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ABATEMENT OF NITRATE POLLUTION IN GROUNDWATER AND SURFACE RUNOFF FROM CROPLAND USING LEGUME COVER CROPS WITH NO-TILL CORN

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Abstract

Agricultural practices can have a significant impact on water quality. The effects of leguminous winter cover crops on leaching of NO_3^- from soil have been investigated in this project. Legume cover crops, by fixation of atmospheric N, can reduce the amount of fertilizer N required to produce summer grain crops. The methods initially used to evaluate cover crop effects on NO_3^- transport included suction probe lysimeters and measurement of NO_3^- in soil samples collected to a depth of 90 cm. These measurements demonstrated extreme spatial variability in NO_3^- distribution and water movement. This made it impractical to compare effects of different treatments. Soil transformations of legume and fertilizer N sources were compared using ^{15}N labelled amendments. Less of the vetch N was found in leachable forms and, after 2 to 3 months in soil, losses of vetch N were smaller than losses of fertilizer N. To resolve the problem of spatial variability and to make direct measurements of leaching, 16 lysimeters were constructed from 55 gallon drums. These were treated with either fertilizer or legume N. Early measurements show greater NO_3^- leaching with legume N, due to the mulch effect reducing evaporative water removal. However, there has been insufficient time to fully evaluate the treatments. This experiment will be continued.

Descriptors: Pollution Load, Runoff, Groundwater, Cover Crops
Surface Runoff

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In addition to the authors several individuals have contributed to this project. This includes Dan McCracken, Steve Corak and Laura Parsons.

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Chapter I - Introduction

Our objectives as stated in the research proposal are summarized as follows:

1. To compare the leaching of NO_3^- in soil treated with N fertilizer and soil with a legume cover crop as the source of N.
2. To compare fertilized and cover crop soil with regard to soil structure, porosity, and infiltration rates.
3. (a) To measure potential rates of soil water consumption under a living cover crop in the spring, under a killed cover crop in early summer, and in soil without a cover crop.
   (b) To relate the resulting approximate soil water budgets to the potential for leaching and surface runoff.

Unanticipated variability in the systems have made it impossible to address these questions in full. In this report we will discuss these problems, review other research we have conducted which provides information related to these objectives, and describe the experimental system which will make it possible to accomplish these objectives in the near future. Complete results of these studies will be made available in future publications.

Background: There exists a critical local and national need for developing and testing crop and soil management systems which will maintain agricultural productivity at a high level while reducing detrimental effects on soil and water resources. Non-point source pollution of ground and surface waters resulting from water and materials moving through and over agricultural soils continues to be a significant problem in some regions, including parts of Kentucky. Generally, about one-half the non-point source water pollution in Kentucky can be attributed to agricultural activities (16).

Of major concern in surface water pollution are soil sediments, pesticides, and fertilizer nutrients. Nitrate and phosphate have been singled out as major causes of accelerated degradation of lake and stream waters. Nitrate and certain pesticides are potentially hazardous to groundwater quality. The amount of fertilizer N applied by Kentucky farmers increased by about 26% from 1976 to 1981 (16). The same trend has continued nationwide since World War II. As fertilizer N use increases, so does the potential for water pollution from cropland.

In an effort to determine ways to alleviate the potential hazards to water quality of non-point source pollution from cropland, we are investigating NO_3^- leaching as well as soil and plant characteristics related to runoff and erosion in a novel cropping system employing legume winter cover crops.

Legume cover crop systems: Three important features of modern corn production are: (a) large amounts of commercial N fertilizer are used, (b) corn requires large amounts of water for high yields, and (c) high rates of soil erosion may occur with conventional tillage on certain soils. No-till corn production with a mulch cover is usually advantageous over conventional till, with regard to the latter two features (5). However, these benefits are dependent to a large extent upon a winter cover crop that can be chemically killed in the sping to provide the mulch. Small grain crops have traditionally served in that role.

One of the greatest challenges in producing no-till corn is managing the nitrogen. Fertilizer N may be lost by leaching and denitrification and immobilized by high C:N ratio organic matter to a greater extent in the no-till system than under conventional tillage (2, 12, 13). In some cases, these effects have resulted in higher rates of N fertilizer being recommended for no-till. In doing so, the potential for NO_3^- pollution of water resources is increased and production cost is increased, since N fertilizer represents one of the greatest costs in corn production.

If a legume winter cover crop were used to form the mulch for no-till corn, it would provide the same benefits as small grains and provide some biologically fixed N as well. Additionally, immobilization of available N that usually accompanies decomposition of a small grain mulch (12) would not likely occur with a legume mulch. The results would be greater use-efficiency of N and less commerical N fertilizer needed.

Research in Kentucky and other states (3, 4, 9) has shown that a legume winter cover crop adapted to the climate of the area can provide a substantial amount of biologically fixed N to a subsequent no-till corn crop. Based on yield responses, estimated amounts equivalent to from 80 to 125 kg/ha fertilizer N have been commonly reported. In Kentucky, Delaware, and New Jersey, hairy vetch has performed best, but crimson clover has been the most prolific producer of N in Georgia and other areas of the Southeast (personal communication with W.L. Hargrove, U. of Ga.).

In our studies, hairy vetch usually produces about 3 to 5 Mg/ha dry matter above ground each winter and spring. This contains about 120 to 200 kg/ha N. When killed in the spring, it forms an excellent mulch cover that would be expected to increase water infiltration, drecrease runoff, decrease evaporation losses, increase soil organic matter, and help provide protection from soil erosion.

Work in Kentucky by Utomo (14) showed that a hairy vetch cover crop, compared to corn residue cover, resulted in a significant increase in soil organic matter in the 0 to 7.5-cm soil depth. There was greater soil water content during the first two months of the corn growing season after the hairy vetch was killed. However, a preliminary study by Ebelhar et al. (3) in that same field in 1980 showed soil water contents under hairy vetch cover crop and corn residue at corn planting (May 16) to be 16.6 and 18.0%, respectively, in the 0-to 7.5-cm depth. In the 7.5-to 15- and 15-to 30-cm depths, soil water values were 17.1 and 16.7%, respectively, under hairy vetch and were 20.3 and 22.3%, respectively, under corn residue.

Studies in progress suggest that legume cover crops act as slow-release N fertilizer. Legumes, after being killed at the time no-till corn is planted, slowly decompose, requiring 60-90 days or longer to mineralize most of the N they contain (J.J. Varco, Dept. of Agronomy, University of Ky., unpublished data). In another study, Huntington et al. (7) observed that the release of legume N to plant available forms occurred slowly but continuously as the subsequent corn crop grew. Based on these observations, it seems plausible that during the early growing season, when conditions for leaching are most favorable, less N would be lost from cover crop systems because less is present as NO_3^- compared to a N fertilized soil.

One interesting result of previous trials with legume cover crops has been that even with recommended rates of N fertilizer, corn yields are greater with cover crops than without them (3). This may be due to the mulch providing water conservation during late summer, better weed control, or a number of other factors (6). A possible beneficial component, which has been examined in this project, is enhanced soil structure with legume cover crops. This could result from more extensive rooting or from greater soil organic matter additions by the legumes. Casual observations support the probability of improved structure, but it has to be quantitatively documented.

Although, the focus in most of these studies has been on agronomic considerations, particularly N uptake and yield of crops, we also recognize the importance of considering the environmental impact of new or modified cropping systems. In this work we address the question of how legume cover crops influence NO_3^- transport from soils to ground and surface waters, with emphasis on NO_3^- leaching.

In legume cover crop systems, we hypothesize that NO_3^- leaching from soils to ground water will be minimized because N is released slowly from the decomposing proteins of the killed legume cover crop. In contrast to inorganic N fertilizer, legume N is not in a leachable form early in the season when soils are wet and leaching potential is greatest.

Chapter II - Research Procedures

Experimental sites: Studies were conducted on a Maury silt loam soil (Typic Paleudalf, fine-silty mixed, mesic). The Maury is a deep well-drained soil formed in residuum of phosphatic limestone. Slopes at this site range from 2 to 6%. The first set of experimental plots was established in 1977 (and so will be referred to as the '77 plots). This experiment involves growing corn under two tillage systems - plowed and no-till - varying commerical fertilizer N rates, and different winter cover crop treatments. The cover crop treatments of interest for this study were: no cover crop, rye cover crop, and hairy vetch cover crop.

The second set of experimental plots was established nearby in 1985 (referred to as the '85 plots). This experiment included N fertilizer rates of 0, 85, 170 and 225 kg N/ha. Cover crop treatments were: no cover crop grown, hairy vetch grown but clipped (5cm ht.) and removed, hairy vetch grown and left, and hairy vetch supplemented with the clippings from the second treatment. Cover crops were seeded in early autumn and killed with herbicide as corn was planted. Corn for all treatments was planted by no-till methods (without soil disturbance).

Infiltration rate: Two concentric cylinders were forced into the soil to a depth of approximately 25 cm forming double rings approximately 50 and 75 cm in diameter. Double rings were installed in the '77 plots. Two suction probe lysimeters had been installed to depths of 30 and 90 cm in the center of each ring. Four replications of the two treatments annually receiving either 100 kg N fertilizer/ha without cover crops or 50 kg N/ha with hairy vetch cover were sampled. Steady state ponded infiltration rate was determined by flooding inner and outer rings to a depth of 5 to 10 cm with water, then periodically measuring the rate of fall in the water surface of the inner ring until this rate became constant. Suction was maintained on the suction probe lysimeters during the infiltration experiment, and water samples were collected and analyzed for NO_3^-.

Suction probe lysimeters: These consisted of ceramic cups sealed to the end of PVC pipes. A hole to 30 or 90 cm depth, equal in diameter to the pipe, was made in the soil and partially filled with a soil slurry then the probe lysimeter was installed. The cap of the tube held two smaller tubing lines, one of which was used to collect soil solution from the ceramic cup, the other was used to apply a vacuum to the sampler. Samples were collected when it was possible during the 1985 growing season, i.e., following rainfall events or infiltration tests.

Drum lysimeters: Lysimeters were also constructed from 55 gallon drums. A sloped bottom and an outlet tube were installed in the drums. Sixteen of these drums were placed in 2 rows in a trench constructed by backhoe. The drum tops were then 5 to 10 cm above the natural soil surface. A wooden frame was constructed between the two rows of drums in the trench allowing access to the outlet tubes and making it possible to backfill soil around the drums. Soil was placed in the drums so as to preserve the natural sequence of soil horizons. Construction was completed in the winter of 1985. In the spring of 1986 drums were amended either with 100 kg/ha N fertilizer or with an approximately equal quantity of N as hairy vetch. Half of the barrels received ^{15}N enriched fertilizer or vetch. Corn was planted in and around the drums.

Transformations of legume and fertilizer nitrogen: The ^{15}N-labeled hairy vetch used in this study was grown under field conditions each spring in submerged 25 x 25 cm plastic pots with the bottoms removed and filled with one part vermiculite and two parts sand and buried to the rim in the soil. Enriched $K^{15}NO_3$ was added to the pots of actively growing vetch at a rate of 30 kg N ha^{-1} about every 2 weeks until 120 kg N ha^{-1} had been applied. The last application was made about 2 weeks before harvesting the vetch. One day prior to applying the treatments all of the above-ground portion of the hairy vetch was removed, cut into approximately 5 cm sections and mixed throughly. The ^{15}N-labeled hairy vetch added to each core was determined on a fresh weight basis.

Soil cores (5 x 20 cm) were obtained from the '77 plots prior to corn planting using a soil core sampler lined with a 5 x 24 cm plexiglass tube and driven into the ground by a slide-hammer. Each soil core contained within a plexiglass tube was trimmed at the bottom to 20 cm in length. The bottom of each tube was then enclosed with fiberglass screen fastened with duct tape.

To simulate plowing (conventional tillage) each soil core was pushed out of the tube and pulverized by hand, returned to the tube, and tamped until the length was again 20 cm. When hairy vetch was to be added to the conventional tillage (CT) soil, about 100 gm of soil was first placed in the tube and then the residue was thoroughly mixed with the remaining soil before adding it to the tube. For the no-tillage (NT) treatment, the residue was simply placed on the soil surface of each core.

Fertilizer N in solution containing enriched $^{15}NH_4{}^{15}NO_3$ was applied to the corn residue treatment cores in 1984, and $(^{15}NH_4)_2SO_4$ was applied in 1985.

The prepared cores were returned to the appropriate plots in the field one day after corn planting and placed flush with the soil surface. Soil samples were taken from the plots each year at corn planting at 0- to 10-, and 10- to 20-cm depths to obtain the residual amount of NH_4^+ and NO_3^-.

In 1984, whole cores were removed 30, 50, 90, and 120 days after they were placed in the field. In 1985, cores were removed 15, 30, 45, 60, and 75 days after they were placed in the field. Cores removed from the field were stored frozen until processed and analyzed.

For NT cores the residue was removed from the soil surface, while for CT cores residue remains were meticulously removed from the soil and any soil adhering to the residue was carefully brushed off. Residue pieces larger than 1 mm were separated from the soil using a sieve. Residue which passed through the 1 mm sieve was separated from the soil by floating it in CCl_4.

A 20-g portion of moist soil was extracted by shaking for 1 h with 200 ml $\underline{M}$ KCl. An aliquot of each sample extract was analyzed for NH_4^+-N and NO_3^--N by the procedures of O'Brien and Fiore (11) and Lowe and Gillespie (8), respectively. Gravimetric water was determined on each soil sample to correct for field moisture content. To determine the ^{15}N atom percent of the inorganic N fraction enough soil was extracted with 1 $\underline{M}$ KCl to obtain 0.5 mg of N. The extract was then steam distilled with MgO-Devarda's allow (1) and the distillate was collected in 0.5 $\underline{M}$ HCl. Soil organic N and residue N content were determined using a micro-Kjeldahl method (1). Prior to digestion the inorganic N fraction was removed by extracting three times with 1 $\underline{M}$ KCl. The digest was steam distilled and the N was collected as NH_4Cl for later determination of the ^{15}N atom percent.

The ^{15}N atom percent of the inorganic and organic soil N fractions and of the residue N were measured with a Consolidated Electodynamics Corporation (CEC) 21-614 mass spectrometer using a freeze-layer technique whereby NH_4^+ is converted to N_2 with NaOBr (15).

Chapter III - Data and Results

Infiltration rate: We had hypothesized that the growth of legume cover crops would increase soil organic matter content, improve soil structure and so increase water infiltration into soil. To test this hypothesis we attempted to measure steady state ponded infiltration rates. The treatments chosen for comparison either had no winter cover crop or had grown a winter cover crop of hairy vetch for 7 years. In both cases corn was the summer grain crop. These were no-till soils; there was no plowing or disturbance of the soil.

Results for an infiltration test conducted during the corn growing season of 1985, after the vetch had been killed and was largely decomposed, are shown in Table 1. The mean infiltration rate was in fact slightly greater for the soils wich had grown winter legumes. However, inspection of the individual replications for these treatments makes it obvious that this difference is not satistically significant. This extent of spatial variability within treatments was not anticipated. Clearly it will not be possible to obtain meaningful treatment comparisons from these data. Since the variability is apparently a property of the system, rather than the technique, it will probably be impractical at this site to evaluate cover crop effects on soil structure and infiltration rates using any available technique.

Table 1: Steady state ponded infiltration rate of soil with and without hairy vetch cover crops.

	Block				
Treatment	I	II	III	IV	Mean
		cm/hr			
No vetch	15.5	3.8	3.0	6.0	7.1
With vetch	9.5	4.5	12.2	9.0	8.8

Suction probe lysimeters: Similar problems were encountered with attempts to evaluate NO_3^- leaching by this approach. This technique has been widely used by others and generally has provided at least a relative indication of NO_3^- transport at depth in the soil profile. Total quantities of NO_3^- collected from these probes at our site are shown in Table 2. Once again, inspection of the variability among replications indicates that these results provide no meaningful comparison of treatment effects. Nitrate concentrations, as opposed to quantities, were also highly variable and provided no useful indication of a possible difference between treatments (data not shown). Volume of soil solution which could be collected also contributed to the variability of the data in Table 2. On many sampling dates several of the 30 cm probes gave no sample, in spite of recent precipitation. Failure to collect soil solution indicates that the soil surrounding the ceramic cup was too dry to release free water at the tension provided by the vacuum within the sampler.

Table 2: Total NO_3^- collected from suction probe lysimeters from June through August, 1985.

		Block				
Depth	Treatment	I	II	III	IV	Mean
cm				µg N		
30	Vetch + 50 kg N	208	537	15,250	4,035	5,008
	No vetch + 100 kg N	4944	0	7,094	0	3,009
90	Vetch + 50 kg N	379	172	1,120	21	423
	No vetch + 100 kg N	86	208	1,498	2,267	1,005

Nitrate concentration in deep soil samples: These measurements were made as one attempt to overcome the problem of variability documented above. Soil samples were collected periodically from the '85 plots. At least 8 cores per replicate plot were composited to minimize variability. Soil was sampled to a depth of 90 cm. (This is a relatively shallow soil in which most plant rooting and nutrient extraction occurs in the top 30 cm and is very limited below 90 cm).

Results are shown in Table 3. These data do provide an indication that NO_3^- is being transported through the profile. At the surface, concentrations were maximal on the first sampling date after fertilizer application. In the next depth increment concentrations peaked 3 to 6 weeks later, while concentrations continued to increase through the season at the greatest depth sampled.

While variability was much less than observed with the previous techniques it was still a problem. Coefficients of variation were typically 20 to 60%.

With few exceptions significant differences between treatments were not commonly observed. In the surface 30 cm concentrations of NO_3^- were intially greater in the plots without cover crops. This would be expected since more inorganic N was added to these plots and the conversion of vetch N to NO_3^- would require some time. After the first month surface NO_3^- was similar for the two teratments. At greater depths there were no consistent differences. Therefore, these results do not provide any evidence that NO_3^- leaching is affected by cover crop treatment.

Table 3: Distribution of nitrate in soil with hairy vetch plus 85 kg N/ha fertilizer or with 170 kgN/ha fertilizer only.

		Nitrate concentration by date					
Depth	Treatment	5/30/85	6/20/85	7/8/85	12/23/85	3/25/86	4/25/86
cm		Mg N kg^{-1} dry soil					
0-30	Vetch + 85kg ha^{-1}N	32.9	27.7	11.2	5.1	7.9	12.9
		(7.3)*	(5.6)	(3.6)	(0.6)	(2.0)	(5.6)
	170 kg/ha^{-1}N only	44.7	39.1	12.4	3.7	8.6	11.5
		(12.5)	(2.5)	(2.8)	(1.0)	(1.8)	(4.2)
30-60	Vetch + 85kgha^{-1}N	3.4	9.8	4.8	3.9	4.4	11.4
		(1.4)	(2.3)	(2.8)	(0.9)	(1.0)	(2.3)
	170 kg/ha^{-1}N only	3.8	6.0	6.8	3.7	4.8	6.7
		(2.9)	(5.1)	(2.7)	(1.4)	(0.8)	(2.8)
60-90	Vetch + 85kg/ha^{-1}N	0.5	0.8	3.5	4.1	4.8	8.6
		(0.3)	(0.7)	(1.3)	(0.9)	(1.7)	(1.3)
	170 kg/ha^{-1}N only	1.4	1.8	3.7	3.1	3.4	8.3
		(1.2)	(1.3)	(2.1)	(1.1)	(0.3)	(2.8)

*Standard deviations are given in parentheses below the man values.

Drum lysimeters: It became apparent during the first year of this project that the methods described above would not be adequate to satisfy our objectives. To solve this problem we began construction of contained lysimeters, large enough to grow plants in, late in the project. Of course, time was inadequate to complete measurements before termination of the project. We anticipate that the useful life of these lysimeters will be 3 to 5 years and we will continue to collect data throughout this period. Final results will be made available in the future.

Early results indicate that this approach will be useful in studying leaching in the cropping systems of interest. Reproducible, consistent differences have been observed in volume of water leached and total N leached. Water volumes have been significantly greater in hairy vetch treated lysimeters (Table 4). This can be attributed to smaller evaporative water loss in the vetch treated barrels due to the well-documented mulch effect.

Since water movement through the profile has been greater in vetch treated barrels, it is not surprising that total N transport has also been greater (Table 5). Nitrate concentrations have not been significantly different (data not shown).

Table 4: Volume of leachate collected from drum lysimeters treated with fertilizer or hairy vetch.

	Volume of leachate by date			
Treatment	5/30/86	6/4/86	6/9/86	6/16/86
		ml/lysimeter		
Fertilizer	1669	599	6	0
Hairy vetch	1535	1008	228	124

Table 5: Nitrate leached from drum lysimeters treated with fertilizer or with hairy vetch.

	Total N leached by date			
Treatment	5/30/86	6/4/86	6/9/86	6/16/86
		mg NO_3^- -N/lysimeter		
Fertilizer	8.6	4.1	<0.1	0
Hairy vetch	9.8	6.6	1.2	0.6

These early results suggest that leaching losses will be greater in systems with vetch. However, it is important to appreciate the limited nature of data collected to this time. This will be considered in the next chapter.

Transformations of legume and fertilizer nitrogen: Losses from the soil of N added as fertilizer vs. hairy vetch can be estimated from these experiments. It should be pointed out that gaseous losses by microbial denitrification cannot be distinguished from leaching losses to ground water using this technique. Also we have not measured labelled N remaining in the soil but below the depth of the cylinder. Thirdly, these experimental systems do not contain growing plants, in contrast to the drum lysimeters, and so are somewhat unrealistic.

As expected, more of the labelled N was found in the inorganic pool for fertilizer treatments than for vetch treatments (Table 6), at least during the first 60 days. More inorganic labelled N was present in the plowed compared to the no-till systems. Inorganic N would be susceptible to leaching loss, in contrast to organic forms. This indicates a greater potential for NO_3^- leaching of fertilizer N than of vetch N.

Table 6: Effects of tillage on the recovery of N from ^{15}N-labelled $(NH_4)_2SO_4$ and hairy vetch as soil inorganic N in 1985.

		Sampling day				
N source	Tillage	15	18	45	60	75
		%				
$(NH_4)_2SO_4$	NT	57	18	22	14	9
	CT	78	38	44	32	8
Hairy vetch	NT	12	4	7	8	13
	CT	47	15	26	23	17

A greater percentage of added labelled N was immobilized in the soil organic fraction for vetch relative to fertilizer (Table 7). This was most apparent after 75 days in the soil. In general plowing of the soil increased tie up in the immobile, non-leaching organic fraction. These results also suggest a reduced potential for leaching in vetch systems.

Table 7: Effects of N source and tillage on N immobilization in 1985.

		Sampling day	
N source	Tillage system	15	75
		%	
Fertilizer	NT	15	15
	CT	22	18
Hairy vetch	NT	11	29
	CT	38	31

Table 8 shows total recovery of added N, that is the sum of inorganic N, soil organic N and N remaining in residues. The N not recovered is presumed to be lost by leaching or denitrification. Losses were considerably greater with fertilizer than with vetch after 75 days. Little N was lost during the first 15 days and there was no remarkable effect of N source. Plowing of the soil did increase recovery, or reduce losses.

In this well-drained soil N leaching is likely to be a more important mechanism of N loss than denitrification. These results indicate that leaching loss was greater when fertilizer was the N source compared to vetch as the N source.

Table 8: Effects of N source and tillage on total ^{15}N recovered in 1985.

N source	Tillage system	Sampling day 15	Sampling day 75
		%	%
Fertilizer	NT	71	22
	CT	97	23
Hairy vetch	NT	77	64
	CT	100	53

Chapter IV - Conclusions

The methods which were to be used to accomplish our objectives have been shown to be inadequate at this site. The primary reason is the extreme spatial variability. This makes it impractical to determine treatment differences with any feasible number of samples. This variability suggests that water and NO_3^- flux from the soil is heterogeneous in space. Previous research in this department does in fact indicate extensive macropore flow in this soil. Simply stated, much of the water and the solutes in it flow down a few holes, cracks or channels through the soil. Under these conditions it might be expected that suction probe lysimeters, which collect water from a small soil zone, would fail to provide a representative sample. In the extreme case water would not flow in the sampling zone and no solution would be collected. This occurred frequently in our experiments.

Another difficulty with these approaches is that they provide single point measurements, in both a temporal and spatial sense. Therefore they do not directly assess flux of water or NO_3^-.

Enclosed lysimeter systems resolve these difficulties primarily by allowing collection of all flow from a defined area but also by sampling a larger volume of soil. An additional advantage is that by employing ^{15}N labelled amendments it will be possible to distinguish soil-derived from fertilizer-derived NO_3^-. Disadvantages of these systems are that soil disturbance is required initially and that construction is costly and time consuming. With the time and resources available during this project we were able to complete construction of 16 drum lysimeters. We have collected some data and we are confident that this approach will work. Data collection will continue for at least 2 more years.

Early results suggested that NO_3^- leaching was greater with vetch amended soil than with fertilizer amended soil. However, we do not expect this relationship to remain constant throughout the experiment. Because the vetch organic material reduced evaporation during late spring and early summer, more water moved through the profile. We anticipate that differences in evaporative water loss will be minimal as the corn canopy closes and the mulch decomposes. Furthermore it is predicted that growth of the cover crop during late fall and early spring will deplete soil water and soil NO_3^-, greatly reducing the potential for NO_3^- leaching at that time of year.

A study of the decomposition and transformations of vetch N using ^{15}N labelled plant material was successfully completed. The results indicate that vetch N, in comparison to fertilizer N, leads to lower concentrations of soil inorganic N and greater immobilization of added N in soil organic matter. This would reduce the potential for NO_3^- leaching. After 2 to 3 months in soil, total losses from a fertilizer N source were greater than from a vetch N source. This could be a result of greater NO_3^- leaching or greater gaseous losses through denitrification. On this soil, leaching is a more plausible loss mechanism.

Soil management and cropping practices will certainly have an effect on the quantity of NO_3^- lost by leaching from agricultural soils. This will have a significant impact on NO_3^- loading in ground and surface waters. In this project we have begun to investigate the potential for legume winter cover crops to reduce NO_3^- leaching. At this time our results do not provide a clear and definite answer. It is to be expected that these effects may be dependent on seasonal, climatic and soil factors. Continued observations using the lysimeters already constructed will help to reveal these relationships and lead to the development of feasible agricultural systems which minimize adverse effects on water quality.

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