THE EFFECTS OF NITROGEN FERTILIZATION AND CULTURAL PRACTICES ON THE GROWTH AND YIELD OF SANILAC PEA BEANS

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ABSTRACT

THE EFFECTS OF NITROGEN FERTILIZATION AND CULTURAL PRACTICES ON THE GROWTH AND YIELD OF SANILAC PEA BEANS

by Roger A. Vinande

Field and greenhouse experiments were conducted in 1967 and 1968 to investigate the effects of various rates and times of nitrogen application, clipping of a cover crop, and various plowing times on the soil moisture and nitrate nitrogen content; and the early growth, nitrogen concentration and uptake of pea bean (*Phaseolus vulgaris* L. var. Sanilac) plants, and bean yields.

Clipping a rye crop which was plowed under one day before bean planting resulted in a five percent increase in soil moisture at bean planting time when compared to rye not clipped.

In 1967 rates of nitrogen applied at 40 and 80 pounds per acre did not affect the moisture content of the soil on August 15 or the bean yield, but the 80 pound nitrogen application on fall plowed soil resulted in a 60 per cent increase in soil nitrate nitrogen content.

The nitrogen fertilizer which was applied preplant increased the bean yield three bushels per acre in 1967 and 2.3 bushels in 1968. There was no significant yield response due to plowing time in 1967, but the plowing time three weeks before bean planting in 1968 resulted in a 1.5 bushel per acre increase as compared to the yield obtained with the plowing time one week before bean planting.

Nitrogen applied at rates of 30, 60, and 90 pounds per acre on spring plowed soil in 1968 did not affect plant dry weights, plant nitrogen concentration and uptake, soil nitrate nitrogen content, or bean yield. Plant dry weights were increased three grams per three plants with the plowing time three weeks before bean planting as compared to the plant dry weights obtained with the plowing time one week before bean planting.

Nitrogen applications of 30, 60, 90, 180, and 360 pounds per acre on fall plowed soil did not affect plant dry weight or bean yield, but the 360 pound nitrogen rate increased the soil nitrate nitrogen content 40.8 ppm as compared to the soil nitrate nitrogen content obtained with the 180 pound nitrogen rate and increased the soil nitrate content even more when compared with the other nitrogen treatments. All nitrogen treatments except the 60 pound rate significantly increased the plant nitrogen concentration as compared to the nitrogen concentration obtained with no nitrogen application.

Cropping with Sanilac pea beans decreased the differences in soil nitrate nitrogen contents of greenhouse soils regardless of the nitrogen treatment. Nitrogen applications of 40 and 80 ppm significantly increased the yield per pot of the first greenhouse crop, but did not affect the plant nitrogen concentration and uptake. The second and third greenhouse crops received almost all of their nitrogen from mineralization and nitrogen fixation, not from initial soil nitrate nitrogen or nitrogen added as a treatment.

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INTRODUCTION

On a worldwide basis nitrogen is more limiting than any other element for crop growth. In soil, nitrogen is the least predictable of the nutrient elements. It is exposed to biological and chemical immobilization; biological mobilization which is dependent upon an interaction of temperature, aeration, water, and type and amount of organic matter; leaching; and denitrification. A deficiency of nitrogen limits yields and reduces quality while too much may reduce yield, reduce quality, and cause lodging.

Nitrogen nutrition of legumes in general has been investigated quite extensively; however, little or no research has been conducted to investigate the nitrogen nutrition of pea beans (*Phaseolus vulgaris* L. var. Sanilac). Pea beans are an important cash crop in the Saginaw Valley of Michigan. Cultural practices such as plowing time, clipping of a cover crop, and time of nitrogen application exert an influence upon the soil-plant nitrogen status which has not been investigated extensively with pea beans.

Field experiments were conducted in 1967 and 1968 to investigate the effects of various rates and times of nitrogen application, clipping of a cover crop, and various plowing times upon:

1. The soil moisture content.

2. The early growth, nitrogen concentration and uptake of pea bean plants.

3. The soil nitrate nitrogen content.

4. The yield of Sanilac pea beans.

A greenhouse experiment to further supplement the field data was conducted in 1968 to investigate the effects of various rates of nitrogen addition upon the dry plant weight, nitrogen concentration, and nitrogen uptake of Sanilac pea beans; and the soil nitrate nitrogen content.

REVIEW OF LITERATURE

Soil Nitrogen

The most important source of soil nitrogen is the atmosphere which is 79.08% N_2 by volume. The plow layer of a fertile prairie soil may contain three tons of combined nitrogen per acre while the atmosphere over an acre will contain 35,000 tons of elemental nitrogen. Very few microorganisms can utilize elemental nitrogen; all other living organisms require combined nitrogen for their survival (Stevenson, 1965).

Most of the nitrogen in soil is organically bound. Inorganic nitrogen such as nitrates and exchangeable ammonium make up only a small part of the soil nitrogen, usually less than two percent, but only the inorganic nitrogen is utilized for direct plant uptake. Substances containing organic nitrogen can be regarded as a reserve of nitrogen for plant nutrition (Harmsen and Kolenbrander, 1965).

Under normal soil conditions inorganic nitrogen is constantly being formed from organic nitrogen by mineralization and inorganic nitrogen is converted to organic nitrogen by soil microbes. All soil microbes consume soluble or inorganic nitrogen for growth (Doryland, 1916).

"Immobilization" is usually used to indicate the process of conversion of inorganic nitrogen to the organic form during decomposition. The term is used with the connotation that the process is microbiological with microorganisms using inorganic nitrogen in cell tissue synthesis that results in organic nitrogen which is partially resistant to further biological breakdown (Hutchinson and Richards, 1921). The terms "release" and "mineralization" have been used to indicate the microbiological transformation of the organic nitrogen to the inorganic form (usually ammonium). The mineralization process makes the nitrogen mobile and available for plant use. The contrasting processes of immobilization and mineralization occur simultaneously and coincident in most soils where organic material is undergoing microbiological degradation. The combined reactions of the transformation of inorganic nitrogen to organic and of organic to inorganic nitrogen is referred to as "microbiological interchange" (Hiltbold et al., 1951).

The organic nitrogen content of fresh residues varies. Wood may contain 0.2 to 0.5% organic nitrogen while leguminous hays may contain 1.5 to 3% organic nitrogen; however, as fresh organic material begins to decompose the quantity of organic nitrogen may change. Residues low in nitrogen tend to increase in nitrogen content if there is nitrogen available in addition to that contained in the residues. High nitrogen containing residues may decrease in organic nitrogen content. These changes in organic nitrogen content occur early in the decomposition process (Allison and Klein, 1962; Broadbent and Tyler, 1962; Winsor and Pollard, 1956a).

When the supply of nitrogen is increased during the process of decomposition the result is an increase in nitrogen immobilization and more humus formation. When insufficient nitrogen is available for the development of microorganisms which decompose the plant residues, an addition of inorganic nitrogen will cause an increase in immobilization. However, when the development of microorganisms is not limited by nitrogen, additional nitrogen is not used in the system and can, if the concentration is great enough, cause a decrease in the rate of microbial action (Allison, 1955; Bartholomew, 1955).

The maximum amount of nitrogen is immobilized when large amounts of easily decomposable plant residues of large C/N ratios are added. Under such circumstances the heterotrophic microorganisms grow so fast that often all the available soil mineral nitrogen is utilized by them. If the C/N ratio of plant residues is larger than 25 to 30 an external source of nitrogen is needed for the degree of decomposition and biological immobilization to be at a maximum. When the C/N ratio is 20 or less, corresponding to about 1.5 to 2% N, no external source of nitrogen is usually required (Allison and Klein, 1962).

Nitrogen which has been immobilized in the decay of crop residues undergoes biological mineralization slowly (Jansson et al., 1955). Jansson (1963) by using tracer nitrogen, found from 2.6 to 4.0% of the nitrogen which had been immobilized from nitrate and from 1.4 to 3.7% of the nitrogen which had been immobilized from ammonium treatments were mineralized and recovered each year by a growing crop of oats. Woodruff (1950), stated that soil organic matter may contain two to three tons of nitrogen per acre but this organic nitrogen is released to inorganic nitrogen compounds at a rate of only one to three percent per year.

Soil organic nitrogen is mineralized at about the same rate as newly immobilized nitrogen. Rates of mineralization have been estimated to be as low as two percent to as high as ten percent per year (Bartholomew and Kirkham, 1960). Old stabilized humus resists decomposition and frequently yields little inorganic nitrogen despite its low C/N ratio (Winsor, 1958).

Soil-Plant Nitrogen Relationships

Plants may use organic forms of nitrogen such as amino acids and amines; however, almost all of the nitrogen taken up from the soil is in two inorganic compounds, ammonium and nitrate. Ammonium seldom persists in well-aerated soils because it is rapidly oxidized to nitrate; therefore, nitrate is the form available to plants (Stevenson, 1964).

Plants contain more atoms of nitrogen than any of the other elements which are obtained from soil or fertilizers (Viets, 1961).

The main channel of removal of inorganic nitrogen from normal soil is plant absorption. Different kinds of crop and soil situations result in different removal patterns. On arable land in temperate climates inorganic nitrogen usually disappears quite rapidly as the crops begin growing. Annual crops absorb nitrogen slowly until their root systems develop, but since perennial crops have a developed root system they can absorb nitrogen as soon as conditions for growth are favorable. They may even absorb some nitrogen in the winter. The amount of inorganic nitrogen in cropped land at harvest time is quite small (Jewitt, 1956; Gasser, 1961).

Nonlegumes do not increase the nitrogen supply and in some instances may even have a depressing effect on the amount of available nitrogen. Nitrate accumulation under corn and oats was less than nitrate accumulation in fallow soil, even if allowance had been made for nitrogen uptake by the crops (Lyon et al., 1923).

According to Scarsbrook (1965), possible explanations for the decrease in available nitrogen because of crop presence are:

1. Root excretions which inhibit mineralization of nitrogen.

2. Root excretions of organic materials which immobilize nitrogen by combining with it.

3. The presence of the crop may increase denitrification.

Nitrogen fixation adds a considerable amount of nitrogen to the soil. Stevenson (1964) stated that biological nitrogen fixation by symbiotic relationship between members of the bacterial genus *Rhizobium* and leguminous plants is still important, despite the enormous expansion of facilities for producing fertilizer nitrogen since World War II. For the majority of the world's soils legumes are still a major source of fixed nitrogen.

Fixation by free-living bacteria and blue-green algae and symbiotic relationships with non-leguminous plants also add nitrogen to the biological nitrogen cycle by nitrogen fixation processes.

Effects of Cultural Practices Upon Soil Nitrogen Supply and Plant Growth

Many of the effects of soil management and cultural practices on crop growth operate through their influence on available soil nitrogen. Plowing affects available soil nitrogen by burying the surface deposited residues. Cultivation and time of plowing affect succeeding nitrogen supplies through immobilization and mineralization processes. Plowing under residues with a low nitrogen content a considerable time prior to planting a crop will increase the available nitrogen supply since the decomposition reactions and net immobilization processes have been supplied with nitrogen before there is maximum nitrogen uptake by the crop. Plowing under residues containing high amounts of nitrogen too far prior to planting a crop may increase nitrogen losses through leaching and denitrification (Bartholomew, W. V., 1965).

Nitrogen fertilization of crops has two main influences on nitrogen tie-up and release of crop residues. It increases residue production and it increases the nitrogen content of the residue material.

Any cropping or cultural practice which has an effect on the production, yield, or composition of crop residues and/or influences the course or conditions of decomposition also influences the tie-up and release of nitrogen and therefore influences the supply of nitrogen (Bartholomew, W. V., 1965).

Nitrogen Fertilization of Legumes

Many species of legumes are not associated with Rhizobia or its strains and thus are not efficient nitrogen fixers. These legumes give the same response to fixed nitrogen as nonlegumes (Van Schreven, 1958). Allos and Bartholomew (1955) found of six legumes tested only soybeans did not give a yield response to N^{15} tagged $(NH_4)_2SO_4$ in solution culture in vermiculite.

Since no references concerning the effect of nitrogen fertilization on pea beans could be found and both soybeans and pea beans are legumes which fix nitrogen, literature dealing with nitrogen fertilization of soybeans will be discussed.

Soybean is a legume which uses atmospheric nitrogen made available by root nodule bacteria living in symbiosis with it as well as nitrogen from the soil. Because of this symbiotic relationship, soybeans grow well in soils with a low available nitrogen content if other nutrients or physical properties are not limiting (Wagner, 1962).

Norman and Krampitz (1945) found that large amounts of mineral nitrogen could reduce nitrogen fixation so it accounted for no more than 30 percent of the total plant consumption. According to Allos and Bartholomew (1959) the addition of small amounts of inorganic nitrogen could actually stimulate the nitrogen fixation process, probably because of increased growth of the plants. The addition of fertilizer nitrogen to legumes in solution culture resulted in increased growth of legumes; therefore, an increased need for and adsorption of nitrogen. Both Norman's et al. (1945) and Allos's et al. (1959) research suggests that soybeans cannot attain maximum yields if they are utilizing just symbiotically fixed nitrogen. Soybeans would fix the maxiumum amount of nitrogen when about 20% of the nitrogen requirement is supplied by mineral nitrogen.

Mederski's et al. (1958) research over seven different growing seasons with the use of ammonium sulfate at rates up to 200 pounds of nitrogen per acre showed an increase in yield of one to five bushels per acre in six of the years which could be attributed to the fertilizer.

Norman (1943) found evidence of luxury consumption of nitrogen by soybeans when the nitrogen was applied late in the growing season. The nitrogen content of the soybean straw increased a greater amount than the yield or nitrogen content of the beans.

Research by Lathwell et al. (1951) indicates that soybean plants must take up nitrogen from the period of bloom to maturity to obtain maximum yield. The number of pods retained was dependent upon adequate nitrogen during the bloom period. Bean yields were closely correlated with the amount of nitrogen accumulated by the plant throughout its life cycle and there was little relation between the percentage nitrogen content of the plant and its yield. Lyons and Early (1952) found that seasonal variance of temperature and rainfall seem to influence symbiotic fixation of nitrogen and to influence indirectly the response of soybean plants to added nitrogen.

METHODS AND MATERIALS

In May 1967 experiments to study the effects of fall versus spring plowing, various spring plowing dates, and various rates and times of nitrogen application on Sanilac variety pea bean yields were initiated on a Wisner clay loam soil on the Bean Commission Research Farm near Indiantown in Saginaw County, Michigan. A randomized complete block design with four replications was utilized. Each experimental plot was 50 feet long and 14 feet wide and the beans were planted in 28 inch rows with a seeding rate of 40 pounds per acre. When the fertilizer was banded, the placement was one inch to the side and one and a half inches below the seed. The beans were planted on June 16 in 1967 and on June 14 in 1968. Two rows forty feet long were harvested from each plot to determine the yield.

Field Procedure

1967 Data

In 1967 the planting time fertilizer consisted of 300 pounds per acre of 8-32-16 fertilizer containing 2% manganese and 2% zinc. Three plowing dates were employed --rye was plowed down four weeks, two weeks, and one day prior to bean planting. The rye on one half of the plots that were plowed two weeks prior to planting was clipped to a height of six inches two weeks before plowing and the rye on one half of the plots that were plowed the day before planting was clipped to a height of six inches four and two weeks prior to plowing. The effects of spring as compared to fall plowing on yields were compared and nitrogen rates equivalent to 0, 40, and 80 pounds per acre were superimposed on the entire experiment. The nitrogen fertilizer was applied broadcast and was disked under prior to bean planting on the fall plowed soil. The nitrogen fertilizer was applied broadcast four weeks before planting to one half of the spring plowed plots and was sidedressed six weeks after planting (July 26) on the other plots. The 0, 40, and 80 pounds per acre rates of nitrogen were applied in the form of ammonium nitrate and were in addition to the 24 pounds of nitrogen per acre applied at planting time. Soil samples for moisture determination were collected on June 15 and August 15 and soil samples for nitrate determination were collected on August 15.

1968 Data

In 1968 the planting time fertilizer consisted of 335 pounds per acre of 0-20-20 containing 3% manganese and 3% zinc. An oat crop was plowed down because rye planted the previous fall had winter-killed. Plowing dates of three weeks and one week before bean planting were used and no clipping was done in 1968. The spring plowed soil received nitrogen at rates equivalent to 0, 30, 60, and 90 pounds per acre applied broadcast 3 weeks before planting and sidedressed as in 1967 and the fall plowed soil received nitrogen applications equivalent to 0, 30, 60, 90, 180, and 360 pounds per acre applied broadcast and disked in prior to planting. Soil samples for nitrate determination were collected on August 15. Whole plant samples (excluding the roots) to be analyzed for nitrogen content and for dry weight data were collected on August 13. Due to an error in application of fertilizer levels in 1968 only 3 replications could be validly used for statistical analysis.

Greenhouse Experiment

The greenhouse experiment was organized in a randomized complete block design with four replications. Three thousand two hundred grams of air-dried sieved Wisner clay loam soil was placed in a one-gallon galvanized steel can lined with a plastic bag. Fertilizer was added in reagent chemical form at a rate equivalent to 150 ppm of 0-32-16 plus 2% manganese and 2% zinc. Phosphorus (P), potassium (K), zinc (Zn), and manganese (Mn) were added per pot in the amounts of 20 ppm K as KH_2PO_4, 21 ppm P as $Ca(H_2PO_4)_2 \cdot H_2O$, 3 ppm Zn as $ZnSO_4 \cdot 7H_2O$, and 3 ppm Mn as $MnSO_4 \cdot H_2O$, respectively. Nitrogen treatments at rates of 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 20.0, 40.0, and 80.0 ppm nitrogen per pot, respectively, were added as ammonium nitrate. Nitrogen was added to the soil only before the first crop, while the other fertilizer materials were added before each of the three crops. Because of the small amount of chemical needed per pot and to get a uniform distribution, the chemicals were added in solution by means of a pipette. Ten bean seeds were planted per pot and were thinned to four plants in the first and third crops and to three plants in the second crop. The whole plants (excluding the roots) were harvested at bloom stage, dried in a forced air oven at 65°, weighed, and ground in a Wiley mill to pass through a 20 mesh screen in preparation for analysis. Soil samples for nitrate determination were collected before and after each crop was harvested. Per cent nitrogen (excluding nitrate nitrogen) was determined by the micro-Kjeldahl method (Jackson, 1958) on both the greenhouse and field plant samples. Soil samples from the field and greenhouse were air-dried, ground, and analyzed for nitrate nitrogen colorimetrically using brucine (Greweling and Peech, 1960).

RESULTS AND DISCUSSION

1967 Field Data

Organic Matter

A broadcast nitrogen application of 40 pounds per acre four weeks prior to bean planting had little affect on the growth of a rye cover crop which was plowed down two weeks before bean planting (Table 1).

TABLE 1.--The amount of organic matter and nitrogen plowed down from a rye cover crop at fourteen days and one day before bean planting.

Plowing Time Before Planting	Amount of Material Plowed Down				
	0 lbs N/a		40 lbs N/a[a]		Weight ratio[b] Top:Root
	Organic Material	N	Organic Material	N	
Days	--------------lbs/a--------------				
14	4251	30.0	4202	54.6	1
1	5327	37.3	8767	114.0	2

[a]Nitrogen was broadcast on the rye cover crop in the form of ammonium nitrate four weeks prior to bean planting.

[b]The weight of tops to roots was based upon data from the areas which received 40 lbs. N/a. All values in the table are based upon oven dry weights.

About two tons per acre (dry weight) of rye stem and leaf tissue was plowed under two weeks prior to planting regardless of nitrogen treatment, but the nitrogen content of the rye tissue was doubled with the addition of 40 pounds of nitrogen per acre when compared to rye tissue with no nitrogen addition. As a result, 55 pounds of organic nitrogen per acre was plowed under where nitrogen was added to the rye while only 30 pounds of organic nitrogen per acre was plowed under where no nitrogen was added. Since approximately two tons of root material was plowed under per acre, the above figures might be doubled to get total nitrogen contribution from rye assuming that the nitrogen content of the root material was comparable to the nitrogen content of the tops.

During the two weeks after the initial plowing date, the rye top growth increased at twice the rate of the root growth. The top growth of the nitrogen fertilized rye doubled in the two-week period between plowing times while the top growth of rye which received no nitrogen increased only 20%. Three times as much nitrogen from rye top growth was plowed down with the nitrogen fertilized rye as opposed to rye which received no nitrogen at the plowing time one day prior to bean planting.

Soil Moisture

The most favorable moisture condition in the seedbed at planting time was 13.7% where the rye cover crop was plowed under four weeks prior to bean planting (Table 2), while the lowest seedbed moisture was 5.6% obtained where the rye cover crop was not clipped and was plowed under one day prior to bean planting. As expected the growing rye cover crop removed large amounts of moisture from the soil. All other cultural practices, which included rye clipping and fall plowing resulted in a seedbed moisture content of about 10.6%. Fall plowing did not give a greater soil moisture content than spring plowing except for the spring plowing date one day before bean planting where the rye was not clipped. Soil plowed four weeks before bean planting maintained the most favorable soil moisture content because it did not have a growing rye crop to use the soil moisture. Clipping the rye showed a small advantageous affect on seedbed moisture content for the plowing time two weeks prior to bean planting, but the effect for the plowing time one day prior to planting was most pronounced. The longer the time the rye was allowed to grow before plowing, the

TABLE 2.--The effect of cultural practices upon the soil moisture of the seedbed at bean planting time.

Plowing Time Before Planting	Soil Moisture
Days	%
240[a]	10.6
28	13.7
14	10.6
14 rye clipped to maintain 6" of growth	10.9
1	5.6
1 rye clipped to maintain 6" of growth	10.6

[a]Fall plowed soil with no winter cover crop planted.

greater the effect of the clipping upon the soil moisture content. Clipping the rye growing on soil which was plowed one day prior to planting greatly reduced the moisture removal by the rye plants.

The moisture content of the soil on August 15 was not affected by the level of nitrogen applied, the time of rye cover crop plowing, or clipping of the rye; but the fall plowed soil contained slightly more moisture than the spring plowed soil (Table 3). The previously noted differences in soil moisture content at bean planting time had disappeared at the later sampling time.

TABLE 3.--The effect of cultural practices and nitrogen fertilizer application upon the soil moisture and soil nitrate nitrogen status at bean bloom stage.[a,b,c]

Rate of N Application	Plowing Time Before Planting											
	240 days		28 days		14 days		14 days rye clipped		1 day		1 day rye clipped	
	Soil moisture	Soil NO_3-n	Soil moisture	Soil NO_3-N	Soil moisture	Soil NO_3-N	Soil moisture	Soil NO_3-N	Soil moisture	Soil NO_3-N	Soil moisture	Soil NO_3-N
lbs/a	%	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%	ppm
0	14.5	12.2	13.0	11.8	13.1	7.8	12.3	4.4	13.3	4.4	13.3	9.3
40	14.6	11.5	12.0	8.2	13.1	5.4	12.6	7.8	13.0	13.6	13.3	6.7
80	14.9	19.4	13.1	12.4	12.4	10.2	13.7	7.4	12.7	9.2	13.1	12.9

[a]Each value represents the mean of eight observations (four replications x two nitrogen application times).

[b]Nitrogen was applied in the form of ammonium nitrate four weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

[c]Soil moisture and soil nitrate nitrogen samples were collected at bloom stage on August 15. Soil samples were taken between the bean rows to avoid contact with the ammonium nitrate fertilizer band which was applied post-plant.

Soil Nitrate Nitrogen

The influence of pre-planting cultural practices and rate and time of nitrogen application upon soil nitrate levels during the bean growing season (mid-August) are given in Table 3. Although the soil nitrate levels late in the growing season did not reflect a consistent response pattern due to treatment, some general trends were evident. The soil nitrate levels were higher in the fall plowed than in the spring plowed soil, and the difference of the soil nitrate content between the fall and spring plowed soil might be accounted for by uptake of soil nitrate nitrogen by the rye cover crop which was plowed under on the spring plowed soil or by greater microbial fixations. No increase in the soil nitrate level was observed where 40 pounds per acre of nitrogen was applied to the fall plowed soil, but a 60% higher level of soil nitrate was obtained where 80 pounds of nitrogen had been added as compared to the no nitrogen addition or the 40 pound nitrogen application. Only the highest level of nitrogen application on the fall plowed soil resulted in a greater amount of available nitrogen being present for plant use at bloom set and pod development time. Perhaps the nitrogen applied at lower rates was utilized by plants and microorganisms or lost due to leaching. The 80 pound nitrogen rate did not consistently increase the nitrate content of the spring plowed soil. Microorganisms which were decomposing the rye cover crop may have utilized the nitrate nitrogen which would accumulate in the soil if no cover crop had been plowed under.

Yield

Neither nitrogen which was applied preplant, nor nitrogen which was applied postplant had any appreciable affect upon the pea bean yields; however, the preplant nitrogen application resulted in a slightly higher yield than the postplant nitrogen application (Table 4). Perhaps the postplant nitrogen application was made too late in the growing season to be effective in increasing the bean yield. Ironically, the yields obtained with the postplant nitrogen application were lower than the yields obtained with no nitrogen application. The late addition of nitrogen may have interfered with nitrogen fixation by the bean plant, but was not sufficient to replace the nitrogen previously obtained by fixation.

TABLE 4.--The effect of the rate and time of nitrogen application and cultural practices upon the yield of Sanilac pea beans.[a,b]

Rate and Time of N Application	Plowing Time Before Planting					
	240 days no cover crop	28 days	14 days	14 days rye clipped	1 day	1 day rye clipped
lbs/a	Yield (bu/a)					
0	17.3	17.7	18.6	15.0	17.6	17.1
40 Preplant	17.4	19.4	19.4	15.7	21.2	16.8
40 Postplant	--	15.9	16.2	15.8	16.7	13.8
80 Preplant	17.5	20.0	20.2	18.5	18.8	17.3
80 Postplant	--	15.4	17.3	13.4	16.5	16.2
LSD (.05)	NS	NS	NS	NS	NS	NS

[a]Each value represents the mean of four replications.

[b]Nitrogen was applied in the form of ammonium nitrate four weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

Nitrogen broadcast on the fall plowed soil did not affect the bean yield regardless of rate. The absence of a yield response to nitrogen application might be explained by the absence of a cover crop which affected the moisture and soil nitrate status of the spring plowed soil. The nitrogen applications, at the rates of application used, were not needed to obtain the highest yield of beans when the soil was fall plowed.

The 80 pound per acre preplant nitrogen application gave the highest yield in all instances, except one, which was the plowing time one day before planting.

The yields were significantly less for the plots where the rye cover crop was clipped than for the plots which were note clipped (Table 5). These results were contrary to what was expected. The reason for clipping the rye was to prevent an excessive growth of rye which, in those years where dry conditions persist at planting time, can adversely affect the moisture content of the soil. Keeping the rye clipped minimized the amount of moisture removed by the growing rye crop while helping to control wind erosion. The rye had reached a height of three to four feet at the last plowing time and under

TABLE 5.--The effect of the plowing time and amount of rye cover crop plowed down upon the yield of Sanilac pea beans.[a,b]

Plowing Time Before Planting		Yield
Days		bu/a
28		17.7
14		18.4
14	rye clipped	15.6
1		18.1
1	rye clipped	16.4
LSD (.05)		1.3

[a]Each value represents the mean of twenty-four observations (four replications x 3 nitrogen levels x two nitrogen application times).

[b]Nitrogen was applied in the form of ammonium nitrate four weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

normal conditions would have caused a dry soil condition; however, no decrease in yield occurred. The extremely wet conditions which prevailed during the month of June prior to planting offers a possible explanation. The rye may have improved the aeration of the soil under the wet conditions so that no adverse results occurred. There was no significant yield difference among the various spring plowing times.

Plots which received the postplant application of nitrogen yielded significantly less than plots which received a preplant nitrogen application (Table 6).

TABLE 6.--The effect of the time of nitrogen application upon yield of Sanilac pea beans.[a,b]

Time of N Application	Yield
	bu/a
Preplant	18.7
Postplant	15.7
LSD (.05)	1.0

[a]Each value represents the mean of 60 observations (four replications x three nitrogen levels x five plowing practices).

[b]Nitrogen was applied in the form of ammonium nitrate four weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

In Table 4 the difference between plowing times was not evident because of the variability among the nitrogen levels and plowing practices; however, when these factors are combined, the effect of the nitrogen application time becomes significant. As stated previously, perhaps the postplant nitrogen application was made too late in the growing season to be effective in increasing the bean yield. Since the postplant application was not incorporated into the soil and the rainfall in August was negligible, the nitrogen may not have become available for uptake by plant roots in time to increase the bean yield.

1968 Spring Plowed Data

Plant Dry Weight

The effects of the rate and time of nitrogen application and the plowing time upon the dry weight of Sanilac pea beans are given in Table 7. There were no significant differences in plant dry weight among the bean plants sampled, but some trends are evident. The postplant nitrogen application was generally less effective than the preplant application in increasing plant weights. As previously noted in the 1967 data, the postplant nitrogen application may have been too late in the season to be effective. There was little rainfall between the time the postplant nitrogen was applied and the time

TABLE 7.--The effect of the time and rate of nitrogen application and plowing time upon the dry weight of Sanilac pea beans at bloom set.[a,b,c]

Time and Rate of N Application	Plowing Time Before Planting	
	21 days	7 days
lbs/a	g/3 plants	
0	35.5	38.1
30 preplant	42.0	38.6
30 postplant	32.0	36.3
60 preplant	50.8	32.9
60 postplant	40.7	30.9
90 preplant	36.5	45.1
90 postplant	43.5	32.9
LSD (.05)	NS	NS

[a]Each value represents the mean of three replications.

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

[c]Plants were sampled at bloom set on August 13.

when the plant samples were collected. The preplant application of 60 pounds of nitrogen per acre caused a marked increase in plant dry weight with the plowing time

21 days before bean planting, although the difference was not significant, and the 90 pound per acre postplant application with the plowing time seven days before bean planting also gave a substantial increase in plant dry weight. The difference in growth response between nitrogen rates and plowing times may be explained by the amount of organic material plowed under. Two hundred seventy five pounds per acre of organic matter with a nitrogen content of 3.75% was plowed under with the first plowing time and 880 pounds per acre of organic matter with a nitrogen content of 1.80% was plowed under with the second plowing time. Because more organic matter from the cover crop was turned under with the plowing time seven days before bean planting than with the first plowing time, perhaps more nitrogen was required for its decomposition. There was little difference in plant dry weight among the other rates of nitrogen application.

The plant dry weights obtained from the plowing time one week prior to bean planting were significantly less than those obtained from the other plowing time (Table 8). Perhaps the previously mentioned theory about the relationship between organic material plowed under and

TABLE 8.--The effect of plowing time upon the dry weight of Sanilac pea beans at bloom set.[a,b]

Plowing Time Before Planting	Dry Weight
Days	g/3 plants
21	39.6
7	36.6
LSD (.05)	2.6

[a]Each value represents the mean of 24 observations (three replications x four nitrogen levels x two times of nitrogen application).

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

the amount of nitrogen needed for decomposition was valid. Another explanation for increased growth with the earlier plowtime is the effect of the cover crop upon the moisture status of the soil. A decrease in soil moisture with the increased growth of the cover crop can only be assumed since no soil moisture measurements were made in 1968.

Plant N Concentration and Uptake

Table 9 shows the effects of rate and time of nitrogen application and plowing time upon the nitrogen

TABLE 9.--The effect of time and rate of nitrogen application and plowing time upon the nitrogen concentration and uptake of Sanilac pea beans at bloom set.[a,b]

Time and Rate of N Application	Plowing Time Before Planting			
	21 days		7 days	
	N conc.	N uptake	N conc.	N uptake
lbs/a	%	mg/3 plants	%	mg/3 plants
0	3.03	1076	2.76	1052
30 Preplant	2.81	1180	2.92	1127
30 Postplant	2.92	934	2.83	1027
60 Preplant	3.05	1549	3.18	1046
60 Postplant	2.93	1193	3.04	939
90 Preplant	3.00	1089	3.10	1398
90 Postplant	2.96	1288	2.89	951
LSD (.05)	NS	--	NS	--

[a]Each value represents the mean of three replications.

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

concentration and uptake of Sanilac pea beans at bloom set. In general, the preplant nitrogen application resulted in a greater nitrogen uptake than the postplant nitrogen application. This was logical since there was little difference in nitrogen concentration between plants which received preplant or postplant nitrogen application and since the plant dry weights were generally greater with the preplant than with the postplant nitrogen application. Nitrogen uptake was obtained by multiplying plant dry weight by the nitrogen concentration. The nitrogen uptake obtained with 60 pounds of nitrogen applied preplant was considerably larger than any of the other uptake values obtained from the earliest plowing time and the nitrogen uptake obtained with the 90 pound nitrogen rate applied preplant was considerably larger than any of the other nitrogen uptake values obtained from the latest plowing time. These treatments were also the ones which gave the largest plant dry weights within their respective plowing times. With the plowing time one week prior to bean planting, the decrease in nitrogen uptake when nitrogen was applied postplant became greater with increased amounts of nitrogen application until the 90 pound per acre rate was reached.

The lowest nitrogen concentration of plants grown on soil plowed one week before bean planting was obtained with the check plot and the highest nitrogen concentration was obtained with the 60 pound per acre nitrogen rate. In contrast, with the earliest plowing time the plants grown on the check plots contained as much nitrogen as the plants fertilized with 60 pounds of nitrogen. The bean plants grown on soil plowed three weeks before planting seemed to receive considerable amounts of nitrogen from nitrogen fixation and mineralization; however, bean plants growing on soil plowed one week prior to bean planting were not receiving as much nitrogen from fixation and mineralization, probably because some of the nitrogen was being used to decompose the cover crop which was plowed down. There was considerably more organic material plowed under one week than three weeks before bean planting.

Soil Nitrate Nitrogen

Nitrate nitrogen content of the soil was quite variable (Table 10). In all instances the nitrogen treatments increased the nitrate level over that of the check. Except for the 30 pound per acre nitrogen rate the soil which received a postplant nitrogen application had a

TABLE 10.--The effect of rate and time of nitrogen application and plowing time upon soil nitrate nitrogen status at bloom set stage of a Sanilac pea bean crop.[a,b]

Time and Rate of N Application		Plowing Time Before Planting: 21 days	Plowing Time Before Planting: 7 days
lbs/a		Soil NO_3-N(ppm)	
0		11.5	9.8
30	Preplant	23.7	16.5
30	Postplant	20.8	14.5
60	Preplant	19.1	21.5
60	Postplant	23.7	24.9
90	Preplant	17.5	14.1
90	Postplant	16.9	55.7
LSD (.05)		NS	NS

[a]Each value represents the mean of three replications.

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

nitrate level equivalent to or greater than soil which received a preplant nitrogen application. The postplant nitrogen application was not as efficient, at least in regard to nitrogen uptake, since it resulted in a lower plant nitrogen uptake and a higher soil nitrate content than the preplant nitrogen application.

The soil nitrate value obtained when 90 pounds of nitrogen was applied postplant on soil plowed one week before bean planting was double that obtained from any other treatment. For some reason the plant nitrogen uptake (Table 9) was inhibited with the above mentioned treatment and the nitrates accumulated in the soil.

Yield

Nitrogen treatments investigated generally did not increase pea bean yields (Table 11). The nitrogen applications generally decreased the yield of beans grown on soil plowed three weeks before bean planting and there was no yield response to nitrogen fertilizer applied to soil plowed one week prior to bean planting. A 30 pound per acre nitrogen rate applied postplant reduced the yield substantially with both of the plowing times; possibly due to an interference with nitrogen fixation. The 30 pound nitrogen rate was not sufficient to replace nitrogen obtained from fixation; however, the 60 pound nitrogen rate apparently did replace the fixed nitrogen

TABLE 11.--The effect of the rate and time of nitrogen application and plowing time upon the yield of Sanilac pea beans.[a,b]

Time and Rate of N Application	Plowing Time Before Planting	
	21 days	7 days
lbs/a	Yield (bu/a)	
0	28.5	25.3
30 Preplant	27.2	26.1
30 Postplant	22.9	23.7
60 Preplant	29.6	25.7
60 Postplant	26.1	24.9
90 Preplant	26.1	24.9
90 Postplant	22.6	24.5
LSD (.05)	NS	NS

[a]Each value represents the mean of three replications.

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

because it increased the yield to a level nearly equal to that of other treatments.

The postplant applications of nitrogen significantly decreased the yield of pea beans (Table 12). Plant

TABLE 12.--The effect of the time of nitrogen application upon the yield of Sanilac pea beans.[a,b]

Time of N Application	Yield
	bu/a
Preplant	26.8
Postplant	24.5
LSD	1.5

[a]Each value represents the mean of 24 observations (three replications x four nitrogen levels x two plowing times).

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

weights and nitrogen uptake were similarly affected with the postplant nitrogen applications.

Yields were significantly greater for the earlier plowing time than for the later plowing time (Table 13). Again the plant weight data showed a similar effect due to plowing time.

The beans in this investigation were receiving enough nitrogen from fixation and mineralization so that additional nitrogen did not increase the yields. The nitrogen applications actually decreased the yields in some instances.

TABLE 13.--The effect of plowing time upon the yield of Sanilac pea beans.[a,b]

Plowing Time	Yield
Days	bu/a
21	26.4
7	24.9
LSD (.05)	0.7

[a]Each value represents the mean of 24 observations (three replications x four nitrogen levels x two times of nitrogen application).

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting (preplant) and six weeks after bean planting (postplant).

1968 Fall Plowed Data

Plant Dry Weight

There is a trend of increased plant weights with additions of nitrogen on the fall plowed soil although the differences in plant weights among nitrogen treatments were not significant (Table 14). The lowest plant weight was obtained from plots with no nitrogen addition while the highest plant weight was obtained from plots which received 30 pounds of nitrogen per acre.

TABLE 14.--The effect of the rate of nitrogen application upon the dry plant weight, nitrogen concentration and uptake, soil nitrate content, and yield of a Sanilac pea bean crop.[a,b]

Rate of N Application	Plant Weight	N Conc.	N Uptake	Soil NO_3-N	Yield
lbs/a	g/3 plants	%	mg/3 plants	ppm	bu/a
0	41.3	3.00	1239	18.9	22.6
30	52.9	3.31	1751	11.0	23.7
60	42.9	3.18	1364	18.8	22.6
90	44.1	3.37	1486	17.9	26.1
180	48.4	3.57	1728	19.3	25.7
360	47.1	3.41	1606	50.1	25.3
LSD (.05)	NS	0.27	--	14.6	NS

[a]Each value represents the mean of three replications.

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting.

The 60 pound per acre nitrogen rate gave a marked reduction in plant weight as compared to the 30 pound nitrogen rate. Perhaps the 60 pound nitrogen application interfered with nitrogen fixation, but was not a sufficient amount of nitrogen to replace nitrogen previously obtained by fixation.

Plant N Concentration and Uptake

Nitrogen concentration and uptake data response patterns were similar to those of the plant weight (Table 14). The nitrogen concentration obtained from plots which received no nitrogen fertilizer was significantly different from the nitrogen concentrations of all other nitrogen treatments except the 60 pound per acre nitrogen rate. Again as observed with plant weight data, the 60 pound nitrogen rate decreased the nitrogen concentration and uptake as compared to the 30 pound per acre nitrogen rate. Plant nitrogen concentration and uptake increased progressively with nitrogen rates of 60 to 180 pounds per acre; however, the 360 pound per acre rate decreased the nitrogen concentration and uptake slightly.

Soil Nitrate Nitrogen

Nitrate nitrogen contents of the soil were not greatly affected by nitrogen treatments, except at the 360 pound per acre rate (Table 14). The soil nitrate content obtained with the 30 pound per acre nitrogen rate was decreased substantially as compared to the zero and 60 pound nitrogen applications, probably because the nitrogen uptake for the 30 pound nitrogen rate was markedly greater than the nitrogen uptake for the zero and 60 pound nitrogen applications. Soil nitrate content obtained with the 360 pound nitrogen rate was significantly larger than nitrate contents obtained with any of the other treatments. Decreases in plant nitrogen concentration and uptake with the 360 pound nitrogen rate may be explained by the high soil nitrate content. The high level of soil nitrate nitrogen could have interfered with early growth of the bean plants possibly by inhibiting nitrogen fixation or root growth in some way.

Yield

Yield responses of Sanilac pea beans to nitrogen applications were not significant; however, trends in yield similar to those previously noted in plant weight, nitrogen concentration, nitrogen uptake, and soil nitrate content were evident. The lowest yields were obtained with the zero and 60 pound per acre nitrogen rates. The 60 pound nitrogen application reduced the yield slightly as compared to the 30 and 90 pound nitrogen applications, probably because of interference with nitrogen fixation as was noted with plant weight and nitrogen concentration and uptake data.

Small amounts of additional inorganic nitrogen have been shown to stimulate nitrogen fixation usually through increased plant growth and nitrogen applied in excess of that needed for an increase in growth directly replaced the fixation process (Allos and Bartholomew, 1959). The 30 pound per acre nitrogen rate substantially increased the plant weight as compared to the zero and 60 pound nitrogen rate. Since the yield and plant weight of the pea beans grown on fall plowed soil with the 60 pound nitrogen rate were nearly equal to the yield and plant weight of the pea beans which received no nitrogen fertilizer, the pea beans may have fixed about 60 pounds of nitrogen per acre.

Nitrogen applications failed to significantly affect the yield of pea beans with either the spring plowed or the fall plowed soil; however, some trends were evident (Table 15). Pea beans grown on spring plowed soil produced a greater yield until the 90 pound per acre nitrogen rate was attained. At this nitrogen

TABLE 15.--The effect of the plowing time and the rate of nitrogen application upon the yield of Sanilac pea beans.[a,b]

Rate of N Application	Yield	
	Fall Plowed	Spring Plowed
lbs/a	--------------bu/a---------------	
0	22.6	28.0
30	23.7	26.4
60	22.6	27.6
90	26.1	25.7
LSD (.05)	NS	NS

[a]Each value for the fall plowed soil represents the mean of three replications. Each value for the spring plowed soil represents the mean of six observations (three replications x two plowing times).

[b]Nitrogen was applied in the form of ammonium nitrate three weeks prior to bean planting.

rate no difference in yield was noted between the plowing times. Nitrogen fertilization was not needed on the spring plowed soil because the yield was greater for the plots which received no nitrogen than for the nitrogen fertilized plots, but the fall plowed soil appeared to have a need for additional nitrogen since the 90 pound nitrogen rate substantially increased the bean yield as compared to the other nitrogen treatments. Perhaps the cover crop supplied enough nitrogen for the beans grown on spring plowed soil and additional nitrogen gave no increased yield response.

Greenhouse Data

The effects of nitrogen application and cropping with Sanilac pea beans upon the soil nitrate status, plant growth, and plant nitrogen concentration and uptake are given in Tables 16 and 17. Considerable variation was observed in the initial nitrate levels of the soil prior to treatment addition and cropping; however, a single cropping reduced the soil nitrate level to a point where only the soil which received 80 ppm of nitrogen contained significantly more nitrate nitrogen than the other treatments. The second and third crops depleted the soil nitrate levels very little indicating that a substantial source of nitrogen, other than the added nitrogen, was available to the plants during the period of growth for each crop.

TABLE 16.--The effect of the rate of nitrogen application and cropping with Sanilac pea beans upon the soil nitrate nitrogen status of a Wisner clay loam soil.[a,b]

Rate of N Application	Sampling Time			
	Initial NO_3 Content[c]	After First Crop	After Second Crop	After Third Crop
ppm	------------------Soil NO_3---	---	---	---
0	21.5	15.7	14.0	11.8
2.5	19.0	8.2	9.9	11.8
5.0	34.5	12.8	12.7	14.0
7.5	25.7	10.8	5.0	12.2
10.0	26.2	16.4	8.6	10.3
12.5	28.2	14.0	8.3	11.4
15.0	38.0	14.3	6.9	10.4
20.0	43.0	11.3	9.6	10.4
40.0	30.8	15.9	17.7	13.5
80.0	35.3	24.6	12.2	13.9
LSD (.05)	12.1	7.1	NS	NS

[a]Each value represents the mean of four replications.

[b]Nitrogen was added to the soil in the ammonium nitrate reagent chemical form before the first crop was planted.

[c]The initial nitrate content is the soil nitrate nitrogen status prior to addition of nitrogen treatments.

TABLE 17.--The effect of the rate of nitrogen application and three crops of Sanilac pea beans upon the nitrogen concentration and uptake and plant dry weight.[a,b,c]

Rate of N	First Crop			Second Crop			Third Crop		
Application	Dry Weight	N Conc.	N Uptake	Dry Weight	N Conc.	N Uptake	Dry Weight	N Conc.	N Uptake
ppm	g/pot	%	mg/pot	g/pot	%	mg/pot	g/pot	%	mg/pot
0	7.4	3.13	231.6	6.9	2.13	147.0	6.4	3.61	231.0
2.5	7.2	2.88	207.4	7.6	2.14	162.6	6.2	3.50	217.0
5.0	7.9	3.03	239.4	6.7	2.08	139.4	5.9	3.62	213.6
7.5	8.2	3.15	258.3	6.9	2.01	138.7	5.6	3.46	193.8
10.0	7.6	2.91	221.2	7.3	2.05	149.7	5.9	3.46	204.1
12.5	7.0	2.83	198.1	6.9	2.03	140.1	5.8	3.52	204.2
15.0	8.2	2.59	212.4	5.6	2.78	155.7	5.6	3.46	193.8
20.0	7.8	2.84	221.5	6.3	2.08	131.0	6.1	3.64	222.0
40.0	9.2	2.92	268.6	6.5	2.31	150.2	5.7	3.48	198.4
80.0	9.6	3.41	327.4	8.0	2.36	188.8	6.1	3.49	212.9
LSD (.05)	1.1	NS	--	--	NS	--	NS	NS	--

[a]Values for the first and third crop represent the mean of four replications. Values for the second crop represent one observation.

[b]Nitrogen was added to the soil in the ammonium nitrate reagent chemical form before the first crop was planted.

[c]Plant dry weight and nitrogen uptake data are calculated on the basis of four plants per pot.

The only response in growth and nitrogen concentration was with the 40 and 80 ppm levels of nitrogen addition on the first crop (Table 17). Nitrogen uptake values followed a similar pattern, and no response to the original nitrogen addition was obtained in crops two or three.

All of the soil nitrogen should have been depleted with the first crop of pea beans even at the highest rate of nitrogen addition if no other sources of nitrogen than the initial and the added nitrogen were available to the plants (Table 18). The bean plants obtained considerable amounts of nitrogen from nitrogen fixation and/or mineralization. A soil nitrate level of about 10 ppm was maintained after each of the three crops even though nitrogen was added only before the first crop. The nitrogen obtained by fixation and by mineralization was sufficient for normal growth of Sanilac pea beans on the Wisner clay loam soil under the conditions studied. Additional nitrogen was not needed provided that a certain minimal amount of nitrate nitrogen, about 10 ppm, was present in the soil at planting time and during early plant growth.

TABLE 18. The relationship between the soil nitrate nitrogen level and the plant nitrogen uptake.[a,b]

Rate of N Application	Total NO_3-N[c] Supply Before 1st Crop	Soil NO_3-N Supply After 1st Crop	Soil NO_3-N Available for Plant Uptake	First Crop N Uptake	Portion of 1st crop N Uptake Available From Soil	Portion of 2nd Crop N Uptake Available From Soil	Portion of 3rd Crop N Uptake Available From Soil
ppm	mg/pot	mg/pot	mg/pot	mg/pot	%	%	%
0	68.8	50.2	18.6	231.6	8.0	3.7	3.0
2.5	68.8	26.2	42.6	207.4	20.5	0	0
5.0	126.4	41.0	85.4	239.4	35.7	0.3	0
7.5	106.2	34.6	71.6	497.7	14.4	13.4	0
10.0	115.8	52.5	63.3	221.2	28.6	16.7	0
12.5	130.2	45.1	85.1	419.3	20.3	13.2	0
15.0	169.6	45.8	123.8	212.4	58.3	15.2	0
20.0	144.9	36.2	108.7	221.5	49.1	4.2	0
40.0	226.6	50.9	175.7	268.6	65.4	0	6.8
80.0	369.0	78.7	290.3	327.4	88.7	21.0	0

[a] Each value represents the mean of four replications.

[b] Nitrogen was added to the soil in the ammonium nitrate reagent chemical form before the first bean crop was planted.

[c] The total NO_3-N supply before the first crop includes the initial soil NO_3-N content from Table 16 plus the added treatment nitrogen.

SUMMARY AND CONCLUSIONS

The influence of nitrogen fertilization and cultural practices upon the growth and yield of Sanilac pea beans under field and greenhouse conditions as evaluated by soil nitrate nitrogen and moisture content, early growth, nitrogen concentration and uptake of pea bean plants; and yield of pea beans was investigated. The conclusions drawn were:

1. Clipping the rye cover crop growing on soil plowed just prior to bean planting reduced the moisture removal by the rye plants by 50%. A rye cover crop planted in the fall and kept clipped to a six inch height in the spring is a practical method for controlling wind erosion.

2. Addition of 40 pounds of nitrogen per acre doubled the nitrogen content of the rye cover crop plowed under two weeks before bean planting and tripled the nitrogen content of rye plowed under one day before bean planting.

3. Pea beans fertilized with a preplant nitrogen application yielded significantly more than pea beans receiving a postplant nitrogen application.

4. Nitrogen fertilizer applications on spring plowed soil regardless of rates, did not significantly increase plant nitrogen concentration, dry plant weight, bean yield, and soil nitrate nitrogen content.

5. Nitrogen fertilizer applications on fall plowed soil significantly increased plant nitrogen concentration and soil nitrate nitrogen content, but not plant weight or bean yield in 1968.

6. The plowing time three weeks before bean planting significantly increased the early growth and yield of pea beans compared to a plowing time of one week before bean planting in 1968.

7. Pea beans grown on fall plowed soil yielded less than beans grown on spring plowed soil.

8. Cropping with pea beans decreased differences in the soil nitrate nitrogen contents of greenhouse

soils regardless of rate of nitrogen application.

9. Nitrogen applications did not affect plant nitrogen concentration and significantly affected the dry plant weight of only the first crop of pea beans grown in the greenhouse.

10. Pea beans grown in the greenhouse obtained most of their nitrogen from nitrogen fixation and mineralization, not from applied nitrogen fertilizer or from nitrate nitrogen initially present in the soil.

Sanilac pea beans in this study did not need additional nitrogen provided that a certain minimal amount of nitrate nitrogen (about 10 ppm) was present in the soil at planting time and during early growth. Bean plants were receiving enough nitrogen from mineralization and fixation to meet their needs.

Postplant nitrogen applications decreased the bean yields when compared to no nitrogen application, probably because of an interference with the already established processes of nitrogen fixation.

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