Soil Nitrogen Recovery by No-Till Corn Using Nitrogen Balance and Isotope Methods

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Fertilizer nitrogen (N) efficiency in no-till cereals production has proven to be reduced at lower N rates relative to conventional tillage using current fertilization practices. Some of the processes that appear to induce the additional losses are denitrification, volatilization and, perhaps most importantly, immobilization. In a typical no-till situation the layer of organic residue that accumulates on the surface of the soil is responsible for accentuating these processes. This type of residue generally has a high C:N ratio that induces inorganic N assimilation into organic N.

One way of measuring N fertilizer efficiency is to evaluate plant N uptake in quantitative terms. The amount of fertilizer N taken up depends on various factors, such as the type of crop, root distribution, type and amount of fertilizer, N distribution in the profile, temperature and rainfall. (Broadbent 1984).

The uptake of N coming from fertilizer can be measured by different methods. A popular one is the difference or N balance method which makes the assumption that the N derived from fertilizer is equal to the total uptake of the fertilized crop less the N taken up by the unfertilized control. Another method. and possibly the best, is the use of isotopically labeled N fertilizer to determine the fraction of total plant N resulting from fertilizer addition. When the two aforementioned methods are compared, results may or may not be equal. The purpose of this paper is to share the authors' observations when comparing these two procedures on two no-tillage corn trials and to suggest an operative mechanism that explains our observations. The field experiments were conducted primarily to evaluate plant uptake of N fertilizer and fertilizer N efficiency for different methods of N fertilizer placement.

The experiments were conducted on two different soils, a Donerail silt loam (Typic Argiudoll) located near Lexington, Ky. and a Pope silt loam (Fluventic Dystrochrept) at Quicksand, Ky during 1983 and 1984. The Pope

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soil, though well drained, contains a subsurface water table. All residues were left on the surface and a winter annual cereal cover crop was grown on the Donerail soil.

On the Donerail soil three different methods of N placement at planting time, including broadcasting, surface banding, and subsurface band placement, were evaluated against an unfertilized control. All treatments but the control received one application of 112 kg N/ha as ^{15}N depleted ammonium nitrate at planting.

For the Pope soil the N placement treatments were broadcasting versus subsurface banding. Both treatments received an application of 90 kg N/ha as ^{15}N depleted ammonium nitrate. An unfertilized control was included as well.

For both soils the subsurface band treatment consisted of a trench 3 inches wide and 3 inches deep located 3 inches to the side of the corn row. The fertilizer was applied to the bottom of the trench and covered. The surface band consists of a 3 inch wide fertilizer application to the soil surface 3 inches to the side of the corn row. Planting dates varied according to spring time conditions (Table 1). Whole plant tissue samples were acquired just prior to harvest at both locations (Table 1) and separated into grain and stover for analysis.

Table 1. Planting and harvest dates and growing season weather data from 1983 and 1984 at both locations.

Location	Soil Series	Year	Date of Planting	Date of Harvest	Rainfall June	Rainfall July	Rainfall Aug.	Average Daily Temp. June	Average Daily Temp. July	Average Daily Temp. Aug.
					-----cm-----			-------°C------		
Lexington	Donerail	1983	31 May	5 Oct.	8.6	2.6	4.1	22.1	26.6	21.2
		1984	22 May	26 Sept.	12.3	9.4	3.4	24.4	22.1	24.4
Quicksand	Pope	1983	5 May	12 Oct.	5.2	5.8	12.5	22.2	25.5	26.1
		1984	18 May	6 Nov.	1.0	12.8	11.8	23.9	23.3	24.4

Weather station data for the months June–August indicated that the 1983 growing season was generally hotter and drier than that for 1984. The Lexington site was generally drier than the Quicksand site both years. Because of this latter fact a total of 18.0 cm of irrigation water was applied from 15 July to 23 August, 1983 and 3.8 cm on 25 July, 1984 at the Lexington location.

The effect of the ^{15}N depleted ammonium nitrate application for different placement methods was evident when the atom % ^{15}N was determined (Table 2). The atom percentage of ^{15}N decreases as the fertilizer is placed in a concentrated band close to the row. The highest percentage of ^{14}N in harvested plant tissue was found for the subsurface band treatments for both soils and both years.

Table 2. Soil and fertilizer N recovery by no-till corn at both locations for both production years.

Placement Treatment	Total N Uptake	atom % ^{15}N Stover	atom % ^{15}N Grain	Fertilizer N Recovery By: Balance	Isotope	Diff.†	Grain Yield
	Kg/ha	%		Kg/ha			
Donerail - 1983							
Cntrl*	98	0.370	0.373	--	--	--	4830
Brdcst	128	0.289	0.290	30	28	2	5900
Srf Bnd	145	0.250	0.261	47	47	0	6030
Sbsrf Bnd	142	0.240	0.247	44	49	-5	6310
$LSD_{0.05}$		0.024	0.027		$LSD_{0.10}$		1170
Pope - 1983							
Cntrl	43	0.363	0.367	--	--	--	3590
Brdcst	70	0.302	0.287	27	13	14	5850
Sbsrf Bnd	83	0.246	0.242	40	27	13	6880
$LSD_{0.05}$		0.015	0.027		$LSD_{0.10}$		1000
Donerail - 1984							
Cntrl	54	0.365	0.366	--	--	--	4110
Brdcst	110	0.298	0.253	56	29	27	6470
Srf Bnd	110	0.277	0.263	56	30	26	6070
Sbsrf Bnd	140	0.257	0.243	86	43	43	6620
$LSD_{0.05}$		0.035	0.026		$LSD_{0.10}$		980
Pope - 1984							
Cntrl	32	0.365	0.366	--	--	--	3290
Brdcst	88	0.267	0.271	56	23	33	7980
Sbsrf Bnd	95	0.260	0.239	63	31	32	8350
$LSD_{0.05}$		0.015	0.048		$LSD_{0.05}$		1200

† Diff. = Fertilizer N (balance method) - fertilizer N (isotope dilution method) = Fertilizer Induced Soil N Recovery.

Cntrl = unfertilized control; Brdcst = broadcast; Srf Bnd = surface band; Sbsrf Bnd = subsurface band.

Total N uptake for the unfertilized controls was less on the Pope soil as compared to the Donerail soil. Control plot grain yields for the Pope reflected the lower native N supply, averaging 3440 kg/ha. Comparable yields on the Donerail averaged 4410 kg/ha.

Additionally, all the N treatments increased the total N uptake. Banding was generally superior to broadcasting in increasing total N uptake and N fertilizer recovery as calculated by both the balance and isotope dilution method in both soils for both years (Table 2). The data indicate that N fertilizer uptake was improved when the fertilizer was located close the row and was the best when the fertilizer was located below the mulch layer, presumably because immobilization was avoided. Yields were generally improved by subsurface banding, which outyielded broadcast N anywhere from 2 to 18%

Even though the trend for N fertilizer recovery by corn is the same when calculated either by the balance method or the isotope dilution method, the actual recovery was generally very different where both methods were compared. In the Donerail soil the calculated fertilizer recovery by the two methods was essentially equal in 1983 (Table 2). In 1984 the fertilizer recovery by the difference method is double that of the isotope dilution method on this soil.

Fertilizer N recovery by the difference method may be expected to be higher than the isotope dilution method because the fertilized plants can develop a larger root system that can explore more soil (Broadbent, 1984). This could be described as fertilizer induced recovery of soil N. In 1983, N fertilized corn grown on the Donerail soil recovered little, if any, additional soil N. Soil N availability as measured by the control was higher than for any other location-year. A lack of sub-surface soil moisture may have played a significant role as well. Irrigation to the soil surface probably stimulated proportionately equal recovery of soil and fertilizer nitrogen. In 1984 there was not as large a moisture constraint and the application of N appears to have stimulated greater recovery of soil N from the Donerail soil. Yields were not greatly different between the two years.

In the Pope soil the recovery of N fertilizer was larger where calculated by the difference method in both 1983 and 1984, though overall uptake and N fertilizer recovery was greater in 1984. In this case there was not a soil moisture constraint because of the subsurface water table. Yields in 1984 were superior to those for 1983 at this location. Recovery of fertilizer N. as calculated by the isotope dilution method, averaged 26% of that applied for both treatments both years. When comparable treatments are considered, the no-till corn grown on the Donerail soil recovered 33% of the applied N. Fertilizer induced recovery of soil N was quite substantial on the Pope soil and accounted for 15 to 35% of the total uptake recorded at harvest.

Yield increases to subsurface placement over broadcasting were generally much less in 1984 (average + 3.5%) than in 1983 (average + 12.3%). When comparing the two soils the yield response to subsurface placement was greater on the Pope soil (average + 11%) than the Donerail (average + 5%), in keeping with the poorer native soil N supply in the former. The response pattern may be related to a substitution of fertilizer N placed proximal to the developing plant for the native soil N that is acquired when N fertilizer is broadcast. This substitution appears to be most important in dry years. It is interesting to think that a major benefit of N fertilizer is to stimulate recovery of soil N. The data also suggests that subsurface N placement at planting may be more beneficial on droughty soils and/or soils with a diminished capacity to supply soil N.

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