A STUDY OF THE CONTRIBUTION OF COVER CROPS TO NITROGEN SUPPLY FOR CORN.

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Abstract

Cover crops (CC) can provide protection from erosion and prevent soil carbon depletion. In many cases CC are fertilized to improve carbon inputs and soil cover, however there are few studies on the residual effect of nitrogen (N) in CC biomass and its contribution to N availability of subsequent crops. In order to elucidate this question, a field experiment with rye as cover crop during fallow for corn was carried out at INTA experimental station Anguil, La Pampa. The four treatments were control (C), and CC fertilized with 0, 40 and 80 kg N ha^{-1} (N0, N40 and N80), in a completely randomized block design. The fertilized CC treatments were later split at V6 of the corn crop, with applications of 60 and 120 kg N ha^{-1} for N40 and N80 respectively (N40+60 and N80+120). Dry matter (DM) and nutrient contents of standing CC and their residues was determined at “drying” of CC, planting and harvest of corn. Corn yields were recorded at maturity. Fertilized CC had significantly higher DM and N contents than N0 throughout the sampling period; loss of N from CC residues was 38.1, 43.6, 50.2 kg ha^{-1} for N0, N40 and N80 respectively, around 90% of this loss occurred between “drying” and planting. Assuming the total N loss from DM, this represented 40, 35 and 22% of total corn N uptake for N0, N40 and N80. The yield response of corn to N40 and N80 was 1.5 and 6.1 Mg ha^{-1}, resulting in N use efficiencies of 0.3 and 0.12 Mg grain per kg N applied, respectively. Fertilizer applied to corn caused yield increases of 5.0 and 1.9 Mg for N40+60 and N80+120, with efficiencies of 0.08 and 0.01 Mg grain per kg N applied, respectively. We concluded that N applied to cover crops could be an efficient practice to enhance N availability for corn.

Keywords: CC dry matter, nutrient contents, corn yield, N use efficiencies

Introduction

Cover crops have been widely used for weed control (Abdin et al., 2000; Gerowitt, 2003) and also have been shown to improve the carbon budget of agricultural production systems (Follett, 2001; Dinesh, 2004; Ding et al., 2006) and improving soil physical properties (Franzluebbers and Stuedemann, 2008). In many cases cover crops are fertilized to attain more biomass for carbon sequestration (Follett, 2001) and to improve soil cover. Fertilized cover crops may affect the emissions of nitrous oxide from soil (Petersen et al., 2011) but also improve nitrogen availability for subsequent crops (Ranells and Wagger, 1997; Mohammadi, 2010). In semiarid or sub-humid environments one of the major problems for including cover crops is their effect on water availability for the main cash crop (Restovich et al., 2012) which might reduce yield potentials. However, preliminary results indicate that in the semiarid Pampa the negative impact of cover crops on water storage would be negligible and no significant yield decrease could be expected (Fernández et al., 2010), coinciding with experiences in other semiarid environments (Fengrui et al., 2000). Under these conditions the efficient management of nutrients in the cover crop cash crop sequence will be crucial to offset the additional cost of cover crop cultivation. In this sense nitrogen is especially important due the manifold losses that occur during fallows and crop growth (Tonitto et al., 2006). Cover crops have been shown to contribute to nitrogen availability of cash crops (Sainju et al., 2006; Mohammadi, 2010; Restovich et al., 2012)ryegrass, oats, barley, vetch, rape seed and forage radish but there are still many uncertainties about the efficiency of nitrogen use that is delivered through the mineralization of cover crop residues, and specifically the synchronization of nitrogen mineralization and plant uptake will determine the nitrogen use efficiency of the system.

Materials and methods

The experiment was carried out at INTA Experimental Station in Anguil, La Pampa, Argentina (latitude: 36º 31' 00'' S y longitude 64º 01' 00'' W). Rye (*Secale cereale Var. Quehué)* was sown as cover crop (CC) on April 12th 2010 with a density of 200 plant m^{-2} in completely randomized blocks with 5 repetitions. In each block 4 treatments were established in 10 x 5 m plots. The treatments consisted in bare fallow (control) 3 levels of nitrogen (N) applied to the CC: 0, 40 and 80 kg ha^{-1} of N (N0, N40 and N80, respectively) which were applied as a solution of urea and ammonium nitrate (UAN) in the Zadoks 21 stage of the crop. After drying the CC, corn was planted on the same plots, and these were divided into 3 levels of N fertilization of the corn crop (0, 60 and 120 kg ha^{-1}), thus resulting in a total of 5 treatments: control, N0, N40, N80, N40+60, N80+120, with total doses of 0, 40, 80, 100 and 200 kg N ha^{-1} among the fertilizer applied to the CC and the corn.

Soil moisture was determined by weight in 0.2 m depth intervals to a total soil depth of 1.4 m in the CC and 2.0 m in corn. Nitrate nitrogen was determined in samples at the same depth intervals to a depth of 1.0 m by extraction was distilled water and calcium sulfate and the chromotrophic acid colorimetric technique. Bulk density (BD) was determined for each depth interval using steel cylinders of known volume and determining the dry weight of the soil contained in that volume. Soil moisture contents were converted to available water (AW, mm) taking into account the depth and BD, and summing all layers. Nitrogen concentrations were converted to mass per hectare (kg N ha^{-1}) using the BD of each depth layer and then summing all layers. AW and N were sampled in 6 opportunities during the crops' seasons: 1. Seeding of CC, 2. CC biomass determination, 3. Drying of CC, 4. Planting of corn, 5. Flowering of corn, 6. Physiological maturity of corn.

In surface (0-0.2 m) samples the following determinations were carried out: total organic matter (OM) by the Walkley and Black method, available phosphorus (P) by the Bray and Kurtz technique, and soil texture by the sedimentation method.

The aerial biomass of CC (DM) was determined by cutting the plant material in an area of 0.25 m^2 in each sub-plot at ground level and determining its dry weight. On the other hand, CC residue dry matter was evaluated by recollecting the total amount of residues in an area of 0.25 m^2 in each sub-plot at planting and harvest of corn. Both CC DM and residue DM were analyzed for carbon contents by dry combustion with a LECO analyzer (model CR-12), for N contents by the semi-micro Kjeldahl method, and for total P contents using atomic emission spectrometry by coupled inductive plasma.

The results were analyzed statistically through one-way analysis of variance and LSD test at $\alpha < 0.01$ with the Infostat software.

Results and discussion

During the growing season of the CC nitrate N in the soil showed no difference (p< 0.01) between N0 and N80 (Table 1), indicating that the applied fertilized was taken up by the crop. The soil N contents were appreciable ranging from 34 to 123 kg ha^{-1} which suggested that even during the cool moths of April to August N mineralization was strong.

Table 1: Total nitrate N contents of the soil in unfertilized (N0) and fertilized (N80) cover crops.

	N-NO_2^- (kg ha^{-1}) 0 – 100 cm				
	April	August	December	April-August	August-December
CC N0	33,9 a	52,8 a	111,6 a	19,0 a	58,7 a
CC N80	33,9 a	44,5 a	122,6 a	12,2 a	78,0 a

The soil mineralized N during the growing season of the CC, during fall and winter, at a rate of approximately 0.11 kg ha^{-1} N day^{-1}, while during the spring months of August to December this rate was considerably higher (0.69 kg ha^{-1} N day^{-1}).

The response to N fertilization in the CC was significant for the N80 treatment from August onward with a final difference of 1592 kg ha^{-1} more in the fertilized CC (Table 2). The differences between N0 and N40 were not significant. The yield response observed in the N80 treatment represented nitrogen use efficiency (NUE) of 19.9 kg DM per kg N ha^{-1}.

Table 2: Cover crop dry matter (CC DM) during the growing season (July and August) and at drying (October) in treatments with 0, 40 and 80 kg ha^{-1} of nitrogen applied as fertilizer.

	CC DM (kg ha^{-1})		
	July	August	October
CC N0	2830 a	3866 b	5464 b
CC N40	3081 a	4736 ab	5868 ab
CC N80	3526 a	4956 a	7056 a

Similar to the differences observed in dry matter production of the treatments, the carbon, nitrogen and phosphorus contents of the CC dry matter were significantly higher in N80 compared to N0 (Table 3). This was directly related to the higher biomass production in the N80 treatment, since the concentrations of these elements in the dry matter were not different among treatments (data not shown).

Table 3: Carbon (C), nitrogen (N), and phosphorus (P) contents of cover crop dry matter at herbicide application (drying) in treatments with 0, 40 and 80 kg ha^{-1} of nitrogen applied as fertilizer.

	C kg ha^{-1}	N kg ha^{-1}	P kg ha^{-1}
CC N0	2358 b	60.4 b	10.0 b
CC N40	2521 ab	78.4 ab	12.0 ab
CC N80	3085 a	94.8 a	13.8 a

If one assumes that the nitrogen contained in the biomass of the N0 treatment was produced by N mineralization, the soil provided 60 kg ha^{-1} of nitrogen to the crop during the growing period from April to October. The N40 treatment yielded 78 kg ha^{-1} N at time of drying, 18 kg more than the control, while the N80 treatment had 35 kg ha^{-1} more N than the unfertilized CC. Thus, for the N40 treatment 22kg ha^{-1} of applied N, representing 55% of the applied rate was not captured by the crop. A similar percentage (56%) was found in the N80 treatment

At planting of the corn crop the residue of the CC already diminished with regards to the dry matter at drying and during the growing season there were also important losses of residue dry matter and the elements contained in it (Table 4). The differences observed between drying of the CC and harvest of corn amount to 1076, 1442, and 1620 kg C ha^{-1}; 38, 44, and 50 kg N ha^{-1}; 8.5, 9.5, and 11.2 kg P ha^{-1} for N0, N40 and N80, respectively. This would imply the CC residues would have provided corn with between 38 to 50 kg N ha^{-1} and between 8.5 to 11.2 kg P ha^{-1}.

Table 4: Residue dry matter nutrient contents at planting and harvest of corn crop.

	DM kg ha^{-1}		C kg ha^{-1}		N kg ha^{-1}		P kg ha^{-1}	
	planting	harvest	planting	harvest	planting	harvest	planting	harvest
CC N0	3018b	2372b	1215b	916b	25.2b	22.3b	3.65b	1.50b
CC N40	4642a	3579a	1911a	1445a	47.5a	34.8a	6.28a	2.50a
CC N80	4649a	3755a	1911a	1465a	48.8a	44.6a	6.08a	2.60a

The response of corn to the nutrients provided by the CC residues was noticeable (Figure 1), with the highest difference in the N80 treatment. The N rates applied to the corn crop itself, however did not produce significant yield improvements over the N80 treatment.

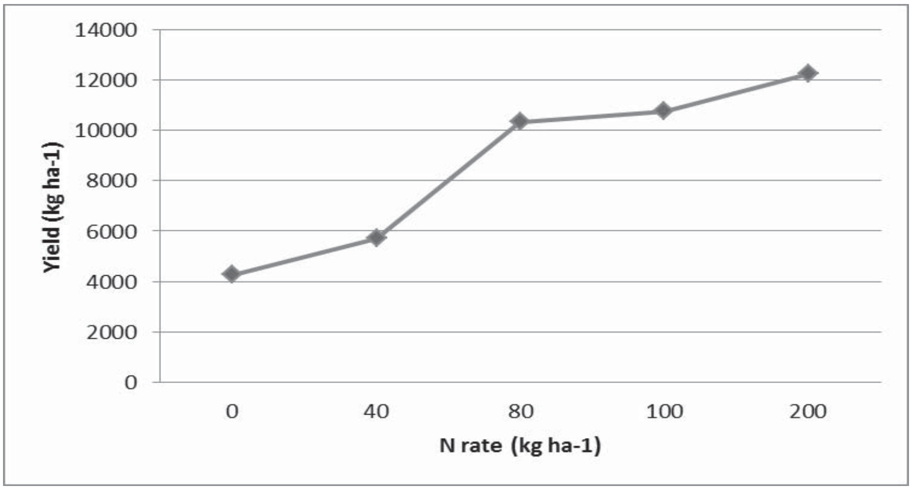

Figure 1: Corn yield in response to the rate of nitrogen applied to the cover crop and corn itself.

Thus, apparently, N applied to the CC was more efficient in terms of improving grain production than the N fertilizer applied to the corn crop itself. This becomes more evident when analyzing the yield responses to the different treatments and the associated nitrogen use efficiencies (NUE) (Table 5).

The N80+120 treatment had the highest yield with 12.3 Mg ha^{-1} ($p<0.01$), while the control without CC yielded only 3.1 mg ha^{-1}. The inclusion of a CC produced a yield response of 1.2 Mg ha^{-1} and the N40 treatment showed no significant difference to N0, while N80 had a response of 6.1 Mg ha^{-1} more yield compared to the control. This treatment also showed the highest NUE (76 kg grain kg N^{-1}), which though was not statistically different from the NUE of N40+60 (64 kg grain kg N^{-1}).The extra 60 kg N ha^{-1} applied to the corn crop in this treatment had a very efficiency (84 kg grain kg N^{-1}), while the rate applied to corn in the N80+120 was very inefficient. This reflected the declining slope of the yield curve shown in Figure 1, and indicated that the optimal rates for corn in this soil might be between 80 and 100 kg ha^{-1}.

Table 5: Corn yield of the different treatments and nitrogen use efficiency (NUE) of fertilizer applied to the cover crop (CC) or corn expressed as kg ha^{-1} of corn grain per kg of nitrogen applied.

Treatment	Grain yield (kg ha^{-1})	Yield Response to CC / N (kg ha^{-1})	Total amount of N applied (kg ha^{-1})	overall NUE (kg grain kg N^{-1} applied)	Yield response to N fertilization in corn (kg ha^{-1})	NUE of N applied to corn (kg grain kg N^{-1} applied)
Control without CC	3123 d	-	0	-	-	
CC N0	4275 cd	1152 c	0	-	-	
CC N40	5723 c	1448 c	40	36 b	-	
CC N80	10340 b	6065 b	80	76 a	-	
CC N40 + 60	10761 b	6486 ab	100	64 a	5038 a	84 a
CC N80 + 120	12247 a	7972 a	200	40 b	1907 b	16 b

The N supplied by mineralization of the CC residue was apparently available to the corn crop, as shown by the yield responses. Similar experiences were found in irrigated corn (Mohammadi, 2010) and for sorghum and cotton in the Great Plains of the US (Sainju et al., 2006), where the effect of the CC was mainly related to the retention of nitrates against leaching losses, but previous research has not shown that fertilizer applied to CC was effectively taken up by the subsequent cash crops with high efficiency.

In order to compare the nitrogen budgets of the different treatments we calculated the total N uptake of the crop assuming a requirement of 22 kg N Mg corn yield^{-1}. The apparent N supply was calculated by the amount of N in the dry matter of the CC and the N applied as fertilizer to the corn crop (Table 6). In N0 the contribution of dry matter derived N was highest with 41% of the total uptake, whereas the proportion declined in the fertilized treatments to 35 and 22% for N40 and N80, respectively. However, these results indicated that residue derived N was an important source for corn in the CC treatments, but soil derived N was the major source in all treatments except N80+120.

Table 6: Apparent nitrogen budget for the different treatments.

	N0	N40	N80	N40+60	N80+120
			kg N ha^{-1}		
Total uptake	94	126	228	237	269
Contribution of CC DM	38.1	43.6	50.2	43.6	50.2
Fertilization	0	0	0	60	120
Total N supply	38.1	43.6	50.2	103.6	170.2
Difference between uptake and supply	55.9	82.4	177.8	133.4	98.8

Conclusions

The results showed that cover crops were efficient in fixing soil and fertilizer derived nitrogen in their biomass, resulting in 55% recovery of the applied N rates in the plant material. Most of this N was supplied to the subsequent corn crop during the growing season with between 38 to 50 kg N ha^{-1} according to the rates applied. Corn yield response to the N applied to the CC was significant at the rate of 80 kg N ha^{-2}, and the highest nitrogen use efficiencies were attained with this rate applied to CC and the split application of 40 kg N ha^{-1} to CC plus 60 kg N ha^{-1} to corn. Residue derived N represented an important contribution to corn N uptake, indicating that fertilization of CC could be an efficient practice to enhance N availability in corn.

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