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CROP PRODUCTION AND MANAGEMENT - Article

Nitrogen recovery efficiency for corn intercropped with palisade grass

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ABSTRACT: Intercropping corn and palisade grass is a technique to increase straw production, soil C contents, nutrient cycling and crop yield. However, concerns arise from nitrogen (N) uptake by the intercropping crop causing reduction in the yield of the corn. Our objective was to evaluate N recovery efficiency (NRE), and the N dynamics in the soil-plant system in corn intercropped with palisade grass. A field trial was carried out in Bahia, Brazil, evaluating two cropping systems: corn (monoculture) and corn intercropped with palisade grass sowed between rows on the same day as the corn crop, with four replicates in a completely randomized block design. Nitrogen (150 kg·ha^{-1}of ^{15}N-urea) was applied at sowing to determine NRE, which means the amounts of N-fertilizer uptake in corn and palisade grass, the amounts of N-fertilizer in soil and the ^{15}N-fertilizer balance. Neither the NRE (63.3% in monoculture and 57.2% in intercropping) nor corn grain yield (9,800 kg·ha^{-1} in monoculture and 9,671 kg·ha^{-1} in intercropping) was affected by intercropping, which accumulated only 2.1 kg·ha^{-1} of N-fertilizer or 1.4% N rate. In addition, palisade grass yielded 2,265 kg·ha^{-1} of dry matter. The balance indicated that 82.4% of N-fertilizer was recovered in the monoculture and 86.9% in the intercropping. Intercropping palisade grass does not affect grain yield or N corn nutrition and has the potential to increase straw production contributing to maintenance of no-till.

Key words: *Urochloa ruziziensis*, Urea, ^{15}N isotope technique, No-till system, Brazilian Cerrado.

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INTRODUCTION

Corn is grown in 16 million hectares in Brazil either during the summer or during the autumn, following soybean and the area cultivated under no-till is increasing rapidly in Brazil (CONAB 2016). However, agricultural expansion in Brazil is occurring in the Cerrado region, which presents high rainfall and high temperatures favoring crop residues degradation. This impairs the formation of a straw mulching to protect soil that is an important component of the no-till system (Maltas et al. 2009; Landers 2007).

Intercropping corn and palisade grass is a management to improve biomass production in agricultural systems that can serve as straw to no-till system or to graze cattle on the crop livestock integration systems concept (Borghi et al. 2013). The integration of pastures into agricultural areas has been demonstrated to serve as a sink for C, with C accumulation rates ranging from 0.82 to 2.58 $Mg \cdot ha^{-1} \cdot year^{-1}$ (Carvalho et al. 2010) and thus serving for increasing soil organic matter (SOM) content of the highly weatherized soils from the Brazilian Cerrado. This kind of diversification in cropping lands increase soil fertility and yield of subsequent crops growing after palisade grass (Crusciol et al. 2015) and can positively affect soil biodiversity. On the other hand, reduction in yield of the main crop (corn) is also a concern that limits adoption of intercropping by growers in the Brazilian Cerrado.

There is a variation between 27% and 66% in Nitrogen Recovery Efficiency (NRE) of corn, which means the amounts of N-fertilizer uptake by plants (Liang and Mackenzie 1994; Ding et al. 2011; Gabriel and Quemada 2011; Rimski-Korsakov et al. 2012) that is mainly explained by the complexity of the N dynamics in the soil-plant-atmosphere system (Wilcke and Lilienfein 2005). Farmers can enhance the sustainability of agriculture lands using cover crops, improving NRE with efficient cropping systems (Noor 2017). Land covered by grass like *Urochloa* spp. and other grasses can improve soil fertility and NRE in cropping systems (Rahman et al. 2005; Crusciol et al. 2015; Couto-Vázquez and González-Prieto 2016). However, despite the many studies exploring NRE in corn, there are uncertainties if intercropping corn with palisade grass will affect NRE by corn.

We hypothesized that palisade grass intercropped with corn in the Cerrado area will not affect NRE and corn yield, on the contrary, will favor the no-till system establishment by increasing straw production. Our objective here was to evaluate NRE by corn and palisade grass, corn yield, N-fertilizer recovery in the soil, and the ^{15}N balance in the corn-palisade grass intercropping system.

MATERIAL AND METHODS

Site Description

A field trial was carried out in São Desidério, Bahia, Brazil (12°S56’41”, 45°W58’47”, 840 m high), located in the Cerrado area of Brazil. The regional climate is Aw according to the Köppen classification, with a hot and humid summer and a dry winter; the mean annual temperature is 20 °C, and the annual precipitation is 1,500 mm. In addition, climate data were measured during experimental period (Fig. 1). The soil was classified as Typic Haplustox (Soil Survey Staff 2014). The experimental area was cropped for many years and soil fertility is enough to corn grown, promoting high potential to N fertilization mainly because low organic matter content. The soil is sandy loam with high potential of N leaching in soil profile. Results of the soil physical and chemical analysis are presented in Table 1.

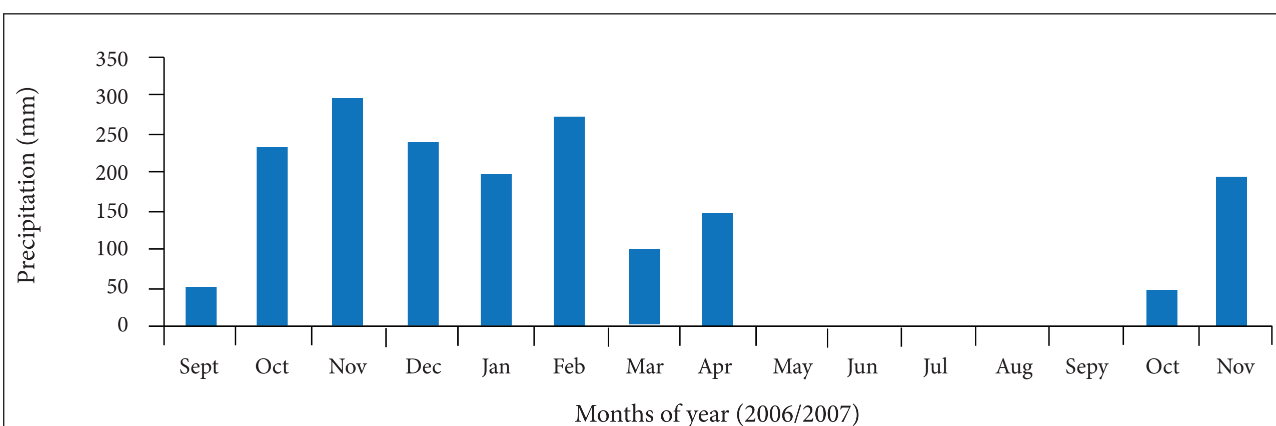

Figure 1. Precipitation during 2006/2007 growing season.

Table 1. Chemical analysis of the soil in the experimental area*.

Depth (m)	Clay** ($g \cdot kg^{-1}$)	pH $CaCl_2$	SOM ($g \cdot dm^{-3}$)	P ($mg \cdot dm^{-3}$)	K	Ca	Mg	H+Al	Al	CEC	BS (%)
					($mmol_c \cdot dm^{-3}$)						
0 – 0.1	140	6.2	15	19	2.2	19	6	8	1	35.2	77.3
0.1 – 0.2		6.3	14	8	1.8	17	6	8	1	32.8	75.6
0.2 – 0.3	210	6.2	10	6	0.9	15	5	9	1	29.9	69.9
0.3 – 0.4		6.0	9	3	0.8	8	4	10	1	22.8	56.4
0.4 – 0.5	200	5.8	9	3	0.6	7	3	10	1	20.6	51.5
0.5 – 0.6		5.6	7	3	0.5	6	3	11	1	20.5	46.3
0.6 – 0.7	210	4.4	9	2	0.4	4	2	15	2	21.4	29.9
0.7 – 0.8		4.4	9	2	0.4	4	2	15	1	21.4	29.9
0.8 – 0.9	220	4.6	7	3	0.5	5	2	14	1	21.5	34.9
0.9 – 1.0		4.6	7	2	0.4	5	2	14	1	21.4	34.6

*Chemical analysis according to the procedures reported by Raij et al. (2001); **Clay content ($g \cdot kg^{-1}$) in soil samples collected in 0.2 m soil layers; SOM: Soil Organic Matter; CEC: Cation Exchange Capacity and BS: Base Saturation.

Experimental Design and Measurements

The treatments consist of two systems: T1 – corn (monoculture) –, and T2 – corn intercropped with palisade grass (intercropping), with four replicates in a complete randomized block experimental design. The hybrid Impact was sown on November 19th 2006 at 0.76 m between rows to obtain final population of 60,000 $plants \cdot ha^{-1}$ using tractor driven multiple NT seeder, in plots with 10 m long and six corn rows. The palisade grass *Urochloa ruziziensis* (Syn. *Brachiaria ruziziensis*) was sown between rows on the same day as the corn crop, with 8 $kg \cdot ha^{-1}$ of seeds (50% of pure live seeds).

Before sowing, 90 $kg \cdot ha^{-1}$ S was applied in the form of gypsum, along with 100 $kg \cdot ha^{-1}$ P_2O_5 and 200 $kg \cdot ha^{-1}$ K_2O (fertilizer 00-10-20). In both treatments, 150 $kg \cdot ha^{-1}$ N-urea was applied just after corn sowing, in a lateral furrow at 0.1 m beside the seed row with 0.08 m depth. At the time of palisade grass tillering, a low-dosage of Nicosulfuron (6 $g \cdot ha^{-1}$) was applied to suppress palisade grass growth. Conventional management of weeds, pest and diseases was adopted by the grower's pattern.

A microplot of 1.0 m × 1.52 m (including one central corn row and two adjacent rows) was installed in the center of all eight plots. Urea labeled with 2.415% atoms^{15}N was applied in these microplots at rate of 150 $kg.ha^{-1}$ in a lateral furrow of the central corn row, as described above.

Corn plants in microplots were harvested on May 12th 2007 in 0.5 m of corn rows. One sample was collected from the central row, with two plants per sample, and another sample for both adjacent rows (with 4 plants per sample). Corn plants were separated in four compartments: stems, leaves, reproductive parts (including bracts, silk, cob and tassel), and grains. The biomass of palisade grass (leaves and stalk) was also assessed in 0.20 m × 0.76 m area in the center of microplots. Roots were sampled by collecting soil from a 0.2 m × 0.76 m trench in the same place of palisade grass assessment, up to 0.6 m (in 0.2 m intervals). Soil was separated from roots using a 2.0-mm mesh sieve, and roots were washed with tap water, dried and stored in paper bags. Biomass of each plant sample was determined after dried in an oven with air circulation at 65 °C for 72 h.

Soil samples were collected at harvest, at the center of the micro-plots up to 1.2 m (in 0.2 m intervals) using a core sampler. Soil was separated from the roots using a 2.0 mm sieve, than was weighed and separated into two subsamples: the first one to determine soil moisture after drying at 105 °C during 24 h; and the other to chemical and isotopic analysis following drying at 65 °C.

The dried plant material was ground in a Willey knife mill and the soil samples in a soil grinder. Plant and soil samples were analyzed for total-N and abundance of ^{15}N atoms using a mass spectrometer coupled with a N analyzer model ANCA-GSL, from Sercon Co. UK.

The amount of N derived from fertilizer (NDFF), N in soil derived from fertilizer (NSDF), N recovery efficiency (NRE), and recovery of N from the soil (RNFS) were obtained following Eqs. 1 and 2.

$$\text{NDFF or NSDF} = [(A - C)/(B - C)] \times TN \quad (1)$$

$$\text{NRE or RNFS} = (\text{NDFF or NSDF/NAF}) \times 100 \quad (2)$$

where: NDFF is the amount of N derived from fertilizer (kg·ha^{-1}); NSDF is N in soil derived from fertilizer; A is the abundance of ^{15}N (% atoms) in the plant or soil sample; B is the abundance of ^{15}N in the fertilizer (2.415% atoms); C is the natural abundance of ^{15}N (0.366% atoms); TN is the total N content in plant or soil sample (kg·ha^{-1}); NRE means N recovery efficiency (%); RNFS is the recovery of N from the soil and NAF is the N rate applied (150 kg·ha^{-1}).

Statistical Analysis

Results were submitted to analysis of variance (ANOVA). When the F-test showed significance in ANOVA ($p < 0.05$), means were compared by a *t*-test to differentiate systems (monoculture and intercropped). When applicable, a Tukey test ($p < 0.05$) was used to compare soil depths, using each soil layer like a treatment. Standard deviation was also presented ($n = 4$).

RESULTS AND DISCUSSION

Nitrogen Recovery Efficiency for Corn and Palisade Grass

Intercropping palisade grass with corn did not reduce corn grain yield. There was also no difference in NRE for corn with or without palisade grass (Table 2). Other authors have also shown benefits of intercropping palisade grass with corn for no-till systems and crop-livestock integration without impairing corn yield (Baldé et al. 2011; Crusciol et al. 2012; Borghi et al. 2013; Ceccon et al. 2013; Almeida et al. 2017a; 2017b).

Table 2. Yield, N accumulation, N derived from fertilizer (NDFF), and N Recovery Efficiency (NRE) for the two cropping systems*.

Plant compartments	Systems	Yield		N accumulation (kg·ha^{-1})		NDFF (kg·ha^{-1})		NRE (%)	
Corn									
Stems	Monoculture	2,461	(273)	13.6	(1.05)	5.8	(3.03)	3.9	(2.02)
	Intercropped	2,556	(225)	12.9	(1.24)	5.7	(0.58)	3.8	(0.39)
		NS		NS		NS		NS	
Leaves	Monoculture	2,903	(459)	44.4	(7.60)	24.1	(3.70)	16.1	(2.47)
	Intercropped	2,499	(314)	33.6	(4.47)	18.3	(3.41)	12.2	(2.27)
		NS		NS		NS		NS	
Reproductive parts	Monoculture	2,941	(376)	12.9	(3.67)	5.4	(1.04)	3.6	(0.69)
	Intercropped	3,101	(318)	15.4	(4.79)	8.0	(2.26)	5.2	(1.5)
		NS		NS		NS		NS	
Shoots	Monoculture	8,305	(1014)	71.0	(10.08)	35.3	(5.58)	23.6	(3.72)
	Intercropped	8,156	(687)	62.0	(6.24)	31.9	(3.27)	21.3	(2.18)
		NS		NS		NS		NS	
Grains	Monoculture	9,800	(853)	148.1	(16.89)	59.5	(18.02)	39.7	(12.01)
	Intercropped	9,671	(645)	139.0	(10.47)	53.8	(18.07)	35.9	(12.05)
		NS		NS		NS		NS	
Whole plant	Monoculture	18,105	(1722)	219.1	(22.27)	94.8	(14.74)	63.3	(9.83)
	Intercropped	17,827	(1205)	201.0	(13.41)	85.7	(19.40)	57.2	(12.93)
		NS		NS		NS		NS	
Palisade grass									
Whole plant	Intercropped	2,265		31.0		2.1		1.4	

*Values in parenthesis are standard deviations ($n = 4$). NS Non-significant for the Student *t*-test.

The palisade grass yielded 2,265 kg·ha^{-1} dry matter at the harvest day (Table 2) and kept growing during the off season until desiccation program to make straw to the next growing season (Almeida et al. 2017a).

The presence of palisade grass also did not affect N uptake by corn (Table 2). For the total N accumulated in corn plants in the monoculture system (219 kg·ha^{-1}N), 148 kg·ha^{-1}N was in the grains, which represent 67.6% of the total N accumulated by corn. In corn intercropped, of the total N accumulated in the plant (201 kg·ha^{-1}N), 139 kg·ha^{-1}N was in the grains (69.1% of the total N in the plant).

The NDFF showed a similar distribution to that of total N, since 62% of the N-fertilizer accumulated by corn in the monoculture (94.8 kg·ha^{-1} N) was in the grains. In the intercropped system, 62.8% of the NDFF was determined in grain. Similar results were obtained by Duete et al. (2008), who estimated 72% and 71% of the total plant N and NDFF, respectively, in grains. Fernandes et al. (2008) verified 73% of total N in corn grain and 72% of NDFF in the grains.

The NDFF in whole plant was roughly 95 and 86 kg·ha^{-1} in monoculture and intercropped, respectively (Table 2). These values correspond to 43.3% of total N accumulated in monoculture and 42.6% in intercropped. These results show that the main source of N for the corn (approximately 60%) was the soil, regardless of the cropping system, which is consistent with the observations of other authors (Stevens et al. 2005; Fernandes et al. 2008; Dourado-Neto et al. 2010). The NDFF obtained in our study is relatively high when compared to other studies performed under field conditions, in which NDFF in relation to the total N accumulated by corn ranged between 18% and 28% (Liang and Mackenzie 1994; Gava et al. 2006).

The higher NDFF values obtained in this study are a consequence of the attributes of the soil in the Cerrado (low clay and SOM contents, Table 1). Under these conditions, there is little soil organic N available to the plants through the mineralization of SOM (Wu et al. 2008), and there is a lower capacity for microbial immobilization of the fertilizer N, thus increasing the N availability to plants. However, even under such conditions, SOM contributed to the majority of the N accumulated in the corn.

Palisade grass sown on the same day as corn produced 2,265 kg·ha^{-1} of dry phytomass (Table 2), which is similar to the 2,487 kg·ha^{-1}obtained by Portes et al. (2000). Freitas et al. (2005) obtained a phytomass of 2,786 kg·ha^{-1} when palisade grass was simultaneously sowed with corn between the corn rows, whereas a yield of 1,392 kg·ha^{-1} was obtained for palisade grass broadcasted during corn sowing. These results indicate that intercropping is effective for formation of straw with satisfactory production of biomass, which is indispensable to maintenance of no-till in tropics, such as Brazilian Cerrado (Maltas et al. 2009; Landers 2007).

Palisade grass absorbed only 2.1 kg·ha^{-1} of N fertilizer, which corresponds to 1.4% of the N rate (Table 2). The NDFF in palisade grass represented 6.8% of the total N absorbed by palisade grass (31.0 kg·ha^{-1}N). Despite extensive root system of palisade grass, the NDFF was not affected. The forage is the subordinated plant in the intercropping system, with restricted light availability, with lower interception of photosynthetically active radiation (Munz et al. 2014), which restricts Nitrogen assimilation by palisade grass (Sugiura and Tateno 2013). This result proves that palisade grass will barely affect the N uptake by corn, not restricting corn N nutrition. Therefore, there is no need to increase N fertilizer rate in corn intercropped with palisade grass.

The NRE was 63.3% in the monoculture (whole plant) and 57.2% in the intercropped (Table 2). Such values are relatively higher than previous results in the literature, in which NRE by corn ranged from 39% to 52% (Liang and Mackenzie 1994; Scivittaro et al. 2003; Alves et al. 2006; Gava et al. 2006; Silva et al. 2006; Duete et al. 2008). The higher NRE obtained in this study can be attributed to the low SOM levels in the soil, contributing little to release of N from SOM mineralization (Dourado-Neto et al. 2010).

Recovery of N-Fertilizer in the Soil

The total N in the soil was higher in the first 0.2 m, which represents 27% of the total N in the 1.2 m soil profile for monoculture and 24% for intercropped (Table 3). Similarly, the N in the soil derived from fertilizer (NSDF) was higher in the 0.2-m layer, with 11.6 kg·ha^{-1}N for monoculture and 13.0 kg·ha^{-1}N for intercropped. These amounts correspond to 44% (monoculture) and 34% (intercropped) of the NSDF accumulated in the 1.2-m soil profile (Table 3). The largest NSDF in the top 0.2 m of soil is a consequence of the fertilizer being applied at this depth and also of the increased immobilization of the fertilizer N by microorganisms in the soil surface.

The recovery of N from fertilizer in the soil (RNFS) did not vary between systems independently of soil depth, except in the layer between 0.6 m and 0.8 m, where there was an increased recovery of 2.4% for monoculture and 5.5% for intercropped (Table 4). There was a difference in the RNFS with depth, with greater recovery of total N applied in the first 0.4 m (8.2% was observed in the first 0.2 m and 5.0% from 0.2 m to 0.4 m) (Table 4). Full recovery in the top 1.2 m of the soil was similar, with 17.7% of N fertilizer in the monoculture and 25.1% in the intercropped (Table 4). Previous researches indicate NSDF ranging from 25 to 37 kg.ha^{-1} and RNFS ranging from 25% to 45% in studies with corn (Kitur et al. 1984; Jokela and Randall 1997; Gava et al. 2006). The relatively lower NSDF and RNFS obtained in our study can be attributed to the higher recovery of N-fertilizer by corn plants obtained herein.

Balance of ^{15}N-Fertilizer in the Soil-Plant System

In the monoculture, 97 kg.ha^{-1}N of total 150 kg·ha^{-1}N applied was recovered by corn, which represents approximately 65% of the N applied (Table 5). Intercropping corn with palisade grass resulted in recovery of N-fertilizer by corn of 90.5 kg·ha^{-1}N, or 60.4% of the N applied. In the above ground of palisade grass was accumulated only 2.1 kg·ha^{-1}N, which was equivalent to 1.4% of total N applied. The amount of N recovered in soil totaled 17.8% in the monoculture and 25.9% in the intercropped. The combined result is a total recovery of 82.4% in the monoculture and 86.9% in the intercropped system. The total recovery of ^{15}N-fertilizer in the soil-plant system obtained in this study was relatively higher than previous researches, which ranged

Table 3. Total soil N and N in the soil derived from fertilizer (NSDF) as a function of the systems*.

Depth (m)	Total N					NSDF				
	Monoculture		Intercropped			Monoculture		Intercropped		
	(kg·ha^{-1})									
0.0 – 0.2	863.1a	(148)	875.0a	(152)	NS	11.6a	(7.42)	13.0a	(2.81)	NS
0.2 – 0.4	572.8b	(140)	530.8bc	(43)	NS	7.2ab	(3.40)	7.6bc	(1.36)	NS
0.4 – 0.6	459.1b	(200)	525.6c	(35)	NS	1.8b	(1.92)	3.6bcd	(1.14)	NS
0.6 – 0.8	544.4b	(230)	707.0ab	(72)	NS	3.6b	(1.10)	8.2b	(2.74)	*
0.8 – 1.0	395.1b	(132)	479.4c	(28)	NS	1.3b	(0.46)	3.0cd	(1.89)	NS
1.0 – 1.2	363.9b	(102)	488.8c	(28)	NS	1.1b	(0.82)	2.3d	(0.50)	NS
Total	3,198.4	(830)	3,606.6	(118)		26.6	(11.88)	37.7	(3.35)	

*Values in parentheses are standard deviations (n = 4). Different letters in the columns indicate a significant difference between depths by the Tukey test ($p < 0.05$); NS: Non-significant difference; and *significant difference between the systems for total N and NSDF, as determined by the Student t-test ($p < 0.01$).

Table 4. Recovery of N from fertilizer into the soil (RNFS) up to the depth of 1.2 m*.

Depth (m)	Systems					Average
	Monoculture (%)		Intercropped (%)			
0.0 – 0.2	7.7a	(4.9)	8.6a	(1.9)	NS	8.2a
0.2 – 0.4	4.8ab	(2.3)	5.1bc	(0.9)	NS	5.0ab
0.4 – 0.6	1.2b	(1.3)	2.4bcd	(0.8)	NS	1.8bc
0.6 – 0.8	2.4b	(0.7)	5.5b	(1.8)	**	4.0bc
0.8 – 1.0	0.8b	(0.3)	2.0cd	(1.3)	NS	1.4c
1.0 – 1.2	0.8b	(0.5)	1.5d	(0.3)	NS	1.2c
Total	17.7	(7.9)	25.1	(2.2)	NS	21.4

*Values in parentheses are standard deviations (n = 4). Different letters in the columns indicate a significant difference between depths by the Tukey test ($p < 0.05$). NS: Non-significant difference and **: significant difference between the systems for RNFS, as determined by the Student t-test ($p < 0.05$).

from 63% (Sanchez and Blackmer 1988), 69% (Baker and Timmons 1994; Gava et al. 2006), and 74% (Tobert et al. 1992). However, total recovery as high as 79% to 82% was also obtained in other studies (Sanchez and Blackmer 1988; Coelho et al. 1991; Timmons and Baker 1992; Gava et al. 2006).

In the balance of ^{15}N, the only difference observed between management systems was a greater recovery of ^{15}N in the intercropping treatment in the roots (3.2%) and in the 0.6 m to 1.0 m soil layer (7,5%) (Table 5). The greater recovery of N in the roots in the intercropping treatment can be attributed to palisade grass roots that were recovered during sieving, since it was not possible to differentiate corn and palisade grass roots during sieving in the field. In addition, the greater recovery in the 0.6 m to 1.0 m can be attributed to deep roots of the palisade grass that died during the growth cycle.

Overall, there was a greater recovery of fertilizer-N in the intercropped treatment (Table 5). In the whole soil-plant system, 82.4% of the fertilizer-N applied was recovered in monoculture, whereas 86.9% was recovered in the intercropping system. This result is associated to the relatively high recovery of ^{15}N-fertilizer in the roots and in the 0.6 m to 1.0 m soil layer in the intercropped treatment. Despite the differences in non-recovered ^{15}N not being significant between management systems (13.1% in the intercropped and 17.6% in the monoculture), it is expected that continuous growing of palisade grass after corn harvest will promote further uptake of N from fertilizer (mainly from deep soil profile), reducing the potential for leaching loss. Future research could focus on evaluating the reduction in losses promoted by intercropping after the harvest of the main crop.

The non-recovered ^{15}N-fertilizer obtained in this study (~15% of applied N) can be associated to losses such as ammonia volatilization, the leaching of N at depths greater than 1.2 m, denitrification and post-anthesis N loss from leaves (Farquhar et al. 1979; Harper and Sharpe 1995). However, the non-recovered ^{15}N is relatively lower than indicated in previous studies (Timmons and Baker 1992; Sanchez and Blackmer 1988; Gava et al. 2006). We expected that applying 150 $kg \cdot ha^{-1}$ N during corn sowing (without side-dress application) would result in higher leaching losses if considered the conditions of the study, namely a sandy soil with low CEC and under high rainfall events. However, different from the expected, the results indicate that growing corn in situations of high yield potential (~10 $Mg \cdot ha^{-1}$) will result in high recovery of ^{15}N-fertilizer →

Table 5. Balance of ^{15}N in the soil-plant system in the monoculture and intercropped systems.

Compartments	Systems				
	Monoculture	Intercropped	Monoculture	Intercropped	
	($kg \cdot ha^{-1}$)		(%)		
Corn					
Grains	59.5	53.8	39.7	35.9	NS
Shoots	35.3	31.9	23.5	21.3	NS
Roots	2.4	4.8	1.6	3.2	*
Whole plant	97.2	90.5	64.8	60.4	NS
Palisade grass					
Whole plant	-	2.1	-	1.4	
Soil					
< 0.6 m	20.6	24.2	13.7	16.1	NS
0.6 – 1.0 m	4.9	11.2	3.3	7.5	*
1.0 – 1.2 m	1.1	2.3	0.8	1.5	NS
Not-recovered					
	26.2	19.7	17.6	13.1	NS
Total					
	150.0	150.0	100.0	100.0	

NS: Non-significant difference and * significant difference in the recovery of 15N between the systems by the Student t-test ($p < 0.01$).

by corn plant and low losses potential. Intercropping palisade grass with corn under such circumstances did not affect grain yield or N uptake by corn and showed potential in further reduce N losses and increasing straw production for no-till maintenance in the Brazilian Cerrado.

CONCLUSION

This study demonstrates that intercropping palisade grass with corn has the potential to increase straw production (2,265 kg·ha^{-1}) not affecting yield or N nutrition of corn. The corn yield was similar when corn was cultivated as a monoculture (9,800 kg.ha^{-1}) or intercropped with palisade grass (9,671 kg·ha^{-1}). Palisade grass accumulated only 2.1 kg·ha^{-1} of ^{15}N-fertilizer (1.4% of applied N) and did not affecte corn N nutrition. The recovery of ^{15}N-fertilizer totaled 82.4% in the corn-monoculture and 86.9% in the corn-palisade grass intercropping. Intercropping palisade grass (*Urochloa ruziziensis*) with corn will not limit corn grain yield and has the potential to increase straw production contributing to maintenance of no-till in the Brazilian Cerrado.

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