satisfactory results one year were at times ineffective or actually detrimental the following season. In view of these facts and of the importance of the bean crop in Michigan agriculture, a careful study of fertilizer usage for this crop was highly desirable.

EXPERIMENTAL

The experimental work in the fertilization of beans was started in 1921 and since that time the use of fertilizer and green manure crops to enrich the soil for growing beans has received major attention in

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the experimental program carried out by the Soils Section of the Michigan Agricultural Experiment Station. A discussion of the results obtained is given in the following report.

EARLY FERTILIZER EXPERIMENTS

During the years 1921-33 inclusive, fertilizer experiments were conducted on 42 farms in 14 counties. On many of the farms the experiments were continued over a period of several years. In all, 10 different soils which occupy large areas in the principal bean-growing sections of the state were represented—Brookston, Conover, Fox, Hillsdale, Macomb, Miami, Napanee, Selkirk, Wauseon, and Wisner.

THE RESPONSE OF BEANS TO VARIOUS FERTILIZER ANALYSES

Prior to 1930 the experiments were confined largely to an effort to determine whether fertilizer was needed on different types of soil and to a comparison of different fertilizer analyses or grades on different soils under variable conditions. A little work was done on the rate at which fertilizer should be applied. The fertilizers were mostly applied broadcast and were worked into the soil just before planting. On the whole, the results were not consistent. On some fields where a large number of plats were included in the tests, the cases of decreased yields, apparently the result of fertilization, were practically as numerous as the cases where fertilizer apparently increased the yield. This was true on two fields in 1921 and according to the data in Tables 1, 2, and 5, on two farms in 1923, on one in 1924, and on two in 1927. From Table 1 it can be seen that the differences between the yields

Fig. 1. Well drained Brookston silt loam in a high state of fertility is an ideal soil for growing beans.

from the treated and untreated plats on Brookston soil were not more than 1.5 bushels except in one instance in which the yield was apparently decreased 2.9 bushels as a result of the application of 250 pounds of 0-12-0 fertilizer. On the Thompson farm in 1924, all fertilized plats, with one exception, yielded less than did the unfertilized plats.

On a Napanee silt loam soil in 1927, six out of fifteen fertilized plats produced fewer beans than did the unfertilized soil. The same was true in four out of nine cases on Hillsdale sandy loam during the same year. The one plat on the Hillsdale soil, however, which received complete fertilizer out-yielded the unfertilized plat by 4.6 bushels.

During the early years of work with different fertilizer analyses, there were several fields where various fertilizer mixtures actually resulted in increased yields but where, in many cases, the increases were small and quite inconsistent, and where it was often impossible to draw any conclusion as to which fertilizer analysis was superior. According to the data presented in Table 2, a large number of comparisons on six farms on Brookston, Napanee, and Miami soil resulted in only three cases in which fertilized plats yielded less than did unfertilized plats but in spite of this fact, the data do not afford information as to which fertilizer analysis was actually best during that year. For example, on the Thurston farm the respective yields for the plats treated with 4-8-0, 4-12-0, and 4-16-0 were 33.3, 31.1, and 32.7 bushels per acre. Additional increments of phosphorous did not result in consistent increases or decreases in yield. Regarding potash, the data are again inconsistent. The plat treated with 0-12-6 yielded 30.1 bushels as compared with 28.5 bushels from the plat which received 0-12-0. At the same time the yield resulting from the 4-16-6 treatment was 30.2 bushels as compared with a yield of 32.7 bushels from soil treated with 4-16-0. Again an addition of 6 per cent potash to the 4-12-0 analysis resulted in an increase in yield from 31.1 to 33.7 bushels per acre. Nitrogen increased the yield slightly on this farm.

During that same year the 4-8-0, 4-12-0, and 4-16-0 treatments on the Parsons' farm resulted in respective yields of 30.4, 21.9, and 27.4 bushels per acre, again indicating the limitations of the data in regard to determining the best fertilizer analysis. In the light of such inconsistencies and considering the fact that on one field during that same year fertilizers failed to produce any increases in yield, the results cannot be valued too highly.

In 1925, fertilizer investigations were conducted on four fields of Brookston soil in Saginaw, Huron, and Tuscola counties. The data presented in Table 3 show that in most cases increases in yield were obtained as a result of fertilizer applications, but in many cases the increases were so small that the average increase for the three farms where the fertilizer was all applied broadcast was only 2.3 bushels per acre. Under the prices which have prevailed during many of the last 15 years, this increase in yield would have been too small to pay for the fertilizer. Furthermore, as in 1924, it was impossible to ascribe the increases in yield to any particular plant nutrient or combination of nutrients. From the data obtained on the Hunt farm, it appears that 200 pounds of 3-12-4 fertilizer drilled with the seed caused an increase in yield of 4.2 bushels per acre, but the reliability of the results is questioned when it is noticed that 100 pounds caused an increase in yield of only 0.3 bushel per acre.

Beans were grown on the Ferden experimental plats, Saginaw County, in 1926, 1927, and 1929. The experiments on this farm were designed largely to study the needs of the soil for potash and to determine the best rate of fertilizer application. Attention was also given to the use of calcium sulphate, lime, nitrogen, and green manure. Although the limitations of data obtained from non-replicated plats are fully recognized, the data in Table 4 indicate that applications of superphosphate alone failed to cause increased yields of beans on this field during the three years of study. Additions of potash to the fertilizer, however, resulted in slight increases in yields over those from superphosphate alone. From the average yields it appears that calcium sulphate, lime and nitrogen all resulted in slight increases in the yields but the differences are so small that in the case of non-replicated plats they must be attributed to experimental error or soil variations. The average yield of all fertilized plats on this farm during the three years was 24.0 bushels per acre as compared with a yield of 22.2 bushels from unfertilized plats. Even if it were certain that this increase of 1.8 bushels per acre could be attributed to the fertilizer applied, the increase is too small to be profitable except during the years when the market price is unusually high.

Perhaps the most outstanding benefits derived from broadcast applications of fertilizer for field beans were obtained on the Heckroth farm located on Wisner silt loam soil near Unionville. According to the data presented in Table 6, all fertilizers resulted in increased yields, and in general the complete fertilizers caused the greatest increases in yield. Of all the mixtures applied, the 4-16-4 seemed the most worthy of recommendation under the conditions which existed on that soil in 1928.

According to the data, the 500-pound applications were superior in two cases and inferior in one case to the 250-pound rate. Such data cannot be used to recommend the higher rate of application.

In comparing the method of applying broadcast with that of applying with a grain drill, it appears that 125 pounds drilled gave practically as high yields as did 250 pounds applied broadcast. Very small differences were obtained in the yields as a result of applying different fertilizers with the grain drill but an indication of injury from fertilizer is apparent from a comparison of the yields obtained from plats treated with 125 and 222 pounds of fertilizer. In two of three cases the larger rate resulted in lower yields and it would appear very likely that this situation may have been due to stand injury caused by too large an amount of fertilizer in contact with the seed. More recent experiments have shown definitely that 75 pounds of 4-16-4 fertilizer applied in contact with the seed caused significant stand reductions. These experiments are discussed later. No response to manganese or magnesium can be observed from the data in Table 6.

Further examples of inconsistency and lack of definite response to fertilizer applications are evident in the 1929 results reported in Table 7. During that year two fields were located on Brookston soil and two were on Selkirk. On the Sturm farm, Brookston soil, the increases in yield due to fertilizer averaged 5.1 bushels per acre, enough to pay for the 400 pounds of fertilizer when beans are worth more than $2.35 per hundred. It is probably true also that increases in yield almost as great would have resulted from smaller applications of fertilizer.

Much smaller average increases in yield were obtained on the other field of Brookston soil and on the two fields of Selkirk soil. Increases in yield on these fields averaging 2.0 to 2.8 bushels per acre were barely enough to pay for the smallest application of fertilizer. No conclusions can be drawn from the data regarding the most desirable rate of fertilizer application.

STUDIES ON ANALYSIS, RATES OF APPLICATION, AND METHODS OF APPLICATION

Starting with 1930, the fertilizer experiments with field beans were broadened to include studies of methods and rates of application. The experiments with different fertilizers were continued along the same lines as in previous years.

From 1930 to 1934 fertilizer tests were conducted near Cass City on the Reagh farm of Miami silt loam soil, as a part of a five-year demonstrational program. The fertilizer was applied through all holes on the grain drill at the time of planting. The results presented in Table 8 show that consistent, though small, increases in bean yields were obtained as a result of the application of complete fertilizer on this farm. The data furnish no clue, however, as to which of the fertilizers was superior. It is significant that in all cases except that of field 8 in 1934 superphosphate alone was inferior to the various complete fertilizers.

During a three-year fertilizer demonstration, 1930-32, near Frankenmuth on the Geyer farm of Brookston silt loam soil, fertilizer had no definite effect on yields. As shown by the data in Table 9, the highest yield in 1930 was obtained on the untreated plat, while in 1931 there were two yields above and two below the untreated plat yield. In 1932 the highest yielding plat produced only 1.8 bushels more than did the untreated plat, and one treated plat yielded less than did the untreated plat.

During the years 1930-33 inclusive, most of the field experiments were designed to show how fertilizer should be applied, as well as what analysis should be applied. In this work fertilizers were broadcast before plowing and after plowing just before planting. These methods were compared with that of drilling fertilizer with the seed at planting time. Likewise, combinations of broadcast fertilizer before and after plowing and applications with the seed were tried. The results of three of these experiments conducted in 1930 are reported in Table 10. The low yields obtained on the untreated plats indicate that these soils were extremely low in fertility. The fertilizers did not appreciably affect the yields with any method of application.

It has often been stated that fertilizers are more beneficial on good than on poor soils. Table 11 presents the results obtained in 1930 on five fields well adapted to bean production. On all of these fields the yields were higher on the fertilized than on the unfertilized plats, but in most cases the increases in yield were not great and several inconsistencies are apparent. For example, where 200 pounds of 0-16-16 were broadcast and 50 pounds of 2-12-6 drilled with the seed on the Hunter farm, the yield was increased from 9.5 bushels to 13.0 bushels. When the application of 0-16-16 was stepped up to 400 pounds, the

Fig. 2. Many farmers plant beans with a grain drill and allow the fertilizer to flow through all the openings in the drill. Since this method places a portion of the fertilizer in contact with the seed it is not recommended.

yield dropped to 11.7 bushels and again when it was increased to 600 pounds the yield was 17.3 bushels.

On the whole, the additional application of 50 pounds of 2-12-6 drilled with the seed was not beneficial. Likewise, side-dressings of 100 pounds of 4-16-8 failed to produce increases in yield on the one farm where it was tried.

During the years of 1931, 1932, and 1933, the experiments were continued along the same plan as in 1930 with experiments on 27 farms in Saginaw, Eaton, Gratiot, Jackson, Genesee, Livingston, Tuscola, and Clinton counties. According to the data for the three years, reported in Tables 12, 14, and 16, fertilizers substantially increased the yields on only three farms and caused slight increases in yield on three other farms. From the data it is impossible to conclude which fertilizer analyses were superior, but there was considerable indication that 0-16-0 was as effective as the mixed fertilizers. On 21 farms during the three-year period, fertilizer was not effective in increasing the yields.

After four years of study on the methods of application described, the data do not indicate the superiority of any one method. Fertilizer plowed under was no more effective than that which was applied broadcast after plowing. Likewise the drilling of some of the fertilizer with the seed failed to make substantial changes in the results.

According to the results presented in Table 13, there was some indication of injury to stand as a result of drilling fertilizer with the seed in 1931. The data presented in Tables 15 and 17 show that no

injuries to stand resulted from fertilizer applications in 1932 and 1933. The experiments during those latter two years did not include applications in contact with the seed.

During the years 1921 to 1933 inclusive, a total of 675 experimental plats received fertilizer applications for beans. A comparison of the yields from the fertilized plats with those from the unfertilized plats in the same field shows that the yields from 217 of them were either less or no greater than those from the unfertilized plats; 458 of the fertilized plats yielded more than the corresponding unfertilized plats, but in only 375 cases or 55.5 per cent did the increases amount to one bushel or more.

FERTILIZER PLACEMENT

During the winter of 1933-34 it was decided that the fertilizer experiments with field beans should be entirely reorganized. The work to date had shown poor response to broadcast applications of fertilizer and some indication of injury when fertilizers were applied in contact with the seed. Since experiments with some other crops had shown good results from fertilizer placed in bands beside the seed it was believed that perhaps the secret in successful fertilizer usage for beans might lie largely in the method of fertilizer placement. The aim, therefore, was to determine the effect of placing fertilizer in bands close to, but not in direct contact with the seed.

To conduct the placement tests with beans it was necessary to have a machine which would place the fertilizer where desired with accuracy. Under the supervision of G. A. Cumings, the Bureau of Agricultural Engineering of the United States Department of Agriculture con-

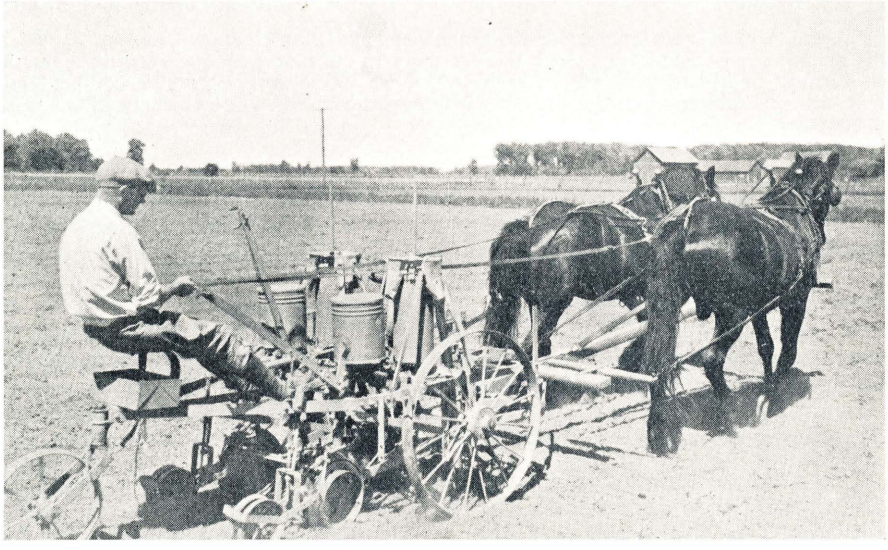
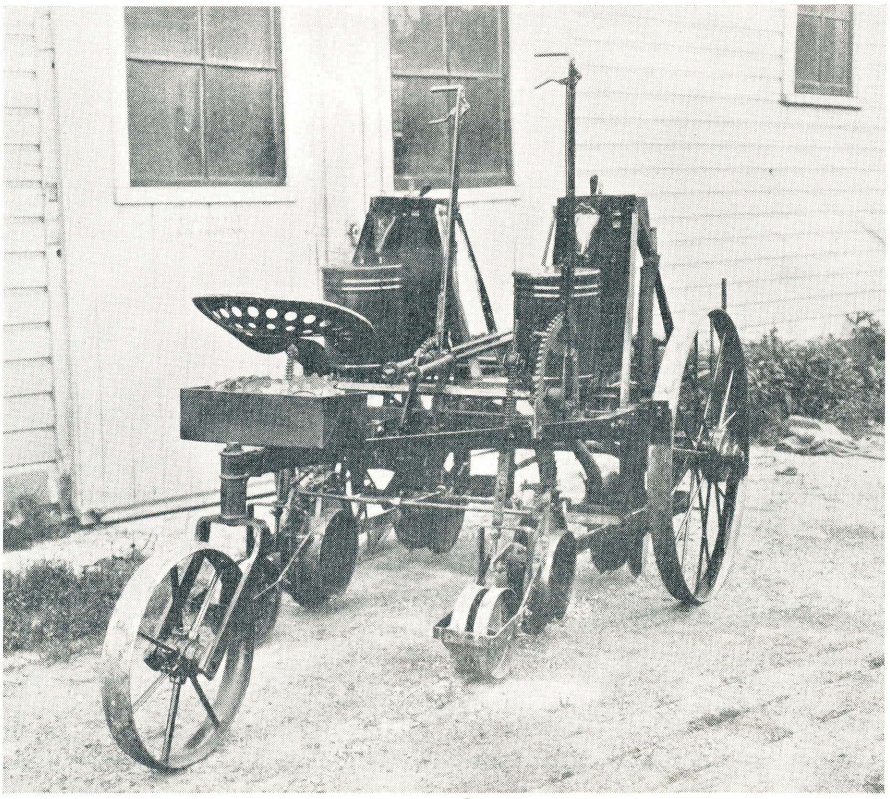


Fig. 3. Planting beans on the Ferden experimental plats with the U. S. D. A. Bureau of Agricultural Engineering experimental bean planter.



(Photo Courtesy U. S. D. A.)

Fig. 4. A close-up view of the experimental bean planter shown in Fig. 3. With this machine it is possible to place the fertilizer in contact with the seed, in a single band under or at one side of the seed, or in two bands on either side of the seed. It is also possible to vary the distance between the bands of fertilizer and the row of seeds.

structed a drill, Figures 3 and 4, which has filled the need very satisfactorily. Since the machine was constructed, four years of cooperative experiments between that Bureau and the Soils Section of the Michigan Agricultural Experiment Station have been conducted. The tests were completed on seven fields in 1934, three fields in 1935, two in 1936, and three in 1937. Two other fields were abandoned, owing to adverse weather conditions. In all, five counties and seven types of soil have been represented in the placement work.

Plan of Field Work

The field technique was carefully planned in order that the first results might be dependable. In 1934, the treatments were replicated four times on four fields and duplicated on three other fields. In 1935, all treatments were replicated four times, while in 1936 and 1937 they were replicated five times. During the last three years all plats have

been arranged in randomized blocks in order that the data might be analyzed by analysis of variance.

Each plat has consisted of two rows 20 or more rods in length according to the dimensions of the field. Row spacings have been 26 and 28 inches. Yield measurements have been obtained by harvesting and threshing 300 or more feet of both rows on each plat.

Stand counts were made soon after emergence of plants from the soil was complete each year.

The placements used in 1934 were as follows:

0 1. Both sides of seed (Parallel bands 1½ inches to the side and 1½ inches below the seed)

0 2. One side of seed (Same as No. 1 except all fertilizer in one band)

0 3. Three-fourths of fertilizer as in (2) and one-fourth in contact with the seed.

0 4. In contact with the seed (75 pounds per acre)

0 5. Both sides of seed as in No. 1 except the bands were level with the seed instead of 1½ inches below.

0 6. Under the seed. One band one inch below the seed.

In 1935, the placements were identical except that in placements 1, 2, 3, 5, and 6 the fertilizer band was 1¾ inches below the seed instead of 1½ inches below. An additional placement, designated as the "grain drill" method, was included. In this method of application, fertilizer was placed in bands seven inches apart with seed planted in every fourth fertilizer band. The placements in 1936 and 1937 were identical with those in 1935.

The fertilizer used in all the placement experiments was 4-16-4 applied at the rate of 300 pounds per acre.

Weather Conditions

Two dry years and two wet years were encountered in the placement work reported. In 1934, the precipitation at Caro during the months of May, June, and July was 0.80, 2.00, and 1.19 inches, respectively, as compared with 1.01, 1.55, and 0.64 inches for the same months in 1936. In contrast, the precipitation in 1935 for those months was 4.26, 6.68, and 1.16 inches and for 1936, 2.11, 3.67, and 3.01 inches, respectively. The months listed are the critical months from the standpoint of injury or benefit from applied fertilizers.

Observations During Early Growth

All experiments were visited several times during the growing season. Some interesting observations were made in these early visits. In 1934, planting was delayed from a week to ten days because the soil was too dry for proper germination. Growth throughout the season was considerably retarded by the lack of moisture. The bands of fertilizer could be found in the soil as late as mid-summer, and from the concentration of roots in the fertilizer zone it was very evident that the fertilizer had greatly stimulated root development.

On July 1, 1935, the beans on plats with the fertilizer under the seed were superior to all others. The unfertilized rows were the poorest

of any, and the rows with the fertilizer in contact with the seed were but slightly better than the untreated rows. The plants on other plats, including those where a portion of the fertilizer was placed with the seed were about equal, and were considerably better than where the only treatment was the 75-pound contact application. On July 11, the size of the plants in the different plats varied in the same order, but the differences were smaller, especially on the Trieber field. On July 22, there were no apparent differences at the Trieber field and small differences at the Reagh field. At the Warren field on this date, the plants which had received fertilizer in bands beside the seed were about the same size as those on the plats where the fertilizer had been placed under the seed. On the unfertilized plats and those where fertilizer had been placed with the seed, the plants were still smaller than on the plats which had received fertilizer in bands separate from the seed.

As a result of the dry weather of 1936, germination was delayed and early growth was very slow. One field was discarded because of poor germination. On July 20, the plants on the Gegler field were largest where the fertilizer had been placed under the seed, while those which had been fertilized in bands beside the seed ranked next in size. Early indications favored the deeper side placement over the side placement level with the seed and the partial contact over the 75-pound contact placement. All of the contact placements were inferior to the side placements. All fertilized plats were superior to the untreated plats.

On July 21, the untreated plats on the Stoutenburg field were very poor and those which had received fertilizer in contact with the seed were but slightly better. At the same time, the plats which had received the fertilizer in side bands or under the seed were much superior to those which had fertilizer placed in contact with the seed.

In 1937, an inspection was made five weeks after planting. On all fields, the unfertilized rows were smaller than those which were fer-

Fig. 5. For beneficial results fertilizers for field beans must be properly applied. The two rows in the center received 75 pounds of 0-16-8 with the seed and 225 pounds in a band at the side. The next two rows to the left received the same total quantity of fertilizer but in bands on both sides of the seed. The two rows to the right of the center rows received 600 pounds of fertilizer in bands beside the seed. Note the two unfertilized rows at the left.

Fig. 6. For best results fertilizer of the proper analysis must be properly applied. The two rows in the exact center were not fertilized. The two rows to the left received 600 pounds of 0-16-0 in bands beside the seed. The next two rows to the left received 300 pounds of 0-16-0 but had 75 pounds in contact with the seed. Note the vacant spaces indicating poor stand. The two rows to the right of the center rows received 300 pounds of 0-16-8 applied in bands beside the seed. The next two rows to the right received the same quantity of 0-16-8 fertilizer but had 75 pounds in contact with the seed. Note again the vacant spaces indicating poor stand.

tilized. At the Horst farm, the contact application appeared to be inferior to the other placements. At Reagh's and Stoutenburg's, the placements under the seed, in a band at one side, or in bands at both sides were about equal to each other and were better than the contact or partial contact placements.

At the end of two months the plants in the unfertilized rows were still smaller than those in the fertilized rows and the plants in the rows which had fertilizer in contact with the seed were still smaller than the plants in the rows which had been fertilized in separate bands. There were no apparent differences at that time in the size of the plants as a result of the various separate band applications.

Effect of Fertilizer Placement on Stand

An examination of the data presented in Tables 18-22, inclusive, shows that in most cases the application of fertilizer in contact with the seed resulted in injuries to germination and a corresponding reduction in stand. In 1934, the application of 75 pounds of fertilizer with the seed resulted in thinner stands on all four fields than were present on the unfertilized plats. Where a total of 300 pounds was applied, 75 with the seed and 225 on one side, a reduction in stand resulted in 9 out of 12 cases. In two of the cases where there was no effect on stand the fertilizer applied was 0-16-0.

On three fields in 1935, the application of 75 pounds of fertilizer in contact with the seed, both with and without an additional side band application, resulted in stands significantly thinner than did the application of all the fertilizer in bands to the side or under the seed. Figure 6 illustrates injury to stand where fertilizer was placed in contact with the seed.

The results obtained on the Stoutenburg farm in 1936 were identical with those of 1935 except that the stand on the plats fertilized as with a grain drill was not significantly thinner than that on the unfertilized plats. A discrepancy also occurred on the Gegler farm (Table 21), where the application of 75 pounds of fertilizer with the seed, but without an additional side band application, resulted in significantly better stands than did the partial contact applications of 75 pounds with the seed and 225 pounds beside it. On the whole, however, the 1936 data indicate serious injury to stand as a result of fertilizer applied with the seed.

In 1937, as in previous years, considerable injury to stand resulted from the contact applications of fertilizer. The application of 75 pounds with the seed resulted in stands which were significantly thinner on all fields than those obtained on the plats where the fertilizer was applied in bands, either beside or under the seed. The two partial contact treatments resulted in stands which were slightly better than those resulting from the contact treatment but greatly inferior to those obtained on the plats where the fertilizer was applied in bands not in contact with the seed. There were no significant differences in stand resulting from the various band placements.

During the four years of placement work, there have been several indications of improvement in stand as a result of fertilizer applied in bands separate from the seed. This was specifically true on the Trieber farm in 1935 and on the rate of application experiment on the Reagh farm in 1937. Throughout the experiments there were occasional cases of improved stand as a result of fertilizer application. The fact also that in several cases the partial contact treatments were less injurious than were the 75-pound contact treatments, (despite the fact that the quantity of fertilizer in actual contact with the seed was the same), is an indication that the additional side application was effective in the prevention of stand injury. This may have been due to increased vigor as a result of a plentiful supply of nutrients at a safe distance from the tender plants.

There were no significant differences in stand as a result of the different rates of application on both sides of the seed.

Effect of Fertilizer Placement on Yield

Substantial increases in yield were obtained in eight of the nine experiments conducted in 1934. As shown by the data in Tables 18 and 19, higher yields were obtained as a result of the applications in bands without contact with the seed than were obtained on plats where the fertilizer was all or partially applied with the seed. The application of 75 pounds of fertilizer in contact with the seed resulted in yields only slightly higher than those obtained from the unfertilized plats. As shown by Fig. 5, the growth of beans was depressed by fertilizer in contact with the seed.

One band of fertilizer gave just as good results as did two bands and there were no differences in the yields where the fertilizer was placed level with the seed and where it was placed 1½ inches below the seed level.

Where the fertilizer was placed under the seed, the yields were

higher in two cases, lower in one case, and about equal in one case to the yields obtained where the fertilizer was placed in a side band.

As indicated by the data presented in Table 20, significant increases in yield were obtained in 1935 on two farms as a result of all treatments except the one with 75 pounds of fertilizer in contact with the seed. On the Trieber farm, all the fertilized plats outyielded the untreated plats but the difference was not significant in one case and just barely significant in two other cases. In fact, the "F" value obtained for the placements is less than the "F" value at the 5% point, which may be interpreted as meaning that the differences shown are due to some factors other than treatment.

Fig. 7. Fertilizers for field beans should be placed in a band one and one-half to two inches below the seed level and one-half inch to the side of the perpendicular plane in which the seeds lie. Left—4-16-4 properly applied at the rate of 300 pounds per acre. Right—no fertilizer.

On both the Warren and Reagh farms the application of 75 pounds of fertilizer with the seed resulted in yields significantly less than did those resulting from any of the other placements. At the Warren farm the only significant difference between any of the other placements was in favor of the application at the sides and on a level with the seed over the placement to one side and below the seed. Excluding the placement with the seed, no single placement at Reagh's was significantly better than any other placement, although the increase from the under seed placement approached significance. When it is remembered that the plats where the fertilizer was placed under the seed appeared superior for a considerable portion of the growing season, it is interesting to note that this placement resulted in the largest yields on both the Reagh and Trieber fields.

It is also significant that the yield from the partial contact placement

was about equal to that from the side placements despite the stand injury which has already been pointed out. This is in contrast with the 1934 results in which the partial contact placement gave a decidedly lower yield than did the side placements.

Because of the unfavorable growth conditions throughout the season, little can be said regarding the yields on the placement plats in 1936. As shown by the data reported in Table 21, no treated plat on the Stoutenburg field yielded significantly more than did the untreated plat, but the plat which received the fertilizer in bands seven inches apart, as with a grain drill, yielded significantly less than did the untreated plat. Although the differences were not significant, the data show that the other plats which received contact and partial contact applications of fertilizer also yielded less than did the untreated plat. Furthermore, all three of the plats on which fertilizer was applied in contact with the seed produced yields significantly less than did the plat with fertilizer on both sides and below the seed.

On the Gegler farm, only the plat with fertilizer on one side of the seed, significantly out-yielded the unfertilized plat, and two of the fertilized plats actually yielded less than did the unfertilized plat.

At first thought it seems that the placement work for 1936 was a failure, but, at least, it is possible to conclude from the Stoutenburg results that fertilizer treatments in contact with the seed are to be avoided. This correlates closely with the 1934 and 1935 results. When it is remembered that most of the fertilizer applied for beans in Michigan is applied in this way the seriousness of the problem is apparent.

The 1937 data recorded in Table 22, show that on the Stoutenburg and Reagh fields the three treatments which included fertilizer in contact with the seed resulted in yields which were definitely lower than those obtained as a result of separate band treatments. At Stoutenburg's, the yields resulting from contact fertilization were actually smaller than the yields from the unfertilized plats. In the case of the 75-pound contact treatment, the difference was significant. At Reagh's, the yields on the plats where all or a part of the fertilizer was placed with the seed were not significantly greater than the yield from the unfertilized area. On both of these fields the application of 75 pounds of fertilizer with the seed and with no additional application, resulted in yields which were significantly lower than any yields from plats where the fertilizer was all applied in bands beside the seed.

The yields at the Horst farm were erratic and while some of the differences between placements were great enough to be significant the results are so clearly at variance with the results obtained on the other two fields, and those obtained in former years, that, from the standpoint of general fertilizer practices, no significance can be attached to them.

From the Stoutenburg and Reagh results it is shown that deeper placement of the fertilizer was better than seed level placement and that application in two bands resulted in somewhat higher yields than did applications in a single band.

The placement of fertilizer under the seed did not produce yields materially different from those obtained as a result of placement in bands beside the seed.

EXPERIMENTS DEALING WITH THE RATE OF FERTILIZER APPLICATION

Experiments on the rate of fertilizer application were carried on in conjunction with the studies on fertilizer placement. Plantings and fertilizer applications were made with the Bureau of Agricultural Engineering drill already described. The 4-16-4 fertilizer was applied at rates of 200, 300, 400 and 600 pounds per acre. The fertilizer was placed in bands on both sides of the seed, 1½ inches out from the seed, and 1½ to 1¾ inches below the seed level. The results of these studies are reported in Tables 18-22 inclusive.

Fig. 8. These McNaughton stacks illustrate the benefit which may result from properly applied fertilizer for field beans if weather conditions are favorable. Left—600 pounds of 4-16-8 applied in bands separate from but close to the seed—24.3 bushels per acre. Right—no fertilizer—16.4 bushels per acre.

As indicated by the data in Table 18, the yields of beans increased consistently with increasing rates of fertilizer application on the Trieber and Dilman farms, but not on the Horst and Buckholz farms. Table 19 presents in all, eight comparisons of 300- and 600-pound applications of three different fertilizers. In all cases, the 600-pound rate caused an increase in yield over the 300-pound rate, but the average increase was only 1.7 bushels per acre, hardly enough to pay for the extra 300 pounds of fertilizer.

On the Warren farm in 1935, all rates of application resulted in yields significantly greater than the yields obtained where no fertilizer was applied, but it required a 600-pound application to give a significant difference over the 200-pound rate. On the Trieber and Reagh farms the 200-pound rate did not result in a significant increase

in yield, while both the 400- and 600-pound rates did cause increases in yield which were significantly greater than the untreated plat yields. On the Reagh farm, however, the higher rates were not significantly better than the 200-pound rate, and on the Trieber farm 400 pounds did not prove to be significantly better than 200 pounds, although the 600-pound application did result in yields significantly greater than those which resulted from the 200-pound rate. The percentage error of the mean for the experiment on rates on the Reagh farm was 4.7%, which indicates a great amount of variability between plat yields and the results should be interpreted accordingly.

The rates of application experiment on the Stoutenburg farm was the only bean experiment in 1936 where significant increases in yield were obtained as a result of fertilizer. The beans fertilized at the rate of 200 pounds per acre yielded significantly more than did the untreated plats, and those treated with 400 pounds of fertilizer produced significantly larger yields than did those which received 200 pounds.

In 1937, the application of 200 pounds of fertilizer produced a significant increase in yield, but the increase in yield resulting from an additional 200 pounds per acre was not significant. At Stoutenburg's, it required 400 pounds of fertilizer to produce a significant increase in yield over the yield from the untreated plat, but the yield from the plat treated with 400 pounds was not significantly greater than that from the plat which received 200 pounds.

The data, as a whole, show that the rate of fertilizer application which gave the largest increase in yield varied considerably from year to year and with the soil type. The largest increase in yield was not always the most profitable increase because of the higher cost of the larger fertilizer application. In general, the results indicate that fertilizer applications in excess of 300 pounds per acre were not economical.

A COMPARISON OF DIFFERENT FERTILIZERS APPLIED IN BANDS BESIDE THE SEED

A study of different fertilizers was also carried on in conjunction with the work on fertilizer placement. In the main, comparisons were made between 0-16-0, 0-16-8, 4-16-8, and 4-16-4. In some of the experiments, treatments of 4-16-0, 4-12-4, and 2-12-6 were also included. All fertilizers were applied in bands beside the seed by means of the Bureau of Agricultural Engineering drill which was constructed for use in the experiments on fertilizer placement. In all the experiments, except that of 1937 on the Ferden farm, the fertilizer was applied in two bands on either side of the seed. The bands were 1½ inches out from the seed and 1½ to 1¾ inches below the seed level.

As indicated by the data obtained in 1934 and presented in Table 19, the 0-16-8 and 4-16-8 fertilizers were superior to the 0-16-0, but the 4-16-8 was not superior to the 0-16-8. Apparently nitrogen was not needed on those fields in 1934.

The data in Table 23 indicate that in 1935, all fields did not respond in the same way to the different fertilizer analyses. Since the "F" value for the Trieber results was below the level required for significance, any differences found in the data for this farm cannot be

ascribed to differential response due to fertilizer analyses. With the exception of the 0-16-0 treatment on the Warren farm, all fertilizer treatments on this farm and on the L. Reagh farm resulted in significant increases in yield. No significant differences however can be found between the yields resulting from the application of different fertilizer analyses. On the Warren farm, the 0-16-8 and 4-16-8 treatments produced significant increases in yield over the 0-16-0 treatment. The plats on the J. Reagh farm were not laid out in a randomized block arrangement but the averages from quadruplicated plats are comparable with the results obtained on the L. Reagh farm. During the 1935 season the 0-16-0 fertilizer apparently gave as good results on the Miami soil as did any other fertilizer used in the experiment.

The data reported in Table 24 show that on the Stoutenburg field, plats fertilized with 4-16-8 were the only ones which produced yields significantly greater than did the unfertilized plats. The 0-16-0 fertilizer had no effect on yields, and the 0-16-8 caused an increase in yield of less than one bushel per acre. In that particular experiment, 2.67 bushels were required for significance.

On three fields in 1937, the response to different fertilizer mixtures, as shown by the data in Table 25, was variable. On the Miami soil the low "F" value shows that the differences in mean yields are due to some factors other than fertilizer treatment.

Two fertilizers on the Napanee soil, 0-16-0 and 4-16-8, increased yields significantly above that from the unfertilized plat. The 0-16-0 was slightly superior to the 4-16-8 although the difference was not significant.

On the Horst farm, Brookston soil, only the 4-16-8 treatment caused a significant increase in yield.

In 1934, the experimental work on the Ferden farm was moved to a new field and beans were included in a three-year rotation with oats and wheat, with sweet clover seeded in the wheat for green manure. Treatments were in triplicate and six fertilizers were applied in bands on both sides of the seed, 1½ inches to the side of the seed and 1½ inches below the seed level. The treatments and the yields for the first four years are recorded in Table 26. During the four years, the increases in yield as a result of fertilizer applications were small but were consistent. The data show that each year the unfertilized plats produced smaller yields than did the treated plats. As would be expected when the response to fertilizer is small, no definite conclusion can be drawn regarding the ranking of the various analyses. From the 1934 and 1937 results it would appear that 0-16-8 was superior to 0-16-0 or 4-16-0 and was equal to a complete fertilizer. Because of the plat layout, the crops in 1934 and 1937 were produced on the same plats. The similarity in the results for those years is significant because of this circumstance. In 1936, the 0-16-0 plat was outyielded only by the 4-16-4 plat and that difference was only 0.6 bushel. The differences in the yields obtained in 1935 as a result of different fertilizer analyses were too small to be considered significant.

Considering the results as a whole, it is evident that no single fertilizer analysis or grade is the best for beans on all soil types and in all seasons. Neither is there any one fertilizer that will give distinctly better results than any other on any soil every year. In general, nitrogen proved of little benefit to the bean crop. Superphosphate alone

proved an economical fertilizer on some soils but for the average conditions of soil and weather encountered during these experiments a fertilizer containing both phosphate and potash as the 0-16-8 gave better results from the standpoint of yield and profit than did superphosphate or the 4-16-8.

The work for the years 1934-37 inclusive, during which time the special planter permitting of various methods of placement of the fertilizer was used, included a total of 866 fertilized plats. Of these, 188 yielded less or no more than the corresponding unfertilized plats, 678 yielded more than the unfertilized plats, and 594 or 68.6% exceeded the unfertilized plats in yield by one or more bushels.

THE ROLE OF STABLE MANURE AND GREEN MANURE IN THE PRODUCTION OF FIELD BEANS

The 1935 bean experiments included some studies on the role of sweet clover as green manure, and stable manure in bean production. For years it had been observed that beans, as a general rule, yielded better on the more fertile soils. Direct additions of plant food, however, had not greatly increased yields. It appeared then that the solution might lie in a general improvement in soil fertility rather than in direct applications of commercial fertilizer. It was recognized that the use

Fig. 9. Sweet clover green manure has resulted in increased yields of field beans. Experiments with green manure and stable manure are being conducted on the Horst and Reagh farms in Tuscola County.

of fertilizers would occupy a key position in the soil improvement program. To test these ideas, experiments were started in 1934 which would furnish information as to the value of fertilizer, sweet clover green manure, and stable manure on the Brookston silt loam farm owned by John Horst, Akron, and the Miami silt loam farm owned by John Dilman, Cass City. The plats were so laid out as to give the effects of each of these materials alone and of various combinations of two materials and of all three materials.

The data presented in Table 27 show that fertilizer alone was of no benefit on the Horst farm and that 0-16-0 alone did not increase the

yield on the Dilman farm. An application of 4-16-4 did apparently cause an increase in yield on the Dilman farm. Stable manure applications were harmful on the Horst farm and beneficial on the Dilman farm. The explanation for this is not apparent but it is known that in past years the Horst soil has received more of this material than has the Dilman soil.

Sweet clover green manure proved to be highly efficient in increasing the yields of beans. On both farms the green manure without fertilizer or stable manure caused increased yields and where it was plowed under in addition to fertilizer applications the yields were considerably greater than on the fertilized plats which received no green manure. Furthermore, in all cases on the Horst farm and in two out of three cases on the Dilman farm sweet clover green manure in addition to stable manure caused higher yields than did stable manure alone. In the one case on the Dilman farm where the condition was reversed, the difference in yield was only 0.7 bushel.

Further experiments along this line were started in 1937 and will be continued for several years. Perhaps the problem of fertilizer usage for beans will be solved by applying fertilizers for preceding green manure crops rather than for the bean crop itself. This seems even more likely when it is remembered that alfalfa and sweet clover are very responsive to commercial fertilizer applications. The response of alfalfa to fertilizer applications has been discussed in various publications.[1]

On the Ferden farm in 1936 it was found that an application of 250 pounds of 4-16-4 fertilizer, applied for wheat in the fall of 1934, had caused a 32.9% increase in the growth of sweet clover on May 21, the date of plowing. A fine crop of beans was grown on this field despite the 1936 drought.

DISCUSSION

Fertilizer experiments with white pea beans were conducted each year from 1923 to 1937 and on two farms in 1921. During that period experiments were located on 57 farms in 18 counties. On many of the farms, the studies extended over a period of several years. In all, 10 different soil series were represented—Brookston, Conover, Fox, Hillsdale, Macomb, Miami, Napanee, Selkirk, Wauseon, and Wisner.

From the data collected from such a large number of experiments over a period of 16 years it would seem a relatively simple matter to draw up definite recommendations regarding fertilizer practices for this crop. Because of the inconsistencies in yields encountered, however, and the total lack of response of beans to fertilizers on many farms the task is difficult.

Prior to 1930 these experiments were confined entirely to an effort to determine whether fertilizer was needed on different types of soil and to a comparison of different analyses on different soils under

[1]Mich. Agr. Exp. Sta. Quart. Bul., **13** (3): 116-118. 1930.
Mich. Agr. Exp. Sta. Quart. Bul., **14** (1): 3-5. 1931.
Mich. Agr. Exp. Sta. Quart. Bul., **16** (3): 191-196. 1933.
Mich. Agr. Exp. Sta. Quart. Bul., **17** (3): 116-130. 1934.
Mich. Cir. Bul. 154, 1936.

variable conditions. During that early work in which most of the fertilizers were applied broadcast and worked into the soil just before planting, the results were not consistent. On some fields where a large number of plats were included in the tests, the cases of decreased yields were as numerous as the cases of increased yields. On a few farms the results indicated a definite but rather small benefit from the fertilizer applications. As a whole the results furnished little ground for recommending the use of fertilizer for beans as a general practice, nor information as to which of several analyses should be used where it was felt fertilizer was needed.

From 1930 to 1933 inclusive a large number of experiments were conducted. The work was broadened to include fertilizer plowed under and drilled with the seed as well as the customary broadcast applications. The plowing under of fertilizer gave no better results than did broadcasting it after plowing. There was very little evidence in favor of drilling small quantities of fertilizer with the seed. In fact, contact applications were in many cases actually injurious, both to germination and to yields.

In recent years there has been a tendency toward row rather than broadcast applications of fertilizer. Experiments have shown better results with several crops from such practices. This is probably due to the fact that when fertilizer is placed in bands close to the seed it is in close proximity to the roots of the plants and does not come in contact with much soil. When there is less contact between soil and fertilizer there is less fixation of phosphate by the soil and more of the element remains in a form easily available to the plants. Furthermore, the application of fertilizer in rows near the seed makes possible the application of fertilizer and the planting of seed in one operation. It is desirable, then, from a standpoint of labor and consequent cost of production.

Since the work from 1930 to 1933 had indicated that contact applications were not desirable and little benefit had resulted from broadcast applications it was decided in 1934 to start a series of experiments on methods of fertilizer placement. Rate of application and fertilizer analysis studies were also included in the plans. As there was no drill available for applying fertilizer in the row, except in direct contact with the seed, the Bureau of Agricultural Engineering of the United States Department of Agriculture was asked to cooperate in these experiments. The Bureau constructed the necessary machine and cooperated with the Soils Section of the Michigan Agricultural Experiment Station in experiments on seven farms in 1934, four in 1935, three in 1936, and three in 1937. Crop failures were experienced on two farms during that time.

During these experiments in fertilizer placement, fairly consistent increases in bean yields were obtained from 300-pound applications of 4-16-4 fertilizer in bands on both sides of the seed, in a single band on one side of the seed, and in a single band under the seed. Analyses of the data show that on some fields the increases in yields were not significant but that on other fields significant increases resulted from the fertilizer treatments. When beans were a fair price the increases on many of the fields were more than sufficient to pay for the fertilizer. The data bring out the fact, however, that beans do not respond like most other crops to applications of plant nutrients in the form of

commercial fertilizers. On some of the same farms where these experiments have been located the yields of wheat, sugar beets, barley, oats, and alfalfa have often been increased as much as 50 per cent and have in many cases been doubled by applications of 250-300 pounds of fertilizer. Furthermore, the results from the other crops mentioned have been such as to make possible certain definite recommendations regarding the best fertilizer analysis to apply under varying local conditions. This has been only vaguely possible in the case of white pea beans.

Some of this difficulty is perhaps due to the extreme sensitivity of the crop to soil and climatic conditions. The latter, of course, cannot be controlled but it is possible to improve the chances of a successful crop greatly by properly selecting and fitting the soil. It is believed that soils low in organic matter content should be avoided in the production of this crop until steps have been taken to add such material to the soil through the application of stable manure or the plowing under of green manure.

Beans are very sensitive to soil moisture conditions. Much can be done in the way of insuring the plants of a plentiful supply of moisture by plowing early and fitting a good seedbed. This is especially true when a green manure crop is to be plowed under. While it is often desirable to wait until a good crop of green manure can grow, it is a grave mistake to plan to plow late and then plant the beans immediately. The exact time which should elapse between the dates of plowing and planting depends on the seasonal conditions, the type of soil, and the quantity of vegetation to be plowed under.

There is little doubt but what response of beans to fertilizers is often nullified by adverse weather conditions during the period of blooming and the setting of pods. It has generally been observed in the field that the plants on fertilized plats during the early part of the growing season made much better growth than did those on the unfertilized plats but that they failed to give correspondingly increased yields. Some investigators have voiced the opinion that this was due to moisture conditions and water requirements. Perhaps when the soil moisture content is low during the blooming period, the greater vegetative growth on the fertilized plats causes a greater demand for water and there is not sufficient for a maximum set of pods. On the unfertilized plats, on the other hand, a smaller demand for water by the leaves of the smaller plants might allow a greater proportionate set of pods. An equalization of yields would then result despite the greater vegetative growth prior to the blooming period. The increased early growth resulting from fertilization has led many to place a false value on the benefits of fertilizing beans.

It has been suggested that inasmuch as there seems to be so many factors other than nutrient supply which limit bean production it may be better to put more effort on first correcting the other factors, insofar as possible, then to turn the attention to the question of fertilizer. It may be that in such a program fertilizers can be used to the greatest advantage by applying them on the grain and green manure crops which precede beans in the rotations. The results of experiments indicate that this is certainly true on those farms which are not equipped to apply the fertilizer in an advisable position in relation to the seed.

CONCLUSIONS

From 16 years of experimental data with fertilizers for white pea beans on 57 farms in 18 counties of the east-central part of Michigan it is possible to draw these conclusions:

1. Broadcast applications of fertilizer for white pea beans resulted in no increases in yield or in increases which in most cases were too small to pay for the fertilizer applied. This condition was not changed by plowing under the broadcast fertilizer.
2. The application of 75 pounds of fertilizer with the seed failed to produce increases in yield. Such application did, on the other hand, result in injuries to germination.
3. The application of 300 pounds of 4-16-4 fertilizer in bands separate from, but close to, the seed caused significant increases in yield which were in many cases great enough to more than pay for the fertilizer applied. No spectacular increases in yield were obtained.
4. Adverse weather conditions, particularly at blossom time, may largely nullify the advantages of fertilizer applications insofar as increased yields are concerned, even though growth of the bean vines may be considerably increased by the fertilizer, especially in the earlier stages.
5. Of the various methods of band placement which were tried in the experiments, the ones most promising were: The placement of the fertilizer in a single band 1½ to 1¾ inches below the seed, and in bands 1½ inches out from the seed. In the applications at the side of the seed, a band on one side of the seed was as satisfactory as bands on both sides of the seed, and placing the bands deeper than the seed was more satisfactory than placing them on a level with the seed.
6. The data show that applications greater than 300 pounds per acre were not economical.
7. As a whole, applications of 0-16-8 gave better results, both from the standpoint of yield and economy, than did applications of 0-16-0 or 4-16-8.
8. In this bulletin results from 1,541 fertilized plats on 57 farms in 18 counties of the main bean growing area of Michigan are considered. In 371 of the 467 cases, or 79.4%, in which the fertilizer was applied in bands under or beside the seed, methods of application which gave best results, the yields were increased by one or more bushels over those from the unfertilized plats. Of the 1,074 plats on which fertilizer was applied by other methods, including those commonly used by farmers, only 598 or 56.6% gave yields one bushel or more larger than the yields of the unfertilized plats in the same field.
9. The plowing under of sweet clover green manure for beans gave very good results on two different soils in 1935. This is in keeping with the idea that perhaps the best place to apply fertilizer for beans would be for the green manure crop preceding the beans rather than for the bean crop directly. This problem is being investigated further.

Table 1. The effect of fertilizers on the yield of beans on two fields in 1923.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre	
		Brookston Soil	
		Owen Farm	Thurston Farm
0–12–0	250	14.4	15.4
0–12–4	250	13.8	19.8
3–12–0	250	15.0	19.8
3–12–4	250	13.8	19.8
3–12–4	500	13.8	——
3–12–10	250	——	16.1
No fertilizer	——	14.4	18.3

*All fertilizer applied broadcast.

Table 2. The effect of fertilizers on the yield of beans on six fields in 1924.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre					
		Brookston Soil			Napanee Soil	Miami Soil	
		Thurston Farm	Hillebrand Farm	Thompson Farm	Sachner Farm	Olsen Farm	Parsons Farm
0–12–0	400	28.5	——	——	——	——	28.1
0–12–6	400	30.1	——	——	——	——	28.3
0–12–12	400	30.7	——	——	——	——	25.5
4– 8–0	400	33.3	——	——	——	——	30.4
4– 8–6	400	28.1	——	——	——	——	27.7
4– 8–12	400	28.9	——	——	——	——	24.0
4–16–0	400	32.7	——	——	——	——	27.4
4–16–6	400	30.2	——	——	——	——	26.8
4–16–12	400	31.1	——	——	——	——	28.9
4–12–0	400	31.1	——	——	——	——	21.9
4–12–6	400	33.7	——	——	——	——	31.6
4–12–12	400	31.8	——	——	——	——	29.2
No fertilizer**	——	27.7	35.7	14.7	17.1	20.5	24.8
6–16–12	200	——	42.0	14.1	——	——	——
3–24–6	200	——	42.0	15.4	——	——	——
3–24–12	200	——	40.2	12.0	——	——	——
3–12–6	200	——	36.1	13.0	——	——	——
6–24–6	200	——	36.3	11.8	——	——	——
3– 8–6	400	——	39.6	13.6	——	——	——
0–16–0	200	——	——	——	——	24.3	——
0–16–0	300	——	——	——	23.0	——	——
0–16–0	400	——	38.4	13.7	——	——	——
0–45–0	142	——	35.1	13.7	——	——	——

*Fertilizer applied broadcast.

**The yields from the unfertilized areas are averages from several systematically arranged plats.

Table 3. The effect of fertilizers on the yield of beans in 1925.

Fertilizer	Pounds per Acre	Yield of Dry Beans in Bushels per Acre					
		Brookston Soil					
		Thurston Farm	Johnson Farm	Hillebrand Farm	3–12–4 Fertilizer		Hunt Farm
		B. C.*	B. C.	B. C.	lbs. D**	lbs. B.C.	
3–24–6	200	26.6	22.1	23.7	——	——	——
3–24–12	200	26.7	20.0	24.8	100	0	26.1
3–12–6	200	24.9	19.0	19.2	100	250	26.7
6–16–12	200	26.3	——	20.3	100	500	24.3
6–24–6	200	25.1	——	23.6	0	250	25.8
3– 8–6	400	27.1	22.0	24.4	0	500	24.9
0–16–0	562	24.8	23.2	22.5	200	0	30.0
0–45–0	200	27.5	21.2***	19.3	200	250	29.1
13–48–0	200	26.3	——	29.6	200	500	30.8
No fertilizer****	——	25.2	18.5	19.6	No fertilizer		25.8

B.C.* refers to broadcast application of fertilizer.

D.** refers to fertilizer drilled with the seed.

*** 400 pounds of 0–16–0 and 142 pounds of 0–45–0 per acre respectively.

**** The yields from the unfertilized areas are averages from two plats.

Table 4. The effect of fertilizers on the yield of beans on the Ferden Farm in 1926, 1927, and 1929. Macomb loam soil.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre			
		1926	1927	1929	Average
0–16–0	250	17.7	20.5	18.0	18.7
0–16–5	250	25.4	27.6	20.4	24.5
0–16–10	250	25.3	25.3	19.7	23.4
0–16–20	250	24.9	24.7	18.4	22.7
0–16–40	250	26.7	24.1	18.5	23.1
0–16–0	500	23.4	25.4	19.3	22.7
0–16–2.5	500	22.1	26.5	21.4	23.3
0–16–5	500	24.6	27.9	23.1	25.2
0–16–10	500	28.1	31.6	23.9	27.9
0–16–20	500	27.2	28.3	21.2	25.6
0–16–0 + $CaSO_4$	500 + 100	27.9	21.3	21.2	23.5
0–16–0 + Lime	500 + 4000	28.4	26.0	23.2	25.9
7–16–20	500	27.8	27.9	23.1	26.3
0–16–20** + Green manure	500	24.9	22.2	24.2	23.8
No fertilizer***	——	23.5	24.1	19.0	22.2

*All fertilizer applied broadcast.

**On this plat sweet clover was seeded with oats or barley, and was plowed under for wheat that same year. This occurred once in a four-year rotation.

***The yields from the unfertilized areas are averages from several systematically arranged plats.

Table 5. The effect of fertilizers on the yield of beans on three fields in 1927.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre		
		Napanee Silt Loam	Miami Silt Loam	Hillsdale Sandy Loam
		Lather Farm	Green Farm	Tanner Farm
0–16–0	250	8.4	——	——
0–16–0	500	11.5	——	——
0–16–4	250	9.7	——	——
0–16–4	500	12.9	——	——
0–16–8	250	10.9	——	——
0–16–8	500	9.4	——	——
4–16–8	250	13.1	——	——
8–16–8	250	11.0	——	——
2–16–4	500	9.9	——	——
4–16–4	500	10.4	——	——
Green manure	——	12.9	——	——
0–16–0 + Green manure	250	11.9	——	——
Manure	12,000	13.0	——	——
0–16–0 + Manure	250 + 12,000	15.3	——	——
0–16–4 + Limestone	250 + 4,000	10.3	——	——
No fertilizer**	——	10.6	12.9	12.3
0–10–0	400	——	14.6	11.8
4–10–0	400	——	19.1	12.2
4–10–12	400	——	24.3	16.9
4– 0–0	400	——	13.1	12.6
4– 0–12	400	——	16.7	15.5
0– 0–12	400	——	13.9	13.0
0–10–12	400	——	16.4	13.7
0–10–0 + Sulfur	400 + 100	——	14.6	10.8
Limestone	4,000	——	13.1	12.2

*All fertilizer applied broadcast. All fertilized plats on the Miami and Hillsdale soils received a uniform application of 2 tons of ground limestone per acre.

**The yields from the unfertilized areas are averages from several systematically arranged plats.

Table 6. The effect of fertilizers on the yield of beans on the Heckroth Farm in 1928. Wisner silt loam soil.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre	Fertilizer**	Pounds per Acre	Yield of Dry Beans in Bushels per Acre
4– 0–0	250	16.0	1–10–3	125	15.2
4– 0–8	250	16.5	0–20–0	125	17.9
4– 8–8	250	19.8	2–16–8	125	15.6
4–16–8	250	16.0			
4–16–8	500	12.7	2–16–8	220	18.9
4–32–8	250	23.6	4–16–4	125	18.9
2–16–8	250	17.9	4–16–4	220	16.5
2–16–8	500	21.9	4–16–8	125	16.0
0–16–0	250	16.0	4–16–8	220	10.9
0–16–8	250	13.2			
No fertilizer***	——	10.1			
8–16–8	250	17.4			
0– 0–8	250	14.6			
4–16–0	250	16.0			
4–16–4	250	19.8			
4–16–4	500	21.2			
4–16–8 + 50 lbs. $MnCl_2$	250	21.7			
4–16–8 + 50 lbs. $MgCl_2$	250	18.8			
4–16–16	250	21.7			

*Fertilizer applied broadcast.

**Applied with grain drill, all holes running.

***The yields from the unfertilized areas are averages from several systematically arranged plats.

Table 7. The effect of fertilizers on the yield of beans on five fields in 1929.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre						
		Brookston Soil		Selkirk Soil		Miami Soil		Fox Soil
		Brooks Farm	Sturm Farm	Hunter Farm		Pearson Farm		Brown Farm
				Series 1	Series 2	Series 1	Series 2	
4– 8–4	400	19.8	21.0	4.3	——	6.7	——	7.1
4–12–4	400	20.0	20.7	8.0	10.7	3.0	4.7	5.4
4–16–0	400	——	20.0	11.3	14.7	6.0	8.8	4.1
4–16–4	200	22.7	——	12.3	13.0	——	——	——
4–16–4	400	21.1	17.5	12.3	10.7	5.4	6.8	6.3
4–16–4	600	22.2	——	13.3	17.0	——	——	——
4–16–8	400	21.8	22.7	11.7	12.7	3.7	8.0	4.7
4–16–16	400	21.1	18.5	11.0	14.0	6.1	5.6	5.8
4–16–32	400	——	18.4	——	——	——	——	4.9
8–16–16	400	——	——	——	——	——	——	3.4
8–16–32	400	——	——	——	——	——	——	5.4
0–16–0	200	16.5	——	13.0	11.7	——	——	——
0–16–0	400	19.8	19.3	9.5	10.9	7.6	7.7	4.7
0–16–0	600	19.2	——	——	——	——	——	——
0–16–8	400	21.0	18.0	11.3	11.0	4.6	7.0	3.7
0–16–16	200	——	——	13.7	13.0	8.7	9.0	——
0–16–16	400	21.8	20.0	10.0	11.7	——	——	4.6
0–16–16	600	——	——	11.0	17.3	——	——	——
No fertilizer**	.....	18.6	14.0	8.8	9.5	9.6	6.3	——

*All fertilizer applied broadcast except in the case of Series 2 on the Hunter and Pearson farms where 50 pounds of 2–12–6 was drilled with the seed in addition to the broadcast treatment.

**The yields from the unfertilized areas are averages from several systematically arranged plats.

Table 8. The effect of fertilizers on the yield of beans on the Reagh Farm from 1930 to 1934. Miami silt loam soil.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre				
		1930	1931	1933	1934	
					Field 2	Field 8
0–16–0	250	17.8	9.7	——	12.8	17.1
2–16–2	250	18.3	10.4	——	18.7	16.3
2–12–6	250	——	11.7	19.5	18.3	15.9
4–16–4	250	——	11.4	18.2	16.9	16.3
4–12–4	250	——	12.9	——	16.8	17.2
No fertilizer	——	16.8	9.7	——	11.9	14.1

*The fertilizer was applied through all holes in the grain drill at the time of planting.

Table 9. The effect of fertilizers on the yield of beans on the Geyer Farm from 1930 to 1932. Brookston silt loam soil.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre		
		1930	1931	1932
0–20–0	250	26.2	—	—
2–12–6	250	26.8	—	—
4–16–4	250	26.5	22.6	40.1
4–16–8	250	—	28.3	39.5
4–12–4	250	—	22.7	38.0
0–20–20	250	—	32.0	—
No fertilizer	—	28.3	23.0	38.3

*A 200-pound portion of the fertilizer was applied broadcast and the remainder was drilled with the seed.

Table 10. The effect of fertilizers on the yield of beans on four fields not adapted to bean production. 1930.

Fertilizer	Pounds per Acre	Yield of Dry Beans in Bushels per Acre						
		Miami Soil				Hillsdale Soil		
		Marr Farm		Aseltine Farm		Tanner Farm	Wilde Farm	
		B. C.*	B.C.D.**	B. C.	P. U.	B. C.	B. C.	P. U.
No fertilizer***	—	3.6	—	2.7	—	5.2	2.1	—
0–16–0	400	—	—	2.3	2.2	—	2.4	1.3
0–16–8	400	4.0	4.8	3.5	2.2	—	1.9	2.2
0–16–16	600	—	—	2.3	3.0	—	—	—
4– 8–4	400	5.2	6.5	—	—	—	—	—
4–12–4	400	6.8	6.6	—	—	—	—	—
4–16–8	400	6.2	9.9	2.0	3.0	—	.7	1.6
4–10–12	—	—	—	—	—	4.9	—	—

*B. C.—Fertilizer applied broadcast; P. U.—Fertilizer plowed under.

**B. C. D.—Regular broadcast application plus 50 lbs. 2–16–6 with seed.

***The yields from the unfertilized areas are averages from several systematically arranged plats.

Table 11. The effect of fertilizers on the yield of beans on five fields adapted to bean production. 1930.

Fertilizer	Pounds per Acre	Yield of Dry Beans in Bushels per Acre													
		Brookston Soil								Selkirk Soil		Wauseon Soil			
		Mellinger Farm		McSweyn Farm		Bauer Farm				Hunter Farm		Banghart Farm			
		B.C.*	P.U.**	B.C.	B.C.D. ***	B.C.	P.U.	B.C.D.	P.U.D.†	B.C.	B.C.D.	B.C.	P.U.	B.C. S.D.††	P.U. S.D.
No fertilizer†††	——	9.4	——	5.0	——	15.3	——	——	——	8.8	9.5	6.6	——	——	——
0–16–0	400	10.0	10.5	5.9	5.7	17.9	18.7	16.6	18.3	9.6	10.9	9.5	8.3	9.7	7.6
0–16–8	400	12.6	12.5	7.7	4.9	15.9	19.0	17.4	19.0	11.3	11.0	10.1	9.7	8.1	9.0
0–16–16	200	——	——	——	——	——	——	——	——	13.7	13.0	——	——	——	——
0–16–16	400	——	——	——	——	——	——	——	——	10.0	11.7	——	——	——	——
0–16–16	600	——	——	——	——	——	——	——	——	11.0	17.3	——	——	——	——
4–16–0	400	——	——	——	——	——	——	——	——	11.3	14.7	——	——	——	——
4– 8–4	400	——	——	8.2	6.3	——	——	——	——	9.3	——	——	——	——	——
4–12–4	400	——	——	7.0	5.1	——	——	——	——	8.0	10.7	——	——	——	——
4–16–4	200	——	——	——	——	——	——	——	——	12.3	13.0	——	——	——	——
4–16–4	400	——	——	7.0	4.6	——	——	——	——	12.3	10.7	——	——	——	——
4–16–4	600	——	——	——	——	——	——	——	——	13.3	17.0	——	——	——	——
4–16–8	200	11.3	11.9	——	——	18.6	16.2	16.7	18.1	——	——	——	——	——	——
4–16–8	400	13.3	13.6	9.6	10.2	15.6	18.5	16.2	16.2	11.7	12.7	——	——	——	——

*B.C. —Fertilizer applied broadcast.
**P.U. —Fertilizer plowed under.
***B.C.D.—Regular broadcast application plus 50 pounds 2–12–6 with seed.
†P.U.D.—Regular plowed-under application plus 50 pounds 2–12–6 with seed.
††S.D. —Side dressed with 100 pounds 4–16–8.
†††The yields from the unfertilized areas are averages from several systematically arranged plats.

Table 12. The effect of fertilizers on the yield of beans on nine fields in 1931.

Fertilizer	Pounds per Acre	Yield of Dry Beans in Bushels per Acre																				
		Brookston Soil				Miami Soil					Wauseon Soil						Selkirk Soil				Hillsdale Soil
		Mellinger Farm		Bauer Farm		Marr Farm		Bosworth Farm		Clark Farm	Bauer Farm				Banghart Farm		Hunter Farm				Brownell Farm
		B.C.*	P.U.**	B.C.	B.C.D.***	B.C.	P.U.	B.C.	P.U.	B.C.	B.C.	P.U.	B.C.D.	P.U.D.†	B.C.	P.U.	B.C.	P.U.	B.C.D.	P.U.D.	B.C.
No fertilizer††	—	7.7	—	24.9	—	7.8	—	4.8	—	4.7	25.2	—	—	—	13.2	—	12.9	—	—	—	5.5
0–12–0	400	—	—	24.3	24.4	—	—	—	—	7.1	—	—	—	—	—	—	—	—	—	—	4.6
0–16–0	400	8.1	9.2	27.3	26.4	10.6	10.8	3.9	5.9	6.6	32.5	36.3	33.8	32.2	14.0	16.7	16.4	15.1	19.7	10.1	5.8
0–16–4	400	—	—	28.2	24.9	—	—	—	—	5.2	—	—	—	—	—	—	—	—	—	—	5.6
0–16–8	400	9.6	8.3	25.6	26.7	7.7	22.7	5.5	4.4	2.4	34.1	36.1	33.1	25.8	12.1	14.1	10.0	12.4	10.2	21.6	5.0
2–16–8	400	—	—	23.1	23.2	—	—	—	—	2.3	—	—	—	—	—	—	—	—	—	—	5.2
4–16–8	200	9.2	10.9	—	—	9.7	5.5	3.7	6.5	—	30.5	36.4	27.3	29.9	14.9	11.8	22.7	25.7	24.4	19.3	—
4–16–8	400	10.5	9.5	21.6	26.0	9.9	9.8	4.0	6.2	6.0	33.6	35.3	30.9	34.0	16.4	16.4	9.4	11.1	11.6	11.4	4.9
4– 8–4	400	—	—	21.3	22.1	—	—	—	—	3.9	—	—	—	—	—	—	—	—	—	—	4.5
4– 8–8	400	—	—	25.0	23.5	—	—	—	—	2.9	—	—	—	—	—	—	—	—	—	—	3.7
4–12–8	400	—	—	—	—	—	—	—	—	0.9	—	—	—	—	—	—	—	—	—	—	6.1
4–12–4	400	—	—	22.2	24.5	—	—	—	—	4.1	—	—	—	—	—	—	—	—	—	—	2.9
4–16–4	250	—	—	28.3	27.7	—	—	—	—	4.4	—	—	—	—	—	—	—	—	—	—	5.2

*B.C. —Fertilizer applied broadcast.

**P.U. —Fertilizer plowed under.

***B.C.D.—Regular broadcast application plus 50 pounds 2–12–6 with seed, except in the case of the Hunter farm where 2–16–2 replaced the 2–12–6.

†P.U.D.—Regular plowed-under application plus 50 pounds 2–12–6 with seed except in the case of the Hunter farm where 2–16–2 replaced the 2–12–6.

††The yields from the unfertilized areas are averages from several systematically arranged plats.

Table 13. The effect of fertilizers on the stand of beans on six fields in 1931.

Fertilizer	Pounds per Acre	Number of Plants per 2 Rods of Row																									
		Brookston Soil							Wauseon Soil						Miami Soil						Selkirk Soil						
		Mellinger Farm				M. Bauer Farm			A. Bauer Farm						Marr Farm				Clark Farm		Hunter Farm						
		CK.*	B.C.**	CK.	P.U.***	CK.	B.C.	B.C.D.†	CK.	B.C.	B.C.D.	CK.	P.U.	P.U.D.††	CK.	B.C.	CK.	P.U.	CK.	B.C.	CK.	B.C.	B.C.D.	CK.	P.U.	P.U.D.
0–16–0	400	143	143	156	123	172	153	127	141	112	107	126	146	96	95	115	151	117	66	80	68	70	59	66	67	58
0–16–8	400	140	140	144	137	169	163	153	160	127	117	152	102	84	135	99	122	133	166	133	62	47	45	57	78	57
4–16–8	400	141	142	150	141	130	147	141	153	110	114	138	113	104	149	151	141	139	122	140	75	57	42	66	59	48
4–16–8	200	141	150	133	137	—	—	—	176	128	124	136	135	111	130	133	142	138	—	—	78	62	44	72	70	51
0–16–4	400	—	—	—	—	177	177	141	—	—	—	—	—	—	—	—	—	—	141	62	—	—	—	—	—	—
4–16–4	400	—	—	—	—	149	155	133	—	—	—	—	—	—	—	—	—	—	116	73	—	—	—	—	—	—
4–12–4	400	—	—	—	—	164	155	158	—	—	—	—	—	—	—	—	—	—	138	75	—	—	—	—	—	—
4– 8–4	400	—	—	—	—	163	145	159	—	—	—	—	—	—	—	—	—	—	109	112	—	—	—	—	—	—
4– 8–8	400	—	—	—	—	194	174	149	—	—	—	—	—	—	—	—	—	—	94	112	—	—	—	—	—	—
4–12–8	400	—	—	—	—	169	161	155	—	—	—	—	—	—	—	—	—	—	106	115	—	—	—	—	—	—
2–16–8	400	—	—	—	—	172	154	158	—	—	—	—	—	—	—	—	—	—	140	140	—	—	—	—	—	—

*CK. —Stand on an adjoining unfertilized plat.
**B.C. —Fertilizer applied broadcast.
***P.U. —Fertilizer plowed under.
†B.C.D.—Regular broadcast application plus 50 pounds 2–16–6 with seed except in the case of the Hunter farm where 2–16–2 replaced the 2–12–6.
††P.U.D.—Regular plowed-under application plus 50 pounds 2–12–6 with seed, except in the case of the Hunter farm where 2–16–2 replaced the 2–12–6.

Table 14. The effect of fertilizers on the yield of beans on seven fields in 1932.

Fertilizer	Pounds per Acre	Yield of Dry Beans in Bushels per Acre																
		Brookston Soil							Miami Soil							Hillsdale Soil		
		Allen Farm			Montey Farm		Trieber Farm		Bosworth Farm			Raubinger Farm		Nourse Farm		Pierson Farm		
		B.C. *	P.U. **	CK. ***	B.C.	CK.	B.C.	CK.	B.C.	P.U.	CK.	B.C.	CK.	B.C.	CK.	B.C.	CK.	
0– 0–4	200	26.9	25.7	25.3	27.5	24.1	26.9	26.9	20.8	24.7	25.6	13.3	12.4	18.3	14.4	27.0	25.5	
0–16–0	100	28.0	28.5	29.0	25.0	24.9	25.6	27.6	28.2	23.4	21.0	16.5	12.4	13.8	17.8	26.4	32.9	
0–16–0	200	26.8	25.9	26.9	28.6	24.0	26.0	23.4	19.3	23.0	18.8	16.8	14.0	17.5	16.8	23.2	27.7	
0–16–4	100	29.5	27.1	23.2	27.3	23.4	26.2	28.7	24.4	22.4	22.6	10.9	10.8	17.1	18.6	24.7	24.4	
0–16–4	200	23.7	14.6	27.6	29.1	24.5	25.9	23.9	24.7	28.0	25.6	15.7	13.6	18.0	20.4	14.4	26.9	
2–16–0	100	26.6	22.1	23.4	30.7	24.2	27.3	26.0	23.4	21.1	23.0	18.0	14.4	19.0	17.0	25.1	26.3	
2–16–0	200	16.5	21.2	20.0	31.1	27.5	25.2	27.1	21.0	23.3	22.5	15.3	12.6	17.1	18.6	18.4	27.7	
2– 0–0	200	15.0	10.5	15.0	28.7	23.8	26.4	28.7	20.7	25.3	23.8	16.7	15.5	17.0	17.8	26.7	23.1	
2–16–4	100	28.4	25.1	24.2	31.7	24.9	26.2	25.8	20.7	26.9	25.9	16.7	13.5	14.8	17.4	22.9	28.6	
2–16–4	200	17.3	23.8	20.9	25.6	19.5	29.2	25.1	18.6	21.8	18.2	15.9	13.2	17.8	17.1	15.8	17.3	
4–16–8	200	29.8	30.0	27.3	29.2	27.3	28.5	30.4	25.5	26.2	24.5	14.6	15.7	15.3	17.8	30.3	31.3	

*B.C.—Fertilizer applied broadcast.

**P.U.—Fertilizer plowed under.

***CK.—Yield of an adjoining unfertilized plat.

Table 15. The effect of fertilizers on the stand of beans on seven fields in 1932.

Fertilizer	Pounds per Acre	Number of Plants per Rod of Row																
		Brookston Soil							Miami Soil							Hillsdale Soil		
		Allen Farm			Montey Farm		Trieber Farm		Bosworth Farm			Raubinger Farm		Nourse Farm		Pierson Farm		
		CK. *	B.C. **	P.U. ***	CK.	B.C.	CK.	B.C.	CK.	B.C.	P.U.	CK.	B.C.	CK.	B.C.	CK.	B.C.	
0– 0–4	200	79	84	84	46	50	58	51	48	53	38	43	46	62	68	37	32	
0–16–0	100	74	81	84	47	54	53	56	49	49	44	44	45	65	51	38	35	
0–16–0	200	80	85	85	43	52	64	57	49	59	39	42	46	62	58	38	35	
0–16–4	100	87	81	79	39	53	51	50	47	53	37	46	46	68	60	39	36	
0–16–4	200	75	85	83	37	51	63	57	43	53	37	42	41	64	68	36	28	
2–16–0	100	79	86	81	42	54	48	52	50	49	42	45	43	56	65	32	32	
2–16–0	200	79	88	78	51	49	50	51	44	50	34	47	44	64	70	38	33	
2– 0–0	200	75	86	87	38	51	53	53	46	53	39	43	48	58	67	50	51	
2–16–4	100	77	86	85	49	56	56	53	51	50	46	48	48	63	62	33	38	
2–16–4	200	78	84	86	47	49	54	55	41	47	39	44	48	62	64	26	31	
4–16–8	200	78	79	84	46	51	59	58	55	48	36	55	38	58	56	37	35	

*CK.—Stand of an adjoining unfertilized plat.

**B.C.—Fertilizer applied broadcast.

***P.U.—Fertilizer plowed under.

Table 16. The effect of fertilizers on the yield of beans on eight fields in 1933.

Fertilizer	Pounds per Acre	Yield of Dry Beans in Bushels per Acre									
		Brookston Soil				Kawkawlin Soil		Miami Soil			Hillsdale Soil
		Allen Farm	Montey Farm	Trieber Farm		Schwab Farm	Nourse Farm	Raubinger Farm		Chant Farm	Pierson Farm
		B.C.*	B.C.	B.C.	P.U.**	B.C.	B.C.	B.C.	P.U.	B.C.	B.C.
No fertilizer	—	14.9	23.6	8.5	12.9	—	8.6	14.8	10.8	13.5	13.8
2 -2-0	200	12.0	22.2	10.9	15.1	—	11.6	12.5	10.5	11.7	16.1
2-16-0	200	15.2	23.5	9.8	10.5	14.9	10.1	12.6	11.3	11.1	16.9
No fertilizer	—	14.0	25.2	15.1	12.4	—	9.8	9.7	10.5	8.0	15.6
2-16-4	200	14.6	23.9	11.2	11.9	16.1	9.7	13.6	9.9	17.8	15.0
0-16-4	200	12.8	23.2	11.3	10.2	13.8	8.3	13.0	9.6	19.7	15.1
No fertilizer	—	12.9	22.2	13.3	11.8	15.6	10.4	10.9	12.0	9.2	14.8
0- 0-4	200	11.1	25.2	11.6	12.8	14.8	12.0	12.6	11.3	11.2	15.9
0-16-0	200	13.1	25.2	11.1	11.4	13.3	22.1	13.6	9.5	12.6	15.1
No fertilizer	—	11.1	20.6	12.1	15.6	15.2	12.1	15.4	11.2	16.3	15.8
2-16-0	100	11.3	22.8	11.6	11.0	12.8	10.7	14.9	10.0	21.7	13.6
2-16-4	100	12.1	20.5	15.2	13.3	10.6	10.8	12.7	10.8	21.9	13.4
No fertilizer	—	12.3	21.0	14.1	14.6	18.0	11.3	10.9	10.6	22.7	13.1
0-16-4	100	15.3	26.7	10.0	11.6	17.8	10.1	13.0	13.5	10.1	13.2
0-16-0	100	17.1	23.9	9.1	9.9	18.3	12.4	10.5	12.1	10.5	16.5
No fertilizer	—	12.8	26.5	9.2	12.3	16.0	15.1	12.0	9.1	12.5	16.5
4-16-8	200	13.6	26.2	11.9	13.2	17.2	18.6	13.9	9.0	15.8	19.2

*B.C.—Fertilizer applied broadcast.
**P.U.—Fertilizer plowed under.

Table 17. The effect of fertilizers on the stand of beans in 1933 on four soils.

Fertilizer	Pounds per Acre	Number of Plants per Rod of Row									
		Brookston Soil				Kawkawlin Soil		Miami Soil			Hillsdale Soil
		Allen Farm	Montey Farm	Trieber Farm		Schwab Farm	Nourse Farm	Raubinger Farm		Chant Farm	Pierson Farm
		B.C.*	B.C.	B.C.	P.U.**	B.C.	B.C.	B.C.	P.U.	B.C.	B.C.
No fertilizer	—	86	74	49	43	50	63	30	34	93	39
2– 0–0	200	83	81	35	39	50	65	29	33	95	45
2–16–0	200	89	82	38	41	51	66	26	37	96	34
No fertilizer	—	84	79	33	40	48	66	37	36	95	28
2–16–4	200	85	80	39	37	52	68	33	33	89	36
0–16–4	200	89	81	36	37	53	70	35	34	88	38
No fertilizer	—	86	80	37	41	49	63	32	36	95	39
0– 0–4	200	87	75	37	46	51	69	37	33	94	39
0–16–0	200	94	82	37	40	58	63	37	37	93	29
No fertilizer	—	87	82	39	39	55	65	32	34	96	36
2–16–0	100	82	82	43	41	56	64	37	31	98	38
2–16–4	100	88	79	36	34	57	69	29	35	92	38
No fertilizer	—	85	81	39	40	50	68	30	32	92	37
0–16–4	100	78	79	34	43	50	69	37	39	88	36
0–16–0	100	87	82	37	37	47	65	36	34	93	42
No fertilizer	—	86	78	48	48	50	64	34	36	89	42
4–16–8	200	86	78	37	39	49	68	33	33	85	33

*B.C.—Fertilizer applied broadcast.

**P.U.—Fertilizer plowed under.

Table 18. The effect of fertilizer placement and rate of application on the yield and stand of beans on four fields in 1934.

Treatment*	Pounds per Acre	Yield—Yield of Dry Beans in Bushels per Acre Stand—Number of Plants per Rod of Row							
		Brookston Silt Loam				Conover Silt Loam		Miami Loam	
		Trieber Farm		Horst Farm		Buckholz Farm		Dilman Farm	
		Yield	Stand	Yield	Stand	Yield	Stand	Yield	Stand
Both sides below	300	27.0	43	24.5	57	22.1	61	19.1	46
One side below—¼ contact	300	26.2	45	24.4	57	23.0	60	19.2	52
One side below	300	25.5	42	24.7	49	——	53	17.8	39
No fertilizer	——	21.5	43	23.9	56	20.4	52	14.3	51
Contact	75	24.1	40	25.6	47	20.7	50	15.0	30
Both sides level	300	——	—	24.7	55	23.2	55	——	—
Under seed	300	27.4	46	25.2	57	24.7	51	17.7	49
Both sides below	200	26.0	43	24.9	59	24.4	57	17.7	43
Both sides below	400	27.2	46	24.1	58	23.7	56	19.1	38
Both sides below	600	28.4	45	24.9	54	25.8	54	20.7	49

*4–16–4 fertilizer was used throughout the experiment. All yields and stand counts are averages of four plats. Fertilizer bands were 1½" to the side and 1½" below seed level.

Table 19. The effect of fertilizer analysis and placement on the yield and stand of beans on three farms in 1934.

Treatment*	Pounds per Acre	Yield—Yield of Dry Beans in Bushels per Acre Stand—Plants per Rod of Row					
		Kawkawlin Loam		Wisner Silt Loam		Miami Silt Loam	
		Fischer Farm		Heckroth Farm		Mahaffey Farm	
		Yield	Stand	Yield	Stand	Yield	Stand
0–16–0 Both sides below	300	21.3	71	14.9	44	19.6	62
0–16–0 One side below—One-fourth contact	300	21.2	61	14.7	45	20.7	56
0–16–0 Both sides below	600	23.1	59	16.7	45	22.1	60
No fertilizer	—	19.9	66	12.9	45	16.4	56
0–16–8 Both sides below	300	25.1	63	20.9	45	23.8	62
0–16–8 One side below—One-fourth contact	300	24.5	59	16.9	33	22.8	48
0–16–8 Both sides below	600	27.9	57	21.6	39	26.0	55
4–16–8 Both sides below	300	25.5	53	18.8	38	23.9	59
4–16–8 One side below—One-fourth contact	300	23.4	54	16.2	30	23.1	51
4–16–8 Both sides below	600	26.9	62	—	31	24.3	53

*In the side placement the bands were 1½" to the side of the seed and 1½" below the seed level. All yields and stand counts are averages from duplicate plats.

Table 20. The effect of fertilizer placement and rates of application on the yield and stand of beans on three fields in 1935.

Treatment*	Pounds per Acre	Yield—Yield of Dry Beans in Bushels per Acre Stand—Plants per 400 Feet of Row					
		Napanee Silt Loam		Brookston Silt Loam		Miami Silt Loam	
		Warren Farm		Trieber Farm		Reagh Farm	
		Yield	Stand	Yield	Stand	Yield	Stand
Both sides below	300	24.7	1661	30.8	1476	25.5	1466
One side below	300	23.0	1599	31.5	1284	24.3	1486
One side below—One-fourth contact	300	23.8	1107	30.8	1037	24.6	1111
No fertilizer	—	19.8	1551	28.7	1138	21.9	1410
Contact	75	21.0	926	29.4	1025	22.6	1091
Both sides level	300	24.8	1456	30.6	1212	24.5	1539
Under seed	300	24.1	1544	31.9	1318	26.2	1418
Grain drill	300	23.5	1092	31.2	1366	25.0	1729
Both sides below	200	22.3	1520	29.7	1224	24.9	1380
Both sides below	400	23.5	1464	31.1	1182	27.7	1440
Both sides below	600	24.9	1444	32.5	1194	27.5	1400
General average	Placements.	23.2	1367	30.7	1232	24.3	1406
	Rates	22.4	—	30.7	1184	25.5	1414
S. E. M.**	Placements.	.599 (2.6%)	80.3 (5.9%)	.697 (2.3%)	40.34 (3.3%)	.777 (3.2%)	73.49 (5.2%)
	Rates	.699 (3.1%)	—	.566 (1.8%)	49.9 (4.2%)	1.198 (4.7%)	89.16 (6.3%)
Difference required for significance	Placements.	1.8	236	2.1	119	2.3	216
	Rates	2.2	—	1.8	159	3.8	285
F	Placements.	7.70	12.26	1.58	15.59	3.48	8.42
	Rates	13.35	—	6.16	0.51	2.14	.04
F (5% point)	Placements.	2.50	2.50	2.50	2.50	2.50	2.50
	Rates	3.86	—	3.86	3.86	3.86	3.86
1% point	Placements.	3.66	3.66	3.66	3.66	3.66	3.66
	Rates	6.99	—	6.99	6.99	6.99	6.99

*4–16–4 fertilizer was used throughout the experiment. In the side placements the bands were 1½″ from the seed. In the below level placements the bands were 1¾″ below the seed. All yields and stand counts are averages from four randomized plats.

**Standard error of the mean.

Table 21. The effect of fertilizer placement and rate of application on the yield and stand of beans on two fields in 1936.

Treatment*	Pounds per Acre	Yield—Yield of Dry Beans in Bushels per Acre Stand—Plants per 400 Feet of Row			
		Napanee Silt Loam		Miami Silt Loam	
		Stoutenburg Farm		Gegler Farm	
		Yield	Stand	Yield	Stand
Both sides level	300	14.1	1139	7.5	1083
Both sides below	300	14.9	1088	8.9	1037
Under seed	300	14.6	1000	8.0	1219
One side	300	15.5	1067	9.3	1134
Grain drill	300	13.4	1004	7.6	873
Contact and one side	300	13.7	770	8.1	835
Contact	75	13.6	862	8.9	1004
No fertilizer	—	14.6	1080	7.8	1077
Both sides below	200	9.7	969	—	—
Both sides below	400	10.8	977	—	—
Both sides below	600	11.5	912	—	—
No fertilizer	—	8.3	873	—	—
General average	Placements.	14.29	1001	8.26	1033
	Rates.	10.10	933	—	—
S. E. M.	Placements.	0.39 (2.73%)	38.50(3.85%)	0.41 (4.96%)	30.72(2.97%)
	Rates.	0.22 (2.22%)	30.64(3.28%)	—	—
Difference required for significance	Placements.	1.12	113.6	1.19	89.0
	Rates.	0.69	101.4	—	—
F	Placements.	3.45	10.60	2.74	17.42
	Rates.	39.36	2.62	—	—
5% point	Placements.	2.37	2.37	2.37	2.37
	Rates.	3.49	3.49	—	—

*4–16–4 fertilizer was used throughout the experiment. In the side placements the bands were 1½″ from the seed. In the below level placements the bands were 1¾″ below the seed. All yields and stand counts are averages from five randomized plats.

Table 22. The effect of fertilizer placement and rate of application on the yield and stand of beans on three fields in 1937.

Treatment*	Pounds per Acre	Averages of Five Randomized Plats Yield—Bushels per Acre Stand—Plants per 300 Feet per Row					
		Brookston Silt Loam		Napanee Silt Loam		Miami Silt Loam	
		Horst Farm**		Stoutenburg Farm**		Reagh Farm	
		Yield	Stand	Yield	Stand	Yield	Stand
Both sides level	300	35.3	1044	20.9	577	23.01	591
Both sides below	300	32.0	1033	22.4	584	26.3	571
Under seed	300	34.8	1012	21.6	580	24.5	555
One side	300	32.0	1058	21.3	563	24.1	610
Grain drill	300	35.5	945	18.0	431	22.7	526
Contact and one side	300	33.1	1038	19.2	524	21.6	491
Contact	75	32.6	959	16.2	446	21.1	481
No fertilizer	—	30.0	1086	19.3	557	20.7	575
Both sides below	200	28.2	729	21.6	618	26.0	622
Both sides below	400	32.2	706	23.5	620	26.3	597
Both sides below	600	35.2	696	23.0	571	28.2	614
No fertilizer	—	26.9	719	19.6	563	21.7	517
General average	Placements	33.17	1022	19.86	532.5	23.01	549.9
	Rates	30.62	712.4	21.93	593	25.54	587.7
S. E. M	Placements	.94 (2.84%)	22.27(2.18%)	.83 (4.18%)	22.81 (4.28%)	.67 (2.92%)	23.17 (5.15%)
	Rates	.86 (2.82%)	28.13(3.95%)	.90 (4.12%)	29.70 (5.01%)	.74 (2.91%)	45.29 (3.45%)
Difference required for significance	Placements	2.77	65.5	2.44	58.6	1.95	67.2
	Rates	2.66	86.7	2.79	91.7	2.29	62.4
F	Placements	4.09	4.68	4.98	9.13	8.13	4.07
	Rates	19.45	3.80	3.81	1.02	13.43	5.60
F (5% point)	Placements	2.50	2.50	2.50	2.37	2.37	2.37
	Rates	3.49	8.74	3.49	3.49	3.49	3.49

*4–16–4 fertilizer was used throughout the experiment. Fertilizer bands 1½″ to the side and 1¾″ below seed level.

**Yield data for placement plats on Horst farm and Stoutenburg farm based on four replications. Stand count data on Horst farm based on four replications. Stand counts on rates of application plats on Horst farm based on 200 feet of row.

Table 23. The effect of fertilizers on the yield of beans on four fields in 1935.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre			
		Brookston Silt Loam	Napanee Silt Loam	Miami Silt Loam	
		Trieber Farm	Warren Farm	L. Reagh Farm	J. Reagh Farm
0–16–0	300	29.4	20.9	25.8	27.1
0–16–8	300	29.4	23.9	25.1	27.8
4–16–8	300	29.0	24.6	26.3	28.2
4–16–4	300	30.8	——	25.5	26.3
2–12–6	300	31.1	22.6	26.8	26.9
No fertilizer	——	28.7	19.8	21.9	22.5
General average		29.9	23.2	25.2	
S. E. M		.645 (2.2%)	.603 (2.7%)	.803 (3.2%)	
Difference required for significance		1.9	1.9	2.4	
F		1.79	14.64	4.79	
F (5% point)		2.90	3.26	2.90	

*The tertilizer was applied in bands on both sides of the seed, 1½" to the side of the seed and 1¾" below the seed level. The yields are averages from five plats.

Table 24. The effect of fertilizers on the yield of beans on the Stoutenburg farm in 1936.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre
0–16–0	300	14.3
0–16–8	300	15.3
4–16–8	300	17.3
No fertilizer	——	14.4
General average		15.3
S. E. M		0.83 (5.45%)
Difference required for significance		2.67
F		2.81
F5% point		3.86

*The fertilizer was applied in bands on both sides of the seed, 1½" to the side and 1¾" below the seed level. The yields are averages from four randomized plats.

Table 25. The effect of fertilizer on the yield of beans on three fields in 1937.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre**		
		Brookston Silt Loam	Napanee Silt Loam	Miami Silt Loam
		Horst Farm	Stoutenburg Farm	Reagh Farm
0–16–0	300	29.9	20.0	24.5
0–16–8	300	30.9	16.1	27.2
4–16–8	300	37.5	18.1	28.2
4–16–4	300	31.1	16.3	27.9
No fertilizer	—	28.2	14.3	24.4
General average		31.5	17.0	26.4
S. E. M		1.48 (4.69%)	1.06 (6.25%)	1.05 (3.98%)
Difference required for significance		4.43	3.18	3.20
F		7.43	4.19	2.96
F (5% point)		3.01	3.01	3.26

*The fertilizer was applied in bands on both sides of the seed, 1½″ to the side of the seed and 1¾″ below the seed level.

**The yields are averages from five randomized plats.

Table 26. The effect of fertilizer on the yield of beans on the Ferden Farm, 1934-1937.

Fertilizer*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre			
		1934	1935	1936	1937
0–16–0	150	25.3	35.1	29.1	31.2
4–16–0	150	26.7	36.8	28.8	31.5
0–16–8	150	27.1	35.4	28.8	33.3
4–16–8	150	27.8	38.4	26.5	34.3
4–16–4	150	27.6	37.5	29.7	32.9
4–12–4	150	28.4	35.6	28.0	33.2
No fertilizer	—	23.6	34.8	25.0	26.7

*In 1934, 1935, and 1936 the fertilizer was applied in bands on both sides of the seed, 1½″ to the side and 1½″ below the seed level. In 1937 it was applied in a single band 1½″ to the side and level with the seed. The yields as affected by treatment are averages from three plats while the yields from the unfertilized areas are averages from four plats.

Table 27. The effect of fertilizer, manure, and sweet clover green manure on the yields of beans on two fields in 1935.

Treatment*	Pounds per Acre	Yield of Dry Beans in Bushels per Acre	
		Brookston Silt Loam	Miami Silt Loam
		Horst Farm	Dilman Farm
0–16–0	150	21.1	23.2
0–16–0 Stable manure	150 20,000	17.9	27.8
0–16–0 Stable manure Sweet clover green manure	150 20,000 —	21.2	31.7
0–16–0 Sweet clover green manure	150 —	23.5	32.7
4–16–4	150	20.7	30.9
4–16–4 Stable manure	150 20,000	18.8	32.0
4–16–4 Stable manure Sweet clover green manure	150 20,000 —	22.6	31.3
4–16–4 Sweet clover green manure	150 —	21.9	33.4
No fertilizer	—	20.0	23.8
No fertilizer Stable manure	— 20,000	17.7	25.3
No fertilizer Stable manure Sweet clover green manure	— 20,000 —	22.3	30.3
No fertilizer Sweet clover green manure	— —	22.8	31.0

*The fertilizer was applied in bands on both sides of the seed, 1½" to the side of the seed and 1¾" below the seed level. The yields from the plats which received commercial fertilizer are averages from duplicated plats on the Horst farm and quadruplicated plats on the Dilman farm. The plats which did not receive commercial fertilizer were not replicated on the Horst farm and were duplicated on the Dilman farm.

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