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Palisadegrass effects on N fertilizer dynamic in intercropping systems with corn

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ABSTRACT

Corn grain yield, nitrogen (N) fertilizer efficiency and distribution to corn alone and three forms of corn and palisadegrass (*Urochloa* spp.) intercropping implantation was investigated. A field experiment with $_{15}$N labeling fertilizer was performed in randomized block design. No form of palisadegrass intercropping implantation affected corn grain yield, total N accumulation and N use efficiency (NUE), which were 8.7 t ha^{-1}, 205 kg ha^{-1} and 37% respectively. The palisadegrass produced on average 1.9 t of dry mass, absorbing a maximum of 6 kg ha^{-1} or 5.5% of N fertilizer during corn growing. Furthermore, the palisadegrass did not affect N fertilizer distribution in soil-plant system, in which 28.2% was recovered in the soil and 40.4% in the plants (corn + palisadegrass). The results show that for the three intercropping implantation methods the palisadegrass did not compete with corn for N fertilizer.

Key words: ^{15}N isotope, Crop-livestock integration, Nitrogen use efficiency, No-tillage, *Urochloa* spp., *Zea mays*.

INTRODUCTION

Plants intercropping is an alternative for the establishment of more sustainable agricultural systems (Scopel et al. 2013). In tropical and subtropical conditions of South America, the intercropping of tropical grain and forage production plants allows harness the additional water of the summer to cultivated grain in order to keep the soil covered during the off-season in areas under no-tillage system (Borghi et al. 2012, Ceccon et al. 2013, Crusciol et al. 2013), or to establish pasture after harvesting the grain (Borghi et al. 2013) in the system concept and crop-livestock integration (CLI).

In Brazil, corn (*Zea mays*) and palisadegrass (*Urochloa* spp.) are the species grown with higher expression in intercropping on agricultural areas, mainly driven by the growing adoption of CLI system. Studies which evaluating the intercropping

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of corn and palisadegrass, with competitive advantage to the grain producing plants, showed that the productive potential of the area was not compromised by the presence of palisadegrass (Borghi et al. 2012, 2013). However, in addition to grain yield other factors should be considered such as the nitrogen (N) use efficiency (NUE) for corn.

There are studies that evaluated the N in corn-palisadegrass intercropping which showed that palisadegrass when shaded by corn does not compromise the N absorption by corn (Barducci et al. 2009, Costa et al. 2012). However, it is not known how much N fertilizer is absorbed by palisadegrass grown under intercropping system, and if this amount allocated to palisadegrass changes or reduces the use of N fertilizer for corn. If this occurs, new calibrations would be required for the rate of N for corn crops intercropped with palisadegrass in order to nourish both crops.

Regarding the dynamics of N in the corn-palisadegrass intercropping, another factor also deserves emphasis: the intercropping implantation method. Due to the diversity of implements and size of farms, palisadegrass seeding can be performed before or simultaneously to corn sowing, broadcasted, mixed with corn fertilizer or in a furrow, parallel to the corn rows (Borghi et al. 2013, Crusciol et al. 2013). There is no information if the forms of intercropping implementation of palisadegrass would change the N nutrition of corn, nor the nutrient dynamics in the soil-plant system.

Although there have been many reports on grain yield in corn-palisadegrass intercropping, much less attention has been paid to the dynamics of the N fertilizer in intercropping systems. This research was conducted with the aim of assessing the amount of N from the fertilizer absorbed by palisadegrass grown intercropped with corn and the impact of palisadegrass in the N fertilizer distribution in intercropping system.

MATERIALS AND METHODS

EXPERIMENTAL AREA AND CULTURAL PRACTICES

The experiment was performed in the 2012/13 crop season at Serrado Chão Quente farm, in Taquarituba-Brazil (23° 587' S, 49°248' W, at 654m). The soil was classified as Hapludalf eutrophic (USDA 1999) with 490 g kg^{-1} clay content in surface horizon and 590 g kg^{-1} clay content in the subsurface horizon. The climate is classified as Cfa (subtropical with well distributed rainfall and hot summer, and average annual temperature of 20 °C). The climate data during growing season is shown in Figure 1.

The result of the chemical analysis of the soil collected before experiment installation of the was pH 5.5 ($CaCl_2$), O.M. 40 g dm^{-3} (dichromate / colorimetry) P, K, Ca and Mg (resin) 19 mg kg^{-1}, 7.6 mmol$_c$ kg^{-1}, 42 mmol$_c$dm^{-3}, 31 mmol$_c$ kg^{-1} respectively, H + Al 34 mmol$_c$ kg^{-1} (pH SMP), Al 0 mmol$_c$ kg^{-1} (titration 1 mol L^{-1}), CEC 115 mmol$_c$ kg^{-1} and V 70%.

On November 10, 2012 the corn hybrid DKB 390 VT PRO was seeded, spaced 0.9m between rows and with a population of 60,000 plants per hectare. The palisadegrass used was *Urochloa ruziziensis* (or *Brachiaria ruziziensis*) and it was sown 4.5 kg ha^{-1} seeds with 86% of cultural value on the same day of the corn in accordance to the treatments. At sowing 152 kg ha^{-1} P_2O_5 as triple superphosphate and 51 kg ha^{-1} K_2O as KCl was provided. N in the form of ammonium nitrate was applied by broadcasting on the same day, after corn sowing, at a rate of 106 kg ha^{-1}.

EXPERIMENTAL DESIGN AND TREATMENTS

The experimental design was randomized blocks with four replications in which the plots consisted of 6 corn rows, 10 m long. Treatments consisted of four cropping systems, one monocrop and three intercrop: (i) broadcast sowing palisadegrass immediately before corn seeding (P. Broadcast);

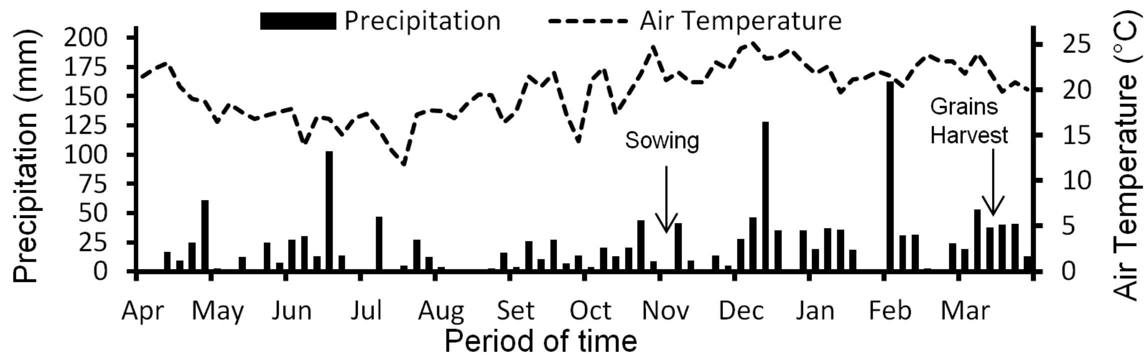

Figure 1 - Air temperature and precipitation during the research period from April to March.

(ii) simultaneous sowing palisadegrass and corn, with palisadegrass seeds placed right between corn rows (P. between rows); (iii) simultaneous sowing palisadegrass and corn, palisadegrass seeds distributed with the fertilizer (P deep); and corn alone. The palisadegrass used was *Urochloa ruziziensis* (syn. *Brachiaria ruziziensis*).

ASSESSMENT AND METHODOLOGY OF THE ^{15}N STABLE ISOTOPE

Microplots were installed in the center of the plots to study the N use efficiency (NUE) using ammonium nitrate enriched (2.65% ^{15}N atoms) at a rate of 106 kg ha^{-1} of N. For isotopic analysis, corn and palisadegrass were collected in the central third of each microplot. Corn plants were separated into the shoot (including leave+stalk+cob+straw), and grains. The palisadegrass assessment was determined with the mass of the shoot (leave+stalk). Soil was also collected in the microplots at three depth (0.0 m to 0.2 m, 0.2 m to 0.4m, 0.4 m to 0.6) to determine ^{15}N recovery.

The dried material was comminuted in a Willey knife mill and Total-N and abundance of atoms (^{15}N%) analyzes was determined using a mass spectrometer coupled with an N analyzer model ANCA-GSL, from Sercon Co. UK. The amount of N derived from fertilizer (NDFF), percent of N fertilizer recovery and N use efficiency (NUE) were calculated as done by Subedi and Ma (2005) and Pierozan Junior et al. (2015).

STATISTICAL ANALYSIS

The results were submitted to normality and variance homogeneity tests as well as an analysis of variance (ANOVA) by the F-test at 5% probability using the Statistical Analysis System software, Windows version 9.2 (SAS Institute 2009).

RESULTS

CORN YIELD AND DRY MASS PRODUCTION

The corn intercropped with palisadegrass did not affect corn yield and dry mass production, regardless of the implantation method ($p > 0.05$). The corn produced on average 8.7 Mg ha^{-1} of grain and 8.8 Mg ha^{-1} of dry mass in the shoot (Figure 2). The ANOVA also revealed no difference ($p > 0.05$) between the three forms of intercropping implantation for palisadegrass biomass. The palisadegrass produced on average 1.9 Mg ha^{-1} of dry biomass (Figure 2).

N ACCUMULATION, PARTITIONING AND USE EFFICIENCY

The total-N in shoot, grain, whole plant corn and aboveground biomass were not influenced by palisadegrass ($p > 0.05$), showing the values of 66.5 kg ha^{-1}, 139 kg ha^{-1}, 205 kg ha^{-1} and 229 kg ha^{-1}

respectively (Figure 3a). The total-N palisadegrass was 34 kg ha^{-1} on average for intercropping systems.

The forms of palisadegrass implantation did not influence the amount of NDFF in the parts of the corn plant (shoot and grains), as well as in the whole plant corn and aboveground biomass ($p > 0.05$).

The NDFF for whole plants corn was on average 26 kg ha^{-1} (Figure 3b), equivalent to 18% amount of N in grains. The other part (82%) of N contained in the grains came from other sources, especially the soil. The NDFF for the whole plant corn was 40 kg ha^{-1}, which represents 19% of the total-N absorbed by whole plant corn. The NDFF in palisadegrass was 4.6 kg ha^{-1} and it represents, on average, 2% of the Total-N absorbed (^{14}N + ^{15}N) by the aboveground biomass intercropping, or 11% of the ^{15}N fertilizer recovered in the corn-palisadegrass intercropping (Figure 3b). Regarding palisadegrass the NDFF was 13% of the Total-N absorbed by plants (34.2 kg ha^{-1}).

The corn and system (aboveground) NUE also did not differ according to the forms of intercropping implantation ($p > 0.05$). The NUE to corn was 37% and the NUE to system was 41%, namely 43 kg ha^{-1} of the applied rate (Figure 3b).

N DERIVED FROM FERTILIZE (NDFF) IN THE SOIL AND N BALANCE

The palisadegrass implantation forms rows did not influence the amount of N fertilizer in any of the evaluated soil layers, nor the total NDFF ($p > 0.05$). On average for the treatments, of all N applied (106 kg ha^{-1}), 49 kg ha^{-1} (46%) remained distributed in soil: 29.7 kg ha^{-1} (28%) in the 0-0.2 m depth, 11.7 kg ha^{-1} (11%) in the 0.2-0.4 m depth and 7.4 kg ha^{-1} (7%) in the 0.4-0.6 m depth (Figure 4).

In addition, three forms of corn intercropped with palisadegrass did not affect N fertilizer balance (Table I). On average 92 kg ha^{-1} or 87% of the applied N was recovered in this research, and the N not recovered in the system was on average 14 kg ha^{-1} or 13% of the N rate.

DISCUSSION

Intercropping systems did not affect corn yield and dry mass, regardless of the implantation methods. Therefore, any forms of corn and palisadegrass intercropping implantation are a viable option for corn grains yield. Regarding palisadegrass biomass, intercropping systems produced satisfactory biomass for the grazing of animals in crop-livestock integration systems, or for mulching in no tillage (Ceccon et al. 2013).

N dynamics, efficiency and balance also were not affected by intercropping methods. The results shows that palisadegrass did not affect the N absorption by corn, and that the N applied as fertilizer which was absorbed by palisadegrass is insignificant, not restricting corn nutrition. Therefore there is no need to increase the rate of N fertilizer in corn when cultivated intercropped with palisadegrass. This fact is important for the economic viability of the intercropping system, because there will be no increase in fertilizer costs.

Despite being a species with extensive root systems, the development of palisadegrass close the corn rows did not increase NDFF. The low N fertilizer recovery by palisadegrass is explained because the forage is the subordinated crop in the intercropping system, with restricted resources, especially light. During cogrowth period the palisadegrass remained shaded with lower interception of photosynthetically active radiation (Munz et al. 2014), which restricted the assimilation of N by palisadegrass (Sugiura and Tateno 2013), even with N fertilizer in the soil.

The N fertilizer leaching was low, since the greater amount of the ^{15}N soil fertilizer- (60%) was in the surface layer (0.2m). Two factors may have contributed to the permanence of N in the soil surface layer: i) the organic matter in soil,

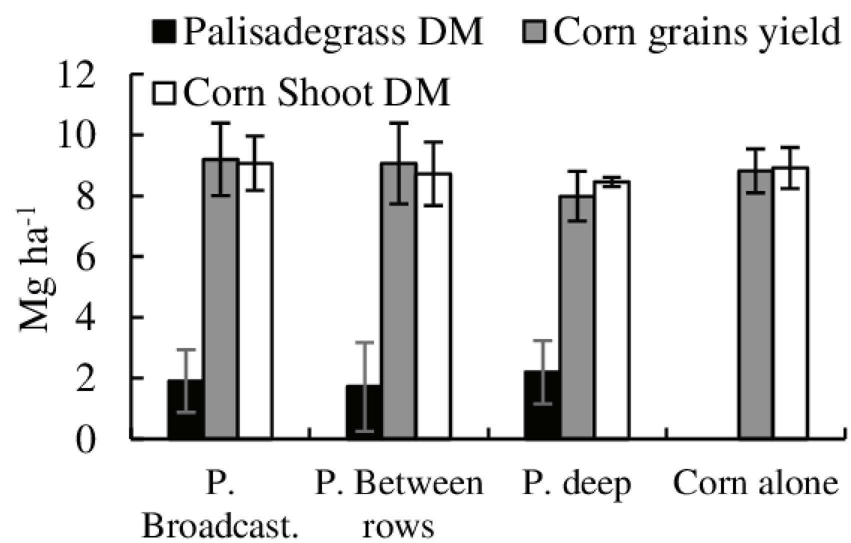

Figure 2 - Dry mass (DM) and grains yield of corn and palisadegrass. The bars represented the standard error of the means.

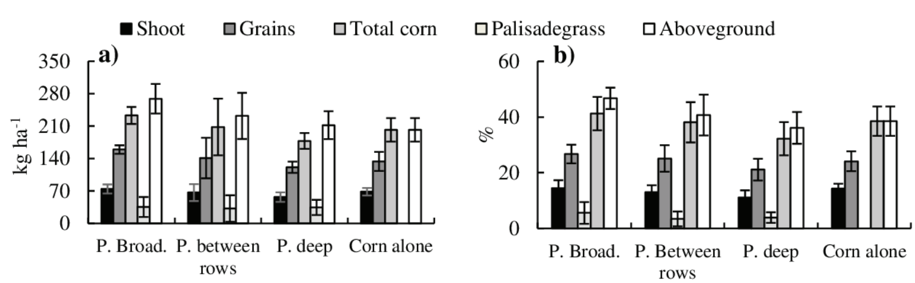

Figure 3 - Total N **(a)** and N fertilizer recovery **(b)** in the corn shoot, grains, total corn (grains + shoot), palisadegrass and aboveground (corn + palisadegrass). Bars represented the standard error of the means

increasing the immobilization of the N unused by corn or palisadegrass; ii) and the supply of N in top dressing, in the moment of greatest demand for nutrient. Other studies have also reported low N fertilizer leaching in these conditions, ranged from 0.8% to 6% of the N applied as fertilizer (Portela et al. 2006, Rimski-Korsakov et al. 2012).

Due to low leaching, it is assumed that most of the N non recovery of this study is probably due to methodological and analytical errors and loss of N by shoot during the senescence of leaves (Francis et al. 1993) and denitrification (Grageda-Cabrera et al. 2011).

The results obtained by this research shows that the intercropping of corn and palisadegrass - a conservationist practice - does not affect corn grain yield and N dynamics during cogrowth period. However, N dynamic may be affected under different soil texture or organic matter level, indicating the need for a specific N study to soil-available N pool. In addition, it is also worth mentioning the need to investigate the N fertilizer

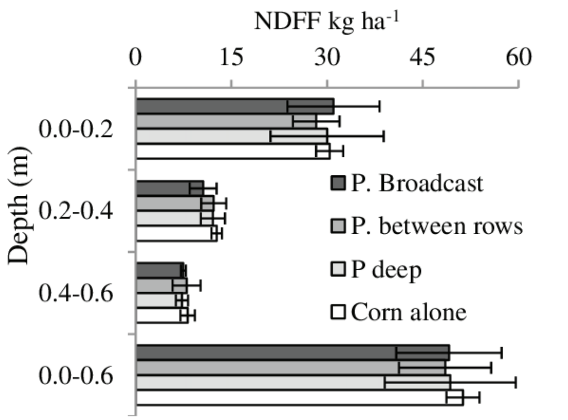

Figure 4 - Distribution of NDFF in soil depths at corn harvest. The bars represented the standard error of the means.

TABLE I
Balance of N fertilizer recovery at different corn growth systems.

Corn growth systems	N recovery	
	kg ha^{-1}	%
P. Broadcast	98.6	93.0
P. between rows	91.6	86.4
P deep	87.5	82.5
Corn alone	92.0	86.8
Means	92.42	87.2
Pr>F	0.74 ^{ns}	
CV %	15.3	

^{ns} not significant at 5% probability of error by the F test.

absorption by palisadegrass in after corn harvest, as this could increase the NUE of the intercropping system.

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