THE EFFECT OF NITROGEN FORMS AND METHODS OF APPLICATION UPON YIELD AND SEVERAL YIELD COMPONENTS OF SOYBEANS (Glycine max. L.)

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

MANSOOR TASDIGHI

1977

ABSTRACT

THE EFFECTS OF NITROGEN FORMS AND METHODS OF APPLICATION UPON YIELD AND SEVERAL YIELD COMPONENTS OF SOYBEANS

BY

Mansoor Tasdighi

The effects of combined nitrogen on yield and some other agronomic characteristics were studied on soybean (*Glycine max*. L). Soil Applications of calcium nitrate were carried out at weekly intervals. A suppressive effect of soil nitrogen on the number of nodules per plant was observed. It was found that yields could be increased by delaying the application of nitrogen fertilization.

Foliar fertilization using three nitrogen sources, each at four rates was studied on soybeans. This study was carried out at the mid-pod fill stage of development and showed a negative correlation between yield and rate of nitrogen fertilizer. The degree of burning was correlated with the solubility and salt index of the fertilizer.

THE EFFECT OF NITROGEN FORMS AND METHODS OF APPLICATION UPON YIELD AND SEVERAL YIELD COMPONENTS OF SOYBEANS (Glycine max. L.)

By

Mansoor Tasdighi

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Crops and Soil Sciences

1977

ACKNOWLEDGEMENTS

The author wishes to express deep acknowledgement to Dr. Taylor J. Johnston who suggested and guided the current project and generously supplied encouragement and advice throughout the course of this investigation. He also wishes to extend acknowledgement to Dr. Everett H. Everson for his appreciable advice and encouragement and for reviewing this manuscript.

The author expresses great appreciation to Dr. Charles E. Cress for his invaluable help in statistical advice and serving in the guidance committee.

The author wishes to express further acknowledgement to his family in Iran for their moral support during his stay in the U.S.A.

The author thanks the students, faculty and staff of this department who made this period interesting and rewarding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (cont.)

INTRODUCTION

Soybeans (Glycine max. L. Merr.) like many other legume plants are able to gain a significant amount of their nitrogen requirements through the fixation of atmospheric nitrogen by specific bacteria that are living symbiotically in the nodules of their roots. The healthier and the more the number of the nodules, the greater the amount of atmospheric nitrogen that is fixed (9). The number of nodules and the percentage of nitrogen fixed are influenced by the available calcium in the medium (3, 12, 13, 32, 35, 43, 61, 64). Smith et al. (67) increased soybean yields from 20 - to 35 bu/ac by applying 4 tons of limestone per acre, which raised soil pH from 5.3 to 6.3. Grower, et al. (17) found that lime, generally, increased early establishment, seedling vigor, and subsequent dry matter yield of legumes. Lime is believed to contribute to the establishment of a proper medium for activation, survival and multiplication of rhizobia in sour soils(3, 53, 61, 64, 79).

The ability of the soybean plant (Glycine max. L. Merr.) to utilize both soil nitrogen (primarily nitrate) and atmospheric nitrogen has complicated the nitrogen status of soybeans. When good nodulation is present on soybean plants, only rarely has the addition of inorganic fertilizer proven profitable. Perhaps workers have simply not learned when, how, or what form of nitrogen to apply without inactivating in part the rhizobium nitrogen fixing bacteria (9).

Many investigators (16, 18, 20, 27, 33, 57) have emphasized the importance of some combined nitrogen in attaining maximum yield. Their yield of soybeans was closely correlated with the amount of nitrogen accumulated throughout the life cycle of the plant. Grain yields was determined by the number of pods and subsequently by the number of seeds retained by the plant, and this in turn was determined by the levels of nitrogen available during the bloom and seed filling periods. The widely accepted inadequacy of the symbiotic nitrogen fixation in soybeans for maximum yields, (21, 22, 24, 25, 30, 33, 41, 48, 63, 78), suggests a need for additional research in nitrogen fertilization of soybeans. From the many studies conducted, most research workers agree that symbiotically fixed nitrogen is adequate at the 20 - bushel per acre level but at the 40 - to 60 - bushel level, from one - third to as much as one - half of the nitrogen in the plant comes from the soil in the form of nitrates and ammonium ions (21, 47, 50). It has also been clearly shown that as the combined nitrogen supply increases, the contribution of the symbiotic bacteria decreases (52, 55, 56). This decrease in efficiency of the bacteria as the combined nitrogen is increased would suggest that relatively low rates of nitrogen fertilizer might be quite ineffective (47).

The objectives of this experiment were: (1) to find a proper rate, time and form of nitrogen application for optimum yield and number of nodules on soybean roots (2) to study the effect of soil fertilization with calcium nitrate on nodulation of soybean plants (3) to find the effects of foliar application of different nitrogen fertilizer sources on seed yield of soybeans.

LITERATURE REVIEW

Questions concerning nitrogen fertilization of soybeans are frequently raised, especially in view of the present supply of fertilizer nitrogen. Many investigators (29, 51, 52, 55, 56, 60, 62, 65, 66), working in this area, have proven that combined nitrogen has negative effects on the number of nodulated roots and thus on the number of nodules.

To explain the effects of nitrogen compounds on the nodule formation, several possibilities have been put forward. Ludwing and Allison (40) propose that variation in C:N quotient during nitrogen assimilation is responsible for the change in the reaction of the legume plant to nodule bacteria. In the presence of low nitrogen, soybean plants contain an excess of carbohydrate, some of which is secreted by the roots into the rhizosphere where it stimulates the growth of micro-organisms (24, 26, 55, 73, 78). But with increasing nitrogen concentration the plant carbohydrate may be tied up in the protein forming process to such an extent that there is little if any carbohydrate excreted from the roots into the rhizosphere (55). If so, there would be little inducement for the bacteria to be attracted to the plant roots.

Rovira (59) indicated that during growth stages of peas actual excretions form the bulk of the material coming from the roots, and hence must play an important role in the stimulation of the micro-organisms on and around the roots. Secretions produced by a particular legume stimulate multiplication of rhizobial strains effective for that species more than ineffective ones or other bacteria (69).

Bacteria secrete materials which may cause root hairs to curl and become crook shaped, prior to actual invasion by the bacteria (9). This may be B-indoleacetic acid (IAA) since pure IAA and filtrates from rhizobia and other bacteria also induce root hair curling (31, 69). It is also known that IAA may be produced by rhizobia from tryptophan excreted by the roots. The curling of root hairs is considered to be the role of auxin. Auxin may also play an important role in the growth of infection threads* and the initiation of the cell division leading to nodule formation. Tanner (70) proposes that the effect of combined nitrogen on nodulation is due to a reduction of auxin concentration in the rhizospher.

Using strains of Rhizobium meliloti; R. trifolii, and R. japonicum, it has been shown that nitrate is reduced to nitrite which inactivates IAA, but that the presence of NH_4++ inhibits the conversion of tryptophan to IAA (70).

Once root hair curling occurs, the host produces extracellularly the enzyme pectinase in response to a stimulus caused by specific rhizobia. Ljunggren (36), in an extensive study, indicated that pectinase activity is influenced by the presence of calcium. It was suspected that the decreased enzyme activities with increasing nitrate concentrations might be due to an ion exchange resulting in Ca++ leakage from the roots into the medium. In this relation, Loneragan (37) suggested that there is a calcium shortage in the host plant. It is evident from Ljunggren's studies that there is a close association between pectinase production and nodulation. The retarding or inhibiting effect of

---

* Threads are formed by the cytoplasm of the host cell and is a thin, continuous line of Rhizobia inbedded in baterial slime (9, 82).

absorbable nitrogen on nodulation works through a delayed or prevented production of pectinase.

It has been shown that prevention of nodulation is reached only above certain soil nitrogen concentration levels. Early supplies with small amounts of mineral nitrogen enable the plant to maintain a reasonable growth rate from the outset. This may cause more rapid plant growth and root development which would then prepare more sites for nodule production (4, 24, 25, 52, 62, 73).

There are a considerable number of literature reviews (i.e. 21, 22, 24, 25, 33, 38, 78) on behalf of inadequacy of nitrogen fixation by the rhizobia living symbiotically on a soybean plant's roots to meet the needs of the plant. Nodulated sobyeans do not make maximum dry weight yields when relying throughout the life cycle predominantly on nitrogen fixation to supply total nitrogen needs of the plant (48). In field experiments carried out by Kang (30), fixed nitrogen was adequate to supply the nitrogen needs of the crop, but 30 Kg N/ha was needed with inoculation for maximum yields. Increased yields and higher content of total nitrogen fertilizer have significantly outyielded those not supplied additional available nitrogen (24).

The time of applying nitrogen fertilizer is of considerable importance. Many researchers (22, 24, 63) have emphasized the requirement of an adequate nitrogen supply at early stages of growth for superior vegetative growth. Availability of mineral nitrogen at the full-bloom growth stage is critical (21, 63). Much nitrogen is needed at this stage for duplication of both genetic and protoplasmic proteins. Shibles and Weber (63) indicate that if nitrogen is limiting at full-bloom or pod and seed setting, abortion of potential storage sites occurs. During bean filling, nitrogen is needed for production of storage proteins.

There is some evidence that nitrogen added below the nodule zone may inhibit nitrogen fixation less than nitrogen applied in the nodule zone. Van Schreven (73); Harper and Cooper (23); and Criswell et al. (10), individually have shown that leghemoglobin levels are reduced less when nitrogen was supplied deep within the root zone. Nodular development and nodule number are inhibited less when nitrogen was placed below the primary zone of nodulation.

The less mobile forms of mineral nitrogen have less retarding effects on nodulation. Allos and Bartholomew (4) have concluded that, in general, the greater the total and attentive immobilization of nitrogen, the larger the fixation. Tanner (70) has concluded that the nitrate forms of combined nitrogen are less suppressive than other forms of nitrogen fertilizer.

As mentioned earlier, calcium plays some physiological roles in favoring nodulation and its effects are local or restricted in increasing the number of root infections (3). Several investigators (61, 64, 74) believe that the influence of calcium toward increasing nodulation is one of keeping the bacteria viable and infective during a long period of time. Albrecht and Davis (3); Loose and Louw (38); and White (79), are of the opinion that the effect of calcium is not necessarily one of keeping alive the bacteria applied as inoculant since liming increases the number of nodules caused by organisms originally present in the soil. In the absence of clacium, bacteria develop chromogenic forms which will not form nodules on legumes (43). With the addition of calcium, these revert to non-chromogenic forms which nodulate the host legume normally.

It has been observed by many researchers (i.e. 2, 46, 64, 68, 79) that calcium and hydrogen ions intereacted on nodulation. In the studies of Albrecht (2) no nodules were produced by the soybean plants at pH 5.0 or lower. In soils with a pH lower than 5.0, the nodulation failure was brought about not so much by the degree of acidity as by the deficiency of the available calcium in the soil. This emphasized the need for consideration of fertilizing with calcium on the less acid soils as well as changing the reaction in those of higher degrees of acidity, if soybeans and possibly other legume crops are to grow well and to be thoroughly inoculated. In this relation, Spencer (68) proposed a combination of both these factors for maximum nodulation, since neither increased pH nor increased calcium supply alone markedly improved nodulation. In addition, Munns (46) has declared that increasing soil aciity increased the calcium concentration needed to achieve better nodulation. Further, Albrecht (1) pointed out clearly that the significance of calcium for the soybean plants rests on its function as an element in the plants' activities rather than on that of reducing hydrogen ion concentrations of the soil or growth medium.

The calcium supply must first meet the requirements for growth and then an additional amount of this element is needed to permit nodule formation. It has been pointed out from previous works (i.e. 3, 28, 37, 74, 75, 76, 77) that the cell walls of calcium-deficient seedlings fail to retain their shape. Almost all of the calcium of deficient cells is located in the wall fraction. There is markedly swollen conditions, the results from the omission of calcium, which is found to lie associated with marked vacuolation. Vacuolation suggests the liklihood that the cell wall has lost its normal rigidity and has permitted extra water to be taken in.

The more soluble forms of calcium appear to be more effective, since the use of calcium by Scanlan (61) both in the form of calcium chloride and calcium nitrate, gave significant increases in nodulation when compared to calcium acetate and calcium carbonate supplemented with acid phosphate. Both of these forms of calcium, when used on soybeans, not only increased nodulation but also increased the percentage of plants having nodules on their roots. Because of the immobility of calcium within the plant a constant supply of this element is required by the soybeans (49).

During recent years, the practice of applying fertilizer solutions directly to the foliage of agricultural plants has received increasing attention. A number of crops have responded well to this method of fertilization, while others have shown no significant effect on yields or are severely damaged by even small applications of fertilizer solutions (15, 45).

The success of minor elements in foliar sprays encouraged investigators to try to supplement or replace soil applications with macronutrient elements (8). Mederski et al. (44), in the studies with six important field crops over a period of three years, concluded that the applications of complete foliar sprays did not serve as an effective supplement to or as a substitute for conventional soil fertilization practices. Later on, Rajan et al. (54), in a review of recent works on foliar application of plant nutrients to crops, concluded that the same rate of fertilizer gives greater increase in crop yields when applied as a foliar spray than when applied to the soil. The effectiveness of fertilizers is conditioned by the rate of uptake and subsequent mobility of the nutrients often is more beneficial when applied as a supplement to rather than as a substitute for soil application of fertilizers (54).

In most recent years, the studies of many researchers (5, 14, 58, 71) have shown promising results for foliar application of macronutrient elements on different crops. Most of the positive responses were obtained when nutrients were sprayed throughout the fruit setting and seed filling periods. Roman Garcia and Hanway (58) postulate that the uptake of nutrients from the soil and their rate of translocation through the xylem is not adequate to supply the requirements of the soybean plants and avoid the normally observed depletion of macronutrients (e.g. N, P, K, and S) from the leaves during the seed filling period.

Theoretically, foliar feeding of plants has many advantages over the conventional method of nutrient uptake from the soil (80). The ease of application; the more accurate and precise control of the nutrient levels of plants; and the greater availability of nutrients are advantages. Also, leaf feeding apparently eliminates many difficulties of soil fertization, such as, fixation, leaching, undesirable pH, limited moisture supply, and nutrient antagonisms. Other advantages which may be credited to foliar feeding are, the economy of fertilizer usage, avoidance of mechanical injury to the roots, and the possibility of the intake of nutrients through the leaves without being affected by low temperatures to the same extent as in absorption by roots. All minerals when sprayed unappropriately caused more or less burning on foliage. Lucas (39) suggests fertilizers can show differences in burn which are measured by a "salt index". This index is compared against an equal weight of sodium nitrate. The salt index for some common fertilizers:

Salt	Salt index*
Potassium chloride	116
ammonium nitrate	105
sodium nitrate	100
Urea	75
Potassium nitrate	74
Ammonium sulfate	69
Calcium nitrate	65
Potassium sulfate	46
Super phosphate (0-46-0)	10
Mono potassium phosphate	8
Gypsum	8
Limestone	5

* From Rader et al., soil Science 55-201-218.

MATERIALS AND METHODS

Field studies were conducted at the Crops Science Research Farm of Michigan State University (CSRF-MSU) at East Lansing, Michigan, on fine sandy loam soil with a pH of 6.0 during 1972 - 1976. A well-adapted variety, "Hark" in Maturity Group I, was used. Plots were not irrigated.

Preliminary studies in 1972 included rates of 25 and 50 pounds of nitrogen per acre in the form of calcium nitrate (15.5% N) applied at planting or at 3, 6, 9 or 12 weeks after planting. A check plot with no nitrogen application was included in a randomized complete block design with three replications. During the growing seasons of 1973 - 1976, the previous studies were improved to weekly intervals and the rates of applications were changed to 45 and 90 pounds per acre of calcium nitrate fertilizer. The times of application began three weeks after planting and ended ten weeks after planting, resulting in ten treatments for each of application rate as follows: check, at planting time 3, 4, 5, 6, 7, 8, 9 and 10 weeks after planting.

The variables were arranged in three replications of a split plot design with rates as the main plots and times of applications as the sub-plots during the studies from 1973 to 1976.

The seeding rate resulted in approximately 15 plants per meter of row in rows 75 cm apart in all years and locations. Each plot was 6.1 meter long and four rows wide. The calcium nitrate fertilizer was applied as a side dressing, 5 cm from each row with a Planet Junior machine. Adequate phosphorus and potassium (250 pounds per acre of 0-26-26 fertilizer) were added at planting time to all plots each year.

In 1976, adjacent soybean plots of the same variety received one foliar application of fertilizer nitrogen at the early pod-fill stage, when the lower pods were just beginning to fill. This study was conducted at CSRF-MSU, in support of the soil fertilization practice. Calcium nitrate, Ammonium nitrate, and Urea solutions were sprayed, each at rates of 10, 20, 30 or 40 pounds per acre, on the leaves of soybean plants in 24 gallons of water per acre, with a Hudson backpack sprayer equipped with a constant pressure control valve. This study was in a completely randomized design with three replications.

One week after the last calcium nitrate application, data to determine the effect of soil nitrogen on nodulation were taken for each treatment. This was done by lifting out one-half meter of the row, washing the soil from the roots and counting the number of nodules. These values were then converted to the number of nodules per plant.

Some other yield components, such as number of pods, seeds, and branches per plant, number of seed per pod and seed size, were measured one week prior to harvesting. These data were taken for each treatment by cutting the plants just above the soil surface in one-half meter of the row and counting the number of pods, branches and seeds. These values were then converted to the number of pods, seeds and branches per plant and number of seeds per pod. A measure of seed size was obtained by weighing one hundred seeds for each treatment. The plants from one-half meter of the row of foliar practice were cut into three equal sections, top, middle and bottom and the same data as above were taken for each section.

The seed yield data for both soil and foliar practices were taken by harvesting 5 meters of the center two rows of each plots. Harvested seeds were dried to a uniform moisture, weighed and recorded as bushels of soybeans seeds per acre.

RESULTS AND DISCUSSION

1) Soil practice:

Results of the 1972 experiment are presented in Table 1 and show a 14.7% yield increase (5.6 BU/A) when 50 pounds of actual nitrogen were applied per acre three weeks after planting when compared to the check plot yield. The six week application increased yields 5.1 bushels per acre, a 13.4% increase.

Because of the similarity of yields of the three and six week applications, the treatments were increased to weekly intervals in 1973 to see if a yield peak had been missed in 1972. Figure 1 and Table 2 show yield results for 1973 and 1975. The 25 pound rate did not give statistically significant yield increases in 1972 so the rates were changed to 45 and 90 pounds calcium nitrate per acre. Although not statistically significant all times, except 3-week, applications at the 90 pound rate gave some increase in yield over the check plots in 1973. For both rates, highest yields were obtained from nitrogen application at either six weeks or seven weeks after planting in 1973. Figure 1 shows a striking resemblance between the 1973 and 1975 yield response

Table 1... Yield of soybeans (BU/A) as affected by Time and Rate of Nitrogen Application in the Soil for 1972

Treatment time	25 lbs N/A	50 lbs N/A
Check (no nitrogen)	38.8	38.0
0 week (planting)	41.1	41.8
3 weeks	40.4	43.6
6 weeks	38.2	43.1
9 weeks	40.1	40.5
12 weeks	39.2	42.2

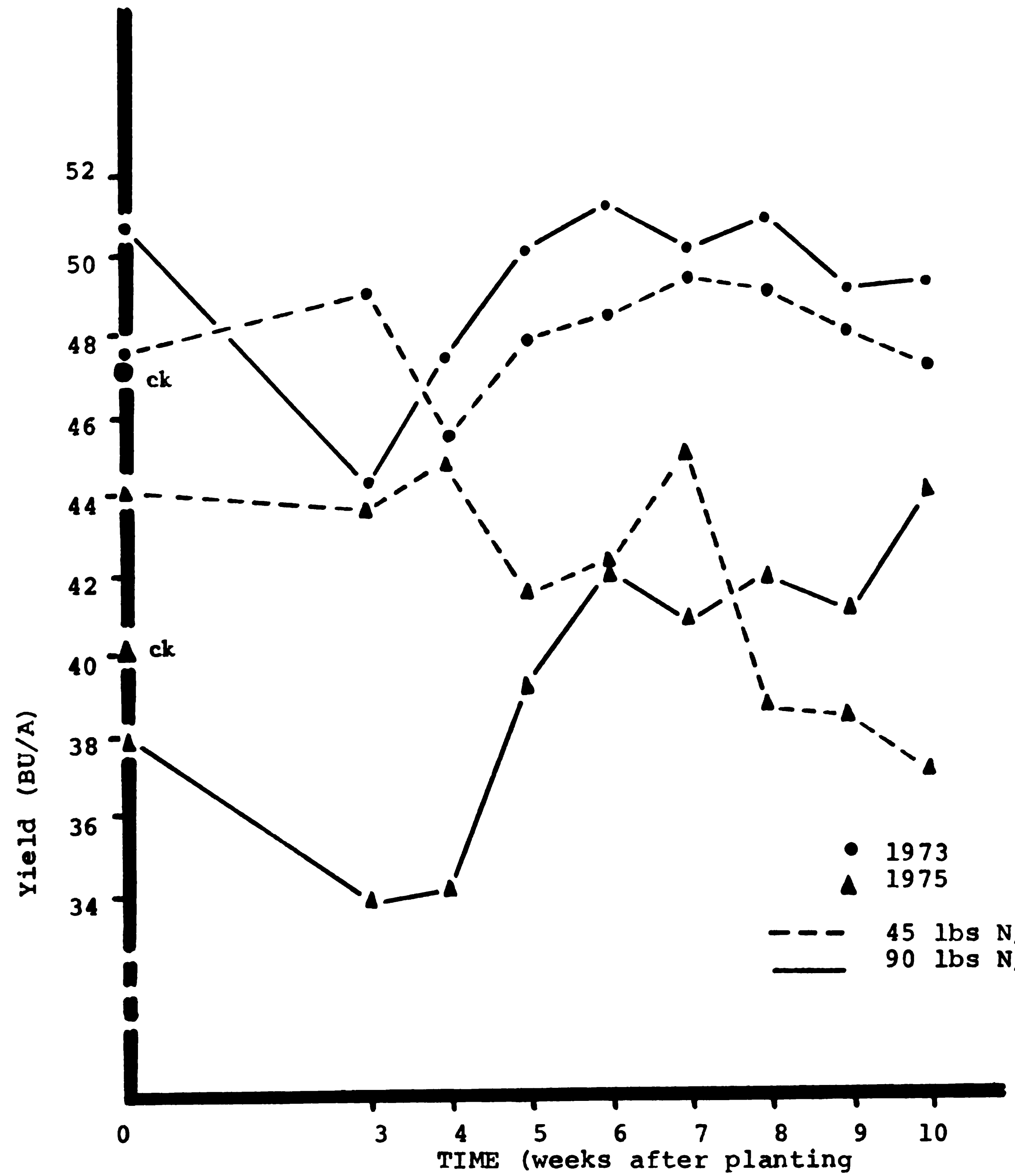


Figure 1... Yield of Soybeans (BU/A) as Affected by the Time and Rate of Nitrogen Application in the Soil for 1973 and 1975.

Table 2... Yield of Soybeans (BU/A) as Affected by Time and Rate of Nitrogen Application in the Soil for 1973 and 1975

Treatment Time	45lbs N/A		90lbs N/A		Average	
	1973	1975	1973	1975	45lbs	90lbs
Check (no N)	47.5	43.7	47.1	36.3	45.6	47.1
0 week(planting)	47.5	44.1	50.7	37.9	45.8	44.3
3 weeks	49.0	43.6	44.2	33.8	46.3	39.0
4 weeks	45.4	44.7	47.4	34.1	45.1	40.8
5 weeks	47.8	41.5	50.1	39.2	44.7	44.7
6 weeks	48.4	42.2	51.2	42.1	45.3	46.7
7 weeks	49.4	45.0	50.1	40.8	47.2	45.5
8 weeks	49.0	38.7	50.9	41.9	43.9	46.4
9 weeks	48.0	38.5	49.1	41.0	43.3	45.1
10 weeks	47.1	37.1	49.2	44.0	42.1	46.6

carried for the 90 pound rate, and even though an explanation is not readily obvious, yields were lowered with the application of 90 pounds of nitrogen three weeks after planting as compared to yields when nitrogen was applied at planting. Although statistically significant only at the 10% level due to variability in results, the 1975 data do show some interesting interactions between time and rate of application (Figure 1). The only yields greater than 40 bushels per acre were obtained when nitrogen application was delayed until at least six weeks after planting at the 90 pound rate.

The 1974 experiment was identical to that of 1973, but a severe drought and lack of irrigation capability caused yields to be extremely low and results highly variable. Consequently, results from 1974 are not included.

In 1975 and 1976 additional data related to the number of nodules per plant, number of seed retained per plant and the number of seeds filled per pod, were recorded for each treatment (Table 3). Although an early frost influenced the final yield results for 1975 (Figure 1), the nodulation data, shown in Figure 2, support the original hypothesis that if nitrogen application is delayed until after nodulation occurs, soybean plants may receive nitrogen from both the inorganic source and symbiotic source.

It is obvious from Figure 2 that as we delayed application of the calcium nitrate more nodules formed on the roots of soybean plants in 1975. The weather information may explain the sharp decline in the number of nodules formed per plant when nitrogen fertilizer was applied seven weeks after planting. At the time of application the soil was well moistened and shortly after application a light rainfall (5.25 mm) contributed to a very favorable situation for the roots to uptake available fertilizer nitrogen in the soil medium.

The yield responses for years 1973 and 1975 are highly significant due to the mentioned early frost in 1975 growing season. This is shown in Figure 1. This figure exhibits a harmonical yield response to the times of calcium nitrate application for 1973 and 1975. As can be seen, yields dropped when calcium nitrate was applied three weeks after planting in contrasts to that of planting time and gradually increased until seven or eight weeks after planting. According to the definition of Carlson (see reference 9), the drop in yield in

Table 3(Part 1)... Effect of Time and Rate of Nitrogen Application in the Soil on some Agronomic Characteristics of Soybeans for 1975 and 1976

1975

Treat-ment	Pods/plant		Branches/plant		Seeds/plant		Seed/pod		Grams/100 seed	
	45	90	45	90	45	90	45	90	45	90
CHECK(no N)	60.8	72.1	3.1	3.4	123.7	151.4	2.0	2.1	15.0	16.5
0 week (planting)	64.1	73.0	3.1	3.2	133.8	143.9	2.1	2.0	16.0	16.0
3 weeks	72.7	68.3	2.8	3.3	158.3	136.3	2.2	2.0	15.5	15.5
4 weeks	62.2	68.0	2.8	3.5	135.8	142.6	2.2	2.1	16.0	17.0
5 weeks	47.1	48.2	2.9	2.9	102.0	98.5	2.2	2.0	15.0	16.5
6 weeks	65.9	61.0	3.9	3.4	138.8	115.8	2.1	1.9	16.0	17.2
7 weeks	61.1	60.4	2.9	3.0	124.8	129.9	2.0	2.2	16.0	15.7
8 weeks	75.0	78.9	3.4	4.4	150.0	153.8	2.0	1.9	16.0	15.5
9 weeks	81.9	99.9	3.8	4.7	174.7	225.4	2.1	2.0	15.5	15.0
10 weeks	69.7	68.6	2.9	2.8	141.9	162.8	2.0	2.5	15.5	17.0

Table 3(Part 2)... Effect of Time and Rate of Nitrogen Application in the Soil on Some Agronomic Characteristics of Soybeans for 1975 and 1976

1976

Treatment	Pods/plant		Branches/plant		Seeds/plant		Seed/pod		Grams/100 seed	
	45	90	45	90	45	90	45	90	45	90
CHECK(no N)	60.3		3.4	3.4	126.1	110.3	2.1	2.2	15.8	16.1
0 week (planting)	68.8		3.5	3.7	191.4	158.0	2.7	2.3	16.0	16.0
3 weeks	53.5		2.9	2.8	106.6	105.6	2.0	2.0	16.6	16.4
4 weeks	55.3		4.0	3.0	117.8	110.5	2.1	2.0	16.0	16.3
5 weeks	54.3		3.4	2.9	121.2	106.8	2.2	2.1	16.7	16.3
6 weeks	46.1		3.0	3.8	103.4	117.0	2.2	2.1	16.7	16.4
7 weeks	72.0		4.4	2.8	164.4	116.4	2.3	2.3	16.3	16.2
8 weeks	64.2		3.2	3.1	139.4	171.0	2.2	2.8	16.9	16.6
9 weeks	44.3		2.6	3.9	91.4	180.9	2.1	2.8	15.8	16.5
10 weeks	56.2		3.4	3.5	125.1	118.3	2.2	2.1	15.9	16.0

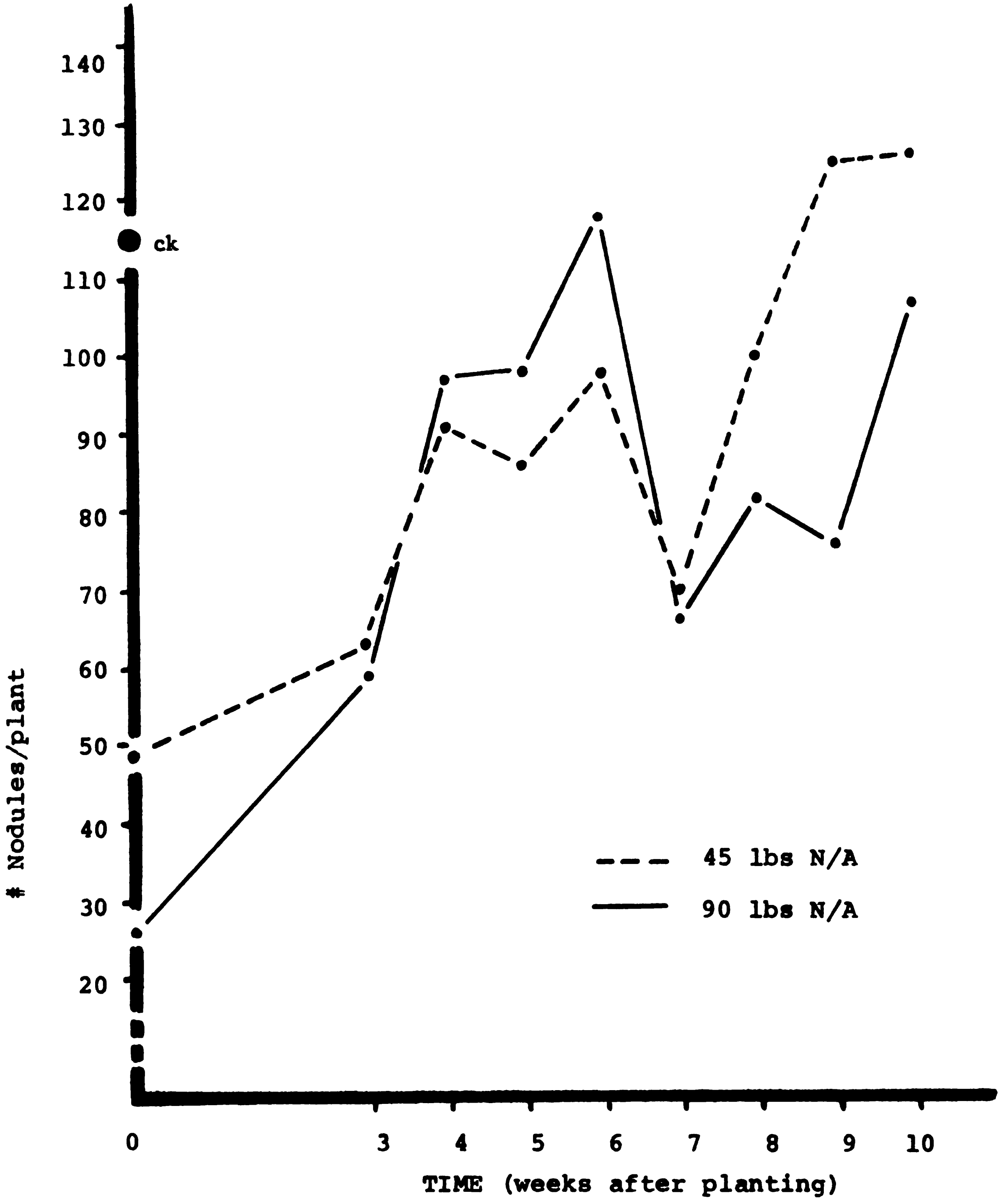


Figure 2... The Number of Nodules per Soybean Plant as Affected by the Time and Rate of Nitrogen Application in the Soil for 1975

the third week application might be due to the retardation of a major part of the nodules which usually form from two to four weeks after planting. Although not statistically significant, the time and rate of calcium nitrate application had some effect on several other agronomic characteristics which affect yields (Table 3).

The number of branches produced per plant and the number of pods retained by the plant increased when the application of calcium nitrate was delayed until nine weeks after planting.

Yield data for 1976 are presented in Table 4. The time of calcium nitrate application had a highly significant effect on the yield response. (Table 5).

The reason for the yield decline at the nine week's application time is not obviously clear but soil moisture conditions before and after application may offer one explanation. At the time of application the soil was very dry and information from the United States Weather Service showed that precipitation sufficient to moisten the soil did not occur. The 90 pound rate gave higher yields than the 45 pound rate when nitrogen application was delayed until eight weeks after planting. The nodulation data (Figure 3) showed that the number of

Table 4... Yield of Soybeans (BU/A) as Affected by the Time and Rate of Nitrogen Application in the Soil for 1976

	1976		Ave. for 1973-75-1976*	
Treatment time	45lbs N/A	90lbs N/A	45lbs N/A	90lbs N/A
Check(no N)	43.22	40.71	44.78^{a}	41.35^{f}
0 week(Planting)	43.43	43.11	45.00^{a}	43.90^{def}
3 weeks	45.22	44.33	45.93^{a}	40.80^{f}
4 weeks	42.50	45.11	44.20^{ab}	42.20^{ef}
5 weeks	46.44	44.54	45.25^{a}	44.61^{de}
6 weeks	44.68	47.16	45.10^{a}	46.80^{d}
7 weeks	44.43	43.39	46.30^{a}	44.78^{de}
8 weeks	47.51	47.48	45.10^{a}	46.76^{d}
9 weeks	36.26	43.54	40.92^{bc}	44.57^{de}
10 weeks	40.63	41.72	41.63^{c}	44.95^{de}

*Means in a column with the same letter are not significantly different from each other with LSD at $\alpha = 0.10$.

Table 5... Analysis of Variance Table for soil Application of Calcium Nitrate at Different Times and Rates (Dependent Variable is yield).

Source of variance	S.S	df	MS	F
Rep	100.00	2	50.00	2.014
Rate	6.85	1	6.85	0.276
Error (a)	49.63	2	24.81	
Time	286.36	9	31.82	3.423**
Rate x Time	111.69	9	12.41	1.335
Error (b)	334.60	36	9.29	
Total	889.13	59		

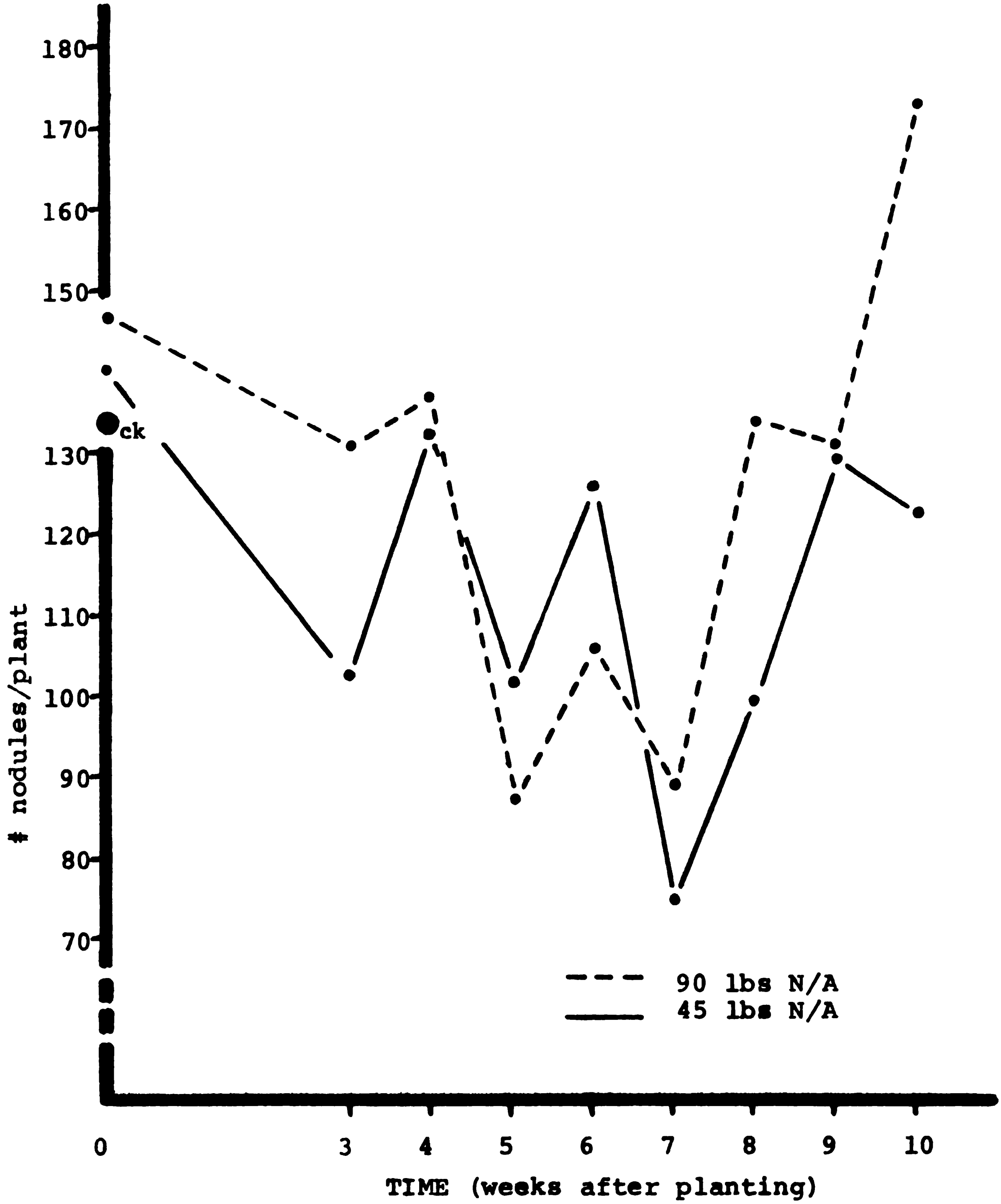


Figure 3... Number of Nodules per Soybean Plant as Affected by the Time and Rate of Nitrogen Application in the soil for 1976

nodules decreased when 45 pounds of nitrogen was applied any time before the eight weeks date when compared to the planting date application. Although not statistically significant, the number of nodules formed when either 45 or 90 pounds of nitrogen was added at planting was greater than the nodules produced on the check plants. This is in agreement with the findings of Carlson (9), that an initial supply of nitrogen is favorable for nodule formation on soybeans. The number of nodules per plant for 1976 was relatively higher than in 1975 and also nodulation response to the time of calcium nitrate applications was much more variable. These variations might have been due to the organic residuals from the previous crop in the field. Sugarbeets were grown in the field in 1975 and this might have increased the C/N ratio of the soil which would create more favorable conditions for nodulation and may interact with the suppressive effect of mineral nitrogen on nodule formation and activities.

The combined results of yield for three years (1973, 1975, 1976) are also presented in Table 4 and show that the highest yields were obtained when the application of calcium nitrate was delayed until six to eight weeks after planting at either 45 or 90 pound rate. The same data are graphed in Figure 4 and again it appeared that the soybean plant can show a positive response to the combined mineral and organic nitrogen added later in the growing season. This is due to the high demand for nitrogen at the reproductive stage in which the symbiotic nitrogen is normally the major source. This holds true for the number of pods retained and the number of seed which produced by single plants (Figures 5 and 6). The three-year average in Figure 4 also shows that, beginning about 5 weeks after planting, the 90 pound rate gave the greater average yield response, indicating the ability of the soybean plant to utilize fairly large amounts of nitrogen during the reproductive stages of development.

The combined nodulation data for 1975 and 1976 are presented in Figure 7. The number of nodules increased when calcium nitrate was applied later in the growing season. As might be expected, the retardation effect of nitrogen on nodulation at the 90 pound rate was higher than that for the 45 pound rate when applied late in the growing season.

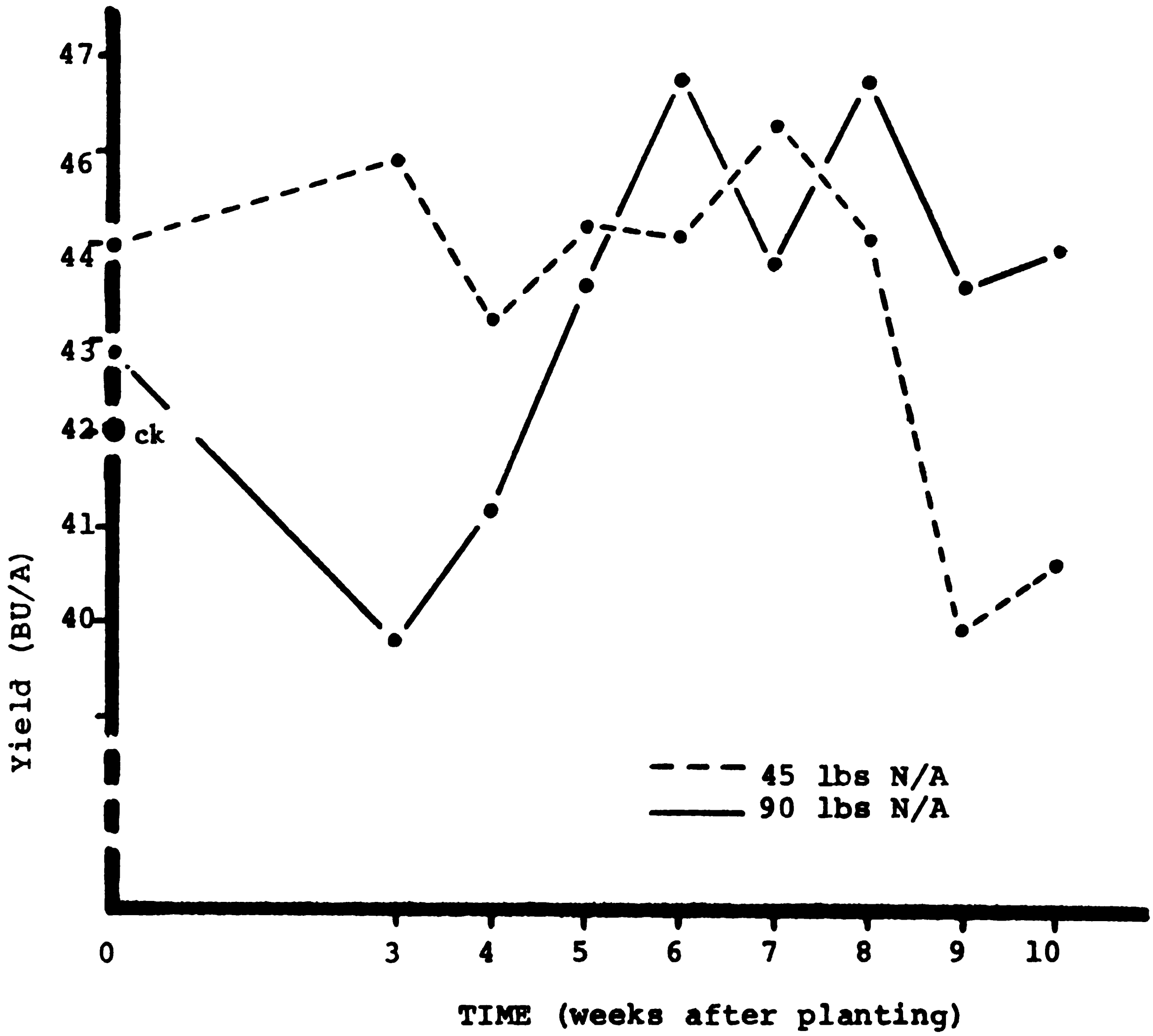


Figure 4... Combined Yields of Soybeans, for 1973, 75 and 1976 as Affected by the Time and Rate of Nitrage Application in the soil.

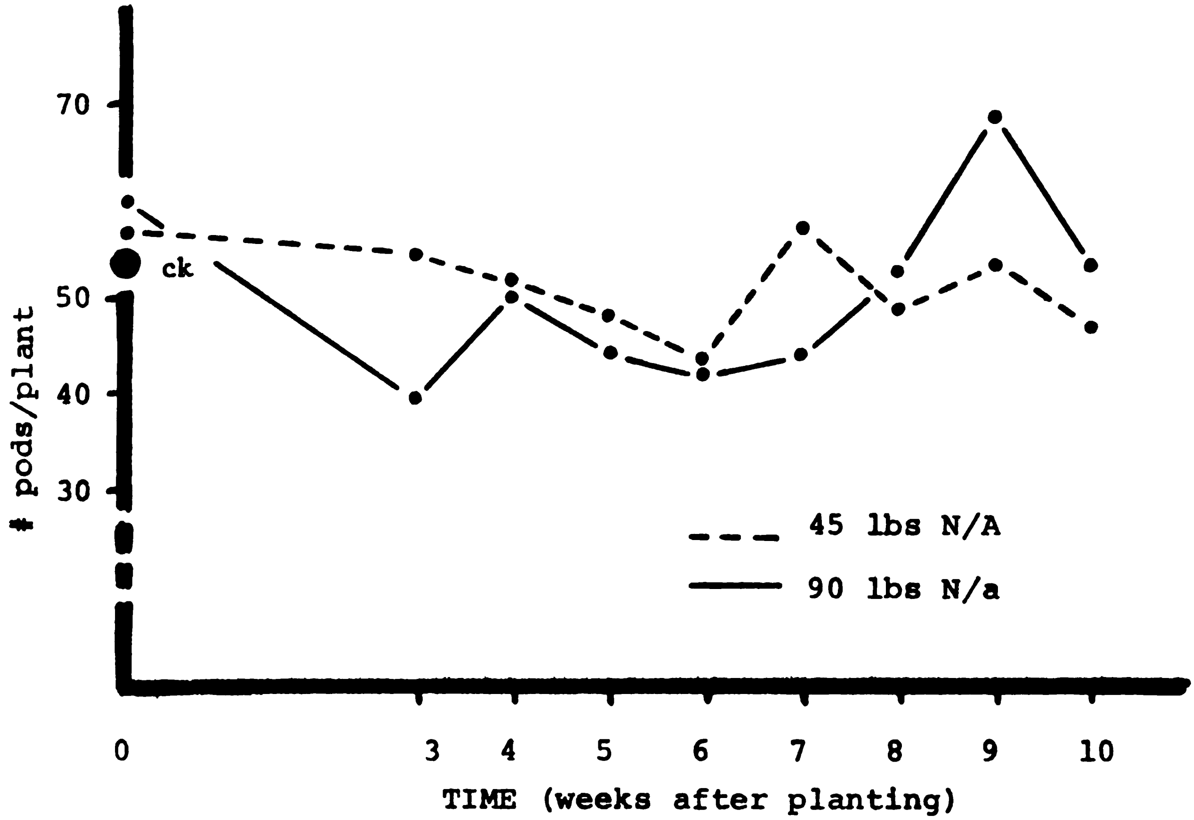


Figure 5... Average Number of Pods per Soybean Plant as Affected by the Time and Rate of Nitrogen Application in the Soil for 1973, 75, and 1976.

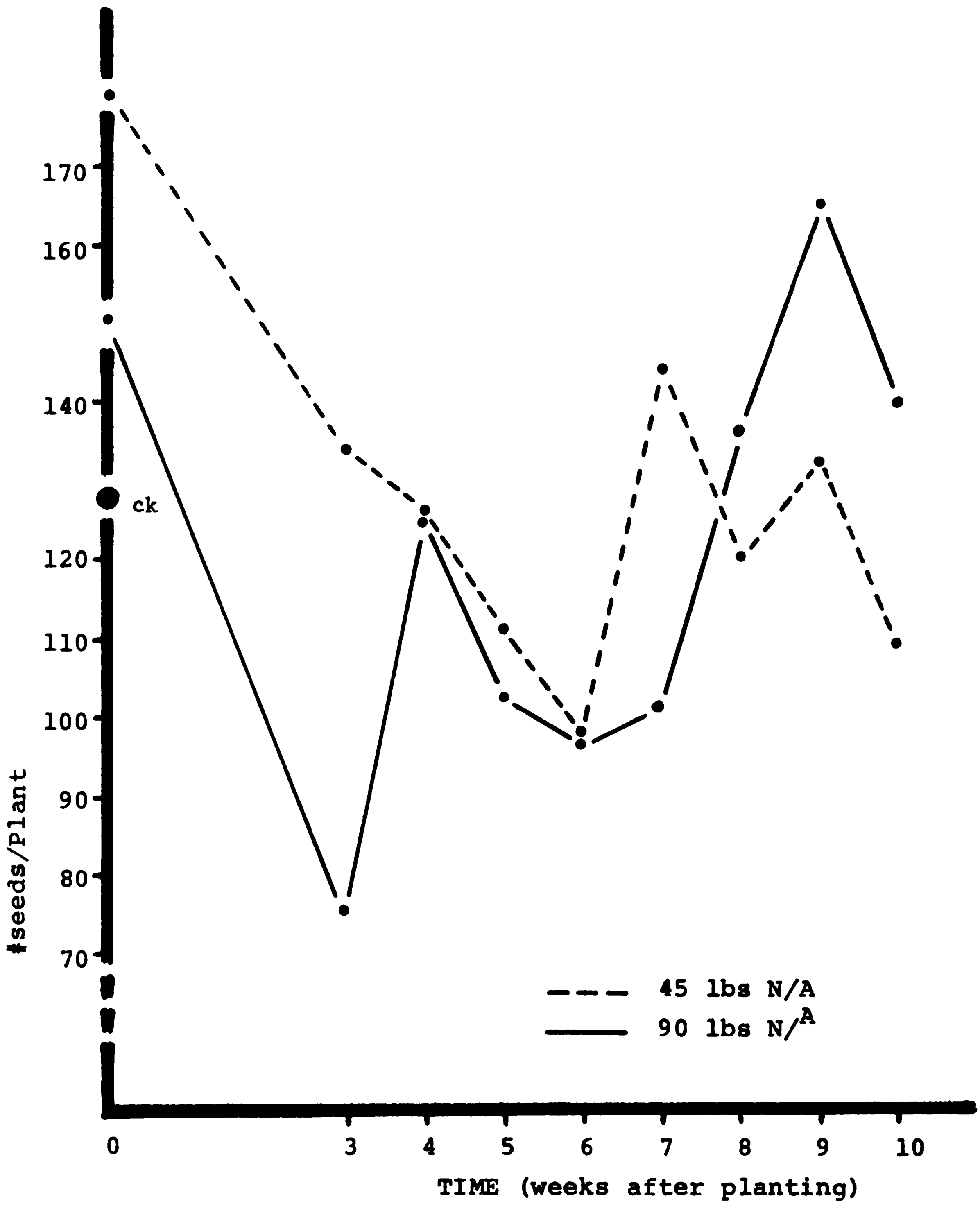


Figure 6... Average Number of Seeds per Soybean Plant as Affected by the Time and Rate of Nitrogen Application in the soil for 1975 and 1976.

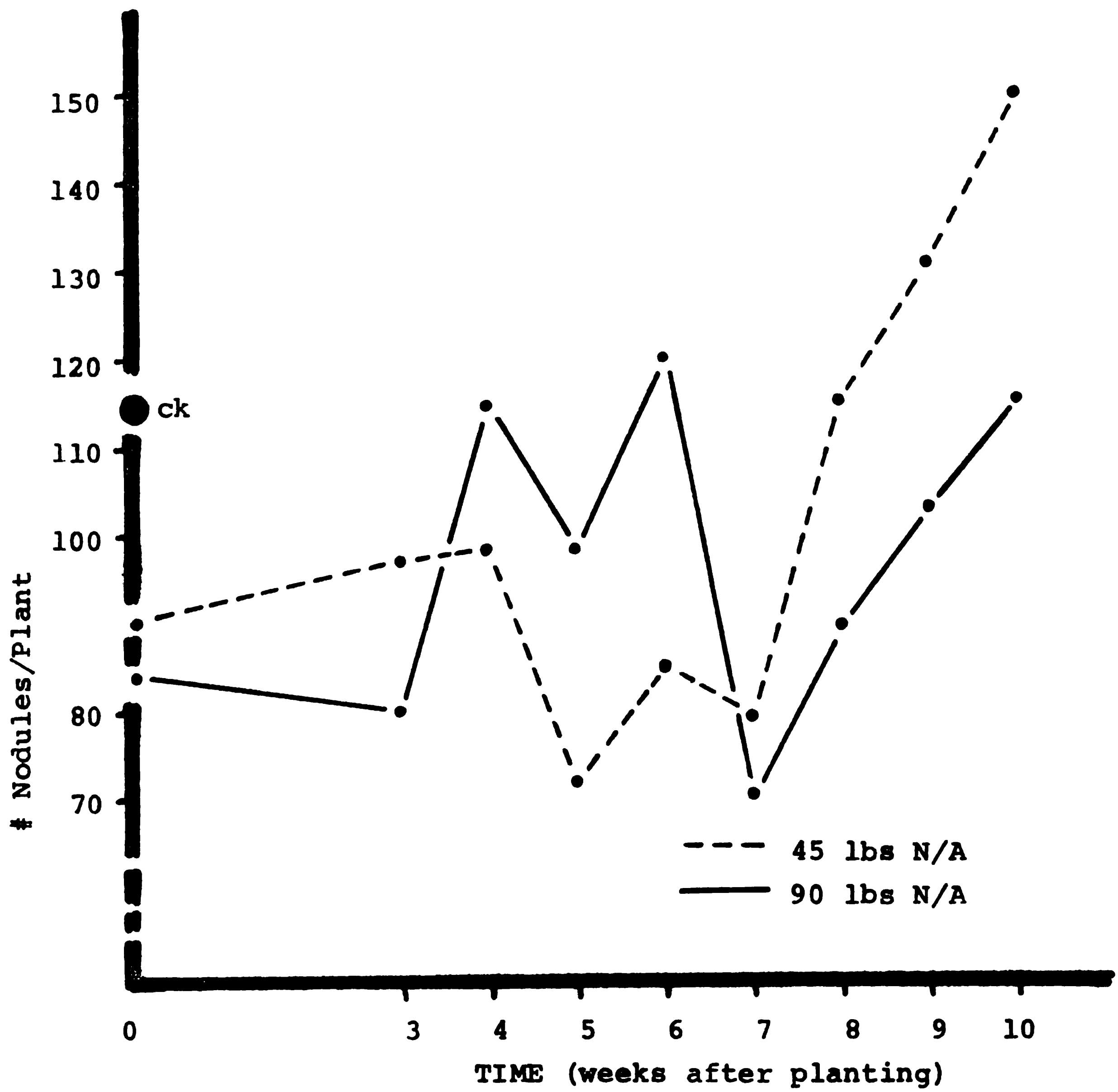


Figure 7... Average Number of Nodules per Soybean Plant for 1975 and 1976 as Affected by the time and rate of Nitrogen Application in the soil.

2) Foliar application:

Table 6 represents yield data for foliar application of three different sources of nitrogen each at four rates of application.

The sources of nitrogen did not show any statistically significant effects on the yield but the effects of rate of application were significant (Table 7). At 10 pounds per acre all nitrogen sources slightly increased the yield (Figure 8). The small difference in the yield response to the source of nitrogen might be due to the degree of solubility in the water and/or absorbability by the leaves. At the 20 pound rate, Urea slightly increased yield of soybeans but at higher rates it caused a steady reduction in yield which was probably due to salt toxicity and obvious leaf burning by urea at the higher rates. Calcium nitrate reduced yield at the 20 pound rate but showed no additional decrease in yields at the higher rates. The lack of yield response to calcium nitrate at the rates higher than the 20 pound is probably due to low solubility in the water and subsequently inefficient absorbtion of this fertilizer by leaves. However, the yields of soybean were higher at 30 and 40 pound rates with calcium nitrate rather than

Table 6... Yield of Soybeans (BU/A)* as Affected by The Rate and Source of Nitrogen Applies as Foliar Spray

Treatment Rate	$Ca(NO_3)_2$	NH_4NO_3	Urea
Check	40.70	40.70	40.70
10 lbs N/A	41.24	42.82	41.60
20 lbs N/A	38.10	40.17	41.89
30 lbs N/A	38.70	37.45	37.76
40 lbs N/A	38.02	31.50	36.01

* Values in a column with the same letter are not significantly different from each other at α = .05 by LSD method.

Table 7... Analysis of Variance Table for Foliar Application of different sources of Nitrogen (dependent variable is yield of soybeans)

Sources of variance	S.S.	d.f.	MS	F
Rate	224.22	3	74.74	6.32*
Treatment	11.74	2	5.87	0.50
Rate x treat	83.52	6	13.92	1.18
Error	283.58	24	11.82	
Total	603.07	25		

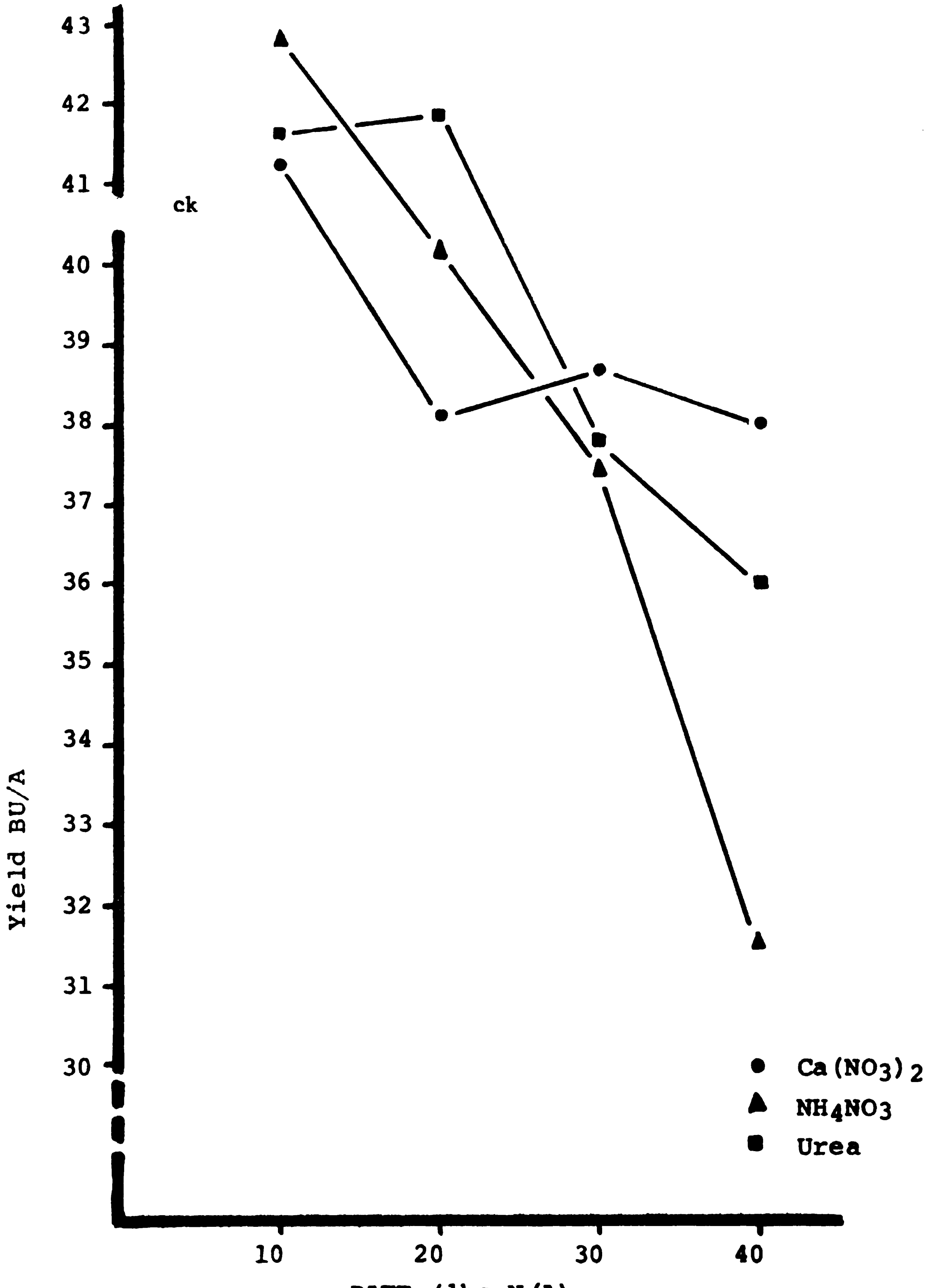


Figure 8... Yield of Soybeans as Affected by Foliar Application of Different Sources of Nitrogen at Different Rates.

with urea or ammonium nitrate which may be due to higher salt index and burning effect of urea and ammonium nitrate.

The yield responses of soybeans, to the foliarly applied nitrogen minerals, appeared to be related to the fertilizer ingredient characteristics. At the lowest rate, 10 pounds ammonium nitrate gave the highest yield in contrast with checks and the other sources of nitrogen fertilizer but at higher rates it reduced the yield very sharply. The reduction in yield might be due mainly to the very high salt index number and ion effect of ammonium nitrate. As it is obvious from Figures 9, 10 and 11 the ammonium nitrate burned the leaves of soybeans more severely than did urea and calcium nitrate, respectively, when applied at the 30 pound rate.

The rate and source of fertilizer nitrogen applied as foliar, to some extent, had some effect on the number of pods per plant and the number of seeds per plant (Figures 12 and 13). For all three nitrogen sources, all rates above 10 pounds reduced seed size (Figure 14). The sources and the rates of nitrogen fertilizer did not have a significant effect on the number of pods per plant,

Figure 9...Burning effect on soybean foliage caused by ammonium nitrate at 30 lbs/A.

Figure 10...Burning effect on soybean foliage caused by urea at 30 lbs/A.

Figure 11...Burning effect on soybean foliage caused by calcium nitrate at 30 lbs/A.

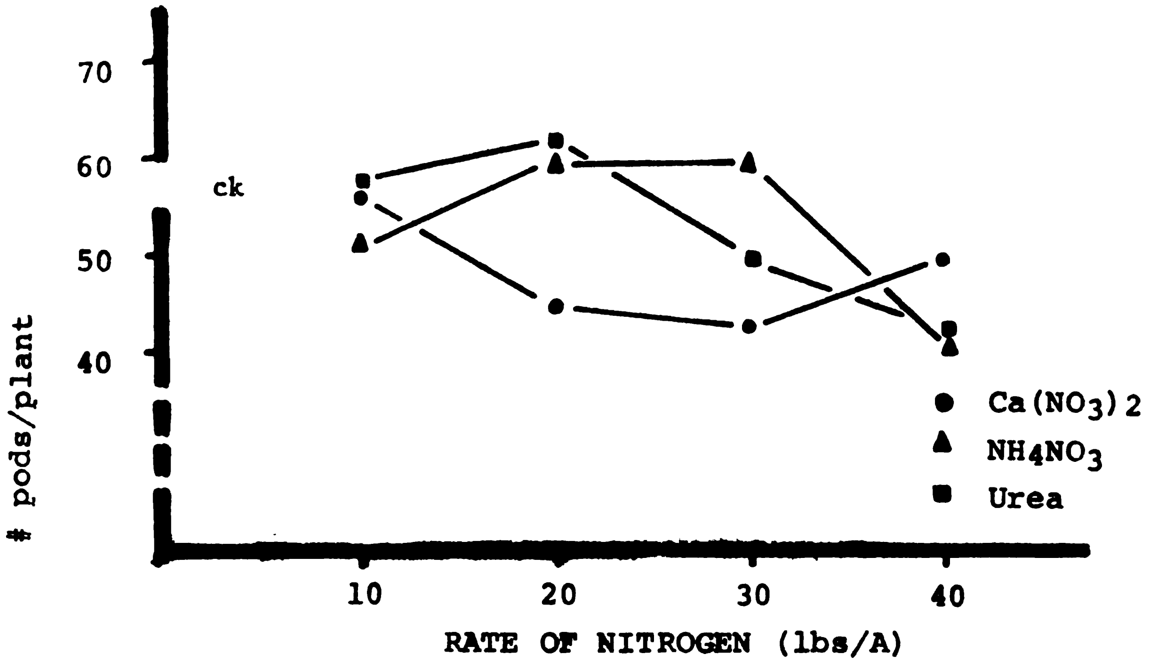


Figure 12 .. Number of Pods per Soybean plan as Affected by the Rate and Source of Nitrogen by Foliar Application.

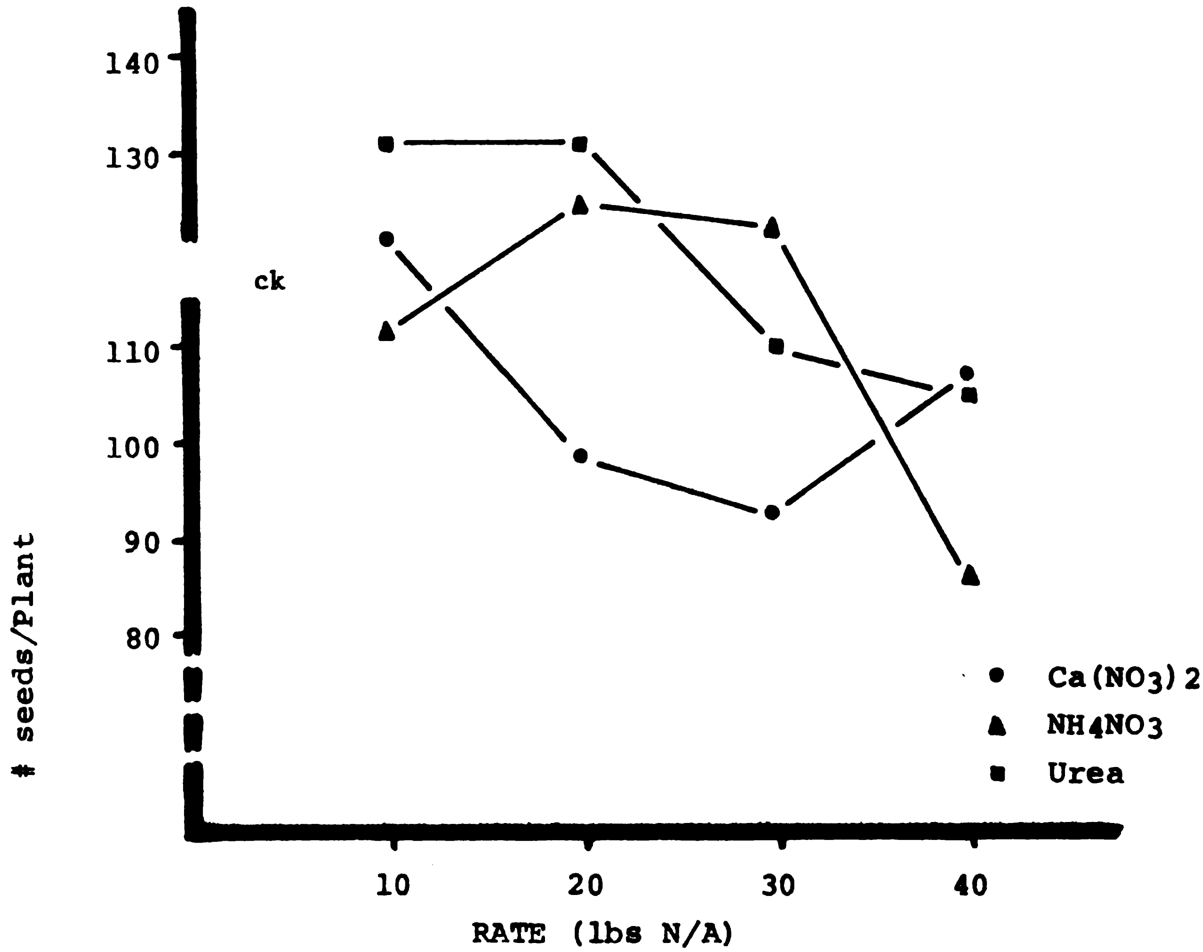


Figure 13... Number of Seed per plant of soybeans as Affected by the Rates and Sources of Nitrogen by Foliar Application.

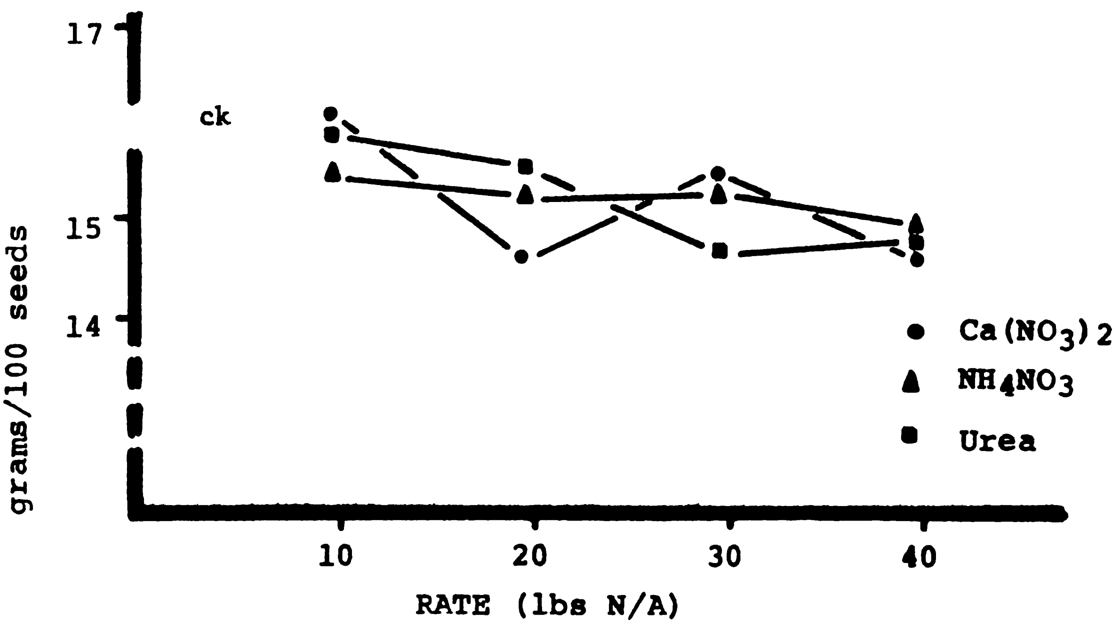


Figure 14... Seed size of soybean plants as affected by the rate and source of Nitrogen by foliar application.

number of seeds per plant or seeds per pod at different positions of the individual plants, such as the top, middle and the bottom, since these plant characteristics were already developed at the time of foliar application.

CONCLUSIONS

Results from this experiment led to the conclusion that the time and rate of nitrogen application can affect the yield of soybeans. When fertilization of soybeans with calcium nitrate was carried out within the first five weeks of the growing season, 45 pounds of actual nitrogen resulted in better yields than the 90 pound rate. After five weeks after planting, it seemed that the soybeans responded more positively to the 90 pound rate rather than the 45 pound rate.

In summary, fertilizing soybeans with nitrogen after nodules have formed on the roots seems to hold some promise for increasing yields. However, decisive conclusions cannot be reached regarding the physiologic or economic returns from delayed application of nitrogen to soybeans based on these studies due to uncontrolled environmental fluctuations. Optimum growing conditions for soybeans occurred only the first year of investigation. Based on the lack of variability in the data of that year the possibility of increased soybean yields by allowing nodulation to occur and then adding nitrogen as a side-dress or foliar spray seems very real. However, additional data is needed before a definitive statement can be made.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Albrecht, W. A. (1932): Calcium and Hydrogen - ion Concentration in the growth and inoculation of Soybeans; J A Am. Soc. Agro. 24: 293 - 806.

2. __________ (1933): Inoculation of Legumes as Related to Soil Acidity; J. Am. Soc. Agro. 25: 512 - 522.

3. __________, and F. L. Davis (1929): Physiological Importance of Calcium in Legume Inoculation. Botanical Gazette: 88: 310 - 321.

4. Allos, H. F. and W. V. Bartholomew. (1959): Replacement of Symbiotic Fixation by Available Nitrogen: Soil Science 87: 61 - 66.

5. Bar - Akiva, A. (1975): Effect of Foliar Application of Nutrients on Creasing of Volencia Oranges: Hartscience 10: 69 - 70.

6. Benson, N. R. and Bulloch, R. M. (1951): Urea Sprays For Fruit Trees Fertilization: Proc. Washington State Horticulture Association 47: 113 -

7. Boynton, D. (1954): Nutrition by Foliar Application: Annual Review of Plant Py. 5: 31.

8. Brasher, E. P. J. R. Wheatley, and W. L. Ogle (1953): Foliar Nutrition Sprays on Vegetable Crops: Delaware Agricultural Experiment Station Bulletin, N - 295.

9. Caldwell, B. E. (1973): Soybeans: Improvement, Production and Uses. The American Society Agronomy: 16: 36; 217 - 218; 353 - 382.

10. Criswell, J. G., Hume, D. J. and J. W. Tanner (1976): Effect of Anhydrous Ammonia and Organic Matter on Components of nitrogen fixation and yield of soybeans. Crop Sci. 16: 400 - 404.

11. Decau, J., Bo-niols, A., Lencrerot, P. and J. Puech: (1975): Competitive or Additive Effects of Non-Symbiotic Nitrogen Nutrition and Bacterial Fixation in Soybean. (From Field Crop Abstract, 1976, 2886).

12. Dobereiner, Johanna (1965): Evaluation of Nitrogen Fixation in Legumes by the Regression of Total Plant N with Nodule Weight. Rhizobium Newsletter, 10: 139 - 145.

13. __________, N. A. Bergalla, and A. Penteado (1964): Host Plant Specificity of Soybeans in Acid Soils: Rhizobium Newsletter 9: 130.

14. Embleton, T. W. And W. W. Jones (1974): Foliar - Applied Nitrogen for Citrus Fertilization: J. Environmental Quality 3: 388 - 391.

15. Foy, C. D., G. Montenegro, and S. A. Barber (1953): Foliar Feeding of Corn with Urea Nitrogen: Soil Science Soc. Am. Proc. 17: 387 - 390.

16. Fuehring, H. D. and R. E. Finkner (1974): Soybean Cultural and Varietal Trials on the High Plains of Eastern New Mexico: Research Report, New Mexico Research Report, New Mexico State University Agricultural Experiment Station: No. 283: 13.

17. Gower, F., Elins, D. M., and Olsen F. J. (1973): Effect of Lime - Pelleting of Seed and Lime Applications on Establishment and Growth of Legumes: Southern Illinois University.

18. Groneman, A. F. (1974): Effects of Deep Placement of Nitrogen, P, and K, Fertilizers on Dry Matter Production, Nodulation Chemical Composition, and Yield of Soybeans. (From Field Crop Abstract 1976, 249).

19. Hanway, J. J. (1975): Interrelated Development and Biochemical Processes in the Growth of Soybean Plants in Lowell: D. Hill (ed) Proc. World Soybean Res. Conference: University of Illinois Urbana.

20. Hera, C. (1974): Response and Current Practice of Grain Legume Crops in Romania: (From Field Crop Abstract, 1974, 3691)

21. Harper, J. E. (1974): Soil and Symbiotic Nitrogen Requirements for Optimum Soybean Production: Crop Science 14: 255 - 260.

22. __________, and R. H. Hageman (1972): Canopy and Seasonal Profiles of Nitrat Reductase in Soybeans (Glycine max. L. Merr.): Plant Phy. 49: 146 - 154.

23. __________, and R. L. Cooper (1971): Nodulation Response of Soybeans (Glycine max. L. Merr.) to Application Rate and Placement of Combined Nitrogen: Crop Science 11: 438 - 440.

24. Hatfield, J. L. and D. B. Egli, J. E. Leggett, and D. E. Peaslee (1974): Effect of Applied Nitrogen on the Nodulation and Early Growth of Soybeans (Glycine max. L. Merr.) Agro. J. 66: 112 - 114.

25. Howell, R. W. (1963): Physiology of the Soybean; in the Soybean (ed. Norman, A. G.) Academic Press, N.Y.; Pp: 83 - 88.

26. Hughes, H. D. and D. S. Metcalfe (1975): Crop Production, third edition; Macmillan: Pp: 379.

27. Hulpai, N. (1973): New Developments in Techniques of Soybean Cultivation in irrigate Conditons: (From Field Crop Abstract, 1975, 8132).

28. Humphrey, B. H. (1963): Calcium in the Walls of Rhizobium trifolii. Rhizobim Newsletter 8: 116.

29. Johnson, H. S. and D. J. Hume (1972): Effects of Nitrogen Sources and Organic Matter on Nitrogen Fixation and Yield of Soybeans. Cana. J. Plant Science 52: 991 - 996.

30. Kang, B. T. (1975): Effects of Inoculation and Nitrogen Fertilizer on Soybean in Western Nigeria - Experimental Agriculture 11: 23 - 31: Iita., Ibadan, Nigeria (from Field Crop Abstract, 1975 #6463).

31. Kefford, N. P., J. Brockwell, and J. A. Zwar (1960): The Symbiotic Synthesis of Auxin by Legumes and Nodule Bacteria and its Role in Nodule Development Aust. J. Biol. Science 13: 456 - 467.

32. Lal, S. B. and R. A. Khanor Kar (1972): Nitrogen Metabolism - A Study of Yield Contribution Factor. PKV Research J (1972) 1: 106 - 108. College of Agriculture; Nagpur, Maharashtra, India (from Indian Science Abstract 10, 2031).

33. Lathwell, D. J. and C. E. Evans (1951): Nitrogen Uptake from Solution by Soybeans at Successive Stages of Growth; Agrono. J; 43: 264 - 270.

34. Lawn, R. J. and W. A. Brun (1973): Symbiotic Nitrogen Fixation in Soybeans. III. Effect of Supplemental Nitrogen and Intervarietal Grafting: Agro J. 65: 22 - 25.

35. Lawn, R. J. and W. A. Brun (1974): 1. Effect of Photosynthetic Source - Sink Manipulations: Crop Science 14: 11 - 16.

36. Ljunggren, H. (1969): Mechanism and Pattern of Rhizobium Invasion into Leguminous Root Hairs. Physiologia Plantarum Supplementum V: Lund: Pp: 48 - 55

37. Loneragan, J. F. (1959): Calcium in the Nitrogen Metabolism of Subterranean Clover: Aust. J. Biol. Sic.: 12: 26 - 39.

38. Loos, M. A. and H. A. Louw (1965): The Influence of Calcium Carbonate Amendments on the Nodulation of White Clover in the Acid Soils: South African J. Agric. Sci.; 8: 729 - 736.

39. Lucas, R. E. (1976): Liquid Fertilizers: Extension Bulletin E - 933. Cooperative Extension Service, Michigan State University, East Lansing, Michigan.

40. Ludwig, C. A. and F. E. Allison (1935): Some Factors Affecting Nodule Formation on Seedlings of Leguminous Plants; J. Am. Soc. Agro; 27: 895 - 902.

41. Lyons, J. C. and E. B. Earley (1952): The Effects of NH4 (NO3) Application to Field Soils on Nodulation, Seed Yield, and Nitrogen and Oil Content of the Seed of Soybeans: Soil Sci. Soc. Am. Proc. 16: 259 - 263.

42. Martin, Leonard and Stamp (1976): Principles of Field Crop Production; Third Edition: Macmillan Pp: 701.

43. McCalla, T. M. (1937): Behaviour of Legume Bacteria (Rhizobium) in Relation to Exchangeable Calcium and Hydrogen ion Concentration of the Colloidal Fraction of the Soil; Res. Bulletin; Missouri Agricultural Experiment Station, No. 256.

44. Mederski, H. J., and G. W. Volk (1956): Foliar Fertilization of Field Crops: Ohio Agricultural Experiment Station Res. Circular 35.

45. Merrill, T. A. (1951): Use of Fertilizer Solutions in Leaf Feeding: Proc. National Joint Committee on Fertilizer Application: Pp: 39 - 40.

46. Munns, D. N. (1970): Nodulation of Medicago sativa in Solution Culture. (v) Calcium and pH Requirements During Infection: Plant & Soil: 32: 90 - 102.

47. Norman, A. G. (1963): The Soybean: Academic Press: Pp: 128 - 131: 141 - 144: 168.

48. __________, and L. O. Krampitz (1945): The Nitrogen Nutrition of Soybeans: II Effect of Available Soil Nitrogen on Growth and Nitrogen Fixation: Soil Sci. Soc., Am. Proc: 10: 191 - 196.

49. Ohlragge, A. J. (1963): Mineral Nutrition of Soybeans: In the Soybean: (ed. Norman, A. G.) Academic Press: Pp: 143 - 144.

50. __________ (1966): Mineral Nutriton of Soybeans: Plant Food Review: Winter, 1966.

51. Olsen, F. J., Hamilton, G. and D. M. Elkins (1975): Effect of Nitrogen on Nodulation and Yield of Soybeans: Experimental Agriculture 11: 289 - 294. Department of Plants and Soil Science: Southern Illinois University: Carbondale, Ill U.S.A.

52. Orcutt, F. S. and P. W. Wilson (1935): The Effect Of Nitrate Nitrogen on the Crbohydrate Metabolism of Inoculated Soybeans: Soil Science: 39: 289 - 296.

53. Piper and Morse (1923): The Soybean: McGraw Hill: Pp: 70 - 75.

54. Rajan, S. V. G., R. S. Murthy, and Kalbande, A. R. (1972): A Review of Recent Work on Foliar Application of Plant Nutrient to Crops: Indian J. Agriculture Chemistry: 5: 1 - 7.

55. Richardson, D. A., D. C. Jordan and E. H. Garrard (1957): The Influence of Combined Nitrogen on Nodulation and Nitrogen Fixation by Rhizobium meliloti dangeard: Cana. J. Plant Sci: 37: 205 - 214.

56. Rios, G. P. and H. L. Santos (1973): Nitrogen Fertilization for Soybeans (Glycine max.) on Cerrado Soils: Pesquisa Agropecuaria Brasileria, Agronomia: 8(6): 63 - 67: Estacao Experimental de Uberaba IPEACO, Minas Gerails, Brazil: from Field Crop Abstract; 1974 (6248).

57. Rios, G. P., Santos, H. L. and Dos (1973): Nitrogen Fertilization for Soybeans on Cerrado Soils. Pesquisa Agropecuaria Brasileria, Agronomia; 8: 63 - 67: From Field Crop Abstract, 1974, (6248).

58. Roman Garcia, L., and J. J. Hanway (1976): Foliar Fertilization of Soybeans During the Seed-filling Period: Agronomy J.: 68: 653 - 657.

59. Rovira, A.D. (1956): Plant Root Excretions in Relation to the Rhizosphere Effect: Plant and Soil: 7: 178 - 194.

60. Rubes, L. (1974): The Effect of Nitrogen and Molibdenum on Nodule Formation in Soybean (Glycine max. L. Merr.) - Rostlina Byroba (1974): 20: 31 - 42: VyzKumny Ustav technickyck plodin a luskovin, 787 12 Sumperk - Temenice, Czechoslovakia From Field Crop Abstract 1976 (1021).

61. Scanlan, R. W. (1928): Calcium as a Factor in Soybean Inoculation: Soil Science: 25: 313 - 324.

62. Shibles, R. M. I. C. Anderson and A. H. Gibson (1975): Soybean in Crop Physiology (ed. Evans, L. T.): Cambridge: Pp: 151 - 190.

63. __________, and C. R. Weber (1966): Biological Efficiencies in Soybean Production: Plant Food Review: Winter, 1966: Pp: 8: 10.

64. Singer, M., A. G. Holding and J. King (1964): The White Clover - Rhizobium Relationship in Acid Hill Soils: Rhizobium Newsletter 9: 117 - 118.

65. Singh, N. P. and M. C. Saxena (1972): Field Study on Nitrogen Fertilization of Soybean: Indian J. Agricultural Science: 42: 1028 - 1031.

66. Sistachs, E. (1974): Nodulation Studies in Soybeans. The Influence of Concentration, Form and Time of Application of Combined Nitrogen on Symbiotic Response: Cuban J. Agricultural Science: 8: 203 - 209.

67. Smith, H. C., Connell, J. (1973): Lime and Molybdenum in Soybean Production: Tennessee Home and Farm Science, No. 85: 28 - 31.

68. Spencer, D. (1950): The Effect of Calcium and Soil pH on Nodulation of Trifolim Subterraneum L. Clover on a Yellow Podsol: Aust. J. Agric. Res: 1: 374 - 381.

69. Stewart, W. D. P. (1966): Nitrogen Fixation in Plants: The Athlone Press: University of London: Pp: 14.

70. Tanner, J. W. (1964): An External Effect of Inorganic Nitrogen on Nodulation: Rhizobium Newsletter: 9: 179.

71. Terent'eva, M. I., Sergeeva, N. I. (1974): Apply Fertilizers in Mixture with Herbicides: From Field Crop Abstracts, 1975 (7301).

72. Thibodeau, P. S. and E. G. Jaworski (1975): Patterns of Nitrogen Utilization in the Soybean: Plants: 127: 133 - 147.

73. Van Schreven, D. A. (1959): Effects of Added Sugar and Nitrogen on Nodulation of Legumes: Plant and Soil: 1: 93 - 112.

74. Vincent, J. M. (1962): Influence of Calcium and Magnesium on the Growth of Rhizobium: J. Genr. Microbiol.: 28: 653 - 663.

75. __________, and J. R. Colburn (1961): Cytological Abnormalities in Rhizobium trifolii due to a deficiency of Calcium or Magnesium. Aust. J. Sci., 23: 268 - 270.

76. __________, and B. A. Humphrey (1963): Partition of Divalent Cations Between Bacteria Wall and Cell Contents: Nature: 199: 149 - 151.

77. __________, and C.H. Jancey (1962): A Calcium Sensitive Strain of R. trifolii: Nature: 195: 99

78. Weber, C. R. (1966): Nodulating and Non-nodulating Soybean Isolines: II. Response to Applied Nitrogen and Modified Soil Conditions: Agron. J.: 58: 46 - 49.

79. White, J. G. H. (1967): Establishment of Lucerne on Acid Soils; in the Lucerne Crop (ed. Longer, R. H. M.) Wellington, New Zealand: Pp: 105 - 109.

80. Wittwer, S. H. (1951): Use of Fertilizer solutions in Leaf Feeding: Proc. National Joint Committee on Fertilizer Application: Pp: 46 - 47.

81. Wittwer, S. H. M. J. Bukova, and H. B. Tukey (1963): Advances in Foliar Feeding of Plant Nutrients: Pp: 425 - 455: in M. H. McVickar, G. H. Bridger, and L. B. Nelson (eds); Fertilizer Technology and Usage: American Soc. Agro.: Madison

82. __________ (1974): Legume Inoculation and Seed Treatment: (Technical Information for Farmers and Applicators): Compiled and written by the Research Staff of the Rudy - Patrick Company Seed Treatment Laboratory: Princeton, Illinois U.S.A.: Pp: 4.

APPENDIX

Table 8... Analysis of variance table for Soil Application of Calcium Nitrate (dependent Variable is Yield)

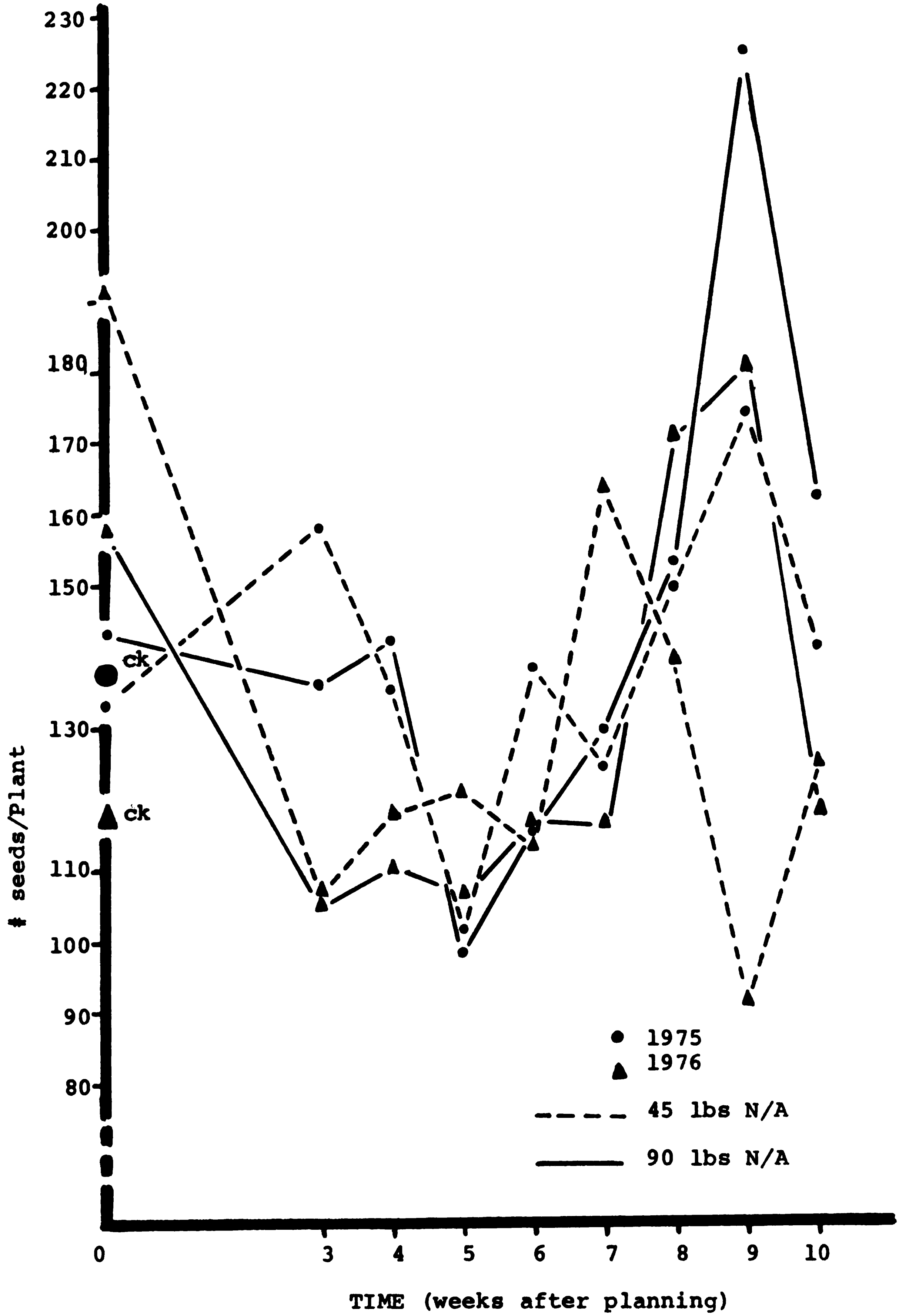
Source of Variance	S.S.	d.f.	MS	F
Year	1914.76	2	957.38	38.33**
Rep (year)	190.72	6	31.80	1.27
Rate	5.35	1	5.35	0.21
Year x Rate	135.04	2	67.52	2.70
Error 1	149.85	6	24.97	
Time	257.64	9	28.63	1.77°
Year x Time	208.00	18	11.56	0.71
Rate x Time	337.86	9	37.54	2.31*
Year x Rate x Time	308.35	18	17.13	1.06
Error 2	1748.39	108	16.19	
Total	5255.98	179		

** Significance at 1% level

* Significance at 5% level

° Significance at 10% level

Figure 15... Number of seed per soybean plant as affected by the time and rate of nitrogen application in the soil for 1975 and 1976



230
220
210
200
180
170
160
150
130
110
100
90
80
seeds/Plant
ck
ck
1975
1976
45 lbs N/A
90 lbs N/A
0
3
4
5
6
7
8
9
10
TIME (weeks after planning)

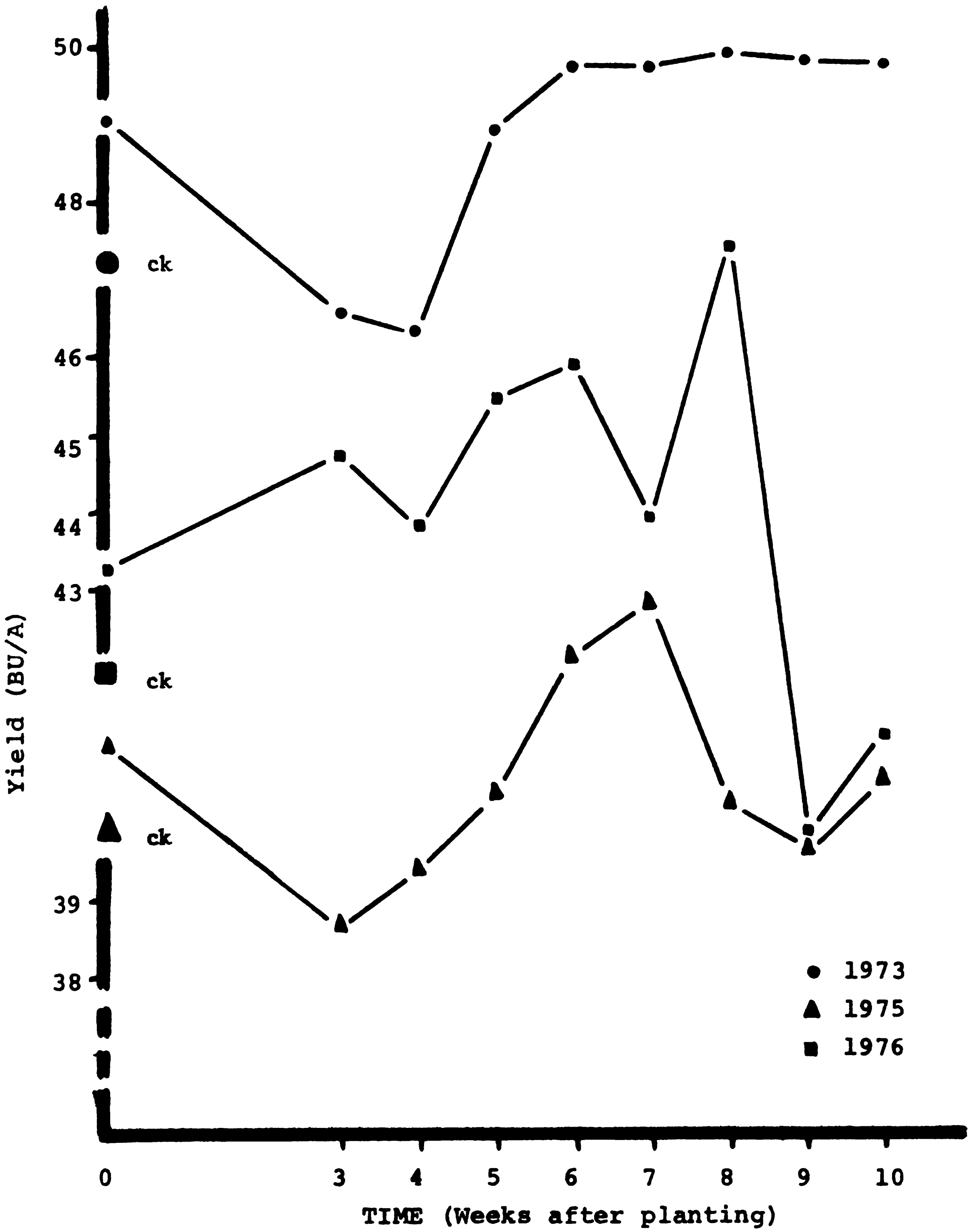


Figure 16... Yield of Soybeans for 1973, 1975, and 1976 as Affected by the Time of Nitrogen Application in the soil. Averaged over both 95 and 90 pound rates