

Residual nitrogen fertilization effect of common bean production on succeeding corn intercropped with Congo grass¹

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ABSTRACT

Crop production in conservation systems involving intercropped cultivations mainly with corn have been proposed as a technology to promote sustainability in the Brazilian Cerrado areas. The objective of this work was to evaluate the influence of residual nitrogen fertilization applied in common bean on subsequent corn sole or intercropped with Congo grass (*Urochloa ruziziensis*) in no-tillage system. The experiment was carried out in randomized blocks with three replicates in a split-plot design. The treatments were composed by two cropping systems (sole and intercropped with Congo grass), and the sub-plots were five doses of nitrogen (0; 40; 80; 120 and 160 kg of N ha⁻¹), applied in topdressing on common-bean (previous crop). There was no effect of cropping systems and residual amount of nitrogen application in the vegetative and reproductive development of corn. Corn intercropped with Congo grass led an adequate formation of crop residue and total land covering target at sustainability of no-tillage system.

Key-words: *Zea mays*; *Urochloa ruziziensis*; crop system; straw.

RESUMO

Efeito residual da adubação nitrogenada no feijoeiro comum sobre o milho subsequente consorciado com braquiária

Sistemas conservacionistas de produção envolvendo cultivos consorciados, principalmente com milho, têm sido propostos como tecnologia para promover a sustentabilidade em áreas do Cerrado brasileiro. Diante desses aspectos, o objetivo do trabalho foi avaliar a influência da adubação nitrogenada residual aplicada no feijoeiro comum em subsequente cultivo de milho exclusivo e consorciado com braquiária (*Urochloa ruziziensis*), no sistema plantio direto. O delineamento experimental utilizado foi o de blocos casualizados, em esquema de parcelas subdivididas, com três repetições. As parcelas foram representadas por dois sistemas de cultivo contendo milho exclusivo e consorciado com braquiária e as subparcelas foram constituídas por cinco doses de nitrogênio (0, 40, 80, 120 e 160 kg ha⁻¹ de N), aplicadas em cobertura no feijoeiro (cultura antecessora). Destaca-se que não houve efeito dos sistemas de cultivo e das doses residuais de aplicação de N sobre o desenvolvimento vegetativo e reprodutivo do milho. O consórcio de braquiária e milho permitiu adequada formação de palhada e total recobrimento da superfície do solo objetivando a qualidade e sustentabilidade do sistema plantio direto.

Palavras-chave: *Zea mays*; *Urochloa ruziziensis*; sistema de cultivo; palhada.

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INTRODUCTION

Although grown in a season with climate unfavorable for maximum agronomic performance, the off-season corn has accounted for approximately 65% of total Brazilian production (CONAB, 2016). Among the main aspects related with viability and expansion of the crop in the off-season is the evolution of conservationist production systems, such as no-tillage and cultivation strategies with perennial forages, especially *Urochloa* species (Pariz *et al.*, 2009; Chioderoli *et al.*, 2012). Among the forages intercropped with corn, Congo grass (*Urochloa ruziziensis*) distinguish due to rapid establishment and excellent formation of straw, considering that the forage produces large amount of dry matter until sowing of the next crop, giving full protection to the soil surface (Souza *et al.*, 2011; Freitas *et al.*, 2013; Cunha *et al.*, 2015). Furthermore, *Urochloa* species are considered great restorer of soil organic matter, in addition to promoting higher nutrient cycling in agricultural production systems (Batista *et al.*, 2011).

Nitrogen (N) is characterized as the main nutrient for corn grain yield, and exerts great effect on the costs of this cereal production. In order to improve environmental sustainability, nutrient management strategies are needed to optimize the use of chemical fertilizers. Optimizing nitrogen fertilizer application to agriculture cropping systems leads to reduce economic and environmental issues, in addition, it is important to prevent nutrient deficiencies that limit the productive potential of the crop (Amado *et al.*, 2002; Kappes *et al.*, 2009). Considering these aspects, it is a constant challenge to establish the prescription of appropriate rates, both for the nutritional and the economic aspects. It should be highlighted that the demand for N may be even greater than the recommended (Batista *et al.*, 2011), so it is extremely important to carry out further studies in this area.

In conservation systems, the preceding crop is seen as one of the main criteria for the recommendation of nitrogen fertilization for growing corn under no-tillage system. The use of Fabaceae species and high amounts of fertilizer used in the agricultural production system may provide residual effect on subsequent crops, reducing the demand for application of nitrogen mineral fertilizers in the following crop (Fernandes *et al.*, 2008).

Scientific results show that stabilization of the no-tillage system provides increase in total soil nitrogen stocks, which is detected by the reflection in the reduction of losses, especially in erosion, leaching and denitrification processes, and with the increase in additions by means of symbiotic process of atmospheric N fixation and the inclusion of organic residue (D'Andréa *et al.*, 2004; Sou-

za *et al.*, 2009). Lovato *et al.* (2004) evidenced that the practice of grass rotation with Fabaceae family and nitrogen fertilization are the preponderant factors for the largest annual addition of N to the soil, a fact directly related to the productivity of corn grain. Therefore, the study of the management of nitrogen fertilization in different cropping systems is of fundamental importance because it is one of the ways to achieve the reduction of costs in cereal production.

Therefore, the objective of this study was to evaluate the influence of residual nitrogen fertilizer applied in the previous common bean in corn intercropped or not with *U. ruziziensis* in no-tillage system.

MATERIAL AND METHODS

The experiment was carried out in Jaboticabal, state of São Paulo, located at latitude 21°14'33"S and longitude 48°17'10" W, at 565 meters above sea level. According to the classification proposed by Köppen, the climate in the region is Aw, characterized as humid tropical, with the rainy season in summer and dry season in winter. The soil is classified as clayey Oxisol, with 533 g kg⁻¹ clay, 193 g kg⁻¹ silt and 274 g kg⁻¹ of sand, mild rolling relief, being grown in the crop years of 2008/09, 2009/10 and 2010/11 with corn and *Brachiaria ruziziensis* in summer following spring common bean.

Chemical analysis of soil fertility in the 0-20 cm layer, according to the methodology described by Raij *et al.* (2001), allowed to observe the following values: pH (CaCl₂): 5.4; O.M. (g dm⁻³): 22; P resin (mg dm⁻³): 82; H + Al; K; Ca; Mg; SB; CEC (mmol_c dm⁻³): 25; 5.7; 28; 13; 46; 71; and V: 65%, respectively.

The experimental design was randomized block in a split-plot design with three replications. The plots were represented by two cropping systems (sole and intercropped-cropped with *Urochloa ruziziensis*), following irrigated common bean crop (grown in the winter-spring period). The subplots were composed of five rates of nitrogen applied in topdressing in common bean crop (0, 40, 80, 120 and 160 kg N ha⁻¹) at the phenological stage V₄₋₄ (50% of plants with four fully expanded trifoliolate leaves) using urea as a source, which were placed at 10 cm from the growing row in continuous fillet.

Common bean cultivar IAC Formoso was sown on August 19, 2011, where 12 viable seeds were mechanically distributed per meter, at spacing of 0.45 m between rows, equivalent to 266,000 plants ha⁻¹. Harvest was performed manually on November, 18, 2011. Corn sowing was carried out on January, 21, 2012, a period considered as second crop (off-season). In both crop systems, the simple hybrid DKB 390 PRO2 was used in the population density of

60,000 plants ha⁻¹, with rows spaced at 0.80m. Sowing fertilization consisted of 330 kg ha⁻¹ of the commercial formula 04-14-08. In topdressing, 80kg N ha⁻¹ and 80 kg ha⁻¹ K₂O was used by employing the commercial formula 20-00-20 at V₄ leaf stage (four fully expanded leaves) and 100 kg N ha⁻¹ via urea in V₆ (50% of the plants with six fully expanded leaves), followed by the application of a water depth of 15 mm by conventional spraying. Each subplot was composed of six corn rows spaced at 0.80 m and 5 m in length. The two central rows of each subplot were considered as the useful area, disregarding 0.5m at each end.

When intercropped with Congo grass, forage sowing was carried out at the density of 400 points of cultural value ha⁻¹ (7.5 kg of seeds ha⁻¹) at the time of corn sowing at the proportion of two rows between the rows of corn. The intercropped corn was conducted under the same procedures as the sole crop. Corn harvest, single and intercropped, was carried out June 4th, 2012. The weather data recorded during corn and Congo grass growth are in Figure 1.

During the experimental period, the following characters were evaluated: a) plant height and first spike insertion height at the end of the cycle of ten corn plants, from ground level to the flag leaf and from ground level to the first spike insertion of the plant, respectively; b) the diameter of rachis, measuring the central third of ten ears; c) the length of the cob, calculated using the average of ten ears; d) the number of rows per ear and of kernels per row, determined by counting the number of grains in a row and the number of rows in each spike; e) the mass of grains per spike, measured by the mean of the mass of grain of ten ears (moisture content adjusted to 13%); f)

1000-grain weight, determined by counting and weighing eight samples obtained from each subplot; g) mass and diameter of the cob; h) grain yield (kg ha⁻¹ to 13% moisture) obtained after harvesting the two central rows of each subplot; i) crude protein content in grains, determined by multiplying the total N in the grains x 6.25, expressed in g kg⁻¹ (Malavolta *et al.*, 1997); j) the grain size distribution was performed by passing the grains through a set of sieves; elongated sieve no. 18 (18/64" pol) and round holes, number 18 (18/64" pol), 20 (20/64" pol) 22 (22/64" pol) and 24 (24/64" pol) (Andrade *et al.*, 2001). After a minute of mechanical stirring, the fraction retained on each sieve was weighed and the data transformed into percentage of grains retained on each sieve.

After the corn harvest, in both crop systems, covering and amount of straw on the soil were determined. For this, two samples per plot were collected with the aid of a wooden frame with inner dimensions of 0.5 × 0.5 m, and the samples were washed and dried in a forced air ventilation oven at 65°C until constant mass. In addition, N accumulated content was determined in the straw according to the methodology of Malavolta *et al.* (1997).

Data were submitted to analysis of variance by F test and means were compared by the method of Tuckey at 5%. Significant effects for residual effect of N and the interaction of cropping systems × residual effect of N were evaluated by polynomial regression analysis.

RESULTS AND DISCUSSION

From the obtained estimates, the morphological parameters and the yield components of the corn were not affected by the presence of forage specie ($p < 0.05$)

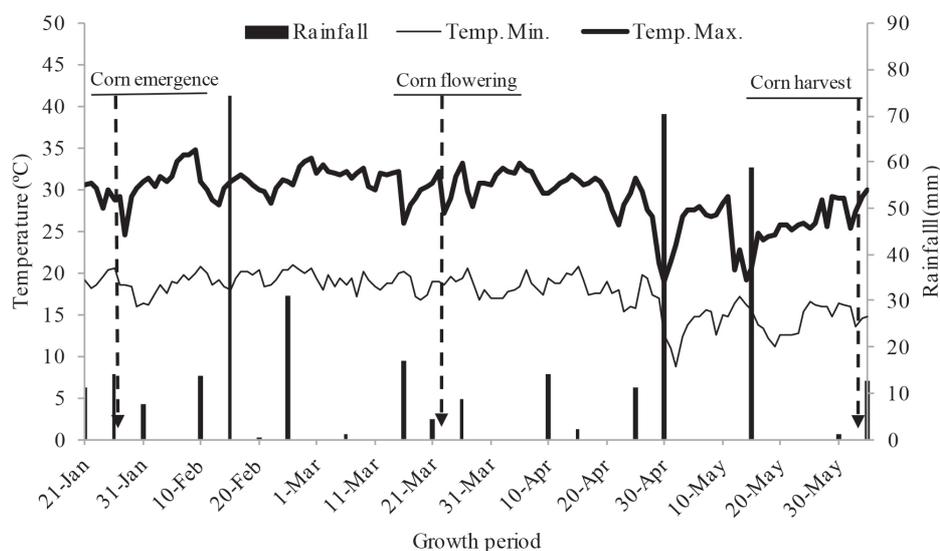


Figure 1: Rainfall (mm), maximum and minimum temperature (°C), every ten days from January to June in 2012, on corn intercropped or not with *U. ruziziensis*. Source: Estação Agroclimatológica do Campus da FCAV/UNESP - Jaboticabal, SP, 2012.

(Table 1), confirming the viability of this practice. Similar results were also obtained by Chioderoli *et al.* (2012) and Freitas *et al.* (2013). The researchers found that the intercropping with Congo grass, sown simultaneously with corn, did not affect corn grain yield, in addition, it increased organic residues input in the no-till crop production system. On the other hand, the results may be variable according intercropping modalities. Results obtained by Richart *et al.* (2010) demonstrated that the presence of the forage, since the beginning of the crop development, may impair the grain yield up to 16% compared to the sole crop.

It is noteworthy that in both crop systems (sole and intercropped), corn obtained grain yield higher than 6,800 kg ha⁻¹ (Table 2), while the average yield recorded for the State of São Paulo, in the same period, was 4,490 kg ha⁻¹ (CONAB, 2013). It is important emphasize that irregular distribution of rainfall occurred during the crop cycle, with water deficit in the critical period of plant development (Figure 1), that is, between the tassel initiation (Vt) and the beginning of silking (R₁) (Fornasieri Filho, 2007). Even under stress condition, the no-tillage system promotes greater water storage in the soil, which changes the soil-water relationship, and favors the development of grain (Stone *et al.*, 2006). In addition, adequate water supply during the dough stage (R₄), phase when assimilates were translocated to grains (Fornasieri Filho, 2007), favoring their formation. Given these factors, the grain yield

obtained exceeds the national average in approximately 2,300 kg ha⁻¹.

Regarding the use of residual N applied to common bean plants grown previously, no effect was observed on the subsequent cultivation for any of phytotechnical and reproductive parameters evaluated (Table 1). The high rate of nitrogen fertilizer (193 kg N ha⁻¹) applied during the corn cycle and the reduction of inorganic N losses by natural processes, resulting from conservationist conditions of the no-tillage system, may have hidden these results. Furthermore, the inclusion of Fabaceae in rotation/succession rotation crop systems may contribute significantly to the N intake in the soil via the symbiotic process with *Rhizobium* bacterias (Lovato *et al.*, 2004; Souza *et al.*, 2011.). According to results observed by Fernandes *et al.* (2008), the absence of residual effect is explained by the fact that the remaining inorganic N fertilizer occur predominantly in the form of organic compounds. Given this aspect, the use by subsequent crops remains generally very low.

Regarding the 1,000-grain weight (Table 2) and the grain size distribution (Table 3 and Figure 2), it can be stated that the development of Congo grass concurrently with corn did not affect the formation and size of reproductive structures. With respect to grain form, approximately 80% of the grains were classified as flat, regardless of the crop system. Due to the wide variation in the size, shape and quality of grain in the ear, grain

Table 1: F-values calculated by analysis of variance for corn parameters under influence of residual nitrogen fertilization of common bean on subsequent corn sole or intercropped with Congo grass (*Urochloa ruziziensis*) in no-tillage system¹. Jaboticabal, SP. 2012

| | Plant height | First spike insertion height | Rachis diameter | Spike length |
|-----------------|--|--|------------------------------------|--------------------|
| Crop system (S) | 4.00 ^{ns} | 3.53 ^{ns} | 2.18 ^{ns} | 0.05 ^{ns} |
| CV (%) | 2.96 | 2.80 | 1.24 | 5.16 |
| N amount (D) | 0.60 ^{ns} | 2.49 ^{ns} | 0.40 ^{ns} | 0.50 ^{ns} |
| CV (%) | 3.26 | 2.21 | 2.55 | 5.11 |
| S x D | 0.33 ^{ns} | 0.65 ^{ns} | 0.13 ^{ns} | 0.78 ^{ns} |
| | Number of grains per row ⁻¹ | Number of grains per spike ⁻¹ | Grain mass per spike ⁻¹ | 1,000-grain weight |
| Crop system (S) | 0.12 ^{ns} | 0.64 ^{ns} | 4.08 ^{ns} | 1.10 ^{ns} |
| CV (%) | 2.43 | 7.52 | 4.37 | 5.68 |
| N amount (D) | 0.11 ^{ns} | 0.26 ^{ns} | 0.52 ^{ns} | 0.19 ^{ns} |
| CV (%) | 5.73 | 4.09 | 9.17 | 7.90 |
| S x D | 1.46 ^{ns} | 0.89 ^{ns} | 0.22 ^{ns} | 0.82 ^{ns} |
| | Cob mass | Cob diameter | Grain yield | Protein content |
| Crop system (S) | 0.76 ^{ns} | 0.87 ^{ns} | 0.01 ^{ns} | 0.04 ^{ns} |
| CV (%) | 13.04 | 1.77 | 11.40 | 9.72 |
| N amount (D) | 0.12 ^{ns} | 0.27 ^{ns} | 0.86 ^{ns} | 0.80 ^{ns} |
| CV (%) | 13.20 | 3.83 | 9.01 | 12.95 |
| S x D | 0.21 ^{ns} | 0.37 ^{ns} | 1.66 ^{ns} | 0.52 ^{ns} |

¹ ^{ns} not significant by the F test at 5% of error probability.

classification is seen as one of the main quality factors, for many researchers attribute this to the high correlation with the weight and grain volume (Baudet & Misra, 1991; Ferreira *et al.*, 2001).

For the production of straw, soil cover and N accumulation in the straw, some advantages of the intercropping with Congo grass were found (Tables 4 and 5). By comparing the two cropping systems, more

promising results were found with the establishment of the intercropping. In this crop system, the amount of straw on the soil surface increased significantly (totaling 8.6 ton ha⁻¹), favoring the soil cover (100%) for subsequent crop sowing. Similar results were verified by Cunha *et al.* (2015), in addition the authors emphasized that the corn and Congo grass modality is an excellent option for increase the deposition and straw persistence in the soil,

Table 2: Corn parameters as affected by different crop systems. Jaboticabal, SP. 2012

| | Plant height (m) | First spike insertion height (m) | Rachis diameter (mm) | Spike length (cm) |
|------------------------------|--|------------------------------------|--|---------------------------------------|
| Corn | 2.36 a ¹ | 1.31 a | 52.0 a | 15.9 a |
| Corn + <i>U. ruziziensis</i> | 2.31 a | 1.33 a | 51.6 a | 16.0 a |
| | Number of grains per row ⁻¹ | Number of rows spike ⁻¹ | Grain mass per spike ⁻¹ (g) | 1,000-grain weight (g) |
| Corn | 27.4 a | 18.0 a | 184.9 a | 322.2 a |
| Corn + <i>U. ruziziensis</i> | 27.4 a | 18.4 a | 179.0 a | 315.2 a |
| | Cob mass (g) | Cob diameter (mm) | Grain yield (kg ha ⁻¹) | Protein content (g kg ⁻¹) |
| Corn | 40.0 a | 29.6 a | 6,879 a | 83.1 a |
| Corn + <i>U. ruziziensis</i> | 41.7 a | 29.7 a | 6,865 a | 83.7 a |

¹ Means followed by the same letter do not differ significantly by the test of Tuckey at 5% of significance.

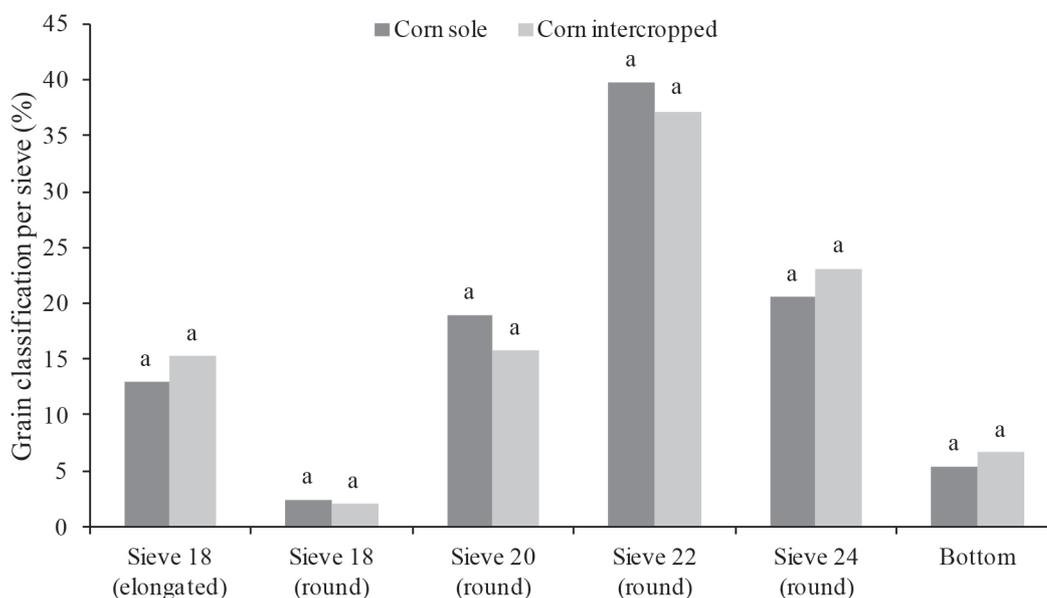


Figure 2: Grain size distribution of corn as affected by different crop system. Means followed by the same letter in each sieve do not differ significantly by the test of Tuckey at 5% of significance. Jaboticabal, SP. 2012.

Table 3: F-values calculated by analysis of variance for corn grain size distribution as affected by different crop systems¹. Jaboticabal, SP. 2012

| Treatment ¹ | S18 (elongated) | S18 (round) | S20 (round) | S22 (round) | S24 (round) | Bottom |
|------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Crop system (S) | 1.80 ^{ns} | 0.34 ^{ns} | 1.40 ^{ns} | 1.10 ^{ns} | 0.88 ^{ns} | 0.96 ^{ns} |
| CV (%) | 33.82 | 34.19 | 43.97 | 16.85 | 35.40 | 57.93 |

¹ ns not significant by the F test at 5% of error probability.

even in Cerrado region, where the predominant environmental conditions favor the decomposition rate of organic residues. According to Correia *et al.* (2013), for the prevailing weather conditions in the north of São Paulo State, it is recommended that the sowing of at least 200 points of cultural value of *Urochloa* seeds in row is sufficient to maintain adequate amount of straw on the soil for the viability and success of the no-tillage system. The rusticity of the *Urochloa* species, associated with the characteristic of moderately tolerant to water stress, favors the dry matter accumulation during the off-season period, enabling the planting of succeeding crops in no-

tillage system, with satisfactory presence of straw on the soil surface (Pacheco *et al.* 2011).

Interaction among the factors in the study for the percentage of soil cover was found (Table 4). In the unfolding of the interaction of cropping systems in N rates applied to the preceding crop, no effect of residual N was found in the percentage of soil cover for intercropped crop (Figure 3). However, when compared to the sole corn, effect of the cropping cultivation system was found for N fertilization, in which the increment in the rate in the preceding crop provided higher covering of the soil surface. These results demonstrate that corn grown in

Table 4: F-values calculated by analysis of variance for amount of straw, soil cover, and nitrogen accumulation in straw under influence of residual nitrogen fertilization of common bean on subsequent corn sole or intercropped with Congo grass (*Urochloa ruziziensis*) in no-tillage system¹. Jaboticabal, SP. 2012

| Treatments ¹ | Amount of straw (t ha ⁻¹) | Soil cover (%) | N accumulation in straw (kg ha ⁻¹) |
|-------------------------|---------------------------------------|----------------|--|
| Crop system (S) | 38.63* | 1205.55** | 100.90** |
| CV (%) | 7.67 | 3.68 | 13.71 |
| N amount (D) | 1.93 ^{ns} | 8.26** | 6.86** |
| CV (%) | 11.55 | 1.97 | 20.24 |
| S x D | 1.15 ^{ns} | 8.26** | 1.83 ^{ns} |

¹ ^{ns} not significant by the F test at 5% of error probability. * Significant by the F test at 5% of error probability. ** Significant by the F test at 1%

Table 5: Amount of straw, soil cover and N accumulation (N) in straw as affected by different crop system¹. Jaboticabal, SP. 2012

| Treatments | Amount of straw (ton ha ⁻¹) | Soil cover (%) | N accumulation in the straw (kg ha ⁻¹) |
|------------------------------|---|----------------|--|
| Crop system | | | |
| Corn | 7.2 b ¹ | 62.5 b | 57.3 b |
| Corn + <i>U. ruziziensis</i> | 8.6 a | 100.0 a | 93.0 a |

¹Means followed by the same letter do not differ significantly by the test of Tukey at 5% of significance.

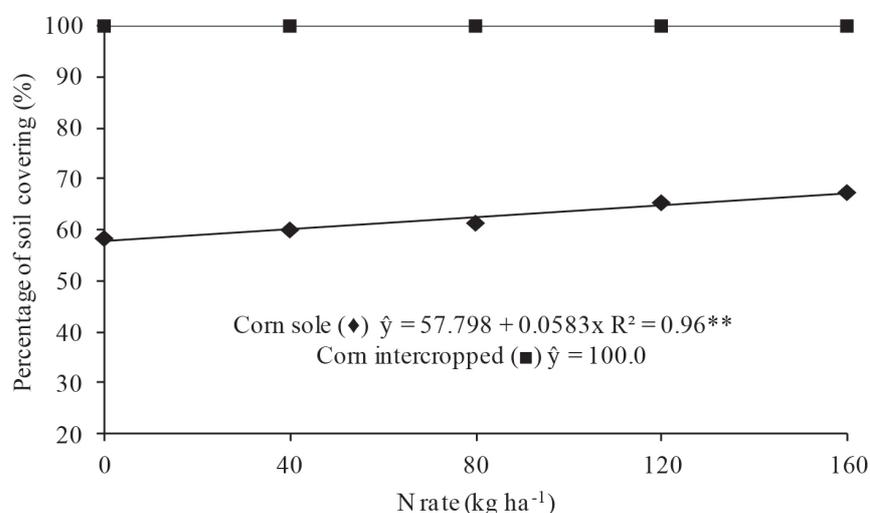


Figure 3: Percentage of soil covering under influence of residual nitrogen fertilization of common bean on subsequent corn sole or intercropped with Congo grass (*Urochloa ruziziensis*) in no-tillage system. Jaboticabal, SP. 2012.

sole crop utilized residual fertilization, which favored plant growth and dry matter production.

The intercropping system with Congo grass achieved the highest N accumulation in the straw, approximately 93 kg ha⁻¹ (Table 5). According to Souza *et al.* (2011), N accumulation in biomass of corn and *U. ruziziensis*, in the second harvest period can reach levels above 140 kg N ha⁻¹. However, these results may vary according to the area, soil and climate conditions during cultivation. In addition to providing improvements in soil chemical properties, positive effects of *Urochloa* species on soil physical properties

have also been reported, due to the high amount of roots of the forage (Silveira *et al.*, 2011).

The application of increasing N rates in topdressing on the previous crop also favored the N accumulation in the straw from sole and intercropped system, confirming the recovery of nitrogen fertilizer (Figure 4). Based in regression analysis, the application of N rates in the previous crop increased linearly N accumulation in the straw. According to Silva *et al.* (2006), the knowledge of the residual effect of nitrogen fertilizer on the crop following its application is essential in order to optimize its use and minimize environmental damage.

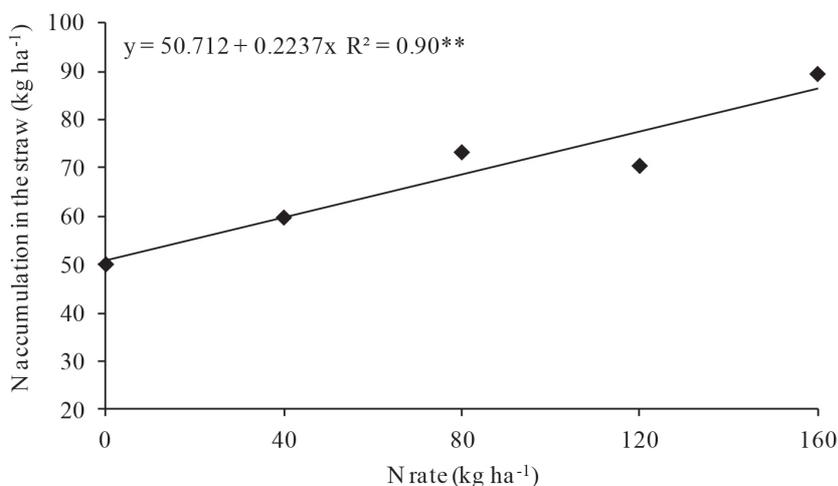


Figure 4: Nitrogen accumulation in the straw of corn sole or intercropped with Congo grass (*Urochloa ruziziensis*) under influence of residual nitrogen fertilization of common bean. Jaboticabal, SP. 2012.

CONCLUSION

Corn intercropped with *U. ruziziensis* led to adequate formation of straw and full coverage of the soil surface, improving the quality and sustainability of no-tillage system. The intercropping system did not reduce growth and corn grain yield, suggesting that *U. ruziziensis* can be recommended to integrate corn production areas, especially in Cerrado region. Nitrogen fertilization on common bean had no effect in corn cropped in succession.

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