THE EFFECT OF NITROGEN FERTILIZER ON THE YIELD AND PROTEIN CONTENT OF ALFALFA AND COMPANION CROPS

By

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AN ABSTRACT

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ABSTRACT

The effect of nitrogen fertilizer on the yield and protein content of alfalfa and companion crops was studied under field and greenhouse conditions. In the greenhouse study five rates of ammonium sulfate were applied to six soils, Brookston clay loam, Miami loam, Oshtemo loamy sand, Conover loam, Hillsdale loam and Fox sandy loam. Each was planted with inoculated alfalfa seed. Three cuttings of alfalfa were removed for yield and protein analysis. The soils were analyzed before the study was initiated and again at the end of the experiment for total nitrogen.

Three soils of varying composition, a Brookston clay loam on the Lee Ferden farm at Chesaning, Michigan; a Hillsdale loam on the University farm at East Lansing, Michigan and a Fox sandy loam on the W. K. Kellogg farm at Battle Creek, Michigan were used for extensive field plantings of alfalfa and companion crops with four rates of nitrogen. Spring plantings were made with oats, barley and wheat. Fall plantings consisted of alfalfa seeded alone in August and alfalfa seeded in wheat. Nitrogen was applied at planting time and as a topdressing on the wheat.

Four additional soils, Oshtemo loamy sand in Barry county, Ockley sandy loam in Calhoun county, Belfontaine sandy loam in Jackson county and Conover loam in Lapeer

county were selected for a source of nitrogen study applied as a topdressing on established stands of alfalfa.

The average yield of alfalfa grown on six soils in the greenhouse increased in a linear manner when 0, 20, 40, 80, and 160 pounds of nitrogen per acre was applied. The yields obtained with additional nitrogen were significant at the 0.01 percent and 0.05 percent level respectively, on the Oshtemo loamy sand and the Miami loam soils.

The average protein content increased in a similar manner when additional nitrogen was applied; however, these increases were not significant. The amount of total protein produced, increased likewise and was significant at the 0.05 percent level. The nitrogen content of the soil was less after the removal of three cuttings of alfalfa. The analysis indicated that 160 pounds of nitrogen per acre was needed to maintain the nitrogen level in the soil.

Applications of nitrogen fertilizer were very beneficial in increasing the yield and protein content of the companion crops in this study. Significant increases were obtained where twenty pounds of nitrogen per acre was used on oats on a Fox sandy loam at the Kellogg farm and on barley on a Brookston clay loam at the Ferden farm. An application of twenty pounds of nitrogen per acre on wheat at planting time gave a significant increase in yield over the check plots at all three locations. Plots topdressed with 20 pounds of nitrogen per acre produced a significantly higher yield of wheat on a Fox sandy loam at the Kellogg farm and on a Brookston clay loam at the Ferden Farm than where no nitrogen was used.

Severe lodging of these companion crops was not encountered until 80 to 100 pounds of nitrogen per acre had been applied either at planting time or at planting time plus topdressing. The test weight was not seriously affected even when the application of nitrogen was 100 pounds per acre.

A significant increase in the protein content was obtained for oats on the Fox sandy loam at the Kellogg farm and on the Hillsdale loam at the University farm, in barley on the Brookston clay loam at the Ferden farm and smaller increases were found in the wheat at all three locations.

The yield of alfalfa following oats, barley or planted alone in August was not influenced by the addition of nitrogen fertilizer. Small increases as well as decreases were found without any definite patterns or trends established. The protein content was much higher in some cases where nitrogen fertilizer was applied.

Nitrogen fertilizer increased the yield of alfalfa when fall planted in wheat and additional nitrogen applied as a topdressing in the spring gave a significant increase on the Fox sandy loam at the Kellogg farm. The same fertilizer treatment gave a small but insignificant increase when spring planted in wheat and additional nitrogen at planting time resulted in a decrease.

Significant decreases in yield resulted also on the

Brookston clay loam at the Ferden farm with a topdressing of 20 pounds of nitrogen per acre on both fall and spring planted alfalfa in wheat. The protein content was increased in all cases where nitrogen fertilizer was applied.

Nitrogen topdressings on alfalfa with three sources of nitrogen failed to produce a significant difference in yield or protein content.

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I. INTRODUCTION

Prior to 1954, research investigations indicated that nitrogen fertilizer applied at planting time may increase the yield and protein content of alfalfa under greenhouse conditions. They also indicated that nitrogen fertilizer improved alfalfa seedings when seeded with wheat in the fall and increased the yield of the companion crops.

The purpose of this study was to continue this work using the same soils as well as additional soils in the greenhouse and to secure several locations throughout the state for field trials.

Farmers of the state of Michigan are encouraged to produce and feed a good quality high protein hay. Cost of production is decreased because less of the costly protein supplement is required.

Agricultural Statistics, 1954, reported that alfalfa hay production for the state of Michigan is on the decline in acreage and that the average yield is only 1.5 tons per acre.

This experiment was proposed to study further the effect of rates of nitrogen fertilizer applications on the yields and protein content of alfalfa under greenhouse conditions as well as alfalfa and companion crops under field conditions. Four rates of nitrogen were applied to four plantings which included (a) alfalfa and oats or barley spring planted, (b) alfalfa planted alone in August, (c) alfalfa seeded with wheat in the fall and (d) alfalfa over-seeded in wheat in the spring.

In addition to the above mentioned plantings, four well established stands of alfalfa were topdressed with 30 pounds of nitrogen per acre from several sources to study its effect on yield and protein content of alfalfa hay.

II. REVIEW OF LITERATURE

The literature dealing with alfalfa and companion crops is voluminous as well as that covering nitrogen but there is little which deals with the direct application of nitrogen to alfalfa.

For many years following Hellriegel and Wilfarth's discovery that legume plants differed from nonlegume plants with respects to nitrogen fertilization and the validation of this fact by Schloesing and Laurent, who showed that the loss of nitrogen from the air was equal to the gain in nitrogen in the soil plus the amount of nitrogen found in the plant, very little work was carried on with nitrogen compared to some of the other nutrients.

During recent years several investigators (1) (3) (9) (17) (26) have found that various increments of nitrogen will increase the yield of alfalfa and companion crops as well as the protein content. The discovery, formulation, and use of N^{15} (1) (26) (47) (53) has been a great aid in the study of nitrogen uptake and utilization by legumes as well as other plants.

Waksman (52) working with soil from ten plots of a nitrogen availability experiment found that crop production was parallel with the number of microorganisms that developed upon the plate. If the manured plots were excluded, the plots receiving ammonium sulfate, acid phosphate, muriate of potash and lime were the best in crop production and produced the highest number of organisms. This was followed by the plots receiving acid phosphate, muriate of potash and sodium nitrate, which shows that ammonium sulfate was more effective in promoting the growth of both plants and microorganisms.

Batham (4) indicated that ammonium sulfate is more effectively nitrified and taken up by the plant than any of the amino acids. He also stated that nitrogen in compounds of both ring and chain structures is more readily nitrified than nitrogen in straight chains and that sulfur in cystine appears to depress nitrification to a certain extent.

Meiklejohn (29), in her review of the nitrifying bacteria, discussed the production of salt petre in the fourteenth century by the process of nitrification as well as the history concerning the discovery of the bacteria responsible for the process. In her list of conditions for nitrate formation, she stated that the pH for nitrosomonas should be between 6.0 and 9.0 and for nitrobacteria 6.3 and 9.4. The necessary minerals are calcium, phosphorus, magnesium, iron and copper. Zinc is not needed and manganese is toxic in mixed cultures. Peptone is poisonous, especially, in the free amino acid methionine.

A favorable C:N ratio for nitrification was upset by the addition of wheat straw by Stojanovic and Broadbent (44). In a study of the immobilization and mineralization rates of nitrogen, they found that 95 percent of the nitrogen added was tied up in two to six day intervals or at a rate of thirty-eight pounds per day. At the same time, only eighteen pounds of nitrogen was liberated. The rate for nitrate nitrogen was faster and 99 percent or fifty-six pounds per day were tied up and thirty-four pounds were released. This study shows that microorganism assimilate nitrogen faster than growing plants while the release is very rapid if the soil conditions are favorable. The authors also stated that nitrogen used by plants is furnished partly by organisms, even, when nitrogen fertilizer has been applied.

There has been quite a discussion on the sources of nitrogen for crop production. Tisdale et al (46) stated that the ultimate role of nitrogen in plant nutrition is its conversion into proteins which are essential in the make up of protoplasm in all living matter. The authors stated that the nitrate and ammonia ions are taken up by the plants. Aside from their solubilities, their organic or inorganic nature, their movement in the soil, and their acidity or basicity effect in the soil; the cost is probably the most important factor in making a choice.

Hutchinson and Miller (22) found that out of twelve nitrogen materials, urea was the best for nitrogen uptake and bartituric acid for total weight when peas were used as the indicator crop. Acetamide produced as much weight of peas as bartituric acid but less nitrogen was taken up. The pea plants assimilated 12.5 mg. nitrogen from ammonium sulfate compared to 8.5 mg. for formimide and 7.0 mg. for alloxan. All of these sources were classified as readily assimilated types of nitrogen.

Treggi (48) obtained the highest yield of lupines and the strongest plants from sodium nitrate in sand and soil cultures, particularly, in the presence of high potash. He attributed this difference to ion interference of Na-K and Ca-Mg, respectfully, which resulted in a differential development of tissues.

In relation to the development of tissues, Bosemark (7) stated that the increase in root length in cases of nitrogen deficiency is due to increased cell length, whereas, growth inhibition at high nitrogen levels is the result of the combined action of reduced cell multiplication as well as elongation. With increasing amounts of nitrogen, the natural auxins in the root increased and this could be the explanation for the different sensitivity of auxin (I-napthylacetic acid) and anti auxin (α parachlorophenoxyiso butyric acid).

The nitrogen requirements for plants may be very small. Shields (39) stated that one part per 120 million parts of water ordinarily supplies enough nitrogen for assimilation purposes, however, in nutrient solutions fifty-five parts per million is frequently maintained. High nitrate concentrations are very detrimental to the innoculation of legume roots by bacteria unless there is an abundant supply of carbohydrates which will promote moderate root growth.

Fred et al (13), in an early report on the factors influencing nodule formation, stated that inorganic salts of high concentration may prevent nodulation and that nitrates and ammonium salts decreased nodulation in most of their studies. They reported that Beijerineck found no ill effect from $Ca(NO_3)_2$ or $(NH_4)_2SO_4$ in his studies and that Giöbel found no ill effects from $NaNO_3$ until 300 pounds had been applied to soybeans and 1000 pounds per acre to alfalfa.

The nitrogen content of plant roots has been studied by McLean et al (27) in relation to their cation exchange capacities. A corelation coefficient of 0.86 was found between the cation exchange capacity and nitrogen content of the roots of twenty species. The authors found that plants with high cation exchange capacity preferred Ca over K or Na and the reverse was true for plants with a low cation exchange capacity. This would enhance the uptake of Ca and Mg which would aid in the release and uptake of phosphorus and depress the uptake of monovalent cations such as K. This could explain why it is necessary to apply larger amounts of K when the nitrogen supply is increased.

Companion Crops

The establishment of alfalfa can be exceedingly difficult, depending upon the companion crop, the weather conditions, the fertility level of the soil, the pH, and moisture supply. Work in this direction has been in progress and must be continued because new varieties of both alfalfa and companion crops are being released for commercial use.

Briggs and Harrison (8) used three varieties of oats, three varieties of barley, German millet, soybeans, sudan grass and buckwheat as companion crops and found all of these were satisfactory in alfalfa plantings if they were removed early either for grain or hay. The best alfalfa yields were obtained with oats and barley cut for grain at a height of three inches and the straw removed.

Smith <u>et al</u> (40) studied the rate of seeding of oats as the companion crop with alfalfa and red clover and concluded that there was no significant difference between the rates ranging from one-half to three bushels per acre. However, their stands were very weedy and the stands on the sandy soils were poor following the high seeding rate.

In many cases it is important to secure a high yield of the companion crop, with high quality or protein content, as well as the establishment of the alfalfa. As a consequence, many investigators have applied high rates of nitrogen to the companion crops by making seasonal topdressings.

Gardner (15) reported that the protein content of winter wheat and winter and spring oats was increased from 11.37 to 12.00 percent with a mid-April application of 200 pounds per acre of nitro-chalk. With another application of 200 pounds per acre in mid-June, the protein percentage was increased to 13.67. Hutchinson and Martin (23) listed the average protein of English oats as 11.56 percent and 12.50 percent for wheat. They also stated that it may vary a great deal in oats depending upon the percent that is kernel and percent that is husk. Varieties will vary as much as 0.2 percent in protein. Hunter (21) reported that yields of barley were lowered with delayed applications of nitrogen but the percent of protein was increased. When split applications of 100 pounds of sodium nitrate were made, large increases in yield and protein content were combined.

Yatozawa (56), experimenting with radioactive P^{32}, showed that topdressing of wheat with nitrogen gave an increase of phosphorus uptake and accumulation. Mulder (30) has pointed out a connection of magnesium nutrition in relation to nitrogen fertilization. In the absence of magnesium, ammonium sulfate did not produce as good a yield as calcium nitrate. This could be caused by an unfavorable soil reaction due to the addition of the ammonium sulfate. In the case of calcium nitrate, the plant could be using calcium to a greater extent than magnesium.

Peterson (33), reporting the results of an eight year study of the effects of nitrogen on yield and protein content of wheat, showed that commercial nitrogen increased the yield or protein content or both and in no case was there a decrease in yield or protein content. When the protein content was up, there was a decrease in yellow berry. Forty pounds per acre appeared to be the most economical rate to apply. For early spring applications the nitrate form was the best, however, either nitrate or ammonia were satisfactory for fall applications. He also reported that the test weight was seldom increased but never decreased.

Hobbs (20) at Kansas State University found that thirty-seven pounds of nitrogen per acre gave an increase in yields of 20.2 percent and at the same time increased the protein content from 11.7 to 12.3 percent. The greatest yield increases were obtained on plots with a high phosphate content which was more conducive to tillering and producing a more plump kernel. There was a slight reduction in test weight but it did not affect the yields.

Williams and Smith (55) at the same station found that nitrogen and phosphorus increased the yields of wheat at all locations tested but potassium had no effect. A preplant broadcast application of nitrogen was as good as later applications. The protein content was increased with nitrogen, nitrogen and phosphorus, nitrogen and potassium, but was decreased with the application of phosphorus. The test weights varied from one location to another due to nitrogen but there was no difference in the source of nitrogen used.

In contrast to the previously mentioned investigations, McNeal and Davis (28) found nitrogen hastened the heading date from one to four days with nine varieties of spring wheat and nitrogen did not reduce the test weight. The authors also stated that there was no significant difference in the protein content even with 100 pounds of nitrogen per acre and that the interaction between varieties and treatments was not significant.

Symbiotic Fixation of Nitrogen by Alfalfa

Many lengthy and varied discussions have been published concerning the amount of nitrogen fixed by legumes as well as the effect of available nitrates on symbiotic fixation. Allos and Bartholomew (1), worked with seven legumes and four grasses grown in one-half gallon pots of exploded vermiculite and fed with a nutrient solution containing up to 432 mg. of nitrogen per pot, reported the magnitude of nitrogen uptake. They found that nitrogen fixation decreased while nitrogen uptake increased with increasing rates of nitrogen. The authors also stated that nitrogen fixation was never completely inhibited nor was all of the nitrogen adsorbed. Lower rates of nitrogen tended to increase growth and uptake of nitrogen more than it did to decrease fixation. However, high rates had less effect on growth but a greater effect on fixation.

Giöbel (17) at the new Jersey Experiment Station recommended some combined nitrogen because it is desirable and highly beneficial for maximum infection and nodule development as well as root development in the early stages of growth since the alfalfa seed are small and do not contain much nitrogen. He also found that the yield and percent of protein increased proportional to the nitrogen fertilizer applied. There was no nitrogen fixed during the growth of the first crop but beginning with the second crop nitrogen fixation took place very readily and the average fixation was found to be 150 to 200 pounds of nitrogen per acre. The amount fixed was inversely proportional to the amount of nitrogen in the soil. Inoculated and non-inoculated alfalfa absorbed nitrates at the same rates and nodule development was hindered by large amounts of nitrates even when added in small quantities over a long period of time.

In 1944 at the Delaware Experiment Station, Davis (9) observed a condition of nitrogen deficiency in alfalfa and upon close examination found no nodules on the yellowish stunted plants. On the normal green colored plants, nodules were present in large numbers. This situation was studied by applying forty-two pounds of nitrogen, phosphorus and potassium alone or in combination in the spring. When the plots were harvested twenty-nine days later, it was obvious that nitrogen alone was responsible for the greatest increases in yield.

Lyon and Brizzell (25) in a study of nitrogen accretion by legumes found that alfalfa fixed 268 pounds of nitrogen per acre per year. It is of interest to note in this work that field beans caused the greatest reduction in nitrogen. The authors stated that when alfalfa is grown in a soil containing 0.12 percent nitrogen, the gain in the soil nitrogen was less than at the low level of 0.084 percent nitrogen but the hay contained a higher content of nitrogen.

McAuliffe et al (26) using N^{15} found that twenty-five pounds of additional nitrogen almost stopped nitrogen fixation in a fescue-clover sod and that fifty pounds of nitrogen completely inhibited fixation. The authors reported that in another experiment 50 pounds of nitrogen did not stop fixation. However, the yields were the same as the check. In one experiment 50-100 pounds of nitrogen increased the yield of the mixture by 300-1000 pounds of dry forage per acre. Walker et al (53) reported that 30 percent of the N^{15} was lost by denitrification and where clover was grown, part of the nitrogen was converted to the organic form before it was recovered. They also found no evidence of the transfer of nitrogen from the clover to the grass. Thornton (47) also working with N^{15} and four legumes found that nitrogen aided or enhanced the fixation of nitrogen and also increased the yields and protein content of sweet and red clover. He also recommended supplemental nitrogen for maximum growth of soybeans. Application at planting time depressed nodulation but the nitrogen was recovered in the roots and tops. In contrast to early applications, which depressed nodulation by 50 percent, late applications of nitrogen went to the seed.

The quality of legumes for green manure or the effect of fertilizers on root-top ratios have been investigated by several workers (3) (10) (14). Baker et al (3) found that a 20-40-40 fertilizer gave a significant increase in yield of both top and roots of red clover and a 40-80-80 fertilizer on sweet clover gave a significant response at the one percent level for both tops and roots. Davis and Turk (10) working with alfalfa and sweet clover found that fertilizers increased the amounts of nitrogen, phosphorus and potassium in the roots and tops but did not increase the calcium and magnesium. The earlier cuttings contained more nitrogen, decomposed faster, for the nitrogen treatment and fertilizer treatments in general, and liberated more ammonia and nitrates.

A corelation analysis was carried out by Fribourg and Johnson (14) on the yields and nitrogen content of roots and tops of six legumes. They found that sweet clover fertilized with 135-150 pounds of nitrogen per acre gave the highest yields with equal roots and tops followed by alfalfa fertilized with 60-120 pounds of nitrogen per acre with a higher top-root ratio. The corelation between dry matter of tops and roots versus the nitrogen yield in tops and roots was 0.976. For dry matter yields of tops versus the nitrogen yield for both top and roots, the corelation coefficient was 0.936.

Establishment of Legumes

The following papers deal primarily with fertilizers used in establishing legumes. Suman (43) stated that the initial fertilizer is the key to establishing clovers on coastal plain soils and recommended 565 pounds per acre of an 0-15-15 fertilizer on sandy soils of low fertility.

There was no increase in yields above 950 pounds of the fertilizer. Woodhouse and Chamblee (49) used 300-500 pounds of an 8-8-8 fertilizer per acre at seeding time and top-dressed with 25-50 pounds of nitrogen annually for a mixture of annual grasses and legumes. For perennial legumes and grasses, they recommend 1000 pounds of a 2-12-12 fertilizer at planting time and topdress with phosphorus and potassium. The authors definitely recommended 10-20 pounds of nitrogen for pure stands of legumes at planting time.

Swenson[1] found in a greenhouse experiment with alfalfa that nitrogen applied at the time of seeding gave increases in both yield and protein content. Field results also indicated that nitrogen was beneficial in establishing alfalfa. Gross et al (19) working with varieties of alfalfa found that varieties differ significantly in yield. They also differ with nitrogen fertilizer but the interaction of varieties and treatments was not significant. Rendig (38) applied calcium sulfate to a sulfur deficient soil and found that 200 and 400 pounds of calcium sulfate increased the yields as well as the sulfur content and increased the percent of nitrogen in the first harvest. There was no significant change in the four following harvests. The amide nitrogen was increased in the first, third, and fifth harvests but the free alpha-amino nitrogen remained the same. The protein was not enriched in methionine by the addition of sulfur but the synthesis of some reduced sulfur contain-

[1]Unpublished data.

ing compound in the unfertilized alfalfa was impeded, presumably by a lack of available sulfur.

Rouse et al (37) reported a reduction in percent stand of clover in a mixture of grasses from 50 percent to 5 percent with the application of 160 pounds of nitrogen per acre. The authors reported a significant increase of crude protein for three of the four types of harvest due to nitrogen fertilizer. Wagner (50)(51) comparing legume nitrogen with fertilizer nitrogen in relation to protein production found that clover seeded in the mixture produced a higher yield than did the grass alone topdressed with 160 pounds of nitrogen fertilizer. Ladino clover fixed 150 pounds of nitrogen per acre when grown with orchard grass or tall fescue. Prince (35) found, as others have reported, that plots receiving 90 pounds of nitrogen per acre gave a significant increase in yield of a mixture of rye grass and clover over those plots where 60 pounds of nitrogen was used. The effect lasted for two cuttings, and the nitrogen content was higher where the 90 pounds of nitrogen was applied. There was a higher percent of clover where the 30 pound rate was used. Four cuttings exhausted the nitrogen supply and the clover fixed only 25 pounds of nitrogen while 69.4 pounds were removed in the hay leaving the rye grass deficient in nitrogen.

Swanson (45), after studying the effect of growing alfalfa for long periods of time, concluded that the nitrogen content of the soil was not equal to the nitrogen content under sod except in semi-arid areas. It was greater here and also in the more humid areas the nitrogen content is greater under alfalfa than in grain cropped soils. He also stated that alfalfa has not added materially to the amounts of nitrogen now present except in the semi-arid areas although alfalfa has prevented a further loss in soil nitrogen and has maintained an equilibrium.

During the last few years several workers (2) (5) (6) (11) (16) (32) (42) (54) have published their results along this line indicating a very popular field of work. There was a wide range of fertilizer recommendations given in these reports which indicated that each location must be given special consideration.

Griffith (18) has pointed out the high requirements of the mineral constituents of alfalfa and the removal of these elements from the soil. Larson _et al_ (24) working with phosphate deficient soils in Iowa has shown that small applications of phosphate were depleted in a very short time whereas heavy applications of phosphorus were still producing good yields of alfalfa hay with a high phosphate content after four years. Gerwig (16) showed a response of alfalfa to 300 pounds of K_2O per acre and recommended 200 pounds of K_2O as well as twenty-five pounds of nitrogen during the year of establishment. Falloon (42) also indicated that a small amount of nitrogen was beneficial at planting time. Purvis (36) stated that small amounts of nitrogen may interfere with the nitrogen fixing bacteria and that it takes

100 pounds of nitrogen per acre to offset this loss. Blaser (5) (6) and Dobson and Woodhouse (11) also recommended about 20 pounds of nitrogen per acre during the first year of establishing alfalfa.

Attoe and Peterson (2), Peterson (32), and Wedin et al (54) did not use a fertilizer containing nitrogen in their experiments but stressed the point of adding high rates of lime, phosphorus and potassium which would contribute to a very favorable environment for root nodule bacteria that might eliminate the need for nitrogen.

III. METHODS OF EXPERIMENTATION

Soil Pot Studies in the Greenhouse

In the fall of 1954, three soils, a Brookston clay loam from the Ferden farm, a Miami loam from the University farm and an Oshtemo loamy sand from the Rose Lake Experiment Station were collected, dried, brought to the greenhouse and weighed into two-gallon glazed pots. For the Miami and the Osthemo, 9000 grams were necessary to fill the pots up to within one inch of the top but for the Brookston only 8000 grams were needed. This left an adequate space for watering to avoid losing any soil.

Several soil samples were taken and composited for chemical analysis. The analysis of the above soils together with three additional soils; a Fox sandy loam from the Kellogg farm, a Conover loam and a Hillsdale loam from the University farm which were used in 1955 are reported in table 1.

TABLE 1.- Composition of soils used in the greenhouse study.

Soil type	pH	% O. M.	% N	P lbs/A	K lbs/A
Miami loam	6.3	2.200	0.125	16	87
Brookston clay loam	6.9	4.903	0.200	78	120
Oshtemo loamy sand	6.8	0.741	0.043	9	56
Conover loam	7.2	3.841	0.157	72	64
Hillsdale loam	6.4	2.206	0.113	50	150
Fox sandy loam	6.6	1.155	0.077	50	200

The pH was measured with the glass electrode. Organic matter determinations were made by analyzing for total carbon and multiplying by 1.724 (34). Total nitrogen was determined by the Kjeldahl method (31) and phosphorus and potassium were analyzed by the Spurway method (41).

The Miami soil was slightly acid and was limed at the rate of two tons per acre using a technical grade calcium carbonate. The Oshtemo was fertilized at the rate of 400 pounds per acre, the Miami received 300 pounds per acre and the Brookston 200 pounds per acre of an 0-20-20. This was according to the current fertilizer recommendations for supplying adequate amounts of phosphorus and potassium (12).

The following year the Fox, Hillsdale, and Conover soils were used and were fertilized at the following rate: the Fox and Hillsdale received 150 pounds per acre of an 0-20-20 and the Conover 200 pounds per acre.

Ammonium sulfate was used both years as the source of nitrogen and applied at the rate of 0, 20, 40, 80 and 160 pounds of elemental nitrogen per acre. All fertilizer materials were banded using the inverted pot method, placing the fertilizer two inches below and one inch to the side of the seed. All treatments were replicated four times.

Canada Grimm alfalfa seed which had been properly inoculated was planted in all six soils. A few days after emergence the plants were thinned to fifteen plants per pot. Three cuttings were taken from each planting for yields and protein content and soil samples were taken at the end of the experiment.

Each yield sample was analyzed for total nitrogen the first year but the following year the replicates were bulked and analyses were carried out in duplicate.

Methods Used in Field Studies

Two types of field studies were carried out. One included rates of nitrogen with various seeding dates, depending upon the companion crop, and the other included different forms of nitrogen at a constant rate on alfalfa.

For the first type, three locations were obtained. These were a Fox sandy loam soil on the W. K. Kellogg farm, Battle Creek, Michigan; a Brookston clay loam soil on the Lee Ferden farm at Chesaning, Michigan; and a Hillsdale loam soil on the University farm at East Lansing, Michigan. These three soils were the same as those used in the greenhouse study.

The treatments were the same as in the greenhouse study except the high rate of nitrogen was omitted, only the 0, 20, 40 and 80 pounds of nitrogen were used. All treatments were replicated four times and were set up either as a randomized block or split plot design. Four plantings were made at each of the three locations.

The first planting of alfalfa consisted of a randomized block with the four rates of nitrogen, and four replications with oats as the companion crop at the Kellogg farm and the University farm and barley as the companion crop at the Ferden farm. All three locations were planted during the month of April, 1955.

The second planting was made in August 1955 at each location. This block was also a randomized block design with four rates of nitrogen, four replicates and alfalfa seeded alone.

The third and fourth plantings were made in September 1955 and consisted of two blocks of wheat each with four levels of nitrogen and four replications. At each of the three locations alfalfa was seeded in the wheat in the fall in one block and overseeded in the wheat in the spring of 1956 in the other block and at this time each plot of wheat and alfalfa was split, one half receiving 20 pounds of nitrogen as a topdressing.

All plots at each location received a blanket application of phosphorus and potassium by applying 500 pounds of an 0-20-20 fertilizer before making the initial planting.

All grain crops were harvested for yield. Protein content and test weights were also measured. Yields were taken from all hay plots from one to four cuttings depending upon the planting date and all samples were analyzed for protein.

The second type of field study was nitrogen carriers which was carried out in 1957 and consisted of a topdressing of alfalfa at four additional locations throughout the state.

In this study thirty pounds of elemental nitrogen was applied in the form of ammonium sulfate, ammonium nitrate and urea to compare with a check. Each treatment was replicated five times at each location. Soil samples were taken and analyzed for pH, phosphorus and potassium as shown in table 2. Two cuttings were taken for yield and protein content.

TABLE 2.- The location, soil type and chemical analysis of soils used in sources of nitrogen study.

		pH		Pounds per acre			
				Phosphorus		Potassium	
County	Soil Type	Sur-face	Sub-soil	Sur-face	Sub-soil	Sur-face	Sub-soil
Barry	Oshtemo loamy sand	6.8	6.1	28	20	233	62
Calhoun	Ockley sandy loam	5.8	5.6	53	42	178	62
Jackson	Belfontaine sandy loam	6.8	6.2	39	35	67	21
Lapeer	Conover loam	6.4	6.2	72	22	275	137

IV. RESULTS AND DISCUSSION

Soil Pot Studies in The Greenhouse

The application of nitrogen to alfalfa in the greenhouse gave varying but interesting results. Nitrogen influenced the yield of alfalfa differently on each soil studied.

Statistical analyses indicate a highly significant difference in yield between the nitrogen treatments applied to the Oshtemo loamy sand and a significant difference for the Miami loam soil. Figure 1 and table 3 show that twenty pounds of nitrogen increased the yield of alfalfa but forty pounds of nitrogen gave a greater percent increase. The additional nitrogen applied gave no substantial increase in yields and did not bring about any detrimental effects.

The Conover soil responded only slightly to the application of nitrogen. The highest yields were obtained with the highest rate of nitrogen as on the Oshtemo, but this increase over the check was not significant. The highest yields were obtained on the Hillsdale and Miami at the eighty pound rate and then dropped with the higher rates of nitrogen. This increase was not significant on the Hillsdale soil. The results obtained on the Fox and Brookston soils were the most erratic of all. The highest yield on the Brookston was obtained from the 160 pound rate and was

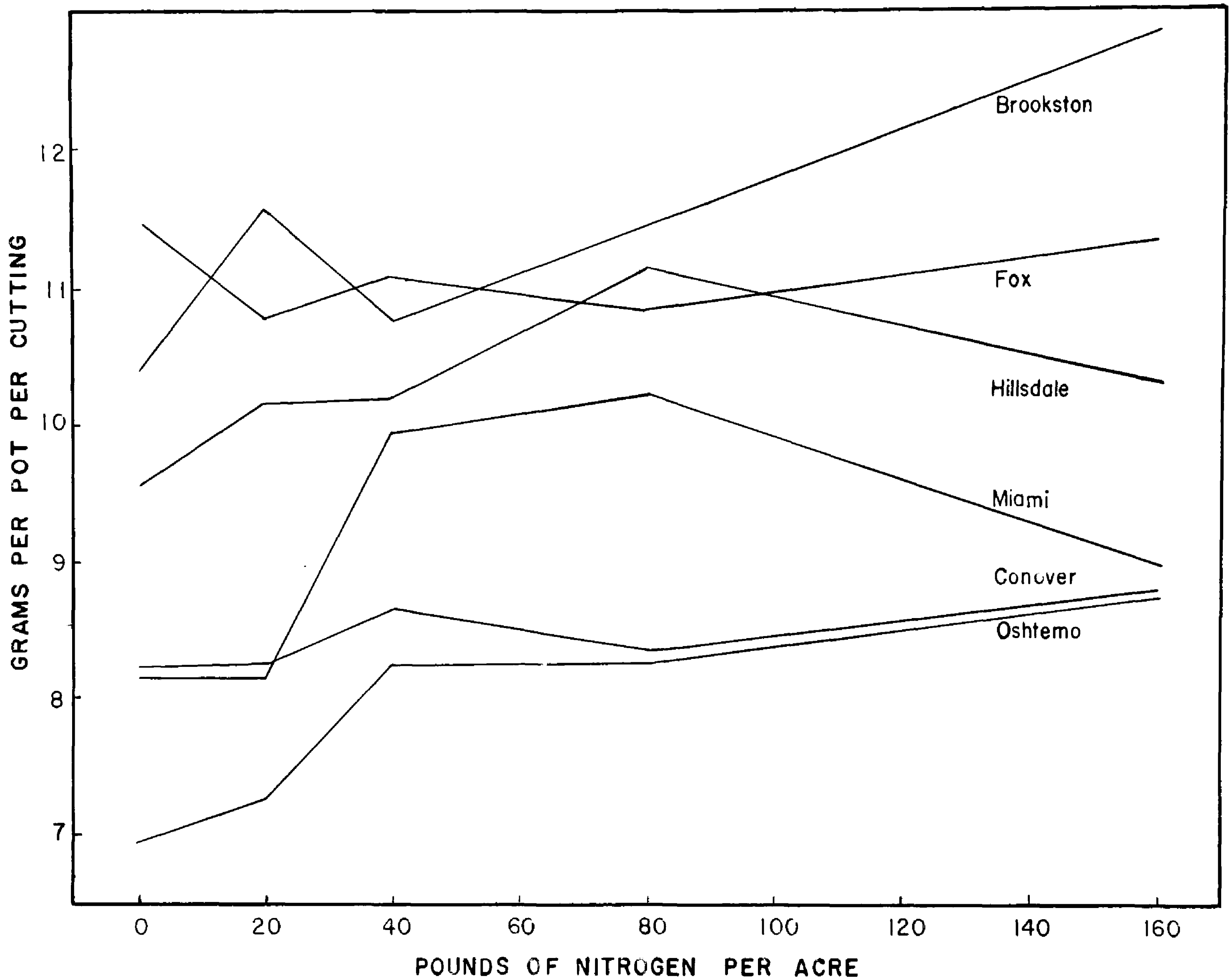

Fig. 1.- The effect of rates of ammonium sulfate on the yield of alfalfa grown in the greenhouse.

TABLE 3.- The effect of rates of application of ammonium sulfate on the mean yield of alfalfa grown in the greenhouse in 1955 and 1956.

Cutting	Pounds of nitrogen per acre				
	0	20	40	80	160
			Grams per pot		
		Brookston clay loam			
1	9.72	10.68	10.52	10.54	11.92
2	11.95	11.81	10.76	12.00	13.65
3	11.33	12.26	10.88	11.81	13.13
Average	11.00	11.58	10.72	11.45	12.90
LSD (.05) 3.49 (.01)	4.67				
		Miami loam			
1	5.85	6.64	8.07	8.72	7.84
2	9.33	9.16	11.00	10.99	9.20
3	9.24	8.62	10.79	10.95	9.97
Average	8.14	8.14	9.95	10.22	9.00
LSD (.05) 2.00 (.01)	2.67				
		Oshtemo loamy sand			
1	6.31	6.46	7.64	8.64	8.85
2	5.94	6.11	7.66	6.67	7.53
3	8.58	9.28	9.49	9.49	9.58
Average	6.94	7.28	8.26	8.27	8.65
LSD (.05) 1.47 (.01)	1.97				
		Fox sandy loam			
1	5.46	4.89	5.51	4.66	4.97
2	12.50	12.40	11.60	12.20	12.50
3	16.51	15.49	16.15	15.60	16.86
Average	11.49	10.93	11.09	10.82	11.44
LSD (.05) 1.92 (.01)	2.56				
		Conover loam			
1	6.05	6.05	6.89	6.22	6.32
2	7.30	6.90	7.50	7.70	7.80
3	11.20	11.88	11.60	11.15	11.99
Average	8.18	8.28	8.66	8.36	8.70
LSD (.05) 2.67 (.01)	3.56				
		Hillsdale loam			
1	4.25	5.04	5.13	5.24	5.78
2	11.97	12.17	12.30	12.07	12.40
3	11.98	13.26	13.15	15.99	13.09
Average	9.40	10.16	10.19	11.10	10.42
LSD (.05) 1.86 (.01)	2.48				
Average of 6 soils	9.19	9.40	9.81	10.04	10.19

still increasing while the Fox was giving a yield somewhat lower than the check.

An interaction between cuttings and treatments was obtained only on the Fox sandy loam soil. Cuttings were highly significant on all soils in the study except for the Brookston clay loam. The yields are given for each soil by cuttings in tables 1, 3, 5, 7, 9, and 11 in the appendix.

Table 3 also shows that while there was no large increase in yield brought about by the addition of large amounts of nitrogen, a small but consistent increase is shown for the average of the six soils.

Analysis of the data given in table 4 shows that there is no significant change in the percent protein found in alfalfa from the addition of large amounts of nitrogen. It is of interest to note here the small but steady increase which occurred over the range of nitrogen treatments, the same as that found in the yield data. A highly significant difference in the percent protein was found among soils, cuttings and in the interaction of cuttings times nitrogen treatments. The Oshtemo loamy sand produced alfalfa with a lower percent protein than any of the other five soils studied. The Hillsdale soil produced alfalfa with the highest percent protein followed by the Fox, Brookston, Miami and Conover. The first cutting produced the highest percent protein and decreased progressively with the second and third cuttings.

The interaction between cuttings and nitrogen treat-

TABLE 4.- The effect of rates of application of ammonium sulfate on the mean percent protein in alfalfa grown in the greenhouse in 1955 and 1956.

Cutting	Pounds of nitrogen per acre				
	0	20	40	80	160
			Percent protein		
	Brookston clay loam				
1	19.86*	20.90	19.09	19.86	19.71
2	18.93	18.74	17.10	17.65	16.02
3	18.20	18.03	17.67	18.49	16.50
Average	19.00	19.22	17.95	18.67	17.41
	Miami loam				
1	18.87	19.28	18.05	19.38	21.14
2	17.49	19.11	15.40	17.96	19.40
3	17.74	17.41	17.30	16.98	17.32
Average	18.03	18.60	16.92	18.11	19.29
	Oshtemo loamy sand				
1	15.89	15.36	15.51	15.46	17.21
2	15.92	17.25	17.23	17.23	17.89
3	14.85	15.18	15.29	15.51	15.77
Average	15.55	15.93	16.01	16.07	16.96
	Fox sandy loam				
1	19.06	19.88	22.25	22.44	23.44
2	19.50	17.80	19.80	17.90	16.90
3	16.08	17.23	16.17	15.91	16.17
Average	18.21	18.30	19.41	18.75	18.84
	Conover loam				
1	18.75	20.12	20.44	21.56	20.00
2	17.70	18.70	19.40	17.80	18.90
3	15.02	14.58	16.17	15.02	16.88
Average	17.16	17.80	18.67	18.13	18.59
	Hillsdale loam				
1	17.25	16.94	19.88	21.33	23.31
2	19.90	19.40	20.30	19.70	18.80
3	15.91	16.79	16.70	17.50	17.50
Average	17.69	17.71	18.96	19.51	19.87
Average of 6 soils	17.61	17.93	17.99	18.21	18.49

LSD (.05) 1.84 (.01)2.44

* Kjeldahl x 6.25

ment points out that some of the nitrogen treatments gave an increasingly higher percent protein for the first cutting while the second and third showed an increase for the first increment of nitrogen and a decrease for the second increment of nitrogen. Cutting two then showed a progressive decrease while cutting three gave a progressive increase in the protein content. The percent protein for soils by cuttings are given in tables 2, 4, 6, 8, 10, and 12 in the appendix.

In table 5 the amount of total protein was calculated from the average percent protein given in table 4 and the mean yield data given in table 3. An analysis of these data shows significance for both soils and nitrogen applied. The ranking of total amount of protein produced from all six soils was parallel to the rate of nitrogen applied.

After the third cutting of alfalfa was removed, soil samples were taken and analyzed for total nitrogen. These data are shown in table 6. Using the data obtained thus far, a nitrogen balance was calculated for the first, third and fifth rates of nitrogen applied, but no real facts were elucidated. However, a general understanding of the variability as shown in figure 1 was pointed out.

TABLE 5.– The effect of rates of application of ammonium sulfate on the total protein produced from four pots and three cuttings of alfalfa.

Soil type	Pounds of nitrogen per acre 0	20	40	80	160
	Grams protein per pot				
Brookston clay loam	25.06*	26.72	23.10	25.66	26.93
Miami loam	17.65	18.17	20.20	22.21	20.82
Oshtemo loamy sand	12.97	13.92	15.88	15.95	17.62
Fox sandy loam	25.11	24.06	25.81	24.41	25.91
Conover loam	16.93	17.68	19.43	18.17	19.44
Hillsdale loam	20.30	21.60	23.20	26.03	24.85
Average	19.67	20.36	21.27	22.07	22.60

LSD (.05) 1.76 (.01) 2.34
* Yield times the average protein content.

TABLE 6.– The effect of rates of application of ammonium sulfate on the residual percent nitrogen found in the soils after the removal of three cuttings of alfalfa.

Soil type	Pounds of nitrogen per acre 0	20	40	80	160
	Percent nitrogen				
Brookston clay loam	0.187*	0.191	0.192	0.196	0.212
Miami loam	0.111	0.116	0.111	0.102	0.107
Oshtemo loamy sand	0.035	0.034	0.040	0.034	0.038
Fox sandy loam	0.077	0.078	0.080	0.077	0.069
Conover loam	0.134	0.137	0.150	0.145	0.150
Hillsdale loam	0.098	0.103	0.109	0.113	0.125
Average	0.107	0.110	0.114	0.111	0.117

LSD for treatment (.05) 0.0058 (.01) 0.0079

* Total nitrogen by Kjeldahl analysis

Results Obtained From Field Studies

Weather conditions in the early part of the 1955 growing season were very mild and all crops planted in this study germinated soon after planting and grew very rapidly. The yield of oats (table 7) grown on a Fox sandy loam at the Kellogg Farm ranged from 40.6 bushels to 73.5 bushels per acre with averages by treatments ranging from 43.8 bushels with no nitrogen fertilizer up to 59.8 bushels with 80 pounds of nitrogen.

Twenty pounds of nitrogen produced 56.3 bushels of oats per acre which was highly significant over the zero nitrogen plots. The amount of weeds in the plots at harvest time was proportional to the amount of nitrogen applied. It was thought that the high rates of nitrogen might weaken the stems and cause lodging; however, no lodging occurred under the prevailing weather conditions of these plots.

The protein content (table 8) of the grain was increased from 12.63 percent with no nitrogen to 15.60 percent with 80 pounds of nitrogen.

The yields of alfalfa harvested from these plots in 1956 with no additional fertilizer applied ranged from 1.85 tons to 2.20 tons per acre for two cuttings (table 9). The 20 pound rate of nitrogen produced a yield that was significant over the 40 pound rate but was not significant over the other two nitrogen treatments. The first cutting was on the average two times more than the second cutting probably because of droughty conditions that existed on

TABLE 7.- The effect of rates of application of ammonium sulfate on the yield of grain harvested in 1955.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
		Bushels per acre		
		Oats, Fox sandy loam		
A	40.6	61.0	62.5	65.6
B	42.4	54.7	53.1	46.9
C	45.3	59.3	54.7	73.5
D	46.9	50.0	54.7	53.1
Average	43.8	56.3	56.3	59.8
LSD (.01) 10.1 bushels				
		Oats, Hillsdale loam		
A	70.3	57.8	51.3	63.0
B	72.9	66.3	57.8	52.5
C	86.5	78.0	54.5	62.2
D	65.3	70.5	63.0	40.7
Average	73.8	68.2	56.7	54.6
LSD not significant				
		Barley, Brookston clay loam		
A	45.6	60.3	63.0	66.6
B	47.2	55.3	56.9	58.4
C	42.3	55.0	56.0	50.0
D	40.4	49.6	50.8	49.6
Average	43.9	55.1	56.7	56.2
LSD (.01) 6.5 bushels				

TABLE 8.- The effect of rates of application of ammonium sulfate on the percent protein of grain harvested in 1955.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
		Percent protein		
		Oats, Fox sandy loam		
A	12.81*	13.52	14.14	15.02
B	12.50	14.89	15.47	17.01
C	12.24	13.26	14.49	14.85
D	12.95	14.67	15.47	15.53
Average	12.63	14.09	14.89	15.60
LSD (.05) 0.78 (.01) 1.13				
		Oats, Hillsdale loam		
A	10.87	12.59	13.17	14.36
B	11.27	13.70	14.89	13.92
C	12.59	12.59	14.23	13.92
D	13.61	12.55	13.92	14.49
Average	12.09	12.86	14.05	14.17
LSD (.05) 1.48 (.01) 2.13				
		Barley, Brookston clay loam		
A	9.90	10.65	11.71	12.90
B	10.52	10.69	11.53	11.93
C	10.60	11.09	11.14	11.97
D	10.43	10.43	11.44	12.06
Average	10.36	10.72	11.46	12.22
LSD (.05) 0.59 (.01) 0.85				

* Kjeldahl x 6.25

TABLE 9.- The effect of rates of application of ammonium sulfate on the mean yield of alfalfa.

Cutting	Year	Pounds of nitrogen per acre 0	20	40	80
		Tons per acre			
		Alfalfa after oats, Fox sandy loam			
1	1956	1.35	1.49	1.25	1.35
2	1956	0.63	0.70	0.57	0.69
Total	1956	1.98	2.19	1.82	2.04
1	1957*	1.95	1.99	1.78	2.03
		Alfalfa after oats, Hillsdale loam			
1	1956	1.94	1.95	1.97	1.99
2	1956	1.34	1.40	1.21	1.23
Total	1956	3.28	3.35	3.18	3.22
1	1957	3.17	2.30	2.66	2.56
2	1957	1.77	1.71	1.57	1.59
Total	1957	4.94	4.01	4.23	4.15
		Alfalfa alone, Hillsdale loam			
1	1956	1.25	1.05	1.19	1.11
2	1956	0.71	0.72	0.72	0.71
Total	1956	1.96	1.77	1.91	1.82
1	1957	2.22	2.24	2.33	2.23
2	1957	1.50	1.63	1.57	1.53
Total	1957	3.72	3.87	3.90	3.76
		Alfalfa after barley, Brookston clay loam			
1	1956	1.85	1.70	1.47	1.31
2	1956	1.53	1.54	1.63	1.48
Total	1956	3.38	3.24	3.10	2.79
1	1957	2.32	2.44	2.59	2.32
2	1957	0.96	1.22	1.02	0.98
Total	1957	3.28	3.66	3.61	3.30
		Alfalfa alone, Brookston clay loam			
1	1956	1.22	1.52	1.70	1.53
2	1956	1.36	1.06	1.48	1.37
Total	1956	2.58	2.58	3.18	2.90
1	1957	2.16	1.93	2.22	2.07
2	1957	0.91	1.08	1.04	1.03
Total	1957	3.07	3.01	3.26	3.10

*one cutting only

this sandy soil.

The protein content (table 10) was much higher for the second cutting since some species of weeds were removed during the first cutting leaving a better stand of alfalfa.

Only the first cutting was taken for yields and chemical analyses during 1957 and by this time the differences in yield were very small giving no significance by statistical analysis. The protein content was the same as the check plot for 1956 but the rest of the treatments showed a slight decrease (table 11).

Poor stands were obtained on the alfalfa plots seeded in August on the Fox sandy loam soil in 1955 and the plots were plowed and seeded to spring oats in 1956 with no fertilizer applied. After the oats were combined another planting of alfalfa was made in August of 1956. No additional potassium or phosphorus was applied at planting time but the same rates of nitrogen were repeated as a crop of oats had been removed since the plots were last fertilized. Poor stands were obtained again and this location was abandoned as far as the August planting was concerned due to insufficient soil moisture at this time of the year.

At the University farm an excellent stand of oats and alfalfa was obtained on all plots seeded during the month of April in 1955 on a Hillsdale loam. Apparent differences from the variable rates of nitrogen could be observed up to the 8th of July when a heavy windstorm and rain passed through the area. The following day the plots were rated as to damage by lodging as some, moderate, and severe. The plots receiving 80 pounds of nitrogen were classified as severe lodging in three of the four replications, the plots receiving 40 pounds of nitrogen were classified as moderate lodging in two replications and as some lodging in one replication. The plots receiving 20 pounds of nitrogen did not appear to be damaged any more than the check plots, but at harvest time these yields were much lower (table 7). In spite of reduced yields these rates of nitrogen gave a progressive increase in protein content (table 8) which indicates a higher quality grain for feeding purposes.

Four cuttings of alfalfa hay were taken off the plots following oats on the Hillsdale loam soil at the University farm, two cuttings in 1956 and two cuttings in 1957. The yields of second cutting for each year were lower than the first cutting but not quite as low in proportion to the yields at the Kellogg farm. No significant increases were found for either year; however, all plots receiving nitrogen fertilizer gave a lower yield than the check plots for the first cutting of 1957 (table 9). The greatest variation in protein content in these four cuttings was found to be in the first cutting of 1956 (table 10). Smaller increases were found in the other three cuttings and the second cutting of each year was higher in protein than the first cutting.

The August seeding at the University farm on the Hillsdale loam soil was far superior to the seeding made at the

TABLE 10.- The effect of rates of application of ammonium sulfate applied in 1955 on the percent protein found in alfalfa hay harvested in 1956.

Cutting	Replication	Pounds of nitrogen per acre 0	20	40	80
		Percent protein			
	Alfalfa after oats, Fox sandy loam				
1	A	13.60	12.45	14.12	15.03
	B	14.12	13.78	13.78	15.03
	Average	13.86	13.12	13.95	15.03
2	A	16.00	16.50	16.95	16.50
	B	16.40	16.50	17.35	16.50
	Average	16.20	16.50	17.15	16.50
	Alfalfa after oats, Hillsdale loam				
1	A	11.05	11.32	13.54	16.18
	B	16.18	11.94	12.91	14.85
	Average	13.62	11.63	13.23	15.52
2	A	19.21	19.21	17.46	19.50
	B	19.89	19.79	18.82	20.56
	Average	19.55	19.50	18.14	20.03
	Alfalfa seeded alone, Hillsdale loam				
1	A	16.34	16.35	17.15	16.09
	B	16.18	16.88	15.03	15.03
	Average	16.26	16.62	16.09	15.56
2	A	18.25	19.32	19.23	17.28
	B	18.84	19.61	18.64	16.80
	Average	18.55	19.47	18.94	17.04
	Alfalfa after barley, Brookston clay loam				
1	A	13.26	14.41	14.41	15.29
	B	14.76	13.08	12.11	15.65
	Average	14.01	13.75	13.26	15.47
2	A	17.67	17.96	19.42	17.87
	B	16.99	17.86	19.42	17.38
	Average	17.33	17.91	19.42	17.63
	Alfalfa seeded alone, Brookston clay loam				
1	A	14.41	15.82	13.52	18.83
	B	14.76	17.50	16.88	16.18
	Average	14.59	16.66	15.20	17.50
2	A	20.49	22.43	21.36	19.52
	B	19.90	21.27	21.65	19.03
	Average	20.20	21.85	21.50	19.28

TABLE 11.- The effect of rates of application of ammonium sulfate applied in 1955 on the percent protein found in alfalfa hay harvested in 1957.

Cutting	Replication	Pounds of nitrogen per acre 0	20	40	80
		Percent protein			
		Alfalfa after oats*, Fox sandy loam			
1	A	13.77	13.32	12.78	12.87
	B	13.94	12.96	12.96	13.32
	Average	13.86	13.14	12.87	13.10
		Alfalfa after oats, Hillsdale loam			
1	A	15.02	13.14	13.05	15.20
	B	13.77	14.21	13.77	14.66
	Average	14.40	13.68	13.41	14.93
2	A	16.27	18.77	18.51	17.70
	B	17.52	19.49	18.33	17.88
	Average	16.90	19.13	18.42	17.79
		Alfalfa seeded alone, Hillsdale loam			
1	A	12.96	14.30	14.30	12.78
	B	12.60	13.95	14.30	12.43
	Average	12.78	14.13	14.30	12.60
2	A	19.44	18.86	19.49	19.31
	B	20.65	19.40	20.03	19.67
	Average	20.05	19.13	19.76	19.49
		Alfalfa after barley, Brookston clay loam			
1	A	12.61	15.56	12.96	15.02
	B	11.89	15.64	13.50	13.95
	Average	12.25	15.60	13.23	14.49
2	A	17.34	16.45	15.82	16.45
	B	17.16	16.63	16.72	16.09
	Average	17.25	16.54	16.27	16.27
		Alfalfa seeded alone, Brookston clay loam			
1	A	15.20	13.59	15.20	13.86
	B	14.48	14.48	15.56	13.50
	Average	14.84	14.04	15.38	13.68
2	A	15.56	15.91	15.20	13.68
	B	15.02	14.66	13.95	13.95
	Average	15.29	15.29	14.58	13.82

* First cutting only.

Kellogg farm on the Fox sandy loam soil. Four cuttings were taken here also and smaller yields were obtained in 1956 than in 1957, indicating that the plants were not as well established when seeded in August as compared to the spring planting (table 9). There was little difference in the yields due to treatments for either year but again the second cutting was much lower than the first. The protein content of the second cutting of 1957 (table 11) was considerably higher than the first cutting following the same pattern as the protein content of 1956 (table 10). Some of these differences can be attributed to the harvest sampling dates.

At the Ferden farm where barley was planted as the companion crop, on a Brookston clay loam, a significant yield response for the barley was found due to nitrogen (table 7). Twenty pounds of nitrogen gave the largest percent increase. Little response was found from additional nitrogen. The percent protein (table 8) of the grain produced a linear effect ranging from 10.36 percent with no nitrogen to 12.22 percent with 80 pounds of nitrogen per acre.

Four cuttings of hay were removed from these plots during the next two years with no additional fertilizer. Yields are given in table 9. Here again there was no difference in yield due to treatments. The yields of the first and second cutting in 1956 were about equal while in 1957 the first cutting was about two times greater than the second. The protein content (table 10) shows a considerable increase due to nitrogen treatments for the first cutting in 1956 and a slight increase for two of the nitrogen rates in the second cutting in 1956. In 1957 the protein content was more or less constant for all nitrogen treatments as shown in table 11.

Soil moisture was adequate for germination on a Brookston clay loam at the Ferden farm in the fall of 1955 and an excellent stand was obtained from the August seeding. The yields are given in table 9 for four cuttings taken from these plots in 1956 and 1957. No significance was shown for treatments in either of the cuttings. The two cuttings taken in 1956 were of about equal size while the first cutting in 1957 was about two times greater than the second cutting which was the same for the alfalfa following barley at this location. There was an increase in protein content in 1956 (table 10) for both cuttings due to nitrogen treatments while in 1957 (table 11) there was a decline in the percent protein.

The hay yield for each of these plantings for the various soil types are given in tables 13, 14, 15, 16 and 17 of the appendix.

Wheat as a Companion Crop

Wheat yields in general did not vary much between locations regardless of nitrogen fertilizer treatments or nitrogen topdressing. Nitrogen treatments gave a significant increase in yields in four of the six blocks while nitrogen topdressing gave a significant increase in only two of the six blocks indicating that in most cases there was an adequate supply of nitrogen (tables 12, 13, 14). Severe lodging was not encountered until 80 to 100 pounds of nitrogen had been applied either at planting time or at planting time plus topdressing.

At the Kellogg farm on a Fox sandy loam both nitrogen treatment and nitrogen topdressing gave a significant increase in yield for the block of wheat that was fall planted and over seeded with alfalfa and topdressed with nitrogen the following spring. The other block of wheat, which was fall planted with alfalfa and topdressed in the spring, did not respond to either (table 12). The protein content (table 15) ranged from 9.48 to 14.87 percent with in treatments and the average for topdressing ranged from 9.63 to 14.68 percent. The test weight shown in table 18 was not seriously affected even with the addition of 100 pounds of nitrogen in any of the six blocks of wheat.

Only the nitrogen treatments gave a significant increase in yield in one block of wheat on the Hillsdale loam soil (table 13). Topdressing with 20 pounds of nitrogen gave a good increase over the check in both blocks but reduced the yields of the treatments where some nitrogen had been applied the previous fall. The percent protein in the grain produced on these plots falls in a very narrow range as shown in table 16.

Additional nitrogen gave a significant increase in the

TABLE 12.- The effect of rates of application of ammonium sulfate on the yield of wheat on a Fox sandy loam soil in 1956.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
	Bushels per acre			
	Wheat and alfalfa fall planted			
A	31.4	41.0	36.5	37.5
B	26.7	30.2	20.6	32.6
C	29.0	31.5	43.5	48.3
D	37.5	37.5	42.4	14.5
Average	31.2	35.0	35.8	33.2
	Topdressed in the spring			
A	27.8	29.0	32.6	33.5
B	26.7	31.5	24.2	32.6
C	35.0	38.7	35.0	33.5
D	41.0	35.0	37.5	19.3
Average	32.6	33.6	32.3	29.7

LSD for treatment (.05) not significant. LSD for topdressing (.05) not significant.

	Wheat over seeded with alfalfa in the spring			
A	24.2	41.2	41.3	40.0
B	35.0	36.4	41.0	38.8
C	35.5	43.5	47.2	44.8
D	29.0	38.6	41.0	44.8
Average	30.9	39.9	42.6	42.1
	Topdressed in the spring			
A	37.5	43.5	40.0	38.7
B	38.6	41.0	38.7	41.0
C	41.0	43.5	42.4	48.8
D	41.0	41.0	40.0	41.0
Average	39.5	42.3	40.3	42.4

LSD for treatment (.05) 5.4 bushels. LSD for topdressing (.05) 3.7 bushels.

TABLE 13.- The effect of rates of application of ammonium sulfate on the yield of wheat on a Hillsdale loam soil in 1956.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
	Bushels per acre			
Wheat and alfalfa fall planted				
A	37.9	43.0	45.6	35.0
B	40.8	49.2	52.0	40.2
C	44.7	55.0	53.0	39.7
D	42.3	51.7	46.0	45.3
Average	41.4	49.7	49.2	40.0
Topdressed in the spring				
A	45.3	45.3	32.0	44.0
B	49.3	45.0	43.0	32.0
C	47.0	34.0	40.2	41.3
D	45.0	43.3	47.3	42.0
Average	46.7	41.9	40.6	39.8

LSD for treatment (.05) 5.7 bu. LSD for topdressing (.05) not significant.

Replication	0	20	40	80
Wheat overseeded with alfalfa in the spring				
A	22.0	39.0	35.5	30.2
B	43.0	39.7	52.7	37.4
C	33.6	26.3	26.7	26.0
D	41.0	51.0	39.4	52.7
Average	35.1	39.0	38.6	36.6
Topdressed in the spring				
A	30.5	19.8	20.6	28.7
B	29.0	41.0	39.7	28.2
C	38.7	48.4	25.5	17.2
D	48.8	35.0	48.3	43.0
Average	36.8	36.0	33.5	29.3

LSD for treatment (.05) not significant. LSD for topdressing not significant (.05)

TABLE 14.- The effect of rates of application of ammonium sulfate on the yield of wheat on a Brookston clay loam soil in 1956.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
		Bushels per acre		
	Wheat and alfalfa fall planted			
A	35.7	34.4	39.3	42.0
B	36.7	37.8	42.0	49.0
C	38.4	38.7	43.3	43.7
D	34.4	37.8	43.5	37.8
Average	36.3	37.2	42.0	43.1
	Topdressed in the spring			
A	44.3	39.5	42.2	43.7
B	43.5	46.6	46.5	43.0
C	38.2	45.5	43.3	33.0
D	44.3	47.2	47.0	52.0
Average	42.6	44.7	44.8	42.9

LSD for treatment (.05) 4.7 bushels. LSD for topdressing (.05) 5.4 bushels.

Replication	0	20	40	80
	Wheat overseeded with alfalfa in the spring			
A	34.4	39.2	42.2	41.2
B	30.8	41.2	40.8	40.0
C	37.4	36.8	40.8	40.8
D	30.2	36.6	37.1	43.0
Average	33.2	38.5	40.2	41.3
	Topdressed in the spring			
A	36.2	43.0	39.6	37.8
B	41.5	46.6	41.8	41.0
C	30.7	40.8	35.2	36.6
D	38.7	35.7	35.6	40.8
Average	36.8	41.5	38.0	39.1

LSD for treatment (.05) 4.6 bushels. LSD for topdressing (.05) not significant.

TABLE 15.- The effect of rates of application of ammonium sulfate on the percent protein of wheat grown on a Fox sandy loam soil in 1956.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
		Percent protein		
	Wheat and alfalfa fall planted			
A	9.82	10.55	12.49	14.05
B	10.69	10.55	12.73	14.87
Average	10.26	10.55	12.61	14.46
	Topdressed in the spring			
A	10.69	12.64	13.60	14.68
B	10.79	12.64	13.90	14.68
Average	10.74	12.64	13.75	14.68
	Wheat overseeded with alfalfa in the spring			
A	9.48	10.59	11.91	11.66
B	9.77	10.30	11.62	11.52
Average	9.63	10.45	11.77	11.59
	Topdressed in the spring			
A	11.23	13.22	14.34	14.58
B	11.52	12.88	15.02	13.95
Average	11.38	13.05	14.68	14.27

TABLE 16.- The effect of rates of application of ammonium sulfate on the percent protein of wheat grown on a Hillsdale loam soil in 1956.

Replication	Pounds of nitrogen per acre 0	20	40	80
	Percent protein			
Wheat and alfalfa fall planted				
A	11.52	11.57	11.18	12.15
B	11.37	11.42	11.90	11.91
Average	11.45	11.50	11.54	12.02
Topdressed in the spring				
A	12.05	10.59	12.64	12.73
B	11.71	12.30	12.15	12.83
Average	11.88	11.45	12.40	12.78
Wheat overseeded with alfalfa in the spring				
A	12.10	12.93	12.64	13.85
B	11.96	12.59	12.44	13.61
Average	12.03	12.76	12.54	13.73
Topdressed in the spring				
A	12.98	13.22	13.17	13.32
B	13.27	13.36	12.88	13.51
Average	13.13	13.29	13.03	13.42

TABLE 17.- The effect of rates of application of ammonium sulfate on the percent protein of wheat grown on a Brookston clay loam soil in 1956.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
	Percent protein			
Wheat and alfalfa fall planted				
A	12.10	10.94	10.64	11.42
B	11.23	10.84	10.74	11.13
Average	11.67	10.89	10.69	11.28
Topdressed in the spring				
A	11.08	11.37	11.42	11.32
B	12.05	11.47	11.32	11.38
Average	11.57	11.42	11.37	11.35
Wheat overseeded with alfalfa in the spring				
A	11.08	11.23	10.89	11.23
B	11.13	11.13	11.37	12.01
Average	11.11	11.18	11.13	11.62
Topdressed in the spring				
A	11.62	11.37	11.91	11.62
B	11.28	11.86	11.76	11.62
Average	11.45	11.62	11.84	11.62

TABLE 18.- The effect of rates of application of ammonium sulfate on the test weight of wheat grown on three soils in 1956.

Date of application	Pounds of nitrogen per acre 0	20	40	60	80	100
			Fox sandy loam			
Fall	55.4*	57.0	56.5		57.5	
Fall and spring		55.9	56.5	56.6		56.6
Fall	56.2	57.1	56.5		56.4	
Fall and spring		56.2	57.4	57.2		56.0
			Hillsdale loam			
Fall	56.8	57.4	57.2		57.4	
Fall and spring		57.0	57.2	56.9		56.8
Fall	55.2	56.4	55.9		55.6	
Fall and spring		55.8	55.3	55.9		55.8
			Brookston clay loam			
Fall	55.7	56.0	55.0		55.7	
Fall and spring		55.9	55.8	55.3		56.1
Fall	54.6	55.4	55.3		55.6	
Fall and spring		55.0	55.0	55.8		55.1

* Average of four replications.

yields of wheat on both blocks on the Brookston clay loam soil (table 14). Nitrogen topdressing was beneficial on the wheat where alfalfa was interplanted in the fall but did not respond significantly in the block where the alfalfa was planted in the spring. The wheat yields in each block indicate that about forty pounds of nitrogen was sufficient for satisfactory production on that soil.

The percent protein (table 17) also shows consistency indicating no luxury consumption or storage in the grain.

The yields of alfalfa following wheat on the Fox sandy loam with no additional fertilizer applied are given in table 19. Only one cutting was taken in 1957 and a significance was obtained only with the nitrogen topdressing when the alfalfa was fall planted with the wheat. The yields of alfalfa when spring planted in wheat were so erratic giving a large error term and therefore were not significant. The percent protein (table 22) was slightly higher for the fall planted alfalfa that was topdressed in the spring. The nitrogen treatments increased the protein content in the spring planted alfalfa but then decreased when additional nitrogen was applied as a topdressing to the wheat at the time of seeding of alfalfa.

Alfalfa fall planted in wheat on the Brookston clay loam in 1955 did not respond to nitrogen treatments or nitrogen topdressing in the spring of 1956. The yields for two cuttings in 1957 given in table 20 shows a significant decrease resulting from additional nitrogen applied as a

TABLE 19.- The effect of rates of application of ammonium sulfate on the yield of alfalfa following wheat on a Fox sandy loam soil in 1957.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
		Tons per acre		
		Alfalfa fall planted in wheat		
A	1.57*	1.50	1.63	1.03
B	1.62	2.13	1.77	1.19
C	1.36	1.28	1.19	1.47
D	1.25	1.38	1.33	1.17
Average	1.45	1.57	1.48	1.22
		Wheat topdressed in the spring		
A	1.73	1.52	1.12	1.31
B	1.18	1.60	1.65	1.46
C	1.38	1.39	1.58	1.23
D	1.75	1.23	1.18	1.42
Average	1.51	1.44	1.38	1.36

LSD for treatment (.05) not significant. LSD for topdressing (.05) .25 tons.

Replication	0	20	40	80
		Alfalfa spring planted in wheat		
A	1.06	1.50	1.19	1.02
B	1.52	1.60	1.25	1.20
C	1.82	1.44	0.73	1.59
D	1.07	1.42	1.42	1.50
Average	1.37	1.49	1.15	1.33
		Wheat topdressed in the spring		
A	1.25	1.14	0.79	1.16
B	1.52	0.96	1.14	1.05
C	1.39	1.18	1.20	1.52
D	1.25	1.37	0.74	0.78
Average	1.35	1.16	0.97	1.13

LSD for treatment (.05) not significant. LSD for topdressing (.05) not significant.

* One cutting only.

TABLE 20.- The effect of rates of application of ammonium sulfate on the yield of alfalfa when fall planted in wheat on a Brookston clay loam soil in 1957.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
		Tons per acre		
	First cutting			
A	2.82	2.83	2.04	2.39
B	2.72	2.41	2.07	2.09
C	1.51	1.99	1.96	2.04
D	1.79	1.95	1.83	2.22
Average	2.21	2.30	1.98	2.19
	Second cutting			
A	0.58	0.55	0.47	0.69
B	0.77	0.61	0.80	0.71
C	0.81	0.95	0.58	0.67
D	0.65	0.92	0.99	0.62
Average	0.70	0.76	0.71	0.67
Average 2 cuttings	2.91	3.06	2.69	2.86
	Wheat topdressed in the spring			
	First cutting			
A	2.14	1.83	1.57	2.38
B	2.28	2.15	2.08	1.92
C	1.48	1.58	2.31	2.43
D	1.87	1.33	1.74	2.61
Average	1.94	1.72	1.93	2.34
	Second cutting			
A	0.41	0.15	0.46	0.51
B	0.80	0.51	0.67	0.51
C	0.78	0.80	0.52	0.29
D	0.72	0.82	0.84	0.48
Average	0.68	0.57	0.62	0.45
Average 2 cuttings	2.62	2.29	2.55	2.79

LSD for treatment (.05) not significant. LSD for topdressing (.01) .59 tons.

TABLE 21.- The effect of rates of application of ammonium sulfate on the yield of alfalfa when spring planted in wheat on a Brookston clay loam soil in 1957.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
	Tons per acre			
	First cutting			
A	2.12	2.58	2.71	2.17
B	1.16	1.56	1.40	1.54
C	1.91	1.89	2.90	1.86
D	2.08	1.92	1.69	2.22
Average	1.82	1.99	2.18	1.95
	Second cutting			
A	0.29	0.53	0.38	0.39
B	0.67	0.45	0.55	0.55
C	0.56	0.50	0.70	0.50
D	0.29	0.37	0.39	0.23
Average	0.45	0.46	0.51	0.42
Average 2 cuttings	2.27	2.45	2.69	2.37
	Wheat topdressed in the spring			
A	2.24	2.35	1.45	2.20
B	0.63	1.42	1.35	0.76
C	1.95	1.46	1.63	1.85
D	2.20	2.39	2.04	2.04
Average	1.76	1.91	1.62	1.71
	Second cutting			
A	0.45	0.35	0.50	0.23
B	0.58	0.44	0.65	0.36
C	0.54	0.63	0.82	0.28
D	0.19	0.20	0.28	0.33
Average	0.44	0.41	0.56	0.30
Average 2 cuttings	2.20	2.32	2.18	2.01

LSD for treatment (.05) Not significant. LSD for topdressing (.05) .50 tons.

TABLE 22.- The effect of rates of application of ammonium sulfate on the percent protein of alfalfa hay following wheat on a Fox sandy loam soil in 1957.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
	Percent protein			
	Wheat and alfalfa fall planted			
A	16.10*	13.78	14.48	15.56
B	14.30	14.14	14.14	16.27
Average	15.20	13.96	14.31	15.92
	Wheat topdressed in the spring			
A	15.20	15.90	14.66	15.38
B	15.02	16.10	15.90	15.38
Average	15.11	16.00	15.28	15.38
	Alfalfa spring planted in wheat			
A	12.96	14.84	14.30	15.02
B	13.86	15.02	14.14	15.38
Average	13.41	14.93	14.22	15.20
	Wheat topdressed in the spring			
A	13.59	13.41	14.48	12.52
B	14.14	14.84	14.14	13.78
Average	13.87	14.13	14.31	13.15

* First cutting only.

TABLE 23.- The effect of rates of application of ammonium sulfate on the percent protein of alfalfa hay following wheat on a Brookston clay loam soil in 1957.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
	Percent protein			
	First cutting			
	Wheat and alfalfa fall planted			
A	13.77	13.95	11.71	12.52
B	13.41	12.35	12.43	12.52
Average	13.59	13.15	12.07	12.52
	Wheat topdressed in the spring			
A	13.41	12.87	13.05	11.44
B	14.13	12.07	12.87	10.37
Average	13.77	12.47	12.96	10.91
	Wheat overseeded with alfalfa in the spring			
A	10.73	12.70	12.25	12.07
B	10.37	12.16	11.53	12.25
Average	10.55	12.43	11.89	12.16
	Wheat topdressed in the spring			
A	10.73	11.18	12.07	12.35
B	11.09	8.94	11.35	13.23
Average	10.91	10.06	11.71	12.79
	Second cutting			
	Wheat and alfalfa fall planted			
A	13.59	15.56	15.56	16.54
B	13.59	15.20	14.39	16.09
Average	13.59	15.38	14.98	16.32
	Wheat topdressed in the spring			
A	16.18	15.47	15.20	16.81
B	16.09	16.72	15.02	17.97
Average	16.14	16.10	15.11	17.39
	Wheat overseeded with alfalfa in the spring			
A	12.96	14.93	13.41	14.12
B	16.09	16.72	15.02	17.97
Average	14.53	15.83	14.22	16.05
	Wheat topdressed in the spring			
A	12.96	15.02	13.41	13.41
B	13.68	15.02	12.69	11.81
Average	13.41	15.02	13.05	12.61

topdressing.

The same results are shown in table 21 for alfalfa spring planted in wheat in 1956. Nitrogen treatments gave a slight but insignificant increase in yields about the same as fall planted but the additional nitrogen gave a significant decrease.

The percent protein in these two blocks of alfalfa are given in table 23 for two cuttings which shows that on a percentage basis the protein content is fairly constant but that the second cutting of hay is much higher than the first cutting. This was found to hold for all plantings of alfalfa and is a complete reversal of what was found in the greenhouse studies (table 4).

Sources of Nitrogen

The sources of nitrogen study was carried out at four locations throughout the state on various soil types with different fertility levels as shown in table 2. The areas selected were at random with no previous knowledge of soil conditions or cropping history and only well established stands of alfalfa were used for this study.

The fertilizer treatments consisted of a check (no nitrogen) and 30 pounds of actual nitrogen per acre applied as 150 pounds of ammonium sulfate, 90 pounds of ammonium nitrate and 60 pounds of urea, respectively.

The first cutting was made on these plots approximately ten weeks after the fertilizer was applied which was followed by a second cutting six weeks later.

Yield increases occurred in three of the four locations as shown in table 24. These increases occurred in the first cutting, indicating that if nitrogen is beneficial in alfalfa production, it must be applied early in the growing season. There was a highly significant difference in cuttings but none of the nitrogen treatments produced significant yields of hay over the check plot.

There were no significant differences found in the protein content due to treatments but a high degree of significance was found between cuttings (table 25).

TABLE 24.- The effect of sources of nitrogen applied as a topdressing on the yield of alfalfa hay harvested in 1957.

Replication	Cutting	Sources of nitrogen: Check	Ammonium sulfate	Ammonium nitrate	Urea
		Tons per acre			
		Oshtemo loamy sand			
A	1	1.72	1.76	1.91	1.68
B	1	1.38	1.34	2.45	1.91
C	1	1.49	1.34	1.54	1.49
D	1	1.71	1.45	1.45	1.61
E	1	1.25	1.84	1.90	1.80
Average	1	1.51	1.55	1.85	1.70
A	2	0.95	1.12	0.85	0.82
B	2	0.81	1.24	1.04	1.01
C	2	1.55	0.95	0.91	1.18
D	2	0.85	1.05	1.25	1.48
E	2	1.08	0.96	1.11	0.83
Average	2	1.05	1.06	1.03	1.06
Average	1 & 2	2.56	2.61	2.88	2.76
LSD (.05)	0.48 tons				
		Ockley sandy loam			
A	1	1.85	2.08	1.99	2.20
B	1	2.03	1.36	1.35	1.59
C	1	1.92	1.63	1.88	2.07
D	1	1.56	2.14	2.02	1.71
E	1	1.79	1.31	1.21	1.85
Average	1	1.83	1.70	1.69	1.88
A	2	0.25	0.29	0.39	0.44
B	2	0.72	0.75	0.58	0.49
C	2	0.58	0.39	0.70	0.55
D	2	0.57	0.85	0.41	0.49
E	2	0.47	0.49	0.87	0.42
Average	2	0.52	0.55	0.59	0.48
Average	1 & 2	2.35	2.25	2.28	2.36

LSD (.05) 0.47 tons.

TABLE 24.- The effect of sources of nitrogen applied as a topdressing on the yield of alfalfa hay harvested in 1957. (Continued).

Replication	Cutting	Check	Ammonium sulfate	Ammonium nitrate	Urea
		Sources of nitrogen			
		Tons per acre			
		Belfontaine sandy loam			
A	1	1.16	1.95	1.70	1.63
B	1	1.76	1.76	1.58	1.33
C	1	1.38	1.58	1.67	1.38
D	1	0.91	1.47	1.83	1.80
E	1	1.72	1.58	1.60	1.23
Average	1	1.39	1.67	1.68	1.47
A	2	0.39	0.57	0.57	0.42
B	2	0.49	0.40	0.38	0.37
C	2	0.30	0.40	0.38	0.39
D	2	0.36	0.40	0.53	0.38
E	2	0.52	0.45	0.57	0.56
Average	2	0.41	0.44	0.49	0.42
Average	1 & 2	1.80	2.11	2.17	1.89

LSD (.05) 0.42 tons

Replication	Cutting	Check	Ammonium sulfate	Ammonium nitrate	Urea
		Conover loam			
A	2	1.57	1.44	1.60	1.38
B	2	1.40	1.50	1.36	1.50
C	2	1.35	1.48	1.30	1.52
D	2	1.78	1.39	1.31	1.54
E	2	1.45	1.23	1.07	1.58
Average	2	1.51	1.41	1.33	1.50

LSD (.05) 0.19 tons.

TABLE 25.- The effect of sources of nitrogen applied as a topdressing on the percent protein of alfalfa hay harvested in 1957.

Replication	Cutting	Check	Ammonium sulfate	Ammonium nitrate	Urea
		Sources of nitrogen			
		Percent protein			
		Oshtemo loamy sand			
A	1	12.61	12.78	13.68	12.70
B	1	12.43	12.25	13.14	12.70
Average	1	12.52	12.52	13.41	12.70
A	2	19.31	19.67	17.16	17.08
B	2	18.77	19.49	17.52	17.08
Average	2	19.04	19.58	17.34	17.08
		Ockley sandy loam			
A	1	11.18	9.84	10.73	11.18
B	1	12.07	9.84	8.41	10.55
Average	1	11.63	9.84	9.57	10.87
A	2	18.33	17.78	19.23	17.97
B	2	19.22	18.24	19.23	18.15
Average	2	18.78	18.01	19.23	18.06
		Belfontaine sandy loam			
A	1	13.23	12.96	12.87	11.80
B	1	13.41	11.71	12.16	11.44
Average	1	13.32	12.34	12.52	11.62
A	2	15.65	18.15	17.79	17.43
B	2	15.82	17.97	17.70	17.08
Average	2	15.74	18.06	17.75	17.26
		Conover loam			
A	2	17.08	16.63	16.27	16.36
B	2	17.52	16.54	16.09	16.72
Average	2	17.30	16.59	16.18	16.54
Total average		15.47	15.28	15.14	14.86

LSD for treatment (.05) 0.96 (.01) 1.30

V. SUMMARY AND CONCLUSIONS

Greenhouse results show that the yield and protein content of alfalfa were increased significantly by the application of nitrogen fertilizer on some soils. Two of the soils, the Oshtemo loamy sand and the Miami loam responded in yield while these two soils as well as the Brookston clay loam, Conover loam and Hillsdale loam produced alfalfa with a higher percent protein. Four significant interactions between nitrogen fertilizer treatments and cuttings were found in the analysis of the protein content while only one interaction was found in the yield data.

The total protein produced was significantly higher when the data from all soils were compiled together even though the yield or protein content was not significant when considered separately. This indicated that a slight increase in yield with a slightly higher protein content was needed to give significant results.

Residual soil nitrogen analysis showed a significant difference in the nitrogen content due to treatments and that these values were lower than those obtained at the beginning of the experiment. The check plots showed the lowest amount of nitrogen. Since the experiment was conducted over a short period of time, therefore, not giving the alfalfa plants very much time for nodulation and nitrogen fixation; it is reasonable to expect a direct removal of small amounts of nitrogen from the soil. Previous studies show that even when the plants are well nodulated, some of the nitrogen is taken from the soil.

The application of nitrogen fertilizer increased the grain yield and protein content of oats and barley by a significant margin in 1955; however, the yield of hay produced on these plots the following two years did not give a significant response to the nitrogen fertilizer applied in the spring of 1955 at the time the grain crops and alfalfa were seeded. The percent protein was increased in 1956, the first year after application but decreased in 1957.

Alfalfa planted alone in August did not respond to the nitrogen applications in yield but the protein content was somewhat higher than the check.

Wheat yields were increased significantly on all three soil types when nitrogen fertilizer was applied at planting time. Additional nitrogen applied as a topdressing the following spring gave increases at two of the three locations. The protein content was increased in all of the six blocks of wheat but the only real increase occurred in the two blocks on the Fox sandy loam soil at the Kellogg farm.

No significant increases in yield of alfalfa grown on these plots were found the following year resulting from fertilizer treatments. One interaction between fertilizer treatment at planting time and an additional topdressing with twenty pounds of nitrogen was found in the wheat and alfalfa fall planted on the Fox sandy loam soil. The additional topdressing was effective in both blocks of alfalfa following wheat on the Brookston clay loam soil.

Hay yields were not taken from the plots following wheat on the Hillsdale loam soil at the University farm due to lodging that occurred the previous year. The stand was very thin on the plots where severe lodging occurred and the yield harvested would not have been a representative sample.

The sources of nitrogen study carried out on four different soils indicated that nitrogen fertilizer applied as a topdressing on established stands of alfalfa does not give a significant increase in the yield or the protein content of the hay.

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VII. APPENDIX

TABLE 1.- The effect of rates of application of ammonium sulfate on the yield of alfalfa grown in the greenhouse in 1955 on Oshtemo loamy sand.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
			Percent protein		
	First harvest, April 5				
A	7.75	7.52	7.60	8.49	11.85
B	5.32	5.21	8.42	8.12	8.47
C	5.59	6.52	7.63	9.84	6.03
D	6.58	6.59	8.92	8.12	9.07
Average	6.31	6.46	7.64	8.64	8.85
	Second harvest, May 1				
A	7.26	6.60	8.68	7.14	8.09
B	5.83	6.06	8.10	6.44	6.64
C	4.62	5.42	6.83	6.31	8.04
D	6.12	6.35	7.09	6.61	7.37
Average	5.94	6.11	7.66	6.67	7.53
	Third harvest, June 3				
A	9.89	10.28	8.24	8.56	10.01
B	7.25	8.71	8.35	11.17	9.09
C	8.80	8.10	11.13	9.83	8.98
D	8.42	10.03	10.25	8.40	10.24
Average	8.58	9.28	9.49	9.49	9.58
Average of 3 cuttings	6.95	7.28	8.26	8.27	8.66

LSD (.05) 1.47 (.01) 1.97

TABLE 2.- The effect of rates of application of ammonium sulfate on the percent protein in alfalfa grown in the greenhouse in 1955 on an Oshtemo loamy sand.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
			Percent protein		
	First harvest, April 5				
A	16.35*	16.53	18.20	14.67	16.61
B	15.47	14.14	15.55	15.91	16.17
C	16.44	13.87	14.23	15.55	18.56
D	15.29	16.88	14.05	15.73	17.50
Average	15.89	15.36	15.51	15.46	17.21
	Second harvest, May 1				
A	18.20	19.35	13.60	16.44	18.47
B	15.11	15.64	17.67	19.62	17.14
C	16.26	16.17	18.03	18.65	18.03
D	14.14	17.85	19.62	14.25	17.94
Average	15.92	17.25	17.23	17.23	17.89
	Third harvest, June 3				
A	13.08	16.17	16.26	17.32	16.26
B	14.14	13.87	16.08	16.26	16.87
C	16.97	16.35	14.23	15.55	14.85
D	15.20	14.32	14.58	12.90	15.11
Average	14.85	15.18	15.29	15.51	15.77

LSD (.05) 2.05 (.01) 2.74

* Kjeldahl x 6.25

TABLE 3.- The effect of rates of application of ammonium sulfate on the yield of alfalfa grown in the greenhouse in 1956 on Hillsdale loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
			Grams per pot		
		First harvest, April 23			
A	5.30	5.79	3.63	4.90	5.50
B	4.70	4.64	6.45	5.50	6.35
C	5.07	4.82	5.90	5.55	6.32
D	3.84	4.94	4.55	5.21	4.94
Average	4.75	5.04	5.13	5.24	5.78
		Second harvest, May 4			
A	13.00	11.70	11.00	11.50	10.90
B	11.80	13.50	13.00	11.70	13.10
C	12.90	11.80	14.50	11.80	11.40
D	10.20	11.70	10.70	13.30	14.20
Average	11.97	12.17	12.30	12.07	12.40
		Third harvest, June 1			
A	13.17	13.66	13.38	12.61	11.27
B	10.82	14.80	13.13	16.52	13.65
C	11.34	13.60	15.28	17.38	12.40
D	12.59	11.00	10.82	17.47	15.02
Average	11.98	13.26	13.15	15.99	13.09
Average of 3 cuttings	9.56	10.16	10.19	11.12	10.42

LSD (.05) 1.86 (.01) 2.48

TABLE 4.- The effect of rates of application of ammonium sulfate on the percent protein of alfalfa grown in the greenhouse in 1956 on a Hillsdale loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
	Percent protein				
First harvest, April 5					
A	17.35*	16.96	19.76	21.12	23.12
B	17.15	16.94	20.00	21.50	23.50
Average	17.25	16.94	19.88	21.33	23.31
Second harvest, May 1					
A	20.05	19.60	22.00	20.30	19.80
B	19.75	19.20	18.60	19.10	17.80
Average	19.90	19.40	20.30	19.70	18.80
Third harvest, June 3					
A	14.92	17.20	16.70	17.15	17.00
B	16.85	16.38	16.70	17.85	18.00
Average	15.91	16.79	16.70	17.50	17.50

LSD (.05) 1.55 (.01) 2.16

* Kjeldahl x 6.25

TABLE 5.- The effect of rates of application of ammonium sulfate on the yield of alfalfa grown in the greenhouse in 1956 on Conover loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
			Grams per pot		
	First harvest, April 23				
A	6.93	6.61	6.05	6.00	7.22
B	6.25	5.57	7.20	6.35	7.67
C	5.92	5.80	7.88	6.25	5.88
D	5.12	6.20	6.45	5.78	4.52
Average	6.05	6.05	6.89	6.22	6.32
	Second harvest, May 4				
A	6.40	7.80	7.40	7.50	9.00
B	6.40	6.20	7.60	7.50	7.40
C	8.80	7.20	7.40	6.80	8.40
D	7.60	6.40	7.70	9.10	6.50
Average	7.30	6.90	7.50	7.70	7.80
	Third harvest, June 1				
A	10.75	13.49	11.10	9.92	13.06
B	9.33	12.13	11.51	10.67	12.30
C	12.17	10.07	12.44	11.27	11.95
D	12.54	11.83	11.34	12.75	11.95
Average	11.20	11.88	11.60	11.15	11.99
Average of 3 cuttings	8.18	8.28	8.67	8.37	8.71

LSD (.05) 2.67 (.01) 3.56

TABLE 6.- The effect of rates of application of ammonium sulfate on the percent protein in alfalfa grown in the greenhouse in 1956 on a Conover loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
			Percent protein		
	First harvest, April 23				
A	19.00*	20.00	20.22	21.76	19.82
B	18.50	20.24	20.66	21.36	20.18
Average	18.75	20.12	20.44	21.56	20.00
	Second harvest, May 4				
A	17.75	18.80	19.80	18.30	18.90
B	17.65	18.60	19.00	17.30	18.90
Average	17.70	18.70	19.40	17.80	18.90
	Third harvest, June 1				
A	15.02	14.69	16.47	15.04	17.68
B	15.02	14.47	15.70	15.00	16.08
Average	15.02	14.58	16.17	15.02	16.88

LSD (.05) 1.76 (.01) 2.45

* Kjeldahl x 6.25

TABLE 7.- The effect of rates of application of ammonium sulfate on the yield of alfalfa grown in the greenhouse in 1955 on Miami loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
			Grams per pot		
First harvest, April 5					
A	6.84	6.85	7.44	9.72	8.10
B	4.91	7.57	8.97	9.26	6.14
C	6.30	5.32	8.02	9.46	9.13
D	5.34	6.84	7.84	6.45	7.98
Average	5.85	6.64	8.07	8.72	7.84
Second harvest, May 1					
A	10.55	9.07	10.78	12.95	9.67
B	9.11	10.23	10.35	9.94	7.19
C	8.84	7.36	10.65	11.96	8.77
D	8.82	9.99	12.21	9.11	11.16
Average	9.33	9.16	11.00	10.99	9.20
Third harvest, June 3					
A	10.05	7.64	8.53	12.79	9.79
B	10.48	9.73	13.33	9.68	7.62
C	8.07	6.68	10.55	11.26	10.78
D	8.35	10.43	10.73	10.07	11.68
Average	9.24	8.62	10.79	10.95	9.97
Average of 3 cuttings	8.14	8.14	9.95	10.22	9.00

LSD (.05) 2.00 (.01) 2.67

TABLE 8.- The effect of rates of application of ammonium sulfate on the percent protein in alfalfa grown in the greenhouse in 1955 on Miami loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
	Percent protein				
First harvest, April 5					
A	17.85*	19.35	19.62	18.74	21.38
B	18.47	18.29	19.35	18.82	20.50
C	18.12	18.47	14.94	18.56	21.30
D	21.03	21.03	18.29	21.38	21.38
Average	18.87	19.28	18.05	19.38	21.14
Second harvest, May 1					
A	16.08	19.00	15.02	16.97	20.68
B	17.14	18.47	15.82	16.98	20.06
C	17.85	19.09	15.20	17.05	18.20
D	18.91	19.88	15.55	20.86	18.65
Average	17.49	19.11	15.40	17.96	19.40
Third harvest, June 3					
A	18.29	18.47	18.03	15.11	18.65
B	16.00	17.49	17.23	18.12	19.27
C	18.12	17.67	16.88	18.29	16.35
D	18.56	16.00	17.06	16.35	15.03
Average	17.74	17.41	17.30	16.98	17.32

LSD (.05) 1.77 (.01) 2.36
* Kjeldahl x 6.25

TABLE 9.-- The effect of rates of application of ammonium sulfate on the yield of alfalfa grown in the greenhouse in 1956 on Fox sandy loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
	Grams per pot				
First harvest, April 23					
A	5.01	5.60	3.88	5.75	5.61
B	6.73	5.18	7.37	4.07	5.27
C	5.04	4.07	5.00	5.15	5.22
D	5.05	4.68	5.79	3.87	3.78
Average	5.46	4.89	5.51	4.66	4.97
Second harvest, May 4					
A	14.50	14.00	10.30	13.00	14.00
B	13.40	11.40	10.80	10.90	13.20
C	11.70	12.00	12.30	14.10	10.80
D	10.40	12.20	13.00	10.80	12.20
Average	12.50	12.40	11.60	12.20	12.50
Third harvest, June 1					
A	17.58	17.58	13.79	14.56	20.12
B	20.37	13.65	18.35	17.51	16.70
C	14.59	15.07	16.96	16.60	15.42
D	13.50	16.07	15.52	13.85	15.20
Average	16.51	15.49	16.15	15.60	16.86
Average of 3 cuttings	11.49	10.96	11.09	10.85	11.46

LSD (.05) 1.92 (.01) 2.56

TABLE 10.- The effect of rates of application of ammonium sulfate on the percent protein in alfalfa grown in the greenhouse in 1956 on a Fox sandy loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
			Percent protein		
	First harvest, April 23				
A	19.30*	19.90	22.15	22.22	23.40
B	18.82	19.86	22.35	22.65	23.48
Average	19.06	19.88	22.25	22.44	23.44
	Second harvest, May 4				
A	19.55	15.36	21.00	18.35	16.90
B	19.45	20.24	18.60	17.45	16.90
Average	19.50	17.80	19.80	17.90	16.90
	Third harvest, June 1				
A	15.36	17.60	16.23	15.95	16.01
B	16.80	16.86	16.11	15.87	16.33
Average	16.08	17.23	16.17	15.91	16.17

LSD (.05) 2.33 (.01) 3.25

* Kjeldahl x 6.25

TABLE 11.- The effect of rates of application of ammonium sulfate on the yield of alfalfa grown in the greenhouse in 1955 on a Brookston clay loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
	Grams per pot				
First harvest, April 5					
A	10.10	9.69	7.30	12.89	12.22
B	8.95	10.93	10.90	10.48	12.51
C	10.90	12.64	14.52	9.47	9.07
D	8.93	9.48	9.37	9.34	13.88
Average	9.72	10.68	10.52	10.54	11.92
Second harvest, May 1					
A	11.73	10.72	6.87	14.50	16.80
B	10.74	14.38	12.86	12.59	12.52
C	14.11	10.83	13.34	10.75	10.09
D	11.21	11.30	9.99	10.18	15.19
Average	11.95	11.81	10.76	12.00	13.65
Third harvest, June 3					
A	12.87	11.97	6.30	12.63	15.39
B	9.64	13.32	12.95	12.13	12.80
C	13.22	12.56	15.47	9.47	7.61
D	9.58	11.20	8.80	12.02	16.60
Average	11.33	12.26	10.88	11.81	13.13
Average of 3 cuttings	10.99	11.58	10.74	11.45	12.89

LSD (.05) 3.49 (.01) 4.67

TABLE 12.- The effect of rates of application of ammonium sulfate on the percent protein in alfalfa grown in the greenhouse in 1955 on Brookston clay loam.

Replication	Pounds of nitrogen per acre				
	0	20	40	80	160
	Percent protein				
First harvest, April 5					
A	17.76*	21.74	19.63	19.00	18.56
B	22.36	21.47	19.35	20.24	20.94
C	19.35	20.79	19.27	19.36	21.21
D	19.97	19.62	18.12	20.86	18.12
Average	19.86	20.90	19.09	19.86	19.71
Second harvest, May 1					
A	19.44	21.21	16.44	20.68	14.85
B	18.74	18.03	16.79	15.55	16.35
C	18.64	19.18	17.67	17.14	18.65
D	18.91	16.53	17.50	17.23	14.23
Average	18.93	18.74	17.10	17.65	16.02
Third harvest, June 3					
A	17.49	18.03	17.94	18.47	15.46
B	18.47	16.97	17.32	18.29	15.91
C	18.38	18.56	17.76	17.67	17.85
D	18.47	18.56	17.67	19.53	16.79
Average	18.20	18.03	17.67	18.49	16.50

LSD (.05) 1.82 (.01) 2.43

* Kjeldahl x 6.25

TABLE 13.- The effect of rates of application of ammonium sulfate on the yield of alfalfa following oats on a Fox sandy loam soil.

Replication	Pounds of nitrogen per acre 0	20	40	80
		Tons per acre		
	First cutting, 1956			
A	1.30	1.60	1.20	1.60
B	1.40	1.65	1.50	1.30
C	1.45	1.60	1.30	1.50
D	1.25	1.10	1.00	1.00
Average	1.35	1.49	1.25	1.35
	Second cutting, 1956			
A	0.64	0.85	0.80	0.70
B	0.78	0.70	0.45	0.85
C	0.40	0.55	0.42	0.35
D	0.70	0.70	0.60	0.85
Average	0.63	0.70	0.57	0.69
Total	1.98	2.19	1.82	2.04

LSD (.05) 0.22 tons.

	First Cutting, 1957			
A	1.90*	1.83	1.32	1.52
B	1.95	2.08	2.02	2.12
C	2.04	1.76	1.73	2.06
D	1.92	2.30	2.05	2.40
Average	1.95	1.99	1.78	2.03

LSD (.05) 0.29 tons - not significant

* Only one cutting in 1957

TABLE 14.- The effect of rates of application of ammonium sulfate on the yield of alfalfa following oats on a Hillsdale loam soil.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
	Tons per acre			
	First cutting, 1956			
A	2.03	1.74	2.29	2.02
B	1.73	2.15	1.94	1.97
C	1.91	2.02	1.50	1.85
D	2.10	1.90	2.16	2.12
Average	1.94	1.95	1.97	1.99
	Second cutting, 1956			
A	1.24	1.31	1.17	1.12
B	1.64	1.52	1.26	1.47
C	0.96	1.26	0.95	0.90
D	1.52	1.49	1.44	1.44
Average	1.34	1.40	1.21	1.23
Total	3.28	3.35	3.18	3.22
LSD -- not significant				
	First cutting, 1957			
A	2.62	2.02	3.05	2.52
B	3.92	2.30	1.93	2.41
C	3.42	2.34	2.99	2.81
D	2.71	2.54	2.66	2.49
Average	3.17	2.30	2.66	2.56
	Second cutting, 1957			
A	1.79	1.71	1.77	1.79
B	2.12	1.92	1.92	1.50
C	1.60	1.35	1.19	1.26
D	1.58	1.85	1.41	1.82
Average	1.77	1.71	1.57	1.59
Total	4.94	4.01	4.23	4.15

LSD -- not significant.

TABLE 15.- The effect of rates of application of ammonium sulfate on the yield of alfalfa when seeded alone in August on a Hillsdale loam soil.

Replication	Pounds of nitrogen per acre 0	20	40	80
	Tons per acre			
	First cutting, 1956			
A	1.36	0.74	1.18	1.31
B	1.13	1.12	0.99	1.28
C	1.29	1.29	1.14	0.72
D	1.22	1.06	1.44	1.11
Average	1.25	1.05	1.19	1.11
	Second cutting, 1956			
A	0.89	0.74	0.85	1.01
B	0.80	0.59	0.59	0.63
C	0.61	0.52	0.96	0.59
D	0.52	1.01	0.46	0.61
Average	0.71	0.72	0.72	0.71
Total	1.96	1.77	1.91	1.82
LSD --not significant.				
	First cutting, 1957			
A	2.15	2.25	2.27	2.20
B	2.50	2.34	2.34	2.22
C	2.37	2.22	2.38	2.37
D	1.87	2.15	2.34	2.14
Average	2.22	2.24	2.33	2.23
	Second cutting, 1957			
A	1.43	1.54	1.47	1.48
B	1.41	1.80	1.72	1.55
C	1.41	1.35	1.27	1.36
D	1.75	1.82	1.82	1.71
Average	1.50	1.63	1.57	1.53
Total	3.72	3.87	3.90	3.76
LSD-- not significant.				

TABLE 16.- The effect of rates of application of ammonium sulfate on the yield of alfalfa following barley on a Brookston clay loam soil.

Replication	0	20	40	80
	Pounds of nitrogen per acre			
	Tons per acre			
	First cutting, 1956			
A	2.22	1.90	1.76	1.63
B	1.67	1.45	0.87	0.78
C	1.95	1.97	1.85	1.76
D	1.55	1.46	1.40	1.08
Average	1.85	1.70	1.47	1.31
	Second cutting, 1956			
A	1.38	1.38	1.35	1.43
B	1.59	1.13	1.68	1.42
C	1.46	1.86	1.41	1.61
D	1.69	1.79	2.09	1.44
Average	1.53	1.54	1.63	1.48
Total	3.38	3.24	3.10	2.79
LSD (.05) not significant				
	First cutting, 1957			
A	2.45	2.31	2.42	2.08
B	2.45	2.35	2.42	2.15
C	2.25	2.45	3.08	2.75
D	2.12	2.66	2.45	2.30
Average	2.32	2.44	2.59	2.32
	Second cutting, 1957			
A	0.70	0.92	1.12	1.20
B	1.16	0.89	1.06	0.82
C	1.20	1.36	0.85	0.98
D	0.77	1.59	1.05	0.92
Average	0.96	1.22	1.02	0.98
Total	3.28	3.66	3.61	3.30
LSD (.05) not significant.				

TABLE 17.- The effect of rates of application of ammonium sulfate on the yield of alfalfa when seeded alone in August on a Brookston clay loam soil.

Replication	Pounds of nitrogen per acre			
	0	20	40	80
		Tons per acre		
	First cutting, 1956			
A	1.21	1.71	2.00	1.65
B	1.32	1.63	1.71	1.53
C	1.10	1.25	1.48	1.23
D	1.23	1.49	1.62	1.71
Average	1.22	1.52	1.70	1.53
	Second cutting, 1956			
A	1.12	0.90	1.41	1.15
B	1.96	1.38	1.55	1.23
C	1.16	1.12	1.58	1.49
D	1.20	0.83	1.39	1.61
Average	1.36	1.06	1.48	1.37
Total	2.58	2.58	3.18	2.90

LSD (.05) 0.63 not significant

Replication	0	20	40	80
	First cutting, 1957			
A	1.96	1.71	2.31	1.98
B	2.19	1.84	2.22	2.14
C	2.37	1.98	2.16	1.99
D	2.12	2.19	2.18	2.15
Average	2.16	1.93	2.22	2.07
	Second cutting, 1957			
A	0.76	0.73	0.91	1.17
B	0.87	1.07	0.86	1.09
C	1.33	1.31	1.25	1.09
D	0.69	1.19	1.12	0.77
Average	0.91	1.08	1.04	1.03
Total	3.07	3.00	3.26	3.10

LSD (.05) not significant