Using Winter Cover Crops to Recycle Nitrogen and Reduce Leaching

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Introduction

Farmers and their advisors are becoming increasingly aware of the interconnections between the use of nitrogen (N) in agriculture and ground water quality. Farmers face a difficult task as they seek to balance the competing goals of maintaining farm profitability, by ensuring an adequate supply of N to the crop, yet avoiding excessive N rates that could degrade groundwater quality. A farmer has several tools at his disposal to work toward this goal, such as: i) adjusting the rate of N to reflect the soils ability to supply N, the farmers expected yield, the previous crop, and recent manure additions; ii) adjusting the time of N application to harmonize with the crop N demand; iii) adjusting the N placement to increase crop N uptake; and iv) modifying the cropping system to take advantage of N conserving crops. This paper will focus on the last tool by discussing the use of winter cover crops to retain N within the soil-crop system and thereby reduce nitrate leaching.

Cover Crops in General

To understand how cover crops can influence nitrate leaching into ground water one must first understand the leaching process in a humid climate such as the Southeastern U.S. Soil nitrate is vulnerable to leaching because it is water soluble and it is not held by soil clays. Therefore, nitrate readily moves through soil with percolating water which ultimately feeds into ground water or surface water. In the Southeast the yearly pattern of percolation is determined by the difference between water inputs (precipitation plus irrigation) and water use through evaporation and crop transpiration. Figure 1 summarizes the estimated monthly percolation for two locations in the Southeast along with the estimated dry matter production rates for corn and a typical grass cover crop. Most of the leaching occurs in December through April (see Figure 1) with little or no percolation occurring in the warm summer months when corn is rapidly growing and crop water use is high. Note that the dry matter production cycle of a typical grass cover crop overlaps with the leaching season in the Southeast. Growing a winter cover crop can reduce nitrate leaching by i) utilizing water for growth and thereby reducing the quantity of percolation, and ii) by absorbing nitrate N to meet the nutritional needs of the cover crop. Winter cover crops can also supply N to the next crop and reduce soil erosion by providing plant cover of bare soil.

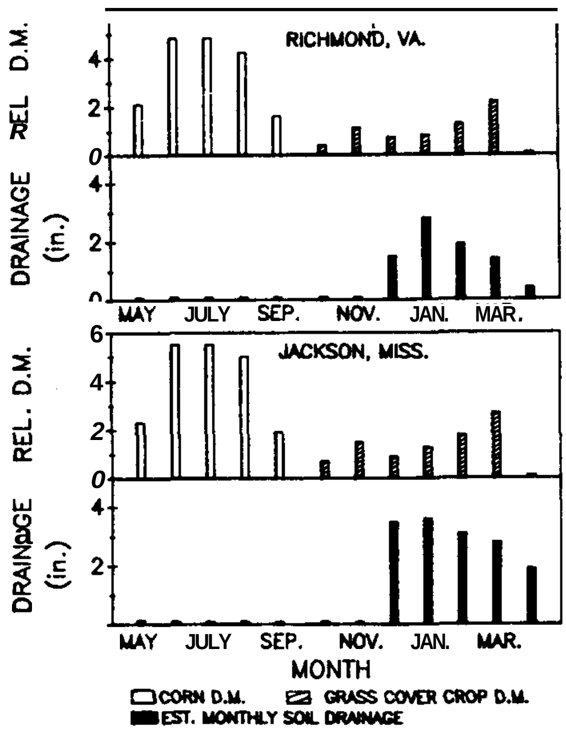

Figure 1. Estimated monthly drainage (solid), corn relative dry matter production (open), and grass cover crop relative dry matter production (cross hatched) at two Southeastern U.S. locations (van Bavel, 1959; Van Bavel and Lillard, 1957).

Cover Crops to Conserve Nitrogen

Recent Field Studies With Nitrogen

The winter cover crops which have been successfully used in the Southeast can be generally classed as legumes or grasses. The legumes have been studied most intensively because of their clearly demonstrated superiority in supplying N to the next crop. For example, typical fertilizer N credits for legumes range from 70 to 100 lbs N/acre for hairy vetch and from 50

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to 80 lbs N/acre for crimson clover. Grass cover crops, on the other hand, generally supply little N to the next crop and often require an additional 10 to 25 Ibs of fertilizer N per acre to compensate for N used during residue decomposition (Ebelhar et al. 1984; Hargrove, 1986; Holderbaum et al. 1990; Mitchell and Teel, 1977; Wagger, 1989). However, if one of our goals is to use winter cover crops to utilize left-over fertilizer N and thereby reduce N leaching, then we should re-examine the ability of legumes vs grasses to achieve this recycling objective. Accordingly, the ARS Beltsville soil N research group, in cooperation with the University of Maryland, conducted a two year field experiment from 1986-1988 on an Atlantic Coastal Plain silt loam soil (near Salisbury, MD) to directly measure the ability of grass vs legume winter cover crops to utilize fertilizer N applied to a preceding corn crop.

The above objective was accomplished by growing corn and adding isotopically labelled fertilizer N (N-15 depleted) as ammonium nitrate at sidedressing, allowing the tagged fertilizer to distribute throughout the corn root zone during summer, and then planting fall cover crops. A direct field measurement of the cover crops ability to recover corn fertilizer N was then made by measuring the uptake of tagged fertilizer in the above ground dry matter of the various cover crops during the following spring. Allowances were also made for tagged N in the root system by reviewing the scientific literature and estimating the percentage of total plant N accounted for in the root system of each cover crop. An intentionally high rate of fertilizer N was applied to the corn (300 Ibs N/acre) in order to ensure an adequate pool of labelled N in the fall and to assess the capacity of the various cover crops to retain N within the soil-crop system. The average recovery of corn fertilizer N by the various cover crops is shown in Figure 2, expressed as a percentage of the labelled mineral N which was present in 32 inches of soil at the time the cover crops were planted. Thus, if the soil contained 100 lbs/acre of corn fertilizer N in the fall and the cover crop contained an estimated 55 Ibs/acre of fertilizer N in mid-April, then the percent recovery would be 55%. The data of Figure 2, clearly show that grasses are superior to legumes in recovering corn fertilizer N. Cereal rye (variety 'Abruzzi') accumulated about 60% of the left-over corn fertilizer N at mid-April, which is its normal kill date in Maryland. Rye accumulated an average of 0.8 percent of the residual corn fertilizer N per day between the breaking of winter dormancy (mid-March) and mid-April. The decline after mid-April is due to N loss associated with the shift to reproductive growth (leaf loss, ammonia loss, lodging). Annual ryegrass (variety 'Marshall') was less aggressive than cereal rye in its early spring growth but by mid-May it had recovered about 53% of the corn fertilizer N. The hairy vetch, crimson clover (variety 'Dixie'), and the native weeds (chickweed) recovered not more than 10% of the corn fertilizer N. Nonetheless, the legumes contained an average of 150 Ibs of total N (fixed N plus soil N plus residual fertilizer N) per acre compared to an average of 80 Ibs N/ac in the grasses. The legume covers were therefore vigorous and healthy but relied more on N fixation to meet their N needs than on recycling fertilizer N (Shipley and Meisinger, 1988).

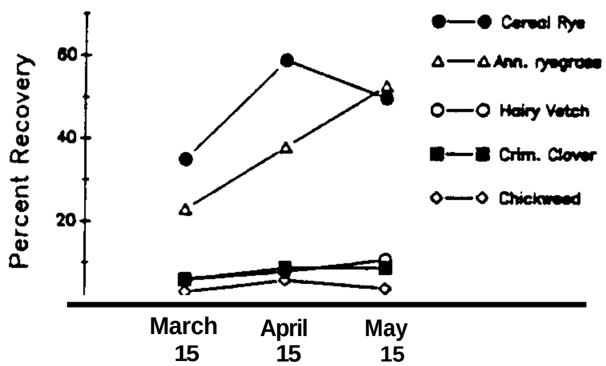

Figure 2. Average percent recovery of residual corn fertilizer N (N-15 labelled) by various winter cover crops in Maryland (Shipley and Meisinger, 1988).

The superior N retaining ability of grass cover crops should also translate directly into lower nitrate concentrations in percolating water. Shallow water table wells were installed in field plots of the above cover crop study and recent percolate draining into these wells was sampled throughout the spring of 1988. The average spring nitrate-N concentrations below cover crop plots corresponding to the data of Figure 2 were: 12 ppm below cereal rye, 18 ppm below hairy vetch, and 17 ppm below weeds (Meisinger and Shipley, 1989). Therefore the greater recovery of corn fertilizer N with cereal rye was also translated into lower nitrate-N concentrations in drainage water.

Lysimeter Studies with Cover Crops

Further confirmation of lower nitrate leaching under grass cover crops can be found in the older lysimeter data from the Southeast. A four year lysimeters study in Alabama was reported by Jones in 1942, which used 30 inch dia. by 30 inch long filled lysimeters and three soil types. Soybean residues containing 75 lbs N/acre were spaded into the soils each October and rapidly decomposed producing nitrate-N. The annual nitrate leaching was determined without cover crops and with winter cover crops of oats or hairy vetch. Results from this study (Table 1) show that the oat cover crop was very effective in reducing leaching with average annual leaching being about 13% of the no-cover treatment. In contrast, the hairy vetch cover had little or no effect on N leaching compared to the control. There was also a marked effect of soil type in this study with the fine textured clay loam soil losing very little N through leaching, compared to the coarse textured soils in which leaching was a major loss mechanism. Conserving N with cover crops should therefore have its largest impact on coarse textured soils that are prone to leaching.

Table 1. Average annual N Leaching losses (Ib N/acre) from lysimeter in Alabama as affected by winter cover crop treatment and soil type (Jones, 1942).

Winter Cover Crop Treatment	Soil Type: Norfolk sa. lm.	Hartsells f. sa. lm.	Decatur cl. lm.
No Cover	51 (-)	38 (-)	5 (-)
Oat Cover	11 (22%)[1]	6 (16%)	0 (0%)
Hairy Vetch Cover	45 (88%)	39 (100%)	5 (100%)

[1]N leached as a percentage of the No cover treatment.

Another long-term lysimeter study (11 years) was reported from Kentucky by Karraker et al., 1950; using 22 inch dia. by 26 inch long lysimeters of disturbed Maury silt loam soil. Annual seedings of Korean Lespedeza added about 180-210 Ibs N/acre to each lysimeter through N fixation. Most of the fixed N was removed through harvested crops, but about 60 Ibs N/acre was added to the lysimeters annually in October through root plus crown residues. These residues decomposed rapidly and liberated N which was vulnerable to leaching. On one set of lysimeters the Korean Lespedeza was not followed by a winter cover crop, but on another set, a rye cover crop was grown. The average drainage, nitrate concentration, and mass of N leached from these lysimeters during the year is summarized in Table 2. It is apparent that the rye cover crop did an excellent job of reducing N leaching. The rye cover crop reduced both the mass of N leached (from 58 to 15 Ibs N/acre) and the nitrate concentration of the leachate (from 16 ppm to 4 ppm) compared to the no-cover lysimeters. The rye cover crop achieved these N leaching reductions primarily through N uptake during the winter and early spring leaching season. Rye also reduced drainage volumes somewhat, but this was not of major importance in this study compared to direct N uptake by the rye.

Table 2. Average N Leaching dynamics during the year from Kentucky lysimeters containing Maury silt loam as affected by cropping system (Karraker, et al., 1950).

Cropping Syskn Description	N Leaching Variable Observed (units)	Winter Jan Feb March	Spring April May June	Svmrnrr July Aug Sept	Fall Oct Nov Dec	Yearly Total
Precipilation	Quantity (in).	11.2	120	11.3	8.1	42.6
Korean	Drainage (in.)	9.2	3.9	1.0	2 0	16.1
Lespedeza	N Leached (lb/ac)	39.0	10.0	1.5	8.0	58.0
No Cover	NO_3 Conc. (ppm)	18.7	11.3	6 6	17.7	15.9
Korean	Drainage (in.)	9.0	3.0	1.0	2 2	15.2
Lespedeza	N Leached (lb/ac)	7.0	0.5	1.0	6.5	15.0
Rye Cover	NO_3 Conc. (ppm)	3.4	0.7	0.4	13.1	4.4

Summary and Practical Applications

The above labelled-N results from our direct field measurements of cover crop utilization of corn fertilizer N, and the earlier lysimeter work in other areas of the Southeast, clearly demonstrates that grass cover crops are superior to legumes in recovering previously applied nitrogen. Grass covers have the potential to markedly increase N retention within the soil-crop system and thereby reduce N leaching into ground water. However, grass cover crops can also have negative effects on the next crop by requiring extra fertilizer N (usually about 10-20 Ibs N/acre) and by using water in the late spring which could reduce germination.

Our goal as applied agriculture researchers should therefore be to integrate current knowledge on grass cover crops into modern cropping systems to improve their capacity to conserve N. Such systems could include i) timely killing of grass cover crops to maximize recycling of fertilizer N and minimize adverse effects on the next crop, ii) using grass-legume mixtures as cover crops to incorporate some of the benefits of each type of cover, and iii) evaluating a broader range of grass cover crop genotypes to select improved types for N conservation. Policy makers can also speed the farmer acceptance of cover crop systems by devising appropriate cost-share programs or other incentives.

The use of winter cover crops to conserve N and reduce leaching is an old practice which has not been exploited in modern agriculture systems. It is time to incorporate this practice into modern conservation tillage systems of the Southeast.

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