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Nitrogen Fertilization of Soybeans

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INTRODUCTION

The soybean is a legume and differs from non-legumenous farm crops in that it uses, in addition to nitrogen from the soil, atmospheric nitrogen made available by root nodule bacteria living in symbiosis with it. This symbiotic relationship makes it possible for the soybean to grow well in soils that are low in available nitrogen if the availability of mineral nutrients or physical properties are not limiting. Furthermore, this relationship apparently limits the response of soybeans to nitrogen fertilizers. The energy requirement of the nitrogen fixing bacteria, however, is met by the host plant through the symbiotic relationship. Therefore, the possibility exists that these bacteria are competing with the host plant for energy which, in the absence of the symbiotic relationship, could be used in seed production. If this is true, then it might be possible to get a direct response to nitrogen fertilization by soybeans in the absence of symbiosis.

Even though soybean yields appear to be generally independent of the level of nitrogen in the soil, the soybean has a high nitrogen requirement. A 40 bushel crop of grain with 6.5 percent nitrogen would contain 156 pounds of this element. This is considerably more nitrogen than most Missouri soils can deliver by mineralization of organic matter.

REVIEW OF LITERATURE

It has been generally accepted for many years that the presence of large amounts of mineral nitrogen in a soil in which a legume is growing would limit nodulation and thus nitrogen fixation. In recent years, direct evidence of the effect of the mineral nitrogen supply on nitrogen fixation has been obtained by using N^{15} tagged nitrogen so as to trace the origin of nitrogen being used by the plant. Norman and Krampitz (8) first showed the value of studies of this kind. Their results for soybeans indicated that large amounts of mineral nitrogen could reduce nitrogen fixation to the extent that it amounted to no more than 30 percent of the total plant consumption. Later Allos and Barthalomew (1), in a similar study, showed that small amounts of inorganic nitrogen would stimulate the nitrogen fixation process apparently through increased growth of the plants. Both of these groups of workers suggested that soybeans could not attain maximum yields if they were feeding on symbiotically fixed nitrogen alone. Furthermore, the combined results of these two investigations indicate that maximum nitrogen fixation would occur for soybeans when about 20 percent of the nitrogen requirement of the plant is being supplied by mineral nitrogen.

In a study at Iowa where inoculated soybeans were compared with those which had not been inoculated but had been treated with urea nitrogen, Nor-

man (7) found that the yield of inoculated beans was intermediate between that for uninoculated ones fertilized with 94 pounds of nitrogen and uninoculated ones fertilized with 157 pounds of nitrogen. The nitrogen treatments as well as the inoculation resulted in the production of seed which had a higher nitrogen content and a lower oil content than that from uninoculated beans which were not fertilized with nitrogen.

Several other workers have reported on the response by soybeans to nitrogen fertilization of field soils. Mederski, Wilson and Volk (6) reported on several different field tests which involved a total of seven different growing seasons. These studies conducted in Ohio involved the use of ammonium sulfate at several rates up to 200 pounds of nitrogen per acre. An increase in yield of from 1 to 5 bushels per acre attributed to the fertilizer was observed each season except 1949 which was a year in which very high yields were obtained with no treatment. In comparing plow-down with side-dress applications (at flowering) they found that the side-dress applications were superior. The work of Lathwell and Evans (4) provides an explanation for this better response from side-dress treatment at flowering. This work shows that soybean plants must take in nitrogen during the period from bloom to maturity for maximum yield. The results indicate that neither the number of blooms produced nor the number of seeds per pod were influenced by nitrogen treatment, but that the number of pods retained was dependent upon adequate nitrogen during the bloom period. The higher yields were attributed to a higher number of pods being retained.

Lyons and Early (5) working in Illinois conducted a study of the effect of fertilization with ammonium nitrate on the nodulation, the seed yield, and the nitrogen and oil contents of the seed of soybeans. A marked response to the treatments which ranged upward to 800 pounds of fertilizer per acre was observed in 1947 which was a hot dry growing season. Plow-down and early side-dress applications gave more consistent increases than did a later side-dress application at flowering. Nodulation was decreased 80 to 90 percent, seed yield was increased by about 10 bushels per acre, and composition of the seed was significantly changed to a higher nitrogen and a lower oil content. In 1949, a season of adequate rainfall and moderate temperature, the nitrogen treatments did not affect yield or the composition of the seed with regard to nitrogen and oil. The degree of nodulation in this season was only slightly depressed by the treatments.

In general, one must conclude that these studies involving nitrogen fertilization of soybeans indicate that there may be seasons in which the soybeans will show a significant positive yield response to nitrogen fertilizaton. These responses are not striking, however, and are not clearly defined with regard to the interaction between nitrogen and the various weather and soil conditions which also may be involved. Two recent comprehensive reviews of soybean literature, one on mineral nutrition by Ohlrogge (9) and one on physiology by Howell (3) call attention to the gaps in our understanding of the nitrogen nutrition of the soybean.

EXPERIMENTAL PROCEDURE

Soybeans were grown at the Midwest Claypan Experiment Farm, McCredie, Missouri, in small field plots of a Mexico Silt loam soil which had been previously cropped to corn and soybeans. The following fertilizers were plowed down as a basic treatment for the field at the initiation of the study: 4 tons of limestone per acre, 1500 pounds of rock phosphate per acre, 90 pounds of available P_2O_5 per acre, and 60 pounds of available K_2O per acre. Average soil test results* for samples collected from the field in November following harvest of the first crop are as follows: See page 23.

Fertilizer nitrogen was applied to the individual plots as the parameter under study. The effect of various nitrogen treatments on the yield and quality of soybeans was studied during three growing seasons which were characterized by significantly different weather conditions. The plots were relocated the third season in a different area (within the same field) so as to again provide a uniform nitrogen level in which to study the influence of the various nitrogen treatments apart from any residual effects from the previous treatments.

Soybean Varieties

Two varieties of soybeans were included in the study, a nodulating and a non-nodulating variety. The Clark variety which readily nodulates in fertile well inoculated soils was selected because of its adaptability to the area and its wide acceptance by Missouri soybean growers. A special variety that does not nodulate even in the presence of the proper symbiotic bacteria was also studied. This non-nodulating variety was supplied by Dr. L. F. Williams of the Field Crops Department. It was selected in his breeding studies from the same parental background as the Clark variety.

These two varieties of soybeans are characterized by an indeterminate type of growth. The total growth is controlled by the growing season and by other environmental factors rather than by genetic limitations. Any beneficial stimulation of nitrogen fertilizers would be expected to result from more rapid growth of the plants accompanied by greater seed production.

The non-nodulating soybean was included in order to test the theory that soybean seed production processes may be in competition for energy with the nitrogen fixing bacteria which are enjoying a symbiotic relationship with the host plant. If this is true, then a non-nodulating soybean variety treated with nitrogen fertilizers might be made to produce a higher seed yield than a nodulated sister variety involved in symbiosis.

Plot Design

The experimental plot design was somewhat different for each year of the investigation. The purpose of this was to study several small plot sizes and arrangements for their effect on the variance of the yield data.

*Methods of analyses described in Missouri Bulletin 734.

For the first two seasons a randomized complete block design was employed with 25 treatments and four replicate blocks. The first year the soybeans were planted in rows spaced 20 inches apart with a test row in the center of the plot and a border row on the boundary between plots. Only the rows in the center of the plot were harvested for yield estimations and these were calculated on the basis of 20 inch row spacings. The second season, the soybeans were planted in rows spaced 40 inches apart and positioned in the center of the plots with no border rows included.

The third season the study was conducted, some of the treatments previously studied were discontinued and the plots were relocated and rearranged to increase the plot width to 80 inches so as to accommodate a 40 inch row spacing but with a border row located on the boundary between plots. The experimental layout was changed to a randomized block-split plot design with four replicate blocks each containing four major plots which were used to test the effects of rate and time of application of the nitrogen materials and three subplots within each of these to test the effect of two different nitrogen carriers vs. a control.

Weather Conditions

The weather conditions for the three seasons during which the study was conducted were markedly different from one another. The monthly rainfall and temperature data recorded at the Midwest Claypan Experiment Farm for these three seasons are reported in Table 1. For the year 1958, moisture was abundant throughout the growing season and the temperature was generally moderate. In 1959, moisture became limiting rather early in the season and the maximum daily temperatures were rather high. Two inches of irrigation water was applied on July 10, 1959, to supplement the limited rainfall. The year 1960 was characterized by adequate moisture in the spring and early summer and again moderate temperatures. Moisture became somewhat limiting in the late summer and

TABLE 1–MONTHLY RAINFALL AND TEMPERATURE DATA RECORDED AT THE MIDWEST CLAYPAN EXPERIMENT FARM FOR THE SOYBEAN GROWING SEASONS OF 1958, 1959, AND 1960

	Year								
	1958			1959			1960		
	In. of	Mean Temp.		In. of	Mean Temp.		In. of	Mean Temp.	
Month	Rain	Max.	Min.	Rain	Max.	Min.	Rain	Max.	Min.
May	3.40	77	53	5.31	78	57	3.01	74	50
June	5.30	82	60	0.03	86	62	3.51	83	61
July	9.23	85	65	3.37	89	63	3.65	85	64
Aug.	2.77	87	64	2.14	91	68	1.30	90	66
Total Rainfall	20.70			10.85			11.47		

early fall, but did not limit to any great extent the yield of the soybeans.

Nitrogen Treatments

The treatment variables under study included different carriers of nitrogen, different times of applying it, and different rates at which it was applied. For the first two years of the study, the nitrogen carriers tested were urea, ammonium nitrate, ammonium sulfate and sodium nitrate. Each carrier was applied at a rate to approximate 60, 120, and 240 pounds of N plowed down per acre and 100 pounds of N per acre as a side-dress application. For the third year, only urea and ammonium nitrate were investigated each being supplied at 50 and 100 pounds of N plowed down per acre and 100 pounds of N per acre as a side-dress application. Each side-dress application was made at three different physiological stages in the development of the plants; immediately before bloom, at full bloom, and at seed set. The before bloom time of side-dress application was discontinued after the first two years of the study. The side-dress applications were made by hand and consisted of dribbling the fertilizer granules in narrow bands on both sides of the row; close to, but not in contact with the growing plants.

Harvesting Procedures

The first year of the study harvesting was accomplished by cutting the test rows of soybeans with a Jeri mower, gathering the soybean plants into bundles with pitch forks, and thrashing them with a plot-sized thrasher. The yield weights were taken in the field at the time of thrashing and at the same time the moisture content of each sample was determined with a moisture meter. The yield results were later converted to a standard 14 percent level of moisture. The second year of the study, the soybeans were cut with pruning shears and then gathered by hand to the thrasher in an attempt to minimize loss of seed in handling. The third year, the soybeans were again cut with a Jeri mower but gathered by hand to the thrasher. Records were obtained in the second and third years by weighing and determining moisture content of the grain in the laboratory. Yields were corrected to a 14 percent moisture level.

Quality Tests

Relative seed weights were obtained by weighing a sample consisting of 100 seeds drawn at random from the harvested lots for each treatment.

Chemical analysis for the total nitrogen and the crude fat contents of the soybean seeds were conducted by the Agricultural Experiment Station Chemical Laboratories. The procedures used were those cited by the Association of Official Agricultural Chemists (2).

The seed weights and chemical analyses were obtained for only one replication (Rep. II) of the plots in the first year of the study but in subsequent years, the results were obtained for all four replications of plots.

RESULTS AND DISCUSSION

Yields

The soybean yields were unusually high in 1958 because of an abundant supply of moisture in the soil throughout the growing season. Nitrogen deficiency symptoms became apparent in the vegetation of the non-nodulating soybeans early in the season. There was some lodging of the Clark soybeans.

The application of fertilizer nitrogen did not result in any significant increases in yield of the well nodulated Clark soybeans, (Table 2). Rather, there

TABLE 2-THE YIELD OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1958

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
			yield in bu/acre		
None	46.5				
Plowdown before planting					
60 lbs N/acre		46.1	47.1	47.9	52.5
120 lbs N/acre		55.1	39.8	46.3	44.5
240 lbs N/acre		35.8	41.2	35.5	30.4
Sidedress 100 lbs N/acre					
at early bloom		43.5	46.5	50.3	46.1
at full bloom		44.8	43.0	47.1	43.8
at small seed		49.4	47.6	46.3	46.7

$L.S.D._{.05} = 7.8$

was a significant yield depression associated with the plow-down treatment of 240 pounds of nitrogen per acre. This was thought to be due largely to salt injury to the young plants resulting from the heavy dosage of fertilizer, although, lodging may also have been a factor. The non-nodulating soybeans did not lodge but these beans did show a yield depression when nitrogen was applied at the 240 lbs. per acre plow-down rate. (Table 3). The depression in yield was observed only for the sodium nitrate and ammonium nitrate carriers, however. These effects are in general agreement with the observation that soybeans are especially sensitive to injury, as seedlings and small plants, by salts of monovalent anions such as chloride and nitrate.

The non-nodulating soybeans which received no supplemental nitrogen treatment yielded approximately 15 bushels per acre less than the Clark soybeans grown in equivalent non-treated plots. A plow-down application of 60 pounds of nitrogen per acre increased the yield of these non-nodulating soybeans by three to five bushels per acre. No additional yield response resulted from plowing down nitrogen at rates higher than 60 pounds per acre.

Side-dress treatment of these non-nodulating soybeans with 100 pounds per acre of nitrogen resulted in higher yields in general than did the plow-down ap-

plications. Of the three times at which side-dress applications were made, that at the full bloom stage which occurred just prior to a four-inch rain resulted in the highest yields.

In general, the highest yields of non-nodulating soybeans receiving supplemental nitrogen were no higher than those for well nodulated Clark soybeans which received no nitrogen treatment.

For the year 1959, the Clark soybeans (Table 4) outyielded the non-nodulating soybeans (Table 5) by less than one bushel per acre suggesting that nitrogen was not as limiting for these non-nodulating soybeans as it was in 1958.

TABLE 3-THE YIELD OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1958

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
			yield in bu/acre		
None	31.3				
Plowdown before planting					
60 lbs N/acre		34.5	36.6	35.5	31.4
120 lbs N/acre		31.8	29.3	32.5	29.4
240 lbs N/acre		37.8	38.1	26.4	28.9
Sidedress 100 lbs N/acre					
at early bloom		39.9	44.5	39.4	31.2
at full bloom		44.3	48.1	45.0	42.6
at small seed		34.6	36.9	41.7	37.0

L.S.D.$_{.05}$ = 7.6

TABLE 4-THE YIELD OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1959

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
			yield in bu/acre		
None	30.2				
Plowdown before planting					
60 lbs N/acre		34.0	30.0	32.0	31.8
120 lbs N/acre		34.2	30.8	30.6	31.6
240 lbs N/acre		32.1	34.2	32.8	33.5
Sidedress 100 lbs N/acre					
at early bloom		31.2	31.0	31.4	30.7
at full bloom		32.3	31.7	29.2	32.0
at small seeds		30.2	30.1	31.0	30.7

No significant differences attributable to treatments.

TABLE 5-THE YIELD OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1959

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
			yield in bu/acre		
None	29.8				
Plowdown before planting					
60 lbs N/acre		31.7	30.4	27.4	29.7
120 lbs N/acre		33.0	35.8	30.3	32.6
240 lbs N/acre		33.6	32.2	33.4	33.0
Sidedress 100 lbs N/acre					
at early bloom		31.3	28.7	27.7	27.4
at full bloom		30.4	26.8	30.3	31.4
at small seed		29.8	30.5	32.3	28.6

No significant differences attributable to treatments.

Furthermore, there were no nitrogen deficiency symptoms apparent in the soybean vegetation during the year. This adequate supply of nitrogen may have resulted, in part, from residual nitrogen of the previous year which became mixed to a certain extent among the small plots as a result of the various operations connected with preparing the seedbed. In addition, the different weather conditions associated with the two growing seasons may have effected different rates of nitrogen mineralization as well as different nitrogen demands by the growing soybeans.

The depression in yields associated with the plowing under of large amounts of nitrate nitrogen which was noted in 1958 did not occur in 1959. The average yields of nitrogen treated plots were just slightly higher than those of control plots, but no statistically significant differences could be detected.

The results of the study conducted in 1960 were similar to those obtained in 1958. The Clark variety of soybean receiving no nitrogen treatment (Table 6) yielded approximately three bushels per acre more than did the untreated non-nodulating variety (Table 7). The Clark variety when treated with nitrogen, yielded slightly higher than when it received no supplemental fertilizer nitrogen, but the difference was not statistically significant.

The yield of non-nodulating soybeans was significantly increased by treatment with nitrogen. The observed response was not as marked, however, as that noted in 1958. Only one bushel per acre of increase in yield over the control could be attributed to plowing down nitrogen at the rate of 50 pounds per acre for these non-nodulating soybeans. Plowing down nitrogen at the rate of 100 pounds per acre resulted in a yield increase of nearly four bushels per acre. When the 100 pound rate was applied as a side-dress treatment the yield response was only about one-half of that for the plow down treatment.

TABLE 6-THE YIELD OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1960

Rate and Time of Applying Treatments (main plot treatments)	Sub-plot Treatments		
	Control	Urea	Ammonium Nitrate
	yield in bushels per acre		
Plowdown before planting			
50 lbs N/acre	28.3	28.2	26.6
100 lbs N/acre	26.0	27.8	26.2
Sidedress 100 lbs N/acre			
at bloom	26.0	28.6	28.4
at seed set	26.1	27.6	28.2

No significant differences attributable to treatments.

TABLE 7-THE YIELD OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1960

Rate and Time of Applying Treatment (main plot treatments)	Sub-plot Treatments			Means* for Main Plots
	Control	Urea	Ammonium Nitrate	
	yield in bu/acre			
Plowdown before planting				
50 lbs N/acre	24.0	24.8	25.2	25.0
100 lbs N/acre	24.2	27.6	28.1	27.8
Sidedress 100 lbs N/acre				
at bloom	24.1	26.0	26.8	26.4
at seed set	23.3	24.7	24.8	24.8
Means for sub-plots	23.9	25.8	26.2	

L.S.D.$_{.05}$ for comparisons among sub-plots within main plots = 2.9.
L.S.D.$_{.05}$ for comparisons among mean yields for sub-plots = 1.4.
L.S.D.$_{.05}$ for comparisons among mean yields for main plots = 2.0.

*yield of control plot was not used in calculating these means.

In general for the three diverse seasons during which the experiment was conducted, the well nodulated Clark variety of soybeans gave no significant yield response to nitrogen fertilizer treatment.

The non-nodulating variety of soybeans, responded in terms of higher yields to nitrogen fertilizers but only under conditions where the soil was nitrogen deficient. The best yields obtained through fertilization of the non-nodulating soybeans were no better than those obtained for the unfertilized nodulated soybean variety.

The possibility of depressing yields of soybeans by adding large amounts of nitrogen was indicated in one season of the three during which the study was

conducted. The nitrate form of nitrogen appeared to be more injurious than the ammonium form.

Seed Weight

The weights per 100 harvested soybean seeds were found in some cases, to be influenced by the nitrogen treatments. In 1958, the weights per 100 seeds were obtained for only one replication of the four which were harvested for the estimation of yield. The results (Table 8) indicate that the plow-down applications

TABLE 8-THE SEED WEIGHT OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1958

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
		grams per 100 seeds			
None	17.02				
Plowdown before planting					
60 lbs N/acre		15.90	15.90	15.48	16.58
120 lbs N/acre		14.86	16.02	16.50	15.93
240 lbs N/acre		14.84	15.06	16.90	15.30
Sidedress 100 lbs N/acre					
at early bloom		17.04	15.66	17.57	15.40
at full bloom		16.34	17.98	17.04	16.00
at small seed		18.26	15.35	17.42	16.94

of nitrogen to the Clark soybeans resulted in a general reduction in seed weights. The side-dress treatments seemingly had no effect. The reducation in seed weights accompanying the plow-down nitrogen treatments did not vary consistently with the rate of nitrogen applied as was the case for the yields. The correlation coefficient between yield and seed size was not significant ($r = .139$).

For the non-nodulating beans grown in 1958, the treatment with nitrogen appears to have had a positive influence on seed weight (Table 9). However, with no replication the results for the one year alone are not very conclusive. The correlation coefficient between yield and seed weight for the non-nodulating variety was negative and again statistically not significant ($r = -.021$).

For the year 1959 when the yields of the two varieties of soybeans under study were similar and neither was significantly influenced by treatment with nitrogen, the seed weights for the Clark variety were also generally uniform (Table 10). The seeds of the nitrogen treated non-nodulating beans, however, were significantly heavier than those receiving no fertilizer nitrogen (Table 11). In general there was a slight increase in seed weight as the rate of plow-down treatment was increased from 60 to 240 pounds per acre of nitrogen. Slight differences occurring for the different times of applying the side-dress treatment are of questionable significance. The correlation coefficients between yield and seed

TABLE 9-THE SEED WEIGHT OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1958

Rate and Time of Applying Treatments	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
		grams per 100 seeds			
None	13.20				
Plowdown before planting					
60 lbs N/acre		13.34	13.45	14.72	13.19
120 lbs N/acre		12.32	15.50	14.58	15.50
240 lbs N/acre		14.94	13.44	15.10	14.96
Sidedress 100 lbs N/acre					
at early bloom		14.41	15.80	14.08	14.10
at full bloom		14.14	14.62	13.54	14.09
at small seed		14.58	13.07	15.14	14.66

TABLE 10-THE SEED WEIGHT OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1959

Rate and Time of Applying Treatments	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	14.8				
Plowdown before planting					
60 lbs N/acre		14.6	14.6	15.1	14.7
120 lbs N/acre		14.7	14.8	14.6	14.7
240 lbs N/acre		15.0	14.6	14.9	14.9
Sidedress 100 lbs N/acre					
at early bloom		15.3	15.4	15.0	14.7
at full bloom		14.7	14.9	15.1	14.8
at small seed		15.3	14.8	15.3	15.1

No significant differences attributable to treatments.

weights were .042 and .124 respectively for the Clark and the non-nodulating varieties. Neither of these coefficients was significant.

The seed weights for the crop grown in 1960 were markedly lower than those for the other two seasons. This was probably because the rainfall was most limiting during the latter part of the 1960 growing season. As was true in 1958, the seeds of the Clark variety (Table 12) were again heavier than those of the non-nodulating variety (Table 13) when not treated with nitrogen.

For the Clark variety there was no significant difference in seed weight among the units of seed harvested from the plots receiving the different nitrogen treatments. A significant correlation coefficient of .403 between yield and

TABLE 11-THE SEED WEIGHT OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1959

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
		grams per 100 seeds			
None	14.3				
Plowdown before planting					
60 lbs N/acre		14.8	15.2	15.5	14.7
120 lbs N/acre		15.4	15.2	15.4	15.4
240 lbs N/acre		15.7	15.2	15.8	15.8
Sidedress 100 lbs N/acre					
at early bloom		15.6	15.6	15.2	15.3
at full bloom		15.6	15.4	15.4	14.9
at small seed		14.8	15.4	15.4	15.4

L.S.D. $_{.05}$ = .6

TABLE 12-THE SEED WEIGHT OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1960

Rate and Time of Applying Treatment (main plot treatments)	Sub-plot Treatments		
	Control	Urea	Ammonium Nitrate
	grams per 100 seeds		
Plowdown before planting			
50 lbs N/acre	11.8	11.6	11.4
100 lbs N/acre	11.8	11.6	11.5
Sidedress 100 lbs N/acre			
at bloom	11.5	11.5	11.8
at seed set	12.1	11.6	11.7

No significant differences attributable to treatment.

seed weight was found for these Clark soybeans. This would indicate that the random variation in yield was associated with a similar variation in seed weight.

The seed weights of the non-nodulating soybeans varied with the different rates at which the nitrogen treatment was plowed down. This seed weight was about four percent greater for the samples from plots treated with 50 pounds of nitrogen per acre as compared with that from untreated plots. The value was about nine percent greater for samples from plots treated with 100 pounds of nitrogen as compared with that from untreated plots. The two nitrogen carriers under study gave similar results.

The correlation coefficient between yield and seed weight for the non-nodulating beans was highly significant ($r = .532$). This correlation indicates that about 27 percent of the variation in yield among the various plots could be attributed to variations in the weights per seed.

TABLE 13-THE SEED WEIGHT OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENT IN 1960

Rate and Time of Applying Treatment (main plot treatments)	Sub-plot Treatments			Means* for Main Plot
	Control	Urea	Ammonium Nitrate	
	grams per 100 seeds			
Plowdown before planting				
50 lbs N/acre	11.4	11.9	11.8	11.8
100 lbs N/acre	11.3	12.3	12.4	12.4
Sidedress 100 lbs N/acre				
at bloom	11.4	11.5	11.9	11.7
at seed set	11.3	11.5	11.2	11.4
Means for sub-plots	11.4	11.8	11.8	

L.S.D.$_{.05}$ for comparisons among sub-plots within main plots = .4
L.S.D.$_{.05}$ for comparisons among means for sub-plots = .2
L.S.D.$_{.05}$ for comparisons of means for main plots = .5

*yield of control plot was not used when calculating these means.

Percentage of Nitrogen and of Fat in the Soybean Seeds

The percentages of nitrogen and of fat in the seeds of the Clark soybeans grown in 1958 are reported in Table 14 and Table 15 respectively. The results indicate that the various nitrogen treatments have not significantly changed the composition of the Clark soybean with regard to these two components.

The percentages of nitrogn and of fat in the seeds of the non-nodulating soybeans grown in 1958 are reported in Table 16 and Table 17 respectively. The results show that the seed harvested from plots which had been fertilized with nitrogen is, in general, higher in percentage of nitrogen and lower in percentage of fat than seed from plots which received no nitrogen fertilizer. The influence of even the highest rate of fertilizer treatment did not, however, alter the composition of the seed to the extent that it became the same as that for the Clark variety. Regardless of treatment, the percentage of nitrogen of the Clark soybean was higher than that for the non-nodulating soybeans seed and the percentages of fat of the Clark seed was lower than that for the non-nodulating soybeans.

Since these chemical analyses were obtained for only one replication of each treatment under study in 1958, it is not possible to attach statistical significance to the differences among the various treatments.

The percentages of nitrogen and of fat in the seeds of the Clark soybeans grown in 1959 are reported in Table 18 and Table 19, respectively. These results show that the nitrogen treatments under study, again, did not significantly influence the composition of these well nodulated soybeans with regard to nitrogen and fat in the seed.

TABLE 14-THE PERCENTAGE OF NITROGEN IN THE SEEDS OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1958

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	6.88				
Plowdown before planting					
60 lbs N/acre		6.72	6.85	6.63	6.66
120 lbs N/acre		6.78	6.64	6.80	6.69
240 lbs N/acre		6.85	6.50	6.44	6.70
Sidedress 100 lbs N/acre					
at early bloom		6.65	6.68	6.68	6.90
at full bloom		6.83	6.81	6.75	6.71
at small seed		6.83	6.82	7.01	6.81

TABLE 15-THE PERCENTAGE OF FAT IN THE SEEDS OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1958

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	18.08				
Plowdown before planting					
60 lbs N/acre		17.56	17.25	18.05	17.77
120 lbs N/acre		17.63	17.50	18.20	17.29
240 lbs N/acre		17.19	18.10	18.52	17.55
Sidedress 100 lbs N/acre					
at early bloom		18.11	18.42	17.57	17.81
at full bloom		17.71	17.65	17.51	17.59
at small seed		17.89	17.57	16.91	17.46

The percentages of nitrogen and of fat in the seeds of the non-nodulating soybeans grown in 1959 are reported in Table 20 and Table 21 respectively. These results indicate that the nitrogen fertilizer treatments caused significant increases in the percentages of nitrogen and significant decreases in the percentage of fat in the seed which was produced. The percentage of nitrogen in the seed was positively correlated and the percentage of fat was negatively correlated with the rate at which the nitrogen was plowed down. The time of applying the nitrogen as a side-dress treatment, also, caused differences in the composition of the seed. The earlier times of application were associated with the higher percentages of nitrogen and the lower percentages of fat. There was no significant difference in composition of the seed which could be attributed to use of the different nitrogen carriers under study.

TABLE 16-THE PERCENTAGE OF NITROGEN IN THE SEEDS OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT FERTILIZER TREATMENTS IN 1958

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	5.31				
Plowdown before planting					
60 lbs N/acre		6.38	5.41	5.66	5.13
120 lbs N/acre		5.09	5.71	5.63	5.78
240 lbs N/acre		5.93	5.61	5.74	6.09
Sidedress 100 lbs N/acre					
at early bloom		5.94	5.87	5.53	5.45
at full bloom		5.72	5.76	5.35	5.89
at small seed		5.61	5.30	5.68	5.77

TABLE 17-THE PERCENTAGE OF FAT IN THE SEEDS OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT FERTILIZER TREATMENTS IN 1958

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	20.74				
Plowdown before planting					
60 lbs N/acre		20.39	21.09	20.36	21.15
120 lbs N/acre		20.99	20.03	20.25	19.98
240 lbs N/acre		19.70	20.07	19.92	18.87
Sidedress 100 lbs N/acre					
before bloom		19.46	19.55	20.53	20.49
full bloom		19.56	19.83	20.76	19.65
small seed		19.82	20.98	19.74	19.37

The Clark soybean seeds from the 1959 crop were again higher in percentage of nitrogen and lower in percentage of fat than were the seeds of the non-nodulating soybeans which received no nitrogen treatment. The non-nodulating soybeans which had been treated with 100 lbs. or more of nitrogen, however, were altered in composition to the extent that their nitrogen percentages were as high as, and their fat percentages were as low as those for the Clark soybeans. The highest rate of plow-down treatment (240 lbs. N/A) yielded soybeans with nitrogen percentages higher than and fat percentages lower than the corresponding Clark soybeans.

The application of nitrogen fertilizers in 1960 to the Clark variety of soybeans again failed to cause a significant change in the nitrogen or fat content of

TABLE 18-THE PERCENTAGE OF NITROGEN IN THE SEEDS OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1959

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	6.11				
Plowdown before planting					
60 lbs N/acre		6.18	6.16	6.24	6.09
120 lbs N/acre		6.12	6.16	6.16	6.17
240 lbs N/acre		6.19	6.14	6.24	6.18
Sidedress 100 lbs N/acre					
at early bloom		6.15	6.19	6.25	6.21
at full bloom		6.17	6.31	6.18	6.14
at small seed		6.16	6.22	6.19	6.13

No significant differences attributable to treatment.

TABLE 19-THE PERCENTAGE OF FAT IN THE SEEDS OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1959

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	20.17				
Plowdown before planting					
60 lbs N/acre		20.14	20.32	20.22	20.13
120 lbs N/acre		20.21	20.33	20.24	20.20
240 lbs N/acre		20.34	20.13	20.18	20.12
Sidedress 100 lbs N/acre					
at early bloom		20.40	20.31	19.92	19.94
at full bloom		19.92	20.28	20.17	19.89
at small seed		20.36	20.08	20.19	20.20

No significant differences attributable to treatment.

the seeds. Table 22 and Table 23 report the percentage of nitrogen and of fat respectively for these soybean seeds.

For the non-nodulating soybeans grown in 1960, the application of fertilizer nitrogen again resulted in a significant increase in the percentage of nitrogen (Table 24) and a significant decrease in percentage of fat (Table 25) in the seeds which were produced. The positive correlation between percentage nitrogen in the seed and the rate of fertilizer application and the negative correlation between the percentage fat in the seed and the rate of fertilizer application were similar to those noted for the 1959 crop. The influence of the time at which the nitrogen was applied as a side-dress treatment to these non-nodulating soybeans also was similar to that noted in 1959. The earlier application gave the higher

TABLE 20-THE PERCENTAGE OF NITROGEN IN THE SEEDS OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1959

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	5.86				
Plowdown before planting					
60 lbs N/acre		5.98	6.00	6.02	6.01
120 lbs N/acre		6.19	6.17	6.18	6.11
240 lbs N/acre		6.32	6.28	6.36	6.36
Sidedress 100 lbs N/acre					
at early bloom		6.27	6.25	6.29	6.21
at full bloom		6.19	6.08	6.15	6.13
at small seed		6.02	6.11	6.10	6.08

L.S.D.$_{.05}$ = .14

TABLE 21-THE PERCENTAGE OF FAT IN THE SEEDS OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1959

Rate and Time of Applying Treatment	Control	Nitrogen Carrier			
		Urea	Ammonium Sulfate	Ammonium Nitrate	Sodium Nitrate
None	20.88				
Plowdown before planting					
60 lbs N/acre		20.71	20.70	20.52	20.54
120 lbs N/acre		20.14	20.10	20.08	20.09
240 lbs N/acre		19.70	19.85	19.88	19.72
Sidedress 100 lbs N/acre					
at early bloom		20.16	20.15	19.98	19.70
at full bloom		20.13	20.56	20.36	20.16
at small seed		20.44	20.23	20.36	20.25

L.S.D.$_{.05}$ = .58

nitrogen and lower fat level in the seed. There was no difference in nitrogen or fat content which could be attributable to use of different nitrogen carriers.

The relative differences between the nitrogen contents of the two varieties of soybean seeds were similar to those noted for the 1958 crop. The response to nitrogen of the non-nodulating beans was not enough to yield nitrogen percentages in the seed which were as high as those observed for the Clark variety. The rate of nitrogen treatment both as plow-down and side-dress of the non-nodulating beans, however, resulted in a lowering of the fat content of the seed

TABLE 22-THE PERCENTAGE OF NITROGEN IN THE SEEDS OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILITY IN TREATMENTS IN 1960

Rate and Time of Applying Treatments (main plot treatments)	Sub-plot Treatments		
	Control	Urea	Ammonium Nitrate
Plowdown before planting			
50 lbs N/acre	6.68	6.59	6.62
100 lbs N/acre	6.64	6.62	6.75
Sidedress 100 lbs N/acre			
at bloom	6.66	6.73	6.71
at seed set	6.65	6.69	6.70

No significant differences attributable to treatment.

TABLE 23-THE PERCENTAGE OF FAT IN THE SEEDS OF CLARK SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1960

Rate and Time of Applying Treatments (main plot treatments)	Sub-plot Treatments		
	Control	Urea	Ammonium Nitrate
Plowdown before planting			
50 lbs N/acre	18.37	18.71	18.60
100 lbs N/acre	18.65	18.78	18.62
Sidedress 100 lbs N/acre			
at bloom	18.20	18.32	18.28
at seed set	18.46	18.37	18.22

No significant differences attributable to treatment.

so that it was as low as or lower than that for the corresponding Clark soybean seed.

For the Clark variety of soybeans, the highest percentages of nitrogen and the lowest percentages of fat were observed in 1958 which was the most ideal season with regard to moisture, of the three during which the study was conducted. The lowest percentages of nitrogen and the highest percentages of fat for the Clark variety were observed in 1959 which was the season in which moisture was most limiting during the early summer months.

For the non-nodulating variety of soybeans which received no nitrogen fertilizer treatment, the highest nitrogen and the highest fat contents were observed in 1959, which was the season in which soil nitrogen was least limiting. Lower nitrogen and fat contents were observed in the other two seasons when moisture was more abundant and soil nitrogen consequently became more limiting. Furthermore, a greater effect of the nitrogen treatments on both the percentage of nitrogen and percentage of fat in the seed was observed for the two seasons during which the moisture was not so limiting (1958 and 1960).

TABLE 24-THE PERCENTAGE OF NITROGEN IN THE SEEDS OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1960

Rate and Time of Applying Treatment (main plot treatments)	Sub-plot Treatments			Means* for Main Plots
	Control	Urea	Ammonium Nitrate	
Plowdown before planting				
50 lbs N/acre	5.46	6.06	5.91	5.98
100 lbs N/acre	5.58	6.37	6.44	6.40
Sidedress 100 lbs N/acre				
at bloom	5.53	6.30	6.40	6.35
at seed set	5.33	5.96	6.13	6.04
Means for sub-plots	5.48	6.17	6.22	

L.S.D.$_{.05}$ for comparisons among sub-plots within main plots = .25
L.S.D.$_{.05}$ for comparisons among means for sub-plots = .13
L.S.D.$_{.05}$ for comparison of means for main plots = .18

*Percentage for control plot was not used in calculating these means.

TABLE 25-THE PERCENTAGE OF FAT IN THE SEEDS OF NON-NODULATING SOYBEANS AS INFLUENCED BY DIFFERENT NITROGEN FERTILIZER TREATMENTS IN 1960

Rate and Time of Applying Treatments (main plot treatments)	Sub-plot Treatments			Means* for Main Plots
	Control	Urea	Ammonium Nitrate	
Plowdown before planting				
50 lbs N/acre	20.10	18.82	19.40	19.11
100 lbs N/acre	19.73	17.99	18.02	18.00
Sidedress 100 lbs N/acre				
at bloom	19.86	17.92	17.52	17.72
at seed set	20.46	18.36	17.81	18.08
Means for sub-plots	20.04	18.27	18.19	

L.S.D.$_{.05}$ for comparisons among sub-plots within main plots = .67
L.S.D.$_{.05}$ for comparisons among means for sub-plots = .33
L.S.D.$_{.05}$ for comparison of means for main plots = .86

*Percentage of control plot was not used in calculating these means.

A negative correlation between the percentage of nitrogen and percentage of fat was consistently observed as one noted the differences in concentration of these components in the seed as they were related to the different varieties under study, the different seasons under study, and the influence of nitrogen treat-

ment on the non-nodulating variety of soybeans.

SUMMARY

A study of different nitrogen fertilizer treatments for their effect on yield and seed quality of the Clark variety and a non-nodulating variety of soybeans was conducted over a period of three growing seasons. The soybeans were grown on a claypan soil which had been adequately fertilized with calcium, phosphorus, and potassium.

The nitrogen treatments did not result in any increase in yield of the Clark soybeans. Nitrogen fertilization did, however, result in significant increases in yield of the non-nodulating soybeans in two of the seasons which were apparently associated with limited soil nitrogen. In one of these cases the side-dress treatments were slightly superior to the plow-down treatments. In the other case the reverse was true. Even when given a liberal nitrogen treatment, however, the non-nodulating soybeans yielded no higher than the well nodulated Clark soybeans.

There was little or no evidence that the seed weight of the Clark soybeans was influenced by the nitrogen treatments under study. The seed weights of the non-nodulating soybeans, however, were found to be affected by the nitrogen treatments. The maximum effect was an increase in seed weight of no more than 10 percent. The seed weight was generally correlated with the yield for these non-nodulating soybeans. The coefficient of correlation was rather low, however, which would indicate that at best only a small part of the yield variation attributed to the different treatments could be explained by variation in seed weight. It is assumed that a factor of greater importance in explaining the effect of treatment on yield is that of the number of mature seeds which were produced. Significant differences in seed weight other than those related to variety or treatment differences were observed among the three crops of soybeans produced. These differences were assumed to be related to the supply of moisture during the latter part of the growing season.

The percentages of nitrogen and fat in the Clark soybean seeds appeared to be influenced somewhat by the differences in weather which were noted for the three growing seasons during which the study was conducted. The composition of these soybeans with regard to nitrogen and fat was not, however, affected by the different nitrogen treatments under study. The percentage of nitrogen and fat in the non-nodulating soybean seeds was significantly influenced by the nitrogen treatments. In general, the percentage of nitrogen was positively correlated and the percentage of fat was negatively correlated with the rate at which nitrogen was plowed down. Side-dress treatments at the bloom stage had a greater influence on composition of the seed than did side-dress treatments later during seed set. Only in the one season during which moisture was most limiting did the nitrogen treatment alter the composition of the non-nodulating soybean seed to the extent that the resulting percentage nitrogen was higher and the resulting percentage of fat was lower than for the Clark variety.

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SOIL TEST RESULTS

OM %	P_2O_5 lbs/A	K lbs/A	Mg lbs/A	Ca lbs/A	pH	H	Salt pH
2.7	288	420	575	5100	6.1	2.5	6.0