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ONE-YEAR CLEAR SEEDED ALFALFA (MEDICAGO SATIVA L.)
AS A NITROGEN SOURCE FOR CORN
(ZEA MAYS INDENTATA L.)

presented by

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ONE-YEAR CLEAR SEEDED ALFALFA (MEDICAGO SATIVA L.) AS A NITROGEN SOURCE FOR CORN (ZEA MAYS INDENTATA L.)

By

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ABSTRACT

ONE-YEAR CLEAR SEEDED ALFALFA (MEDICAGO SATIVA L.) AS A NITROGEN SOURCE FOR CORN (ZEA MAYS INDENTATA L.)

By

Athumani Kassim Kissiwa

Previous research on alfalfa (*Medicago sativa* L.) resulted in recommending older stands in crop rotations. This study was conducted under two soil types with objectives of (1) comparing the amount of N fixed by 1-, 2-, and 3-year-old alfalfa evaluated by a subsequent corn crop (*Zea mays indentata* L.) with or without N, and (2) determining the effect of four rates of N on corn yields following 1-year-old alfalfa.

Grain and stover yields after 1-year-old alfalfa removed or left lay were similar. If unfertilized, grain and stover after 1-year-old alfalfa produced 85 and 81% as much as after 2- or 3-year-old stands. Grain yields following 1 year of alfalfa increased proportionately more with N after 1 year than after older stands of alfalfa.

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INTRODUCTION

The rationale of the use of commercial nitrogen fertilizers has recently been under constant criticism from various viewpoints. Under different cropping systems, and soils and climatological data, the crop utilization efficiency varies from less than 50 to 70 percent (Owens, 1960; Broadbent and Nakashima, 1968). There has always been a quantity of nitrogen which is unaccountable in N balance studies. Part of this loss is due to leaching of nitrates out of the soil profile and denitrification.

Riazi et al. (1978), when studying leaching patterns of two soil types, observed that NO_3 losses as exhibited by Cranborne and Mansfield loam were of the order of 91 and 94% respectively. Leaching of nitrate under maize at Samaru, Nigeria, was at rates greater than 0.3 cm per cm of rainfall (Jones, 1973). Different sources of nitrogen fertilizers had leaching losses ranging from 19 to 50% (Matousch, 1979).

The frequent rise of crude oil and natural gas products has resulted in exorbitant price hikes of N fertilizers in the last decade. The price of N has skyrocketed from $107 to $426 a metric ton in the last ten years. Dependence on commercial N fertilizers will mean a continued soaring costs of farm operations.

The ecological and economical aspects of biological nitrogen are exemplified by comparing the world industrial nitrogen fertilizer production of 46 million metric tons a year in 1977 with the biological production fo 100-200 million metric tons. At present, 20 to 30% of this biological nitrogen fixation is used directly in agriculture (Warner, 1980).

Therefore, a good and practical alternative to chemical - N fertilizer is within our reach through the utilization of leguminous crops. It ought to be realized that the State of Michigan grows substantial hectarages of both leguminous crops (0.45 million ha alfalfa) and corn (1.2 million ha corn).

Hence, rotation of leguminous crops and corn, with improved agricultural husbandry like plowdown, crop rotation sequence, and green manuring can be beneficial in reducing our complete reliance on industrial nitrogen.

The objectives of this research were:

1. to compare the amount of N fixed by one-, two-, or three-year-old stands of clear-seeded alfalfa[1] as evaluated by a subsequent corn crop with or without added N fertilizer, and
2. to determine the effect of four different levels of nitrogen on corn yield following one year of clear-seeded alfalfa.

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[1]Clear seeded alfalfa is a new method of seeding alfalfa which is seeded in early spring with a herbicide to control broad- and narrow-leaved weeds and permits harvest of two or three cuttings of alfalfa in the seeding year. Three or four cuttings per year are normally made in subsequent years (Tesar, 1980).

LITERATURE REVIEW

Historical Background

Crop rotation is an age-old practice used to improve productivity of soils. The crop preferred is usually a legume, although nonleguminous crops in some instances are used in crop rotation sequences. The legumes fix atmospheric nitrogen which becomes a distinct addition to the soil when the crop is plowed under. White (1970) reported that Roman farmers used legumes and manures to supply essential plant nutrients for centuries. According to Pieters (1927) the use of green manure crops was recorded in the early historical agricultural records. The practice was followed by the Chinese approximately 3,000 years ago. Long-term rotation experiments dating back to the second decade of this century have been reported at Nebraska (Hastings, 1936).

There are a number of advantages of using crop rotation over continuous monoculture cropping. It was reported that sufficient nitrogen was available from alfalfa during both the first and second years of cropping to produce over 6.25 mt of cron per hectare without N fertilization (Boawn et al., 1965). Besides the addition of nitrogen to the soil, crop rotation ensures that the organic matter content of the soil is maintained and improved through decomposition of the legume crop. When a leguminous crop is plowed under, soil tilth is improved by promoting crumb structure. In a study of the stability of soil crumbs, Hide and Mitzegar (1939) found a higher carbon and nitrogen content, a large proportion of difficulty oxidizable carbon and a wider C:N ratio in well aggregated than in poorly aggregated soils.

Crop rotation also improves the water holding capacity of soils as a result of the improvement of structure and possibly by the addition of humus content of the soil. Humus and decomposing organic matter have the ability of absorbing water at higher capacities. Lander et al. (1923) reported that in one sandy soil, the moisture equivalent was raised by 2.75%, which is substantial for such soils having a very low moisture equivalent. The opening of the soil by the roots of legume crops such as alfalfa may facilitate increasing water percolation rates.

Application of organic matter increases the quantity of water entering the soil, but there are numerous views with regard to the exact mechanism. Musgrave and Norton (1937) showed that, in three years, the loss of soil by erosion in a control plot receiving no manure was about seven times that in a green-manured plot. Plots without green manure lost 2.72 to 6.22 cm more rain water than green-manured plots.

Amount of N Fixed by Legumes

The amount of nitrogen fixed by different leguminous plants is determined by plant type and environmental and soil management practices. Bolton et al. (1976) found that, after 13 years of continuous study, a two-year alfalfa sod fixed 110 kg/ha/year. The amount of nitrogen fixed by three tropical legumes viz *Macroptilum atropurpereum* cv. Siratro, *Glycine wightii* cv. Cooper and *Desmodium introtum* cv. Green leaf was in the range of 100-140 kg N/ha/year. Eaglesham et al. (1979) found that a cultivar Tvu 1190 of cowpeas fixed nitrogen at the rate of 14 kg N/ha/year. Heichel et al. (1981) showed that alfalfa fixed most nitrogen followed by red clover and birdsfoot trefoil at a magnitude of 206,160 and 124 kg N/ha in their respective seeding years. Similar type of findings have been reported (Nyatsanga and Pierre, as quoted in Soil and Water, 1981; Ahlawat et al., 1981).

Varietal differences exist in terms of nitrogen fixation within the same species. Brockwell and Helly (1966), when apprais-ing nodulation and nitrogen fixation interaction between hosts and rhizorbia of diverse origins, reported no significant bacterial strain x alfalfa cultivar interaction. Sharma et al. (1973) found that an Indian cultivar of alfalfa fixed 14% more N than an Aus-tralian cultivar, Seetin and Barnes (1981) noted that six clones of alfalfa differed significantly for nodulation, root type, and acetylene production.

Soil Management Factors in Relation to Crop Rotation

Crop sequence has been linked with differential response of various cropping patterns. In long-term sugar beet rotation experi-ments, Robertson et al. (1964) reported that the highest sugar beet yield was produced in a rotation in which sugar beets followed beans which were preceded by sweet clover. The lowest yield was obtained in a rotation which did not include a green manure or cover crop immediately prior to sugar beets. Voss and Shrader (1979) when studying seven crop rotation sequences found that a corn, corn, corn, oats, meadow (CCCOM) rotation outyielded six other crop rotations even if the succeeding corn crop after those rotations got more of N fertilizer. The same researchers also noted that the effectiveness of the meadow crop in supplying nitrogen to the following corn crop yield was related to meadow yield. The higher the yield of hay, the more N is supplied to the corn. Roger et al. (1979), when evaluating efficiency of eight rotation sequences on the amount of nitrogen added to the soil, showed the rotations corn, oat, meadow, meadow, meadow (COMMM) and corn, corn, oats, meadow, meadow (CCOMM) required less than 20% of the N fertilizer recommended for corn after other rotations. Giri and Rajat (1979) reported that the yield of millet was increased significantly by 22.6, 24.2, and 12.1% when grown after groundnuts, cowpea, and pigeonpea, respectively. Under Nigerian conditions, the yield of corn grown after groundnut (*Arachis hypogea*), sorghum and cotton was greater in the following magnitude: maize following groundnut, maize following cotton, maize following sorghum (Jones, 1975).

Legume Stand Age

Although many studies have shown the beneficial effects of two to several years of alfalfa preceding corn, only one study--Voss and Shrader (1979)--has been conducted on the effect of one year of alfalfa, compared to two or more years of alfalfa, on the yield of a subsequent corn crop.

Lyonn and Bizzell (1933) noted that the more often alfalfa occurred in the rotation, the more nitrogen present in the crops. Robertson (1952), when studying seven crop rotation sequences, found that corn yields were markedly increased by the production of legume and legume-grass mixture in the rotation. The highest yield occurred where corn followed one or two years of alfalfa-brome grass. Heichel et al. (1981) reported that the least amount of N fixed by alfalfa was shown by first and fourth year of seeding while the greatest were second and third year which fixed nitrogen at the rate of 48 kg/ha/year.

Bolton et al. (1976) reported that a two-year alfalfa sod system produced a significant yield increase over continuous corn and over a one-year alfalfa sod system. The effect of a two-year alfalfa-sod every four years in the cropping was equivalent to 110 kg N/ha/year on continuous corn in producing corn yield. The big contribution of nitrogen from one- and two-year legume meadows was evident in all experiments. Crops which followed showed no response from fertilizer nitrogen the first year after legume. Hastings (1936) found that the highest yield of oats were obtained from plots which were previously sown after six-year alfalfa than after two- or three-year alfalfa.

Green Manuring

Different methods of efficient utilization of crop rotation are in use. One is using legumes in rotation as a green manure crop. Albrecht (1937) when comparing incorporation versus application of clover on the soil surface found that the nitrogen content of the treated soil was raised less over the untreated plot than when this legume was applied on the surface. This indicates a more complete decay of this material and a lower amount of its nitrogen remaining in the soil after incorporation than when the clover was on the surface.

Greaves and Jones (1950) demonstrated that the removal of the alfalfa crop did not measurably decrease the total nitrogen content of the soil. When the crop was returned to the soil, a highly significant increase in nitrogen resulted. Nelson et al. (1940) noted that cotton/corn were improved following the use of green manure in summer. El-Damaty and Mobarek (1962) showed that in addition to chemical fertilizers, treating the soil with green clover green manuring, with peanut green manuring or with compost in equal quantities, resulted in a significant increase in sesame or corn yield over a control treatment which was only fertilized. Robertson et al. (1964) observed that in different crop rotation sequences, the lowest sugar beet yields were produced in cash crop rotations that did not include a green manure or cover crop immediately previous to the sugar beets. A study in Canada showed that two-year clover, when plowed under and evaluated by barley, outyielded both two six-year rotation (2 barley, 4 legumes) and a six-year rotation (barley, plowdown, barley, barley, hay, hay) by more than 763 and 81 kg/ha respectively (Alberta Forage Seed Council, 1981).

Time of Plowing Under

Time of plowing under a legume crop has its significance in crop rotation. Incorporation of green manure crops to the soil resulted in N losses when applied at different seasons. Jones (1945) found that when summer annual legumes were added to the sandy soils, nitrogen losses were affected by the legume and time of turning under the legume. The amount of N leached increased as the percentage nitrogen contained in different legumes increased which was in the following order: crotolaria (Crotolaria spectabilis), cowpeas (Vigna sinensis), and soybeans (Glycine max). When the soybeans were plowed under in the fall, 70% of the added nitrogen was leached from Norfolk sandy loam and 52% from Hartsells fine sandy loam. This loss was reduced to 38% on both soils when soybeans were not plowed until spring. Late summer until September is the best time to plowdown forage legumes as a green manure (Heichel et al., 1981). It is reported that optimum nitrogen fixation and organic matter are reached shortly after clovers are in full bloom (William, 1981). Once the crop starts to mature, it will take much longer to decompose and release plant nutrients for succeeding crops.

Some of the increase in the yield occurred in the second year after the sweet clover was plowed under. Robertsen (1964) reported that where the alfalfa brome grass was harvested as hay, the subsequent beet yield averaged 1.4 metric tons less than when not harvested.

Time Duration Before N Fixed is Fully Realized

The availability of nitrogen fixed by a legume crop to succeeding crops depends on the rates of decomposition of leguminous crops. Decomposition of legumes is much slower at higher altitudes and low rainfall than at low altitudes and higher temperatures. Jenny et al. (1949) found that in a prehumid tropical area, nearly 100% of the alfalfa was decomposed in one year. Decomposition of alfalfa in the first year ranged from 50 to 70% under California conditions.

In some areas, the beneficial effect of rotation has been extended beyond one year. Williams et al. (1976) showed that the beneficial effect of a legume for corn lasted for at least four years after the soil was plowed under. Nitrogen availability from the residues during the second growing season was not more than 7.5% of that originally contained in alfalfa and 3.5% of that contained in red clover. Stephens (1952) recommended a 15-day interval between plowing under a cover crop and planting the following crop to allow the green manure to pass through the heat period of decomposition.

Success with Crop Rotations

The increased use of crop rotations has of late gained popularity as described by various researchers. Frisbourg and Bartholomew (1956) found that on the basis of nitrogen applied, the mean efficiency of alfalfa in supplying nitrogen to the corn crop was about 34% of that of ammonium nitrate. Burhani and Mansi (1967) found that the legume Dolichos lablab was ideal for increasing the yield of a subsequent cotton crop when compared with sorghum. Other workers reporting similar results include Strickler et al. (1959), Boawn et al. (1965), Schmid et al. (1959), Voss and Shrader (1979), Giri and De (1979), and Russel (1939).

Tucker et al. (1971) found no appreciable increase in the yield of wheat following alfalfa. Newton et al. (1939) observed that wheat after alfalfa yielded less than wheat after timothy due to intense water competition by alfalfa which consequently deprived future crop needs.

MATERIALS AND METHODS

Experiments were initiated in 1978 at two different sites to study the amount of nitrogen fixed by alfalfa after one, two, or three years of growth as evaluated by a subsequent yield of corn with or without N application.

Experiments 1 and 2 were similar for harvests and designs.

Experiment 1: East Lansing, Hillsdale sandy loam, three years of alfalfa, one year of corn with two levels of nitrogen fertilizer on the corn. 1978-1981.

The experiment was established as a split-plot, randomized complete block with three replications of Vernal and Iroquois alfalfa. The plot sizes were 10.4 by 6.7 m and 9.1 and 7.6 m. The treatments were as follows: (1) one-year alfalfa, clear seeded in 1980; (2) two-year alfalfa, clear seeded in 1979; and (3) three-year alfalfa, clear seeded in 1978.

Top growth of alfalfa plants was harvested from a 0.91 by 0.91 m area. A hole 0.91 by 0.91 m was dug from each main plot (Figure 1) between May 1 to 8 and roots removed from each of four depths: 0 to 15, 15 to 30, 30 to 60, and 60 to 90 cm. The roots from each depth were washed with water and detergent, counted, and dried at 65°C for 48 hours and dry matter determined for each of the four depths.

Figure 1. Method used to obtain alfalfa roots for weighing and N evaluations.

On May 8, the alfalfa was plowed under to an approximate depth of 20 cm. Phosphorus and K were applied on May 13 after plowing at rates of 31 and 121 kg/ha when the corn was planted. The variety of corn was Michigan 5922 (single-cross) planted with kernels approximately 30 cm apart in 0.91-m rows (approximately 36,000 seeds per hectare). The experimental area was sprayed with Princep and Lasso herbicides for the control of grassy and broad-leaved weeds.

On July 6, 1981, each main plot was randomly split: one-half received 112 kg N/ha in the form of ammonium nitrate while the remaining half was unfertilized.

The daily rainfall data throughout the growing season for this and subsequent experiments are presented in Table 1.

The corn crop was harvested between October 8 to 12, 1981. Ears and stovers were harvested from each subplot. The numbers of harvested plants were counted and fresh weights determined. Samples of both ears and stover were taken separately from each subplot and dried at 65°C for 48 hours for dry matter determinations. The corn was shelled and the dry matter of grain was determined (Martin and Leonard, 1967). Yields are expressed as grain with 15.5% moisture.

Experiment 2. East Lansing, Conover loam soil, three years of alfalfa, one year of corn with two levels of nitrogen fertilizers in 1982. 1979-1982.

The experiment was established as a split plot, randomized complete block with four replications of Iroquois alfalfa. The plot sizes were 9.1 by 7.6 m and 9.1 by 6.1 m. The treatments were as follows:

Table 1.--Precipitation (mm) with deviations from normal for two years at the Michigan State University Experimental Farm, East Lansing, 1981 and 1982

Month	1981		1982	
	Precipitation	Deviation	Precipitation	Deviation
April	24.1	-57.3	58.4	-23.0
May	78.2	+ 7.6	89.9	+19.3
June	93.5	-14.4	133.1	+25.3
July	39.6	-31.8	40.9	-30.5
August	81.8	+ 4.3	31.7	-45.8
September	130.3	+48.7	113.0	+31.4
October	121.9	+70.6	11.7	-39.6
Total	596.4	+27.7	478.7	-62.9

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April	24.1	-57.3	58.4	-23.0
May	78.2	+ 7.6	89.9	+19.3
June	93.5	-14.4	133.1	+25.3
July	39.6	-31.8	40.9	-30.5
August	81.8	+ 4.3	31.7	-45.8
September	130.3	+48.7	113.0	+31.4
October	121.9	+70.6	11.7	-39.6
Total	596.4	+27.7	478.7	-62.9

1. One-year alfalfa, clear seeded in 1981 cut and removed
2. One-year alfalfa clear seeded in 1981, cut and left lay
3. Two-year alfalfa clear seeded in 1980
4. Three-year alfalfa clear seeded in 1979

Alfalfa yields were determined in three cuttings in the seeding year and in four cuttings in each subsequent year from an area 0.91 by 8.23 m using a Carter self-propelled harvestor. A 1,000-gram fresh weight sample was taken from each plot, dried with forced air to 65°C for 48 hours, and weighed to determine percentage dry matter.

The remainder of this experiment was identical to Experiment 1.

Experiment 3. East Lansing, Conover loam, one-year year clear seeded alfalfa followed by corn with four levels of nitrogen. 1981-1982.

Iroquois alfalfa was seeded at 13.5 kg/ha on April 1, 1981. P and K were applied at rates of 24 and 137 kg/ha, respectively on April 15. On August 12, potato leafhoppers (Empoasca fabae) were controlled with Sevimol insecticide. The experiment was established as a randomized complete block with three replications. Plot sizes were 9.1 by 6.1 m.

The alfalfa was disked and plowed under to an approximate depth of 20 cm on May 9, 1982. P and K were applied at the rates of 24 and 93 kg/ha, respectively. Michigan 5922 corn was planted in

0.76-m rows with 30 cm between plants (47,000 seeds per hectare). Lasso and Atrazine herbicides were used to control grassy and broad-leaved weeds.

Nitrogen fertilizer was applied as a side dressing to treatment plots at 0, 56, 112, and 224 kg N/ha. The corn was harvested from plots measuring 7.6 x 2.3 m.

Laboratory Procedure

Experiments 1 and 2

The roots from all four depths from each main plot were pooled and ground together. Soil samples from each horizon were ground separately.

Total percentage of nitrogen of both soils and root samples were determined using the Kjeldahl method for total nitrogen. A 0.2-gram sample of either soil or roots was digested with concentrated H_2SO_4, then steam distilled in the presence of 10N NaOH solution. The distillate was collected in 5 ml H_3BO_3 indicator and titrated with 0.01078 N H_2SO_4.

The percentage nitrogen of the sample was calculated using the following formula:

$$\%N = \frac{(T - B)\ N\ (1.4)}{W}$$

where: T = ml of 0.01078 N H_2SO_4 used in titrating sample solution

B = ml of 0.01078 N H_2SO_4 used in titrating blank solution

N = normality of H_2SO_4 (0.01078 N)

W = weight in grams of soil/roots sample used (0.2 grams)

Statistical Procedure

Yield data for alfalfa, root weights, total nitrogen content of soil and roots, and corn yield (third experiment) were analyzed in accordance with the randomized complete block design of the field experiment.

Data for corn, stover, and grain yield (Experiments 1 and 2) were analyzed as a split plot design (Steel and Torrie, 1980). Seeding year treatments were taken as units and nitrogen fertilizer levels as subunits.

RESULTS AND DISCUSSION

Experiment 1. Hillsdale Sandy Loam. 1978 to 1981

Alfalfa Yields

Seeding-year plus other subsequent dry matter forage yields of 1-, 2-, and 3-year-old alfalfa were 5.5, 22.3, and 30.4 mt/ha, respectively (Table 2). Significant forage yield difference ($p = 0.05$) was found as alfalfa stands increased in age as expected.

Table 2.--Dry matter yields of roots and forage and total yields in metric tons per hectare prior to plowing (spring, 1981) of 1-, 2-, and 3-year-old stands. Experiment 1.

Seeding year; Stand age in years	Yields and Year Harvested					
	Roots	Forage				Total
		3rd	2nd	1st	Total	
1980; one	1.6	--	--	5.5	5.5	7.1
1979; two	3.3	--	18.7	3.6	22.3	25.6
1978; three	3.8	15.0	12.9	2.5	30.4	34.2
LSD (0.05)	1.0				5.6	4.0

Dry matter yields of alfalfa roots from 1-, 2-, and 3-year-old stands were 1.6, 3.3, and 3.8 mt/ha, respectively. Root production from 2- or 3-year-old alfalfa was higher than from roots of 1-year-old alfalfa; no significant yield difference was found between the roots of 2- or 3-year-old stands, although there was a trend of greater production of the 3-year-old roots.

The distribution of alfalfa roots within horizons (0 to 15, 15 to 30, 30 to 60, and 60 to 90 cm) is presented in Table 3.

Table 3.--Dry weight of roots to 90-cm depth and percentage root weight distribution at four depths of 1-, 2-, and 3-year-old alfalfa. Experiment 1.

Seeding year; stand age in years	Dry weight, mt/ha	% Root Weight by depth in cm			
		0 to 15	15 to 30	30 to 60	60 to 90
1980; one	1.6	75	15	6	4
1979; two	3.3	75	15	7	3
1978; three	3.8	72	18	7	3
Average		74	16	7	3
LSD (0.05)	1.0	n.s.	n.s.	n.s.	n.s.

Irrespective of the age of the alfalfa stand, all four horizons exhibited a similar root distribution pattern. Root weight decreased with soil depth with 74, 16, 7, and 3% of the roots in 0 to 15, 15 to 30, 30 to 60, and 60 to 90 cm depths, respectively. Since the last one-third (60 to 90 cm) of the sampled root depth had only 3% of the total weight of the 90-cm depth sampled, it is likely that the sampled 90-cm depth accounted for at least 90% of the total root weight for the maximum root depth. The determinations for total root N per hectare as calculated later should therefore be about 90% or more of actual total root N per hectare. The progressive dry matter increase of alfalfa roots as the stand becomes older was a result of greater dry matter accumulation of the alfalfa root system as the stand becomes older.

Total dry matter yields of forage and roots from 1-, 2-, and 3-year-old stands increased significantly from 7.1 to 25.6 to 24.1 mt/ha, respectively (Table 2).

Soil N

Percent of total N in the soil declined with the soil depth (Table 4). In the first horizon (0 to 15 cm), soil percentage N

TABLE 4.--Soil nitrogen (percent total nitrogen) at four soil depths sampled before plowing under alfalfa seeded in three different years. Experiment 1.

Seeding year; stand age in years	Depth in cm			
	0 to 15	15 to 30	30 to 60	60 to 90
	%N			
1980; one	0.078	0.042	0.023	0.009
1979; two	0.110	0.064	0.024	0.010
1978; three	0.119	0.068	0.025	0.010
LSD (0.05)	0.020	0.028	n.s.	n.s.

taken from 1-, 2-, and 3-year old stands was 0.078, 0.110, and 0.119%, respectively. The percent total N from soil following 1-, 2-, and 3-year old stands for each of the remaining soil horizons decreased with depth. Soils following older alfalfa stands for the upper two depths had a significantly higher percentage of N than soils following 1-year-old alfalfa.

Root N

Percent N in 1-, 2-, and 3-year-old alfalfa roots was 2.01, 1.56, and 1.40%, respectively (Table 5). One-year-old alfalfa roots

Table 5.--Nitrogen percent and amounts of N in roots from 1-, 2-, and 3-year-old alfalfa. Experiment 1.

Seeding year; Stand age in years	% N in roots	kg N/ha	lb N/A
1980; one	2.01	32.1	28.6
1979; two	1.56	50.4	45.0
1978; three	1.40	53.0	47.3
LSD (0.05)	0.19	14.3	

had a higher N percent than 1-, 2-, and 3-year-old alfalfa roots. This finding implies that as the tissue gets older, nitrogen content decreases at the expense of more crude fibre accumulation.

Total N contents of 1-, 2-, and 3-year-old alfalfa roots when plowed under was 32.1, 50.4, and 53.0 kg/ha, (28.7, 45.0, and 47.3 lbs. N/A), respectively. Older roots had higher total N content than 1-year-old roots.

The root N data suggest that N percentage decreased significantly as the roots became older. Despite the fact that the N percentage of older stands was low, the effect was counterbalanced by greater dry matter of older stands which consequently resulted in an overall higher total N content as the stands became older.

Any difference which could be manifested by a subsequent corn yield would be attributed to soil N, nitrogen fertilizer applied and root N of the alfalfa stands.

<u>Grain Yield</u>

Yields of corn grain (15.5%) following 1-, 2-, and 3-year-old alfalfa were 6.6, 7.3, and 7.5 mt/ha (105.5, 116.4, and 119.6 bu/A), respectively (Table 6 and Figure 2). Grain yields following 2- and 3-year-old alfalfa were 10 and 12% respectively greater, after 1-year-old alfalfa. Grain yield following 2- and 3-year-old alfalfa were similar.

Corn fertilized with 112 kg N/ha following 1-year-old alfalfa produced 36% more grain (31.8 bu/A) per hectare then when unfertilized. The increases due to N fertilization were much smaller --15 and 19%--for corn grain yields after 2- and 3-year-old alfalfa stands. The yield of corn gran following 1-year-old alfalfa was significantly lower than after 2- and 3-year-old alfalfa stands when

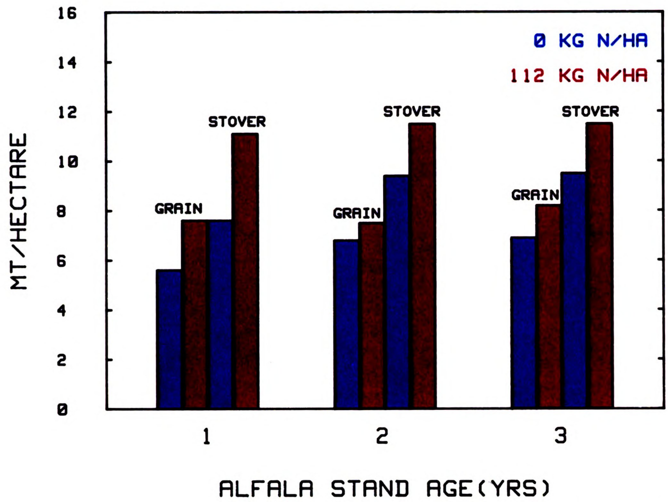

Figure 2. Yield of corn grain (15.5% moisture) and stover (100% DM) in metric tons per hectare grown after plowing under 1-, 2-, and 3-year-old alfalfa stands with 0 or 112 kg N/ha added to the corn.

Table 6.--Yields of grain (15.5% moisture) and stover (100% DM) of corn in metric tons per hectare (bu/A) grown after plowing under 1-, 2-, and 3-year-old alfalfa stands with 0 or 112 kg N/ha added to the corn. Experiment 1, Hillsdale Sandy Loam, 1978 - 1981.

Fertilizer, kg N/ha	Grain			Stover			Total		
	Total	Increase, 112 over 0 kg N/ha		Total	Increase, 112 over 0 kg N/ha		Yield	Increase, 112 over 0 kg N/ha	
	mt/ha (bu/A)	mt/ha	bu/A (%)		mt/ha	T/A (%)		mt/ha	T/A (%)
One-year-old alfalfa removed									
0	5.6 (89.3)	--	--	7.6 (3.4)	--	--	12.3 (5.5)	--	--
112	7.6 (121.1)	2.0	31.8 (36%)	11.1 (4.9)	3.5	1.5 (46%)	17.7 (7.9)	5.5	2.4 (44%)
Average	6.6 (105.5)			9.3 (4.1)			15.0 (6.7)		
Two-year-old alfalfa removed									
0	6.8 (108.4)	--	--	9.4 (4.2)	--		15.0 (6.7)	--	--
112	7.8 (124.4)	1.0	16.0 (15%)	11.5 (5.1)	2.1	0.9 (22%)	18.1 (8.1)	3.1	0.4 (26%)
Average	7.3 (116.4)			9.9 (4.4)			16.5 (7.4)		
Three-year-old alfalfa removed									
0	6.9 (110.0)	--	--	9.5 (4.2)	--	--	15.3 (6.8)		--
112	8.2 (130.7)	1.3	20.7 (19%)	11.5 (5.1)	2.0	9.0 (21%)	18.4 (8.2)	3.3	0.4 (20%)
Average	7.5 (119.6)			10.0 (4.5)			16.8 (7.5)		
LSD (0.05) stand age	0.7			0.6			1.0		
LSD (0.05) N	0.2			0.9			0.8		
LSD (0.05) N within the same stand age	0.4			1.5			1.3		
LSD (0.05) two different stand ages at the same/different N levels	3.6			3.4			3.4		

no N was added. When N was added, however, grain following alfalfa of different ages were fairly similar (range of 7.6 to 8.2 mt/ha--121.1 to 130.7 bu/A) indicating there was less available N in the soil after one year of alfalfa than after two or three years of alfalfa.

Stover Yield

Dry matter yields of stover following 1-, 2-, and 3-year-old alfalfa were 9.3, 9.9, and 10.0 mt/ha (4.1, 4.4, and 4.5 T/A), respectively, (Table 6 and Figure 2). Stover yields following 2- and 3-year-old alfalfa were greater than following 1-year-old alfalfa.

Stover from N-fertilized corn following 1-year-old alfalfa yielded significantly more--46%--than when not fertilized. The increases were much lower--22 and 21%--for stover after 2- and 3-year-old alfalfa stands. The yield of stover following 1-year-old alfalfa stand was significantly lower than after 2- and 3-year-old stands when no N was added. When N was added, stover following alfalfa of different ages was fairly similar (range of 11.1 to 11.5 mt/ha or 4.9 to 5.1 T/A).

Total Yields

Total dry matter yields of grain and stover following 1-, 2-, and 3-year-old alfalfa were 15.0, 16.5, and 16.8 mt/ha (6.7, 7.4, and 7.5 T/A), respectively (Table 6). Total yields following 2- and 3-year-old alfalfa were greater then following 1-year-old alfalfa.

Total yields were increased significantly by 44% when corn was fertilized following 1-year-old alfalfa. The increases were much lower--21 and 20--following older alfalfa stands. Total yields following 1-year-old alfalfa were lower than after older alfalfa when no N was added. When N was added, total yields following alfalfa of different total yields following alfalfa of different ages were fairly similar (range 17.7 to 18.4 mt/ha or 7.9 to 8.2 T/A).

From the preceding results of grain, stover and total yields of corn, the values are in agreement with the expectation as suggested by soil percentage N and N contained in 1-, 2-, and 3-year-old stands. The nitrogen percentage of the soil following 1-year-old alfalfa was significantly lower than the respective values from soils preceded by 2- and 3-year-old alfalfa. Total root N contained in 1-year-old alfalfa roots was also significantly lower than the corresponding values from 2- and 3-year-old roots (Table 5). These two factors coupled together were manifested by a significantly lower yield of grain and stover following 1- compared to 2- or 3-year-old alfalfa.

Fertilizing corn with 112 kg N/ha showed that grain, stover, and total yields following 1-, 2-, and 3-year-old alfalfa responded significantly to N fertilization. The increment, however, decreased following older alfalfa stands. This finding strengthens the fact that N increased the total yield of grain and stover following 1-year-old alfalfa more than when corn followed 2- and 3-year-old alfalfa because of significantly low soil percentage N as well as significantly lower total N contained in alfalfa roots of one- then in two- and three-year-old alfalfa.

RESULTS AND DISCUSSION

Experiment 2. Conover loam. 1979-1982

Alfalfa Forage Yields

Total dry matter forage yields of 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa cut and removed were 5.5, 6.2, 15.9, and 36.9 mt/ha, respectively (Table 7). There was a significant yield increase in total yield, as expected, as the stand increased in age.

Alfalfa Root Yields

Dry matter yields of alfalfa roots from 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa cut and removed were 2.1, 2.1, 3.2, and 3.8 mt/ha, respectively (Table 7). Roots from 1-year-old alfalfa had lower yields than roots from 2- or 3-year-old which had similar yields.

The distribution of alfalfa roots within depths 0 to 15, 15 to 30, 30 to 60, and 60 to 90 cm is presented in Table 8. Average root weight decreased with depth of the soil with 62, 19, 14, and 5% of the roots in the 0 to 15; 15 to 30, 30 to 60, and 60 to 90 cm depth, respectively. Older stands, when compared to 1-year-old stands, appeared to have more of the roots in the top 15 cm, and less in the bottom 60 cm, but the differences were not significant. Therefore, any difference which would be manifested by subsequent

Table 7.--Dry matter of roots, forage, and total yields in metric tons per hectare just before plowing (spring 1982) 1-year-old alfalfa cut and removed, 1-year-old cut and left lay, and 2- and 3-year-old stands with forage removed. Experiment 2.

Seeding year; Stand age in years	Yields and Year Harvested					
	Roots	Forage				Total
		3rd	2nd	1st	Total	
1981 cut and removed; one	2.1	--	--	5.5	5.5	7.6
1981 cut and left lay; one	2.1	--	--	6.2	6.2	8.3
1980 cut and removed; two	3.2	--	12.0	3.9	15.9	19.1
1979 cut and removed; three	3.8	18.7	13.4	4.8	36.9	40.7
LSD (0.05)	0.7				1.3	2.0

Table 8.--Dry weight of roots to a 90-cm depth and percentage root weight distribution at four depths of 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, 2- and 3-year-old alfalfa stands with forage removed. Experiment 2.

Seeding year; Stand age in years	Dry weight mt/ha	% Root Weight by Horizon in cm 0 to 15	15 to 30	30 to 60	60 to 90
1981 cut & removed; one	2.1	58	20	16	6
1981 cut & left lay; one	2.1	61	16	17	6
1980 cut & removed; two	3.2	65	18	14	3
1979 cut & removed; three	3.8	66	20	10	4
Average		62	19	14	5
LSD (0.05)	0.7	n.s.	n.s.	n.s.	n.s.

corn yields following alfalfa of different ages would be partly due to total root weight to the 90 cm depth and not root weight distribution, particularly since 90% of the roots are likely in the top 90 cm.

Total Yields

Total dry matter yields of forage and roots from 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa were 7.6, 8.3, 19.1, and 40.8 mt/ha, respectively (Table 7). The yields from 2- and 3-year-old stands were greater than from the 1-year-old stands.

The dry matter yields of roots (Table 7) increased significantly as the stand became older. Dry weights of roots of 1-year-old alfalfa were 48 and 42% lower than in 2- and 3-year-old alfalfa. This finding can be explained as a result of the growth of alfalfa root system as the stand became older.

The difference between 1-year-old alfalfa cut and removed or cut and left lay in terms of forage yield difference, although not significant, might be due to decay of forage which was left lay after harvests.

Soil N

The percent of total N in the soil decreased with greater profile depth as presented in Table 9. At 10 to 15 cm depth, percentage total N of the soil following 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old

Table 9.--Soil nitrogen (percent total nitrogen) of four soil depths sampled before plowing (spring 1982) under alfalfa seeded in three different years. Experiment 2.

Seeding year;	Depth in cm			
stand age in years	0 to 15	15 to 30	30 to 60	60 to 90
1981 cut & removed; one	0.075	0.054	0.021	0.011
1981 cut & left lay; one	0.077	0.055	0.022	0.011
1980 cut & removed; two	0.116	0.084	0.023	0.013
1979 cut & removed; three	0.120	0.085	0.023	0.014
LSD (0.05)	0.015	0.018	n.s.	n.s.

alfalfa cut and removed were 0.075, 0.077, 0.116, and 0.120%, respectively. The percent total N of the soils following 2- and 3-year-old was greater than from 1-year-old alfalfa stands.

Root N

Percent N in roots of 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa cut and removed was 1.85, 1.68, 1.69, and 1.52%, respectively (Table 10). The differences were not significant, but it appeared that the roots had a higher percentage N in the younger stands. Cutting alfalfa and leaving it lay increased the amount of soil N which, in turn, may have inhibited nitrogen fixation by alfalfa roots, thereby reducing the capability of the roots in fixing nitrogen.

Total N contained in roots of 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa when plowed under were 38.4, 35.3, 54.8, and 57.9 kg N/ha (34.3, 31.5, 48.9, and 51.7 lbN/A), respectively (Table 10). Roots in the 2- and 3-year-old alfalfa has 48 and 57% more N than the average of 1-year-old stands. There was no significant difference in root N of 2- or 3-year-old alfalfa where the tops were removed or left lay.

Despite the fact that the total N percentage of roots of older stands was low, the effect was counter-balanced by greater dry matter yields of older stands which resulted in an overall higher total N as stands became older. Since the percent of N in the soil

Table 10.--Nitrogen percentage and amounts in roots from 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa with forage removed. Experiment 2.

Seeding year; stand age in years	% N in roots tissue	kg N/ha	lb N/A
1981 cut and removed; one	1.85	38.4	(34.3)
1981 cut and left lay; one	1.68	35.3	(31.5)
1981 cut and removed; two	1.69	54.8	(48.9)
1979 cut and removed; three	1.52	57.9	(51.7)
LSD (0.05)	n.s.	16.2	

increased as the stand increased in age, any difference in subsequent corn yield would be attributed to soil N, nitrogen fertilizer, and root N.

Grain Yield

Average dry matter of grain of corn fertilized with N or unfertilized following 1-year-old alfalfa cut and removed or cut and left lay, and 2- and 3-year-old alfalfa cut and removed were 6.4, 6.5, 6.8, and 6.9 mt/ha (102.3, 103.6, 108.4, and 110.0 bu/A), respectively (Table 11 and Figure 3). Grain yields of unfertilized corn following 2- and 3-year-old alfalfa cut and removed were greater than yields following 1-year-old irrespective whether cut and removed or left lay. Average yields of grain of unfertilized corn after 1 year of alfalfa cut and removed or left lay was 5.4 (85.3 bu/A). This was 88 and 85% of the corn grain yield after 2 and 3 years of alfalfa.

Grain yields of corn fertilized with nitrogen following 1-year-old alfalfa cut and removed or cut and left lay were 43 and 41% greater than when not fertilized. The increases were much smaller--25 and 19%--for 2- and 3-year-old alfalfa stands. The yields of corn grain following one year of alfalfa were smaller than after 2- and 3-year-old when no N was added. When N was added, grain yields following alfalfa of different ages were fairly similar (range of 7.6 to 7.6 mt/ha or 119.6 to 121.1 bu/A).

Table 11.--Yield of grain (15.5% moisture) ans stover (100% DM) of corn in metric tons per hectare (bu/A) grown after plowing under 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa stands with 0 or 112 kg N/ha hadded to the corn. Experiment 2. Conover loam. 1979-1982.

Fertilizer, kg N/ha	Grain: Total mt/ha	Grain: Total (bu/A)	Grain: Increase, 112 over 0 kg N/ha mt/ha	Grain: Increase, 112 over 0 kg N/ha bu/A (%)	Stover: Total	Stover: Increase, 112 over 0 kg N/ha mt/ha	Stover: Increase, 112 over 0 kg N/ha T/A (%)	Yield: Total	Yield: Increase, 112 over 0 Kg N/ha mt/ha	Yield: Increase, 112 over 0 Kg N/ha T/A (%)
One-year-old alfalfa cut and removed										
0	5.4	(85.3)	--	--	7.2 (3.2)	--	--	11.4 (5.1)	--	--
112	7.6	(121.2)	2.3	36.7 (43%)	9.7 (4.3)	2.5	1.1 (35%)	16.1 (7.2)	4.7	2.2 (41%)
Average	6.4	(103.0)			8.4 (3.7)			13.7 (6.1)		
One-year-old alfalfa cut and left lay										
0	5.4	(86.1)	--	--	7.2 (3.2)	--	--	12.0 (5.3)	--	--
112	7.6	(121.2)	2.2	35.1 (40%)	9.8 (4.4)	2.6	1.1 (37%)	15.3 (6.8)	3.3	1.5 (28%)
Average	6.5	(103.6)			8.5 (3.8)			13.6 (6.1)		
Two-year-old alfalfa removed										
0	6.1	(97.2)	--	--	8.5 (3.8)	--	--	13.6 (6.1)	--	
122	7.6	(121.2)	1.5	24.0 (25%)	9.9 (4.4)	1.4	0.7 (16%)	16.4 (7.3)	2.8	1.2 (21%)
Average	6.8	(109.2)			9.2 (4.1)			15.0 (6.7)		
Three-year-old alfalfa removed										
0	6.3	(100.4)	--	--	8.8 (3.9)	--	--	14.1 (6.3)	--	--
112	7.5	(119.6)	1.2	19.2 (19%)	10.0 (4.5)	1.3	0.6 (15%)	16.5 (7.4)	2.4	1.1 (17%)
Average	6.9	(110.6)			9.4 (4.2)			15.3 (6.8)		
LSD (0.05) stand age	0.8				0.7			0.9		
LSD (0.05) N	0.6				0.4			0.8		
LSD (0.05) N within the same stand age	0.9				0.6			1.0		
LSD (0.05) two different stand ages at the same/different N level	1.1				0.9			1.3		

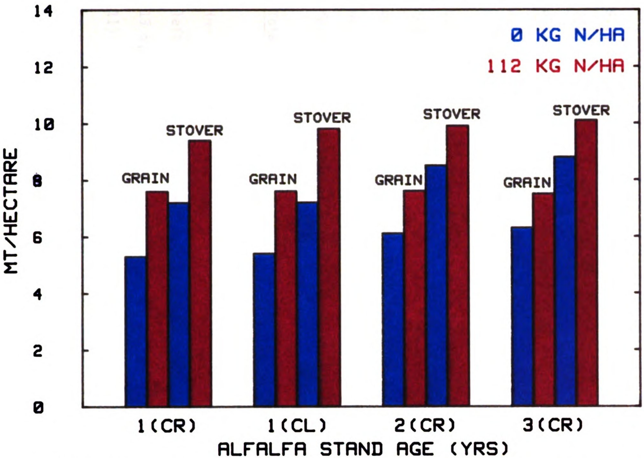

Figure 3. Yield of corn grain (15.5% moisture) and stover (100%) DM) in metric tons per hectare grown after plowing under 1-, 2-, and 3-year-old alfalfa stands with 0 to 112 kg N/ha added to the corn.

Stover Yield

Average dry matter dry matter yield of stover following 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa cut and removed were 8.4, 8.5, 9.2, and 9.4 mt/ha (3.7, 3.8, 4.1, and 4.2 T/A), respectively (Table 11 and Figure 3). Stover yields following 2- and 3-year-old alfalfa cut and removed were greater than following 1-year-old alfalfa stands. Increases of stover from fertilizing corn following 1-year-old alfalfa cut and removed or cut and left lay were significant--35 and 37%. The increases were much smaller--16 and 15%--for the 2- and 3-year-old alfalfa stands. When no N was added, the yields of stover were lower than after 2- and 3-year-old stands. When N was added, stover yields following alfalfa of different ages were fairly similar (range of 9.7 to 10.1 mt/ha or 4.33 to 4.5 T/A).

Total Yields

Average total dry matter yields of grain and stover following 1-year-old alfalfa cut and removed, 1-year-old alfalfa cut and left lay, and 2- and 3-year-old alfalfa cut and removed were 13.7, 13.6, 15.0, and 15.3 (6.1, 6.1, 6.7, 6.8 T/A), respectively (Table 11). Grain and stover yields following 2- and 3-year-old alfalfa were significantly greater than after 1-year-old alfalfa stands. Significant grain and stover increases from fertilizing corn following 1-year-old alfalfa cut and removed or left lay were 41 and 28%. The increases were much lower--21 and 17%--for 2- and 3-year-old alfalfa. The yield of grain and stover following 1-year-old alfalfa stands were significantly lower than after 2- and 3-year-old stands when no N was added. When N was added, grain and stover following alfalfa of different ages were fairly similar (range of 15.3 and 16.5 mt/ha or 6.8 to 7.4 T/A).

The preceding results of yields of grain, stover, and total yields are in conformity with the expected trend as exhibited by soil N and root N in alfalfa stands of varying age. Percentage N of the soil from alfalfa of different ages increased significantly in the following order of magnitude: 1-year-old alfalfa cut and removed < 1-year-old alfalfa cut and left lay < 2-year-old alfalfa, and < 3-year-old alfalfa. Total root N contained by 1-year-old alfalfa roots was significantly lower than the corresponding values obtained from 2- and 3-year-old roots, previously because of less total dry matter in the young stands. These two factors when coupled together resulted in significantly lower yield following 1-year-old alfalfa compared to yields following both older alfalfa stands.

When corn was fertilized with 112 kg N/ha, grain, stover, and total yields following 1-year-old alfalfa cut and removed or cut and left lay, and 2- and 3-year-old alfalfa responded significantly to N fertilization. The increment, however, decreased as corn followed older alfalfa stands. Yields of grain and stover after 1-year-old alfalfa stands increased more than following older alfalfa stands because of significantly low soil N, as well as significantly lower total N contained in alfalfa roots with respect to grain and stover following 2- and 3-year-old alfalfa stands.

RESULTS AND DISCUSSION

Experiment 3. Conover loam. 1981-1982

Grain Yield

Fertilizing corn at 0, 56, 112, and 224 kg N/ha after 1-year-old alfalfa cut and removed increased grain yields significantly to 5.5, 6.8, 7.8, and 9.5 mt/ha (87.9, 108.4, 124.4, and 151.5 bu/A), respectively (Table 12 and Figure 4). Yield increases for each kg of N applied over no N were 0.023, 0.021, and 0.018 mt between 0 to 56, 0 to 112, and 0 to 224 kg N/ha (0.410, 0.365, 0.315 bu/lb N), respectively. Yield increases per each unit N applied decreased as the rate of N increased with the greatest decrease occurring between the two highest rates of N.

Stover Yield

Stover yields obtained from fertilizing corn with 0, 56, 112, and 224 kg N/ha following 1-year-old alfalfa increased significantly to 5.5, 7.3, 8.4, and 10.2 mt/ha (2.5, 3.3, 3.7, and 4.5 T/A), respectively (Table 12 and Figure 4). Yield increases per kg of N applied over 0 kg N/ha decreased from 0.032, 0.026 to 0.021 mt/kg between 0 to 56, 0 to 112, and 0 to 224 kg N/ha, respectively.

Total Yields

The total dry matter yield of grain and stover obtained from fertilizing corn with 0, 56, 112, and 224 kg N/ha increased

Table 12.--Yield of corn grain (15.5% moisture) and stover (100% DM) in metric tons per hectare (bu/A) grown with 0, 56, 112, and 224 kg N/ha added after plowing under a stand of 1-year-old alfalfa that was cut and removed. Experiment 3.

Fertilizer, kg N/ha	Yield							
	Grain				Stover		Total	
	Total mt/ha	(bu/A)	Increase mt/kg N	Increase bu/lb N	Total mt/ha (T/A)	Increase per kg N	mt/ha (T/A)	Increase per kg N
0	5.5	(87.9)	--		5.5 (2.5)	--	10.0 (4.5)	--
56	6.8	(108.4)	0.023	(0.410)	7.3 (3.3)	(0.032)	13.0 (5.8)	(0.050)
112	7.8	(124.4)	0.021	(0.365)	8.4 (3.7)	(0.026)	15.0 (6.7)	(0.044)
224	9.5	(151.0)	0.018	(0.315)	10.2 (4.5)	(0.021)	18.8 (8.4)	(0.036)
LSD (0.05)	0.45				1.1		1.3	

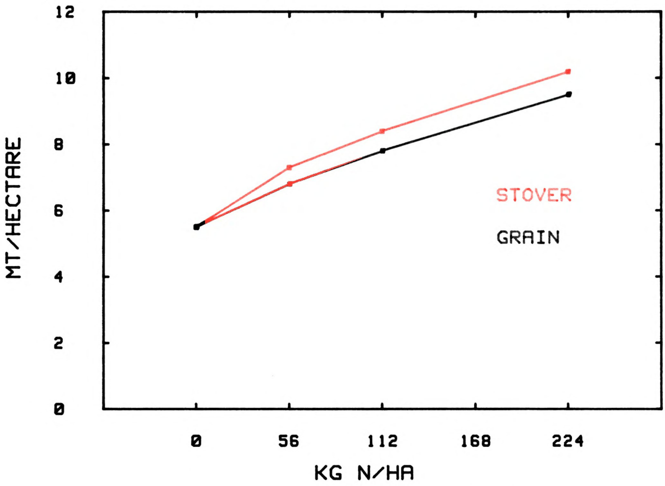

Figure 4. Yield of corn grain (15.5% moisture) and stover (100% DM) in metric tons per hectare grown with 0, 56, 112, and 224 kg N/ha added after plowing under a stand of 1-year-old alfalfa that was cut and removed.

significantly to 10.0, 13.0, 15.0, and 18.8 mt/ha (4.5, 5.8, 6.7, and 8.4 T/A), respectively (Table 12). Yield increases per kg of N applied over 0 kg N/ha decreased from 0.050, 0.044 to 0.036 mg/kg between 0 to 56, 0 to 112 and 0 to 224 kg N/ha, respectively.

Taking into consideration the amount of N in the roots of 1-year-old alfalfa, as well as the soil N of the Conover loam aoil under study, fertilizing corn with different levels of nitrogen gave a diminishing response (Figure 4) for grain, stover, and total yields as the rate increased. This trend of diminishing response is due to the fact that as one increases the level of N, each succeeding unit of increase required more N than the previous unit (Figure 4).

SUMMARY AND CONCLUSION

1. Two- and three-year-old alfalfa had 41 and 50% greater root dry matter yields than 1-year-old alfalfa.

2. Soil N after 2- and 3-year old alfalfa was greater than after 1-year-old alfalfa. The values ranged rom 0.075 to 0.120%, with percentage total N from 1-year-old alfalfa 62.5% of the 3-year-old stand.

3. There was no difference in soil N between 1-year-old alfalfa removed or left lay.

4. The total amount of N to a depth of 90 cm in roots of 2- and 3-year-old alfalfa was 49 and 57% greater than in 1-year-old alfalfa. The total amount of N in roots in 1-, 2-, and 3-year-old alfalfa was 35.3, 52.6, and 55.4 kg/ha. The 2- and 3-year stands had as an average of 66% more N than 1-year-old alfalfa.

5. Grain and stover yields of corn grown after 2- or 3-year-old alfalfa were 18 and 23% greater than corresponding yields following 1-year-old alfalfa.

6. The yields of grain after 1-year-old alfalfa were 82 and 80% and for stover 85 and 82% of yields following 2- and 3-year-old alfalfa.

7. With the addition of 112 kg N/ha, grain and stover, yields were increased over unfertilized corn grown after alfalfa. This

increase for grain was greatest after 1-year-old alfalfa (40%) and least after 3-year-old alfalfa (19%).

8. Grain yields did not increase with the addition of 112 kg N/ha when corn was grown following three alfalfa stands of varying ages (7.5 - 8.1 mt/ha).

9. Nitrogen fertilization increased yields of grain and stover when the corn was grown after 1-year-old alfalfa cut and removed. Smaller yield increases were obtained per unit of N applied as N rate was increased.

Conclusion

The finding of this study compared the difference between 1-, 2-, and 3-year-old clear seeded alfalfa in a crop rotation program. Grain yields following 1-year-old alfalfa were lower than from older stands. The yield was 85 and 83% of the 2- and 3-year alfalfa. This shows that, even though the amount of N fixed by 1-year-old alfalfa was lower than by 2- and 3-year-old alfalfa, there is still some validity in using it to supplement chemical N fertilizers or to use it as the sole N source if N prices increase astronomically or if nitrogen is unavailable as in developing countries.

Lack of difference between 1-year-old alfalfa cut and removed or left lay in terms of N contained in the roots, residual soil N, forage yields and corn yields suggests that cutting alfalfa and leaving it lay is not more beneficial in adding N to the soil than cutting and removing alfalfa from the field for livestock feeding.

The study is also of agronomic importance to those developing countries that allocate a substantial amount of their meagre foreign currency to import chemical N fertilizers. Properly planned and managed rotation programs with a legume such as alfalfa left for only one year followed by a cereal crop could benefit those countries tremendously in raising their agricultural production at very marginal costs.

Research is now being conducted in at least one state to develop new alfalfa cultivars with higher N-fixing characteristics. This improvement could be made, to a great extent, in many nondormant varieties that are high yielding and suitable for plowdown crops.

BIBLIOGRAPHY

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Ahlawat, I. P. S.; A. Singh; and C. S. Saraf. 1981. Effect of winter legumes on the nitrogen economy and production of succeeding cereals. Expl. Agric. 17:57-62.

Albrecht, W. A. 1937. Method of incorporating organic matter with the soil in relation to nitrogen accumulations. Miss. Agr. Exp. Sta. Res. Bull. 24a.

Boawn, C. Louis; J. L. Nelson; and L. Crawford. 1965. Residual nitrogen from ammonium mitrate fertilizer and from alfalfa plowed under. Agron. J. 55:231-235.

Bolton, E. F.; V. A. Birks; and J. W. Aylesworth. 1976. Some effects of alfalfa, fertilizer, and time on corn yield in rotations in clay soil during a range of seasonal moisture conditions. Can. J. Soil Sci. 56:21-25.

Broadbent, F. E. and T. Nakashima. 1968. Plant uptake and residue value of six tagged nitrogen fertilizers. Soil Sci. Soc. Am. Proc. 32:338-392.

Brockwell, J. and F. W. Helly. 1966. Symbiotic characteristic of Rhizorbium meliloti. An appraisal of the systematic treatment of nodulation and nitrogen interactions between hosts and rhiborbia of diverse origins. Aust. J. Agric. Res. 17: 885-899.

Burhani, H. O. and M. E. Mansi. 1967. The effect of crop rotation on cotton yields. J. Agric. Sci. 68:255-261.

Eaglesham, A. R. J.; V. Vanga Rao; and D. Leskow. 1979. Effect of fertilizers on nutrient leaching pattern of two soil types. Agron. Abstr. 1516.

El-Damaty, A. H. and M. Mobarek. 1962. Studies on virgin sandy soils at the Tahree Province of the U.A.R. Soil Sci. J. U. A. R. (2).

Fribourg, H. A. and W. V. Bartholomew. 1956. Availability of nitrogen from crop residues during first and second year after application. Soil Sci. Soc. Am. 20:505-508.

Giri, G. and R. De. 1979. Effect of proceding grain legumes on dry land Pearl Millet in N. W. India. Expl. Agric. 15:169-172.

Greaves, J. E. and L. W. Jones. 1950. Influence of legumes on soil nitrogen. Soil. Sci. 69:71-76.

Hastings, S. H. 1936. Irrigated crop rotations in Western Nebraska, 1912-34. U.S.D.A. Tech. Bull. 512.

Heichel, G. H.; D. K. Barnes, and C. P. Vanu. 1981. Nitrogen fixation of alfalfa in the seeding year. Crop Sci. 21: 330-335.

Hide, J. C. and W. H. Mitzegar. 1939. Soil aggregation as affected by certain crops and organic materials and some chemical properties associated with aggregation. Soil Sci. Soc. Am. Proc. 4:19-22.

Jenny, H.; S. P. Gessel; and F. T. Bingham. 1949. Comparative study of decomposition rates of organic matter in temperate and tropical regions. Soil Sci. 68:419-432.

Jones, R. J. 1945. Nitrogen losses from Alabama soils in Lysimeters as influenced by various systems of green manure crop management. J. Am. Soc. Agron. 34:574-585.

Jones, M. J. 1974. Effect of previous crop on yield and nitrogen response of maize at Samaru, Nigeria. Expl. Agric. 10:273-279.

Jones, M. J. 1975. Leaching of nitrate under maize at Samaru, Nigeria. Trop. Agric. 52:1-10.

Lander, P. E.; B. H. Wisdon; and M. Mukandlal. 1923. A study of factors operative in the value of green manure. Pusa. Agric. Res. Inst. Bull. 149.

Lyon, T. L. and J. A. Bizzel. 1933. Nitrogen accumulation as influenced by the cropping system. J. Am. Soc. Agron. 25: 266-272.

Martin, J. H. and N. H. Leonard. 1967. Principles of field crop production. The Macmillan Co., New York.

Matousch, O. 1979. Leaching losses from various nitrogen fertilizer sources. Soils and fertilizers. 38 No. 10:333.

Musa, M. M. and H. O. Burhani. 1974. The relative performance of forage legumes as rotational crops in the Gezira. Expl. Agric. 10:131.

Musgrave, G. W., and R. A. Norton. 1937. Soil and water conservation investigation at soil conservation experimental station. Mission Valley Low Regions, Caluda Iowa, Prog. 1931-37. U.S.D.A. Tech. Bull. 558.

Nyatsanga and Pierre. 1981. Quoted in Soil and water. Crops and Soils Magazine, June/July 1981, p. 8.

Nelson, M.; W. A. Carnes; and A. B. Bowen. 1940. Soil organic matter and nitrogen as influenced by green manure crop management on Norfolk coarse sand. J. Am. Soc. Agron. 32: 840-845.

Newton, R.; R. S. Young, and J. G. Malloch. 1939. Nitrification under and after alfalfa, brome, timothy and western rye grass 1 Nitrogen absorption of hay crop and succeeding wheat crop. Can. J. Res. C17:212-231.

Owen, L. D. 1960. Nitrogen movement and transformation in soils as evaluated by a lysimeter study utilizing isotopic nitrogen. Soil. Sci. Soc. Am. Proc. 24:372-376.

Pieters, A. J. 1927. Green manuring principles and practice. New York: John Willey and Sons. 1927.

Riazi, A. H.; L. Gouglas; and J. B. Field. 1978. Effect of fertilizer on nutrient leaching. Pattern of two soil types. Agron. Abstr. 1978, p. 196.

Robertson, L. S. 1952. A study of the effects of seven systems of cropping upon yields and soil structures. J. Am. Soc. Sug. Beet. Tech.:255-265.

Robertson, L. S.; J. R. Guttay; and R. L. Cook. 1958. Sugar beet production in Michigan as affected by cropping sequence and fertility level. J. Am. Soc. Sug. Beet. Tech. 10:65-75.

Robertson, L. S.; R. L. Cook; C. D. Piper; and R. H. Dawdy. 1964. Sugar beet production as affected by crop sequence and fertility levels. J. Am. Soc. Sug. Beet Techn. 13:305-313.

Roger, L.; W. Higgs; and J. Pendioton. 1975. Crop rotation and nitrogen crop sequence comparisons and soils of the drift area of South East Wisconsin. Res. Bull. R2761.

Russel, C. 1939. The values of legume for soil improvement. Miss. Agri. Exp. Stn. Bull. 366:1-10.

Schmid, A. R.; A. C. Caldwel; and R. A. Briggs. 1959. Effect of various meadow crops, soybean, and grain. Agron. J. 51: 160-162.

Sharma, P. B.; A. Singh; and R. Singh. 1973. Symbiotic nitrogen fixtion by winter legumes. A comparative efficiency between an Indian and an Australian on Medicago sativa. Ind. J. Agric. Res. 7:159-163.

Seetin, M. W. and D. K. Barnes. 1981. Variations among alfalfa gerotypes for rate of autylene reduction. Crop Sci. 17: 783-787.

Steel, R. G. D., and J. H. Torie. 1980. Principles and procedures of statistics. McGraw Hill Book Company. New York.

Stephens, J. L. 1952. Winter legume cover crops for the coastal plain of Georgia. Georgia Coastal Plains Exp. Stn. Bull 23.

Stickler, F. C.; W. D. Shrader; and I. J. Johnson. 1959. Comparative value of elgume and feritlizer nitrogen for corn production. Agron. J. 51:157-160.

Tucker, B.; M. B. Cox; and G. V. Echi. 1971. Effect of rotations, tillage methods and N fertilization in winter production. Agron. J. 63:699-705.

Voss, R. D., and W. D. Shrader. 1979. Crop rotations. Effect on yields and response to nitrogen. Iowa State University Agronomy. 1979.

Warner, D. 1981. Nitrogen fixation and production biology. Field Crop Abstr. 33, #11, Abstracts 9415.

White, D. 1970. Fallowing, crop rotation and crop yields in Roman times. Agric. History. Vol. XLIV:281-290.

William, E. A.; H. D. Morris; and R. N. Dawson. 1970. Effect of cropping systems and nitrogen levesl on corn (Zea mays). Yields in the soutern Predmont Region. Agron. J. 62:655-659.

________. Plowdown--a strategy for the eighties. 1981. Alberta Forage Seed Council, unnumbered mimeo.