Nebraska Research

Nitrogen Loss from Corn Plants During Grain Fill

By Dennis Francis

Nebraska research has shown that substantial amounts of nitrogen (N) can be lost from corn plants prior to plant maturity. These volatile N losses are not clearly understood and can lead to over-estimation of N losses via leaching and denitrification.

WHILE THE MERITS of N fertilizer for increasing crop productivity are well understood, our knowledge of the various ways N can be lost from the soil-plant system and the associated environmental impacts is fragmented. Some pathways for N loss have been known for decades, while others have only recently been recognized. Calculations for N fertilizer use efficiencies are typically based on the amount of N found in the crop at maturity. It is commonly perceived that maximum accumulation of N by plants occurs at maturity. However, it is more typical for maximum N accumulation of many grain crops to be reached sometime between pollination and maturity.

Agronomists have been aware for some time of numerous reported instances where the total amount of N in the aboveground parts of grain crops actually decreased before maturity. In cases where loss occurs or even when N level remains static, the questions become: 1) Did the crop cease taking up N during grain fill? 2) If N uptake continues, why doesn't total plant N content increase? 3) What is the pathway and fate of any N lost from living plants?

Nitrogen Loss from Plants

Published research over the last decade has shown relatively large amounts of volatile N compounds (mainly ammonia, NH_3) can be lost from aboveground vegetation of various grain crops. These losses largely occurred during grain development. Reported volatile N losses have been as high as 69 lb/A for winter wheat and 40 lb/A for soybean. Generally, N losses increased as the amount of applied fertilizer N increased.

Under favorable growing conditions, many corn hybrids achieve maximum N accumulation between silking and the grain's milk stage (**Table 1**). During kernel fill, large amounts of N can be translocated from vegetative tissue to the grain. One method of monitoring N translocation to the grain and determining if additional N is being taken up from the soil is by the use of isotopically labeled N fertilizer (^{15}N). Isotopic techniques provide a means for differentiating and tracing N coming from the various sources (soil, fertilizer, etc.). By being able to trace its fate, the interactions of labeled N within the soil-plant system can be studied.

Nitrogen balance studies using isotopically labeled N have been a valuable aid in expanding our knowledge of N interactions in various cropping systems. In labeled N balance studies it is common to have 5 to 25 percent of the applied fertilizer missing or unaccounted for from the soil-plant system at the end of the growing season. Previously, leaching and volatile N losses from the soil, mostly thought to be associated with denitrification, were assumed to be major reasons for this missing N. Recent findings indicating that substantial N loss can occur from plant tops do not translate into increased amounts of N being lost from soil-plant systems. Rather, these data identify another mechanism to explain some of the unaccounted for N loss noted above.

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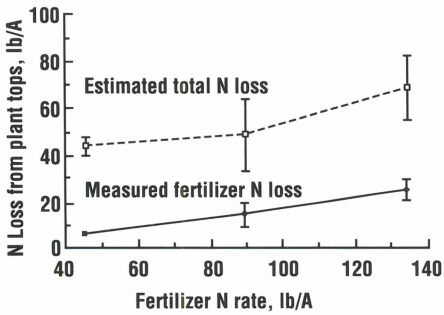

Figure 1. Measured post-anthesis fertilizer N losses from aboveground biomass of corn and the estimated total N losses using ^{15}N depleted fertilizer. Bars denote standard errors of the means.

Nebraska Studies Quantify Losses

One objective of our study was to quantify, under field conditions, N loss from corn plants during grain fill. Two irrigated corn studies, which had isotopically labeled N fertilizer applied, were used to determine the amount and location of labeled N in the aboveground plant parts. At site 1, fertilizer N rates of 45, 89 and 134 lb/A were applied at the three-leaf stage as labeled ammonium nitrate (NH_4NO_3) to Stauffer S7767 corn hybrid.

The total amount of N in the corn plants reached a maximum at the blister stage and remained constant for all treatments through maturity. However, for the three labeled treatments, isotope data showed that 15, 17 and 20 percent of the labeled N that was in the plants at the blister stage was missing by maturity. If one assumes that non-labeled N is lost at the same time and rate as labeled N, then total N losses from the aboveground plant material for the three treatments would be 44, 49 and 70 lb/A of N (**Figure 1**). Net N in the plant tops remained constant after the blister stage for these plots, which means that similar amounts of N were taken up as were lost during the final 55 days of grain fill.

At site 2, labeled N treatments of 67, 134, 201 and 268 lb/A were applied at the six-leaf stage to Pioneer corn hybrid 3379. In this case maximum N accumulation occurred when the grain was at the milk stage (**Table 1**). For the three highest fertilizer rates, total plant N decreased before maturity was achieved. Labeled N losses from the plant tops across the four N rates ranged from 6 to 31 lb/A, which extrapolates to total N losses of 40 to 72 lb/A. All four fertilizer treatments showed that less than half of the labeled N that left the leaves and stalks between the milk stage and black layer development was translocated to the grain.

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Table 1. Labeled fertilizer N in different plant parts of corn at milk and black layer growth stages (mean of four replications at site 2).

Fertilizer N rate, lb/A	Growth stage	Labeled fertilizer N in plant parts, lb/A		
		Leaves	Stalks	Grain
67	Milk	14 ± 2[1]	4 ± 1	8 ± 2
	Black layer	3 ± 1	2 ± 1	11 ± 2
134	Milk	35 ± 5	12 ± 3	21 ± 4
	Black layer	6 ± 1	5 ± 1	28 ± 4
201	Milk	39 ± 6	21 ± 5	26 ± 5
	Black layer	8 ± 3	10 ± 2	40 ± 2
268	Milk	52 ± 5	33 ± 3	35 ± 3
	Black layer	13 ± 1	18 ± 4	64 ± 3

[1]Mean ± the standard deviation.

Table 2. Corn Yield Challenge data summary, 7-year average.

Year	Yield, bu/A	Market price, $/bu	Revenue, $/A[1]	Expenses, $/A[2]	Expenses, $/bu	Net return, $/A[3]
1992	183	2.10	383.99	101.09	0.55	282.90
1991	145	2.50	362.32	117.32	0.81	245.00
1990	158	2.30	363.20	119.80	0.76	243.40
1989	170	2.38	403.98	123.86	0.73	280.12
1988	155	2.74	423.59	117.80	0.76	305.79
1987	168	1.53	256.75	103.20	0.61	153.55
1986	145	1.38	200.59	106.95	0.73	93.64
Average	160	2.13	342.06	112.86	0.70	229.20

[1]Yield (bu/A) x Market Price
[2]Fertilizer, Seed & Chemical Expenses Only
[3]Revenue–Expenses

year about 30 individuals participate. There are rewards for the winners with the highest yields and highest profits. There is also a prize and recognition for the highest no-till yield. This promotes conservation of the most important resource, the soil.

In the final analysis, Yield Challenge entrants have gained from the experience . . . in terms of learning more about production input efficiency, higher profitability and resource conservation. The Yield Challenge is continuing in 1993. ■

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The mechanisms and reasons why volatile N losses occur from plants is not understood. Some researchers attribute N losses mainly to inefficient N translocation and reassimilation within the plant.

However, this does not explain why large losses are noted in some studies while only negligible amounts are detected in others. Research is needed to determine which environmental and physiological factors affect or control N loss processes. Nitrogen availability and moisture stress are two factors which appear to do so.

Summary

It may seem inconsequential whether N losses are coming from the soil or plants, but it becomes important as we continue to look for ways to improve N fertilizer use efficiencies. For example, failure to consider volatile plant N losses will result in overestimation of N losses from the soil by denitrification and leaching. Proper accounting of all N losses from the soil-plant system is needed to fully assess each loss component. This information is necessary as we attempt to develop appropriate means to improve N fertilizer use efficiencies and to properly evaluate any proposed new management strategies. ■

Soil Fertility Manual Slide Sets Available

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The 10-chapter slide package consists of 320 color 35mm slides and includes printed scripts for each chapter. The slides are a true companion to the chapters in the *Soil Fertility Manual.* They help to illustrate the agronomic terms, soil-plant relationships, and principles of fertilizer and lime use addressed in the manual.

For additional information or to place an order, contact: Circulation Department, PPI, 655 Engineering Drive, Suite 110, Norcross, GA 30092; phone (404) 447-0335, fax (404) 448-0439. ■