Tillage effect on seasonal nitrogen availability in corn supplied with legume green manures

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Abstract

It has been shown that legume green manures have great potential for replacing a substantial amount of the N fertilizer required for corn (Zea mays L.) production. An experiment was conducted in central Pennsylvania (USA) to study seasonal fluctuation of nitrogen (N) availability in corn with conventional tillage (CT) and no-till (NT) following red clover (Trifolium pratense L.) and hairy vetch (Vicia villosa Roth) green manures double-cropped with winter wheat (Triticum aestivum L.). Samples of corn, weeds, and soil were taken periodically and analyzed for total N content in plant tissue and soil nitrate-N content. The sum of plant N (corn plus weed) and soil nitrate-N in the upper 45 cm profile was used as an indicator of total available N. Under CT, total available N increased rapidly upon legume incorporation and reached 80% of the maximum within 4 weeks. Under NT, total available N increased steadily after the legumes were killed with herbicides and reached a maximum within 7 to 8 weeks. Seasonal corn N accumulations with the legume N source were similar to those where corn followed fallow with 200 kg N ha$^{-1}$ fertilizer with CT, but were less than those in the same fallow 200 kg N ha$^{-1}$ treatment with no-till. Dry weather conditions together with weed competition reduced N availability to the no-till corn compared to the CT treatments. The seasonal fluctuations of total available N and corn N uptake suggest good synchronization between N availability from the legume green manures and N accumulation by corn plants in both tillage systems under the conditions of this study.

Introduction

The practice of incorporating legumes into corn (Zea mays L.) production has received renewed interest in recent years. In addition to being valuable for conserving soil and nutrients, legumes used as winter cover/green manures can fix appreciable amounts of nitrogen (N) that is potentially available to the successive corn crops. Winter legumes have provided all or most of the N for succeeding corn crops in some studies (e.g. Utomo et al., 1990), but have been less successful in others (e.g. Huntington et al., 1985). The growth of a corn crop supplied with legume green manure as the major N source is largely influenced by the seasonal N availability in the soil-crop system and the pattern of N uptake under a particular set of environmental conditions. Many studies have been done to estimate fertilizer N equivalence and apparent N recovery (efficiency) of legume green manure N sources (e.g. Stickler et al., 1959; Hesterman et al., 1987). However, these evaluation methods are based on corn grain yield and total N uptake data at the time of harvest and thus cannot determine whether it is the N or some other factors that were limiting corn growth and N uptake during the growing season; also, if N was limiting, to what extent and at what growth stages was it limiting?

Sarrantonio and Scott (1988) investigated seasonal net N mineralization of hairy vetch (Vicia villosa Roth) green manure in corn managed with both conventional tillage (CT) and no-till (NT). They estimated seasonal net N mineralization by summing the measured soil inorganic N contents plus the N accumulated in corn, which was estimated by using a sigmoidal function passing through three measured points during the growing season. They found that in one site-year the net N mineralization increased rapidly in the early to
mid-season under both CT and NT, while in another site-year rapid N mineralization did not occur until the end of the season (October) with both tillages. The authors concluded that the timing of hairy vetch N release was very favorable for corn uptake in the first case, but had the potential for inefficient N utilization by the corn and over-winter leaching losses in the second case. Huntington et al. (1985) also reported a poor synchronization between N availability from hairy vetch green manure and N uptake by a no-till corn crop in Kentucky (USA). They found that the majority of N mineralization occurred after corn silking.

To utilize legume N to the fullest extent, a better understanding of seasonal N availability and accumulation in corn following a legume green manure under a particular set of management methods and environmental conditions is necessary. We conducted an experiment in central Pennsylvania (USA) to study the effect of red clover (Trifolium pratense L.) and hairy vetch (Vicia villosa Roth) double-cropped with winter wheat (Triticum aestivum L.) on seasonal N availability and N accumulation in succeeding corn managed with conventional tillage or no-till. The two legume species were chosen based on their winter hardiness, N-fixing capacity, and proven ability as winter cover crops in the area (Govere, 1989). Corn following a fallow treatment and receiving a range of commercial N fertilizer rates were also included for comparison. Specific objectives were to study the impact of red clover and hairy vetch green manures and tillage on (i) seasonal N availability; (ii) seasonal corn N accumulation; and (iii) the synchronization between N availability and accumulation.

Materials and methods

Experimental design and field management

The field experiment was conducted from 1990 through 1992 at Penn State’s R.E. Larson Agricultural Experiment Station in central Pennsylvania (USA) on a Murrill silt loam (fine-loamy, mixed, mesic Typic Hapludult). The soil pH (1:1, soil/H2O) was 6.7 and available P, K, and Mg were in the optimum range based on soil analyses. The soil plow layer (0 to 25 cm) contained 26 g kg⁻¹ organic matter and had a cation exchange capacity (CEC) of 11.8 cmolc kg⁻¹.

Red clover was broadcast into a winter wheat crop at a seeding rate of 9 kg ha⁻¹ on April 18, 1990, and hairy vetch was planted with a no-till drill at a rate of 22 kg ha⁻¹ on August 9, 1990 after the wheat harvest. On May 17, 1991 after taking legume samples to evaluate drymass and total N content, corn variety Doebler’s 61X was planted into strips where the legumes were incorporated into the soil by plowing and disking (CT) or where the legumes were left on the soil surface after herbicide killing (NT). A second corn crop after the legume green manures (Pioneer 3527) was planted on May 6, 1992 with the same tillage methods as in 1991.

The experimental design was a randomized complete block, split-plot design with four replications. The main plots consisted of six treatments which were the combination of legumes or fallow and tillage methods: corn following fallow, clover, or vetch with conventional tillage or no-till. The subplots, 4.56 by 15.2 m in size, received broadcast ammonium nitrate fertilizer N at rates of 0, 50, 100 kg N ha⁻¹ for the first year corn after the legumes (1991) and 0, 75, 150 kg N ha⁻¹ for the second year corn (1992), and 0, 50, 100, 150, 200 kg N ha⁻¹ for corn after fallow in both years. At planting, 10-30-10 (N-P₂O₅-K₂O) starter fertilizer was banded below and to the side of the seed at rates of 112 kg ha⁻¹ to all treatments in 1991 and 1992.

Soil sampling and analysis

Throughout the 1991 and 1992 corn seasons, soil samples were taken biweekly from all subplots receiving 0 broadcast N fertilizer and from subplots of fallow 200 kg N ha⁻¹ treatments. Eight cores from each subplot, 2.5 cm in diameter, were taken to 45 cm and separated into 0 to 25 cm (Ap horizon) and 25 to 45 cm (upper B horizon) and composited. Samples were placed in paper bags and dried in a forced-draft oven at 60 to 70 °C. After drying, soil samples were ground to pass a 2 mm screen and stored in plastic bags for lab analysis. Soil nitrate-N concentration was determined by a Technicon automated analyzer (Technicon Instrument Corp., 1977a) in 2 M KCl extracts (1:10, soil/extractant, 1 hour shaking). Soil ammonium-N was not measured based on a report by Fox and Piekielek (1978) that the ammonium-N contents in a number of soils with corn crops in Pennsylvania (USA) were relatively constant, ranging from 2 to 5 mg kg⁻¹, and were not affected by previous cropping or fertilizer history.

Plant sampling and analysis

In both the 1991 and 1992 growing seasons, seasonal N accumulation in the above-ground portion of corn was