The effect of tillage practices on a leek crop's nitrogen utilisation from a grass-clover sward

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Key words: grass-clover ley, leek, soil tillage, green manure, nitrogen availability, residual mineral nitrogen

Abstract

A grass-clover ley may serve to build soil fertility. However, destruction of the sward may result in a high mineral N content in the soil profile in autumn. We have therefore investigated if non-inversion tillage is feasible for destruction of a grass-clover sward. We also examined how mode and timing of destruction would affect the N availability as reflected by total N uptake of the subsequent main crop leek (Allium porrum) and the residual mineral N. Early destruction in March appeared to be the least favorable option due to the highest residual mineral N content at values of total plant biomass and N uptake not higher than those obtained after late destruction of a repetitively mulched grass-clover sward. Non-inversion tillage proved to be successful for destruction of a grass-clover sward. It did not lower total plant biomass and N uptake by leek when compared to mouldboard ploughing. Grass-clover management history and time of destruction were decisive for the N availability.

Introduction

Conservation agriculture practices in organic agriculture include reduced tillage and permanent soil cover with green manures. Destruction of green manure crops by non-inversion tillage presents some challenges in organic agriculture, such as a greater pressure from weeds (Peigne et al. 2007). A grass-clover ley may serve to build soil fertility. Biologically fixed N by clover will be recovered by the subsequent main crop. However, destruction of the sward may cause a high mineral N content in the soil profile in autumn. Our first research hypothesis was that mode and timing of sod destruction would affect N availability as reflected by total N uptake of the subsequent crop and residual mineral N. Our second hypothesis was that residual mineral N, total plant biomass and N uptake would be affected by the tillage method, either conventional (mouldboard ploughing) or reduced by non-inversion tillage using a chisel plough. Would non-inversion tillage be sufficient for sod destruction?

Materials and methods

The effect of green manure in a reduced tillage system was assessed in a multi-year field trial at the Institute for Agricultural and Fisheries Research (ILVO) located in Flanders, Belgium. A grass-clover ley (*Lolium perenne*, *Trifolium pratense* and *Trifolium repens*) was established in September 2010 after flax (*Linum usitatissimum*). It was either mown and harvested or mulched during the 2011 growing season. In 2012, the ley was destroyed either on March 19th (gm 1) or on May 18th (late destruction). In case of late destruction, two variants occurred: 1) cutting and removal of a full-grown grass-clover sward (gm 2) and 2) repeated mulching of a grass-clover sward (gm 3). The method of destruction for all three treatments was to cut above-ground plant parts from the root system using an Actisol equipped with goosefoot shovels in a shallow setting and then to use a rotary harrow. For preparatory soil tillage just before planting leek (*Allium porrum*) on June 20th, we used either conventional tillage with a mouldboard plough (CT) or reduced non-inversion tillage (RT) with the Actisol down to a depth comparable to mouldboard ploughing. Combining three green manure variants and two tillage methods resulted in six soil management treatments. These treatments were arranged in the field according to a split-plot design with four replicates and with tillage as the main plot factor and green manure as the subplot factor. Individual subplots were 7.5 m by 30 m. In 2012, the N release from the grass-clover green manure and utilisation by the leek crop was examined. No fertilisers were applied. The N input by the grass-clover green manure (below- and aboveground plant parts) was determined for the different green manure variants. With regard to gm 3, the plant shoot biomass and N content were determined just before mulching on March 14th, April 16th and May 8th. The N amount

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determined in plant shoots on March 14th was also representative for gm 1. The N yield of the full-grown grass-clover sward (gm 2) was determined just before mowing on May 8th. At every turn, grass-clover was mown and collected on 4 strips of 1.6 m by 4 m for each replicate. Stubble biomass and N content were determined on gm 2 plots of each replicate by collecting the stubble on four times 0.16 square meter after removal of the full grown cut on May 8th. Root biomass and N content were determined by digging out soil cores with an upper surface of 0.01 square meter in the 0-15 and 15-30 cm soil layers of gm 2 plots on April 3rd. Four soil cores were taken per replicate. Roots were separated from soil particles by washing and sieving. The N input from stubble and root system was assumed to be equal for the different green manure treatments, although differences probably exist but would be rather small compared to differences in plant shoot biomass. Regrowth of the destructed grass-clover sod was assessed in a semi-quantitative manner. Just before main tillage operations, the degree of coverage by grass clumps (%) was estimated on June 15th. On August 1st, the number of grass clumps were counted under the leek crop.

At leek harvest on October 30th, total plant biomass, dry matter, N content and residual mineral N (i.e. NO_3^--N & NH_4^+-N) in the soil profile (0-90 cm) were determined. The ratio between the mineral N content of the 0-60 cm soil layer and that of the 0-90 cm soil layer was calculated (Nmin 0-60 : Nmin 0-90).

Mineral nitrogen content was extracted (1:5 w/v) in a 1 M KCl solution according to ISO 14256-2 and measured with a Skalar SAN++ continuous flow analyzer. Soil moisture content was determined as the weight loss at 105 °C. To determine plant parts dry matter content, crop subsamples were dried in a ventilated oven at 70°C during at least 48h. Their N content was determined on ground dried plant material according to the Kjeldahl method (ISO 5983-2).

Split-plot ANOVA was applied (Gomez and Gomez 1984). If a significant interaction was found between the tillage and green manure factor, data analysis was continued per variant of the tillage factor. The Scheffe method was applied for multiple comparison of the means of the green manure variants.

Results

The coverage by grass clumps just before main tillage operations was 2.3, 3.4 and 3.8% for gm1, gm 2 and gm 3, respectively. Coverage was significantly different between gm 1 and gm 3 (P<0.05). Grass clumps did not hinder plant bed preparations after RT nor after CT. The number of grass clumps on August 1st was low under CT (< 1 per 100 m^2). Under RT, 9, 30 and 28 grass clumps per 100 m^2 were counted for gm1, gm 2 and gm3 (mainly in the plant rows), respectively. A significant difference appeared between gm 1 and gm 2 (P<0.05). However, these numbers were manageable by mechanical weed control and some hand-weeding.

Rather high differences between fresh organic matter and N input were observed between the green manure variants (Figure 1). For gm 1, where a short canopy was cut and left as mulch on the field, the N input was 46 kg N ha^{-1} higher than the input for the gm 2 variant (where a full grown cut was removed)(Figure 1). The highest N input was obtained by gm 3 (three times repeated mulching). Differences in total plant biomass of leek and N uptake by leek were consistent with differences in the measured N input by grass-clover: a significantly lower N uptake was observed for gm 2 compared to gm 1 and gm 3, and a significantly lower total plant biomass for gm 2 than for gm 3 (Table 1). The soil organic N buildup by the grass-clover ley previous to the introduction of the green manure variants was assumed to be equal for the whole field or at least for the different replicates. It did not mask the differences in N availability caused by the more recently formed N, as Hansen et al. (2005) concluded in their study of residual N effects of grass-clover leys of different ages.

An interaction occurred between both factors affecting residual mineral N. In case of CT, early destruction (gm 1) showed a significantly higher residual mineral N than late destruction as in gm 2 and gm 3 (Table 1). In case of RT, residual mineral N for gm 2 was significantly lower than for both other green manure variants.

Both factors significantly affected mineral N distribution in the 0-90 cm soil profile at harvest, as expressed by the 'Nmin 0-60 : Nmin 0-90' ratio, which was 4% higher for RT compared to CT and 7% higher in case of late compared to early destruction.

The risk for N leaching losses at the end of the growing season was highest in the case of early destruction of the grass-clover ley (gm 1). This was due to both the highest residual mineral N and the location of mineral N lower in the soil profile. Obviously, under RT, the risk was lowest in the case of late destruction with removal of a full-grown grass-clover cut (gm 2). However, this green manure variant resulted in the lowest leek total plant biomass and N uptake. No significant effects from the tillage factor on leek total plant biomass and N uptake were observed.

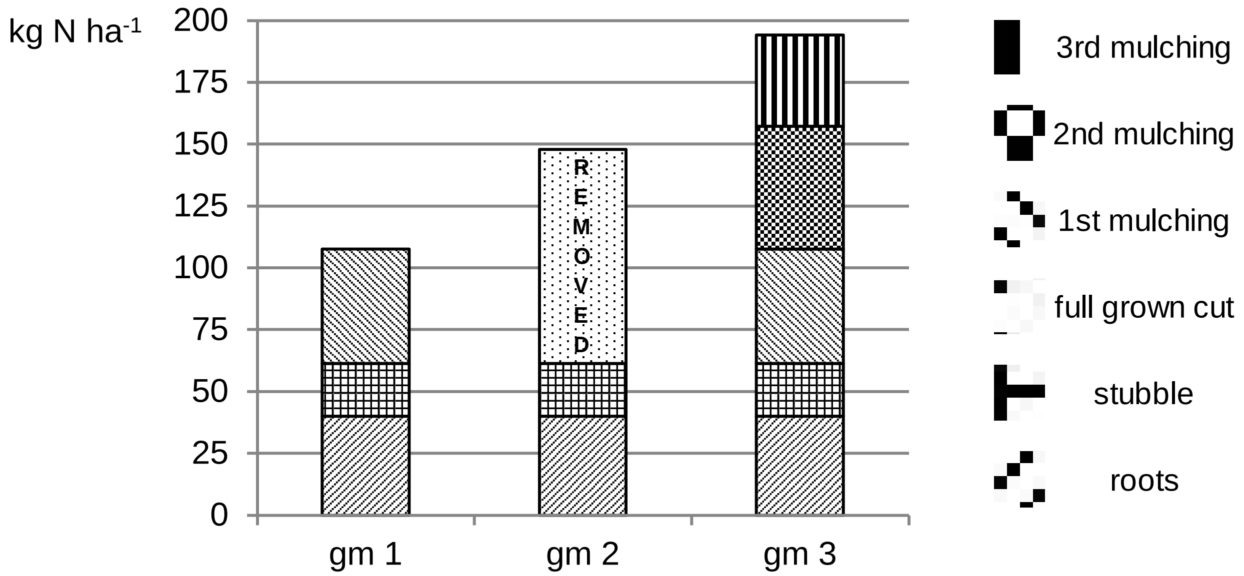

Figure 1. N input by below- and above-ground plant parts of the grass-clover green manure (full-grown cut represented no input because it was removed)

Table 1: Leek total plant biomass and N uptake and residual mineral N (Nres) for the different tillage and green manure variants

			CT	RT		gm 1	gm 2	gm 3	
total plant biomass		$t\ ha^{-1}$	49	50		50 ab	46 a	53 b	*
total N uptake		$kg\ ha^{-1}$	115	118		122 b	103 a	125 b	*
Nres 0-90	CT	$kg\ ha^{-1}$				107 b	91 a	94 a	*
	RT	$kg\ ha^{-1}$				133 b	75 a	122 b	*
Nmin 0-60 : Nmin 0-90		%	63	67	**	60 a	67 b	67 b	*

*significant at P<0.05 and ** significant at P<0.01; significant differences between green manure variants are indicated with different lower-case letters

Discussion

Our experiment has demonstrated that grass-clover destruction can be combined with a non-inversion tillage practice. The residual effect in our experiment in the first year is of the same order of magnitude than this reported by Eriksen (2001) following three years of grass-clover ley (i.e. 115 kg N ha^{-1}) whereas our ley was only half as old. This is in accordance with Hansen et al. (2005), who stated that the age of grassland at the time of ploughing has little effect on the residual N amount. N uptake and plant growth were proportional to the input of recently-formed organic N. Time of destruction, however, seemed to be decisive for its utilisation by the leek crop. Early destruction resulted in a high N availability but low degree of utilisation. Both the choice of time of green manure destruction and mowing regime are important factors in N availability and utilisation after destruction of a green manure crop. These findings deserve further attention in both research and practice.

Acknowledgments

This research was carried out within the frame of TILMAN-ORG project (www.tilman-org.net) funded by CORE Organic II Funding Bodies, being partners of the FP7 ERANet (www.coreorganic2.org).

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