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Nitrogen fertilization for summer corn in succession to cover crops under direct drilling system in Western Paraná - Brazil

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The quality of vegetal residues from crops and green manure can influence the mineralization/immobilization rate of nitrogen and the subsequent utilization of this nutrient by the following crops. The aim of this study was to evaluate the effect of nitrogen rates applied to the cover of summer corn, succeeding winter cover crops under direct drilling system. The experimental design consisted of randomized blocks with four replications in a scheme with subdivided plots. The main plot was composed of two crops previous to corn: Common oat (*Avena strigosa Schieb*), forage turnip (*Raphanus sativus*) and a fallow area (weed). The subplot consisted of four rates of nitrogen (0, 30, 60 and 120 kg ha^{-1}). The production components analyzed were: Ear diameter, rows of grains/ear, mass of 100 grains and yield. Cover crops did not affect the components of corn production. The corn cultivated in succession to forage turnip showed responses to nitrogen fertilization.

Key words: *Avena strigosa* Schieb, *Raphanus sativus*, *Zea mays.*

INTRODUCTION

The cultivation of corn (*Zea mays* L.) during the summer crop in Paraná accounts for 24% of the national production. The state's corn crops have accounted for 26% of the Brazilian production in recent years, with about 12.61 million tonnes (Demarchi, 2010). The first crop, or summer crop, is conducted from October to February; in such period the technological level of production increases due to weather and water conditions.

The use of cover crops along with mineral fertilization and maintenance of straw over the soil can increase the stocks of organic N in the soil (Sainju et al., 2005).

According to Fernandes and Libardi (2012), the advance and widespread of the direct drilling system and the re-covering of the soil increase the total stock of N in the soil, resulting in new agricultural recommendations.

Cover crops play an important role in the direct drilling system, including protecting the soil from erosion, increasing soil organic matter, improving chemical, physical and biological quality, and promoting carbon sequestration, what allows producers to reduce costs on fertilizers and herbicides for weed control (Carvalho et al., 2011, Rosa et al., 2012; Rosolem and Calonego, 2013).

Nitrogen (N) is the most required nutrient in larger quantities and the one that most influences corn productivity; it is also the main factor that burdens the

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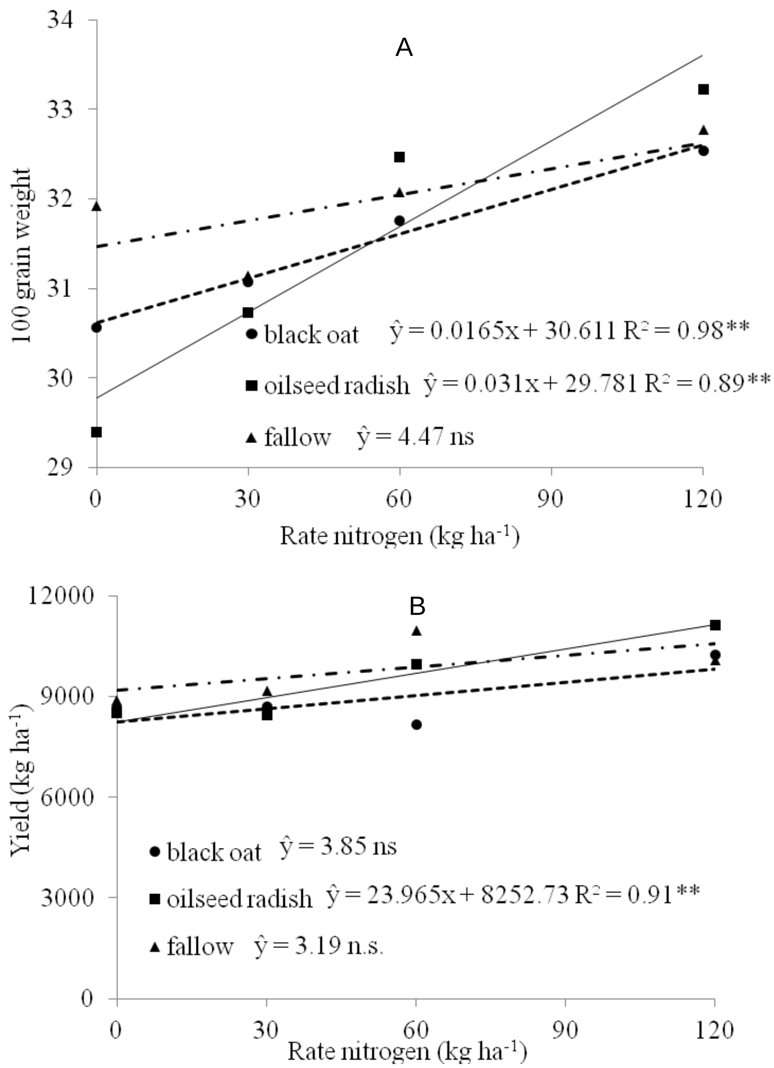

Figure 1. 1000-grain weight (A) and grain productivity (B) of maize about cover crops and rates of nitrogen.** = significant at 1%probability; ns = not significant.

cost of production of such crop. Another aspect to be considered concerning to the nitrogen fertilization of corn is the source of mineral nitrogen. Slow-release nitrogen fertilizers, according to Cantarella (2007), are better used by plants, since their release is gradual, what reduces losses by leaching and volatilization, increasing fertilizer efficiency on the crop. One option that can be used is a product called Sulfammo, which presents 22% nitrogen, in amide and ammoniacal form.

Silva et al. (2006) observed maximum technical efficiency of nitrogen on corn with rates of 205 and 175 kg ha^{-1} in succession to common oat and forage turnip, respectively. According to Roselem et al. (2004), graminoids have elevated ratio C/N and dry matter production, however, when corn is being cultivated in succession in tropical areas, it is necessary to perform nitrogen supplementation. The aim of this study was to evaluate the effect of preceding crops associated with nitrogen levels in corn crops under stabilized direct drilling system.

MATERIALS AND METHODS

The work was conducted under field conditions in the agricultural year 2012 to 2013, in an agricultural area in the municipality of Medianeira, PR, Brasil, which presents as its geographic coordinates longitude 54° 04'16'' W, latitude 25° 20'09'' S and altitude of 286 m. The climate is humid subtropical with hot summers, with an annual average of 21°C (Iapar, 2011). The average monthly rainfall is shown in (Figure 1, Table 1).

The soil used in the experiment was collected on the same property, at a depth of 0 to 20 cm and classified as eutroferric Oxisol (LVe) (EMBRAPA, 2006). The results of the chemical analysis of the soil before the establishment of the experiment are shown in Table 2.

Table 1. Rainfall recorded during the experiment.

Months	May	June	July	Aug.	Sept.	Oct.	Nov.	Dez.	Jan.	Feb.
Rainfall (mm^{-1})	86	53.3	102	0	97	162	96	300	0	239

Table 2. Chemical attributes of an oxisol before the establishment of the experiment.

Camada	pH	C	P	H+Al	Ca+Mg	K	CTC	V
(cm)	$CaCl_2$	(g dm^{-3})	(mg dm^{-3})	----------------(cmol$_c$ dm^{-3})----------				(%)
0-20	5.30	16.53	19.50	4.61	9.31	0.51	14.43	68.05

C, Carbono; P, phosphorus; Al, aluminum; H+Al, Hydrogen + aluminum, Ca+Mg-calcium + magnesium; K, potassium; S, sum of bases; CTC, cation exchange capacity; V, %base saturation.

The experimental design consisted of randomized blocks with treatments arranged in a scheme with subdivided plots, with four replications. The plots, measuring 50.4 × 4.20 m, were established by winter cover crops: Common oat (*Avena strigosa Schieb*), forage turnip (*Raphanus sativus*) and a control treatment (witness), without growing cover crops (fallow). Subplots measured 16.8 × 4.20 m, with four rates of nitrogen under cover fertilization in the corn crop (0, 30, 60 and 120 kg ha^{-1}).

The cover species were mechanically sown in winter, May 5, 2012, in succession to a soybean crop, with its sowing density following the technical recommendation for each crop. Plant desiccation was performed on August 16, 2012 by using herbicide glyphosate (2.275 g i.a. ha^{-1}) and subsequent mechanical handling through a crusher model Triton©. The dry matter production of cover crops present in the plots was not determined.

Corn was sown mechanically, on September 16, with basic fertilization in all plots of 210 kg ha^{-1} of NPK formulation 13-06-9. The corn used was the hybrid Pioneer 30F53, considered as medium cycle, recommended for normal season planting (summer). Density of 4.1 seeds per meter was used, with distance of 0.70 m between lines, totalizing 58.000 plants ha^{-1}. The seeds were treated with Thiamethoxam in a dose of 210 i.ag/100 kg seeds. For the control of weed in post-emergence, 1650 g of atrazine i.a. ha^{-1} + 148 g of mesotrione i.a. ha^{-1}, were applied, when corn plants presented six fully expanded leaves. The application of nitrogen rates to the cover in the subplots was performed manually beside the plants when they were in V6 (six fully expanded leaves).

During corn harvest, the two central rows of each plot were sampled, discarding 0.50 m from each end. Five ears of each line were collected and separated to determine the following yield components: Number of grain rows per ear (by counting the grain rows of each ear, individually); ear diameter (with the aid of a caliper); mass of 100 grains (average mass of five subsamples of 100 grains corrected to 13% moisture) and productivity (mass of grains produced in the two central lines of each plot corrected to 13% moisture by estimating the productivity kg ha^{-1}).

The results were subjected to analysis of variance, by using the F test at 5% for comparing cover crops, and polynomial regression analysis, for studies of N rates on coverage, using the statistical package Assistat® version 7.5 beta (Silva and Azevedo, 2002).

RESULTS AND DISCUSSION

The yield components of ear diameter and rows of grains/ear were not affected by cover crops and nitrogen rates, not fitting in any regression model tested (Table 3). As for the mass of 100 grains and productivity, the results were increased by rates of nitrogen, regardless of the previous crop. The interaction cover crop x N rates interfered only in the mass of 100 grains (Table 3).

The yield components ear diameter and number of rows/ear did not suffer influence of the corn sowing in succession to cover crops, regardless of the dose of N applied to the coverage, what partially corroborates studies conducted by Souza et al. (2003), in which the cover crops common oat and forage turnip did not affect length and diameter of irrigated corn ears. However, it disagrees with Ohland et al. (2005), who studied corn crops in succession to hairy vetch and forage turnip and observed an increase in ear diameter in the succession hairy vetch/corn regardless of the rates of N applied. Souza et al. (2011) and Casagrande and Fornasieri Filho (2002) found no effect for rates of nitrogen in the coverage in the number of grain rows per corn ear.

When cover crops were common oat and forage turnip, it was possible to observe a crescent linear adjust for yield component mass of 100 grains (Figure 1A). One could verify good correlation for that component, which is one of the most correlated to crop productivity, given that the highest values, obtained with the dose of 120 kg ha^{-1}, were 32.5 and 33.22 g for the successions common oat/corn, and forage turnip/corn, respectively. Superior results were found by Silva et al. (2006), when working with the successions hairy vetch/corn and forage turnip/corn. The authors verified linear adjust up to the dose of 250 kg ha^{-1} with 37.4 and 35.8 g. Casagrande and Fornasieri Filho (2002) found differences for mass of 100 grains only between hybrids C444 and C333B, with values 22.9 and 29.6 g, respectively.

For grain productivity, the results were significant with crescent linear adjust only for the succession forage turnip/corn, with values of 11,131 kg ha^{-1} for the dose with 120 kg ha^{-1} (Figure 1B). It must be highlighted that the productivity was increased due to the climatic conditions at the experiment location, and also for being a summer

Table 3. Diameter of ear, Rows per ear, 100 grain weight and grain productivity of maize about cover crops and rates of nitrogen.

Cover crops	Diameter of ear	Rows per ear	100 grain weight	Yield (kg ha^{-1})
Black oat	48.42	16.40	32.53	8,932
Oilseedradish	52.02	16.73	33.22	9,510
Fallow	52.10	16.51	32.77	9,785
CV (%)	13.37	4.49	4.01	11.45
Teste F			Values of F	
Cover crops (C)	1.527^{ns}	0.829^{ns}	$0.863^{n.s}$	2.840^{ns}
Rate (R)				
CV (%)	13.22	3.40	2.76	12.41
Linear reg.	0.004^{ns}	0.114^{ns}	47.286**	18.777**
Quadratic reg.	1.198^{ns}	0.230^{ns}	0.575^{ns}	1.167^{ns}
Interaction (CxR)	1.011^{ns}	0.354^{ns}	2.698*	1.841^{ns}

Means with different small letters in the columns are statistically different at (**) 1% and (*) 5% of probability or no significant (^{ns}) Tukey test.

crop. Ohland et al. (2005) when working with crops preceding corn, forage turnip and hairy vetch did not observe effects from preceding crops and interaction, however, the corn cultivated after the hairy vetch produced an average of 9,809 kg ha^{-1}, followed by the forage turnip, with 9,447 kg ha^{-1}; such yield is equivalent to twice the state of Mato Grosso do Sul. Roselem et al. (2004) observed higher corn productivity in succession to millet with nitrogen fertilization applied to the coverage; however, such fertilization of 120 kg ha^{-1} was not enough to supplement the needs of the crop after common oat.

In the succession common oat/corn and fallow/corn, none of the models evaluated in the analysis of regression adjusted to the data, showing that there was no answer of productivity in function of nitrogen fertilization. Lourente et al. (2007) verified maximum corn productivity of 6,838 kg ha^{-1}, obtained after a wheat crop, and 6,509 kg ha^{-1} after common oat for the rates with 140 and 137 kg ha^{-1} of nitrogen, respectively. Silva et al. (2012), in a study in western Paraná, verified yields of 3,928 kg ha^{-1} of summer corn with rates of 7 tonnes per ha^{-1} of poultry litter being used as nitrogen source.

Conclusion

Cover crops did not influence corn yield components. Corn, when cultivated in succession to forage turnip presented responses to nitrogen fertilization.

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