Comparing nitrate-N losses through leaching by field measurements and nitrogen balance estimates

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Introduction

The main N losses from humid and subhumid regions and from irrigated agriculture is through leaching and denitrification (Fageria and Baligar, 2005). The Pampa region in Argentina (30–40°S and 57–66°W) has a humid to subhumid climate (rainfall ranging from 800 to1000 mm) with water excess that generally occur at the beginning of the growing season and during the fallow period. Corn is the crop with the greatest potential for leaching losses of N because of its high demand for N, which leads to high N application rates, and because the growing season of corn coincides with the period of high precipitation in the region. Sainz Rozas et al. (2004), working on soils from the Pampas, estimated that 20% of the N applied as fertilizer to corn under NT was not recovered using N balance, and it was assumed to have been lost as NO_3^- leaching.

Although the N balance method is a valuable tool to estimate N losses (Meisinger et al., 2008), the sum of errors incurred when each one of the pools is determined, could lead to incorrect estimations of the amount of leached NO_3^-. Furthermore, great care must be taken when interpreting the results and calculating the losses via leaching if all the components of the N balance are not measured. However, studies comparing the leaching of nitrate measured in the field with estimated nitrate leaching from an N balance under contrasting soil water availability conditions have not reported in the literature.

The aim of this study was to estimate the amount of N leached (Nl) using an N balance technique and compare estimated Nl with measured Nl in the field for five growing seasons.

Materials and Methods

The experiment was made on a Typic Argiudoll soil planted with corn under three rates of N-fertilizer (0, 100, and 200 kg N ha^{-1}). The trial spanned five growing seasons, some of which were wetter- and others drier-than-historical average for the region. Nitrate leaching was determined using suction cups installed 1 m below the soil surface, while drainage was estimated with the LEACH-W model and N balance was estimated with field data. Analyses of variance were performed with SAS version 6.12 software (SAS Institute, 1989-1996). The estimated parameters were compared among N rates and cropping seasons as repeated measurement using a mixed linear model (PROC MIXED). Mean comparisons were evaluated with a significance level of 0.05 using LSMEANS. Simple and multiple linear regressions were utilized for analysis of information.

Table 1. Monthly rainfall (mm) in the period analyzed.

	Rainfall (mm)											
Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
2001	119	119	106	48	69	66	26	118	103	156	198	123	1251
2002	152	71	147	40	197	18	45	100	90	276	169	39	1342
2003	124	90	167	61	69	61	64	49	54	108	142	136	1124
2004	28	97	47	154	9	27	86	125	32	51	70	62	788
2005	67	48	88	4	17	70	51	109	59	60	85	103	760
2006	119	125	21	52	1	79	59	11	45	76	27	113	728
98-97	103	80	77	58	63	46	48	34	46	94	66	113	827

Table 2. N balance in the soil system – corn by N treatment for the growing seasons 2001-2002; 2002-2003; 2003-2004; 2004-2005 2005-2006

Growing season	Available N			Determined components of N balance						
	Nf	Nmin	Nii	Np	Nr*	Ng*	Niin	Nl	Nif	Nne
	kg ha^{-1}									
2001-2002	0	122	61	115	8	5		30	25	30
2001-2002	100	122	51	199	11	13	12	62	26	12
2001-2002	200	122	48	253	13	14	9	68	53	27
2002-2003	0	128	111	134	9	5		52	39	52
2002-2003	100	128	73	155	8	13	12	59	39	74
2002-2003	200	128	89	227	12	14	9	78	71	84
2003-2004	0	75	30	67	4	5		3	26	3
2003-2004	100	75	34	87	5	13	12	18	31	62
2003-2004	200	75	40	151	8	14	9	41	38	95
2004-2005	0	54	19	56	4	5		0	8	0
2004-2005	100	54	23	61	3	13	12	1	3	84
2004-2005	200	54	34	98	5	14	9	2	14	147
2005-2006	0	91	26	96	6	5		0	10	0
2005-2006	100	91	27	113	6	13	12	0	16	60
2005-2006	200	91	34	143	8	14	9	0	29	123

(*) N estimated using the data reported by Sainz Rozas et al. (2004).
N from fertilizer; Nmin: organic mineral N; Nii: inorganic initial N; Np: N absorbed by biomass area; Nr: N absorbed by roots; Ng: N lost as gases (N2, N2O, NH3); Nl:N lost through leaching; Ne: N lost through erosion; Nif: final inorganic N.

Results and Discussion

ANOVA of crop yield

Grain yield was different by N rate and growing season, but there was no interaction between these two variables. Crop yield increased with N rate (Fig. 1a) and the highest yields were obtained in those growing seasons where the average annual rainfall was above the historical average (Fig 1b; Table 1).

Estimation of Nl using the simplified N balance

There was no interaction effect between nitrogen and growing season on Nne (p= 0.0867). Although Nne was significantly affected by Nrate (p=0.0001), it was not affected by growing season (p= 0.0595). For the growing seasons 2001-2002 and 2002-2003, average values of Nne and Nl for N rates of 100 and 200 kg N ha-1 were 43 and 55 kg N ha^{-1}, and 60.5 and 73 kg N ha^{-1}, respectively. For the drier than historical average growing seasons (2003-2004; 2004-2005 and 2005-2006), average values of Nne and Nl for N rates of 100 and 200 kg N ha^{-1} were 69 and 122 kg N ha^{-1} 6.3 and 14.3 kg N ha^{-1}, respectively. In addition, a relationship was determined between Nne and precipitation amount during the growing season (PP) and AN (Nii + N fertilizer) (Nne= 58.8 - 0.098*PP + 0.41*AN; r^2= 0.65). This indicates that over-estimation was greater for drier than average growing seasons (Table 1) and when drainage was negligible. These results suggest that existence of other mechanisms of N loss not measured in this work that became much more relevant when water availability decreased.

In soils under no-tillage and corn monoculture, the amount of N fertilizer which is still in organic form at the end of the growing season was reported to vary between 24 and 65 kg N ha^{-1} (Kitur et al., 1984; Jokela and Randall, 1997; Stevens et al., 2005), which are values greater than those found in this investigation (Niin, Table 2). However, for the same region and for similar tillage system, Divito et al. (2011) reported that particulate organic N and potential Nmin in the surface layer (0-20 cm) were not changed by N fertilization.

On the other hand, Francis et al. (1993) reported that losses through volatilization of NH_3 from plants increase when N concentration in corn plant is high and under water stress conditions, factors which increase the concentration of ammonia in the apoplast and therefore of NH_3-N losses from the leaves.

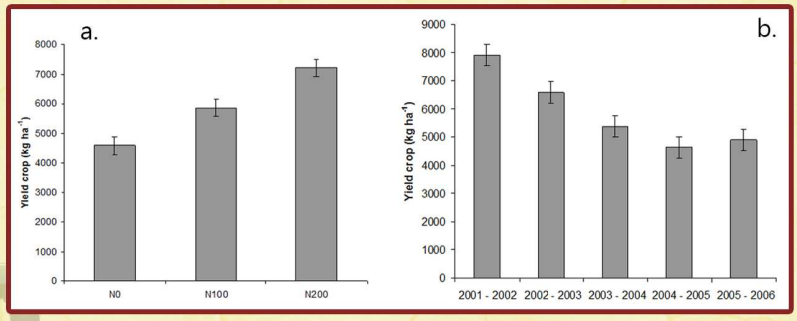

Fig 1. Yield crop in function of: a) N treatment and b) cropping seasons. The bars indicate standar error.

Conclusion

Measured and estimated components of a nitrogen balance over five growing seasons encompassing contrasting soil water availabilities are discussed in this work. The conditions analyzed are representative of regions in the world growing corn on well structured soils of the Mollisol order.
Numerous studies have measured nitrate leaching or estimated it through N non-recovered but few researchers have compared measured and estimated values of nitrate leaching. Results of this investigation suggest that Nl had a low contribution to N non-recovered in dry growing seasons. Furthermore, the N balance over-estimates nitrate leaching (Table 2), particularly in dry years

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