SCAP
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Nitrogen use efficiency by cotton varieties

Eficiência no uso de nitrogênio por variedades de algodão

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ABSTRACT

This study aimed to evaluate the nitrogen use efficiency by different cotton varieties in an Acrisol. The design was completely randomized in a 5x2x5 factorial. The factors consisted of five nitrogen rates (0, 250, 500, 750 and 1000 mg dm^{-3} of soil), two cotton genotypes (FiberMax 910 and FiberMax 966) and five repetitions, using urea as source N (45% N). The following variables were studied: dry matter production of plant shoots, nitrogen content, nitrogen concentration, N use efficiency, efficiency of nitrogen applied, physiological efficiency, agro-physiologic efficiency and recovery efficiency. The results showed that there was a significant linear effect of nitrogen application in the dry matter production, nitrogen content and nitrogen concentration of cotton plant. The nitrogen use efficiency varied with the genotypes and type of efficiency calculated, and with increasing doses of N, less N was recovered by cotton plants.

Keywords: Efficiency, *Gossypium hirsutum* L., mineral nutrition, nitrogen fertilization

RESUMO

O presente trabalho teve por objetivo avaliar a eficiência de utilização do nitrogênio por diferentes variedades de algodão em um Argissolo Vermelho-Amarelo. O delineamento utilizado foi inteiramente casualizado em esquema fatorial 5x2x5. Os fatores constituíram-se de cinco doses de nitrogênio (0, 250, 500, 750 e 1000 mg dm^{-3} de solo) duas variedades de algodão (FiberMax 910 e FiberMax 966) e cinco repetições, utilizando-se como fonte a uréia (45% N). Foram determinadas as seguintes variáveis: produção matéria seca parte aérea, teor de nitrogênio, conteúdo de nitrogênio, eficiência de utilização N, eficiência do N aplicado, eficiência fisiológica, eficiência agrofisiológica e eficiência de recuperação. Os resultados permitiram concluir que a produção de massa seca, o teor e conteúdo de nitrogênio em plantas de algodão são influenciados pelas doses de nitrogênio. A eficiência de utilização do nitrogênio varia de acordo com os genótipos e o tipo de eficiência calculada; e com o aumento das doses de N, menos N foi recuperado pelas plantas de algodão.

Palavras-chave: Eficiência, *Gossypium hirsutum* L., nutrição mineral, adubação nitrogenada

Introduction

Cotton represents great economic and social importance worldwide as it is among the ten largest sources of wealth in the agricultural sector. In the Brazilian agribusiness, cotton production has emerged as one of the main activities. The estimated cotton planted area in the 2009/2010 crop in Brazil was 836 0000 hectares with an estimated production of approximately 1993.8tons of seed cotton (CONAB, 2010). According to Macedo (1996), the Brazilian *Cerrado* has an area of approximately 207 million hectares, of which approximately two thirds of this area is considered suitable for food production. However, Machado *et al.* (2001) report that the *Cerrado* has certain limitations such as high acidity and low natural fertility (Fageria, 1998).

The selection of genetic materials adapted to conditions of low soil fertility increases the utilization of fertilizers, promoting greater production in soils of low fertility (Fernandes and Muraoka, 2002). According to Yan *et al.* (1995), the solution to increase productivity and reduce production costs is the selection of efficient genotypes in the uptake and use of nutrients, which is defined, according to Goedert and Lobato (1980), as the genotype ability to acquire the nutrient from the soil, incorporate it and use it.

According to Beltrão (1999), cotton requires relatively large amounts of nitrogen compared with the demand for other elements, to obtain maximum yield. Nitrogen is the nutrient most absorbed by cotton plants, and therefore, it plays an important role in plant growth and development, especially of vegetative organs, stimulates growth and flowering, regulates the plant cycle, increases productivity and improves the fiber length and strength when applied in appropriate doses (Beltrão, 1999).

The nitrogen efficiency depends basically on the following factors: doses applied, sources used, time and form of application, climatic conditions, intensity of cultivation area, availability of phosphorus, potassium, calcium and magnesium, cropping system, rotation of crops and use of growth regulators (Castro, 2004).

Furlani and Buzetti (2001) reported that when nitrogen was applied 30 days after plant emergence, the doses of 40 and 70 kg N ha^{-1} provided the highest plant height values when compared with those observed for doses of 30 kg ha^{-1} N. According to Campos *et al.* (1995), as the dose of N increased from 0 to 50, 100, 150 and 200 kg ha^{-1}, a significant and directly proportional effect occurred in terms of cotton production. Grespan and Zancanaro (1999), Oliveira *et al.* (1988) and Campos *et al.* (1995) reported that the application of increasing doses of N (0, 60, 120 and 180 kg ha^{-1}) increased productivity up to the dose of 120 kg ha^{-1}.

Bondada *et al.* (1997) reported that the nitrogen requirement by cotton is high, especially during the reproductive phase, when the bolls import large amounts of N from leaves, causing a decline in the photosynthetic activity. Thus, the importance of the correct time, form of application and appropriate application of nitrogen fertilizer should be emphasized.

Mendes (1965) observed that the period of greatest N uptake is from 30 to 90 days after emergence. Furlani Júnior *et al.* (2001) found that the application and split nitrogen fertilization at doses of 20, 40 and 70 kg ha^{-1} caused positive responses when it was performed at 40 days after emergence.

According to Gerik *et al.* (1998), nitrogen uptake is proportional to the photosynthetic capacity and to the dry mass accumulation of cotton plants. In this context, among the macronutrients, nitrogen shows the largest use increment. The reasons are its high absorption rate by the cotton plant, its low availability in *Cerrado* soils and the physiological role that nitrogen plays in plant growth and development (Camacho *et al.*, 2009).

Given the above, this study aimed to evaluate the nitrogen use efficiency by different cotton varieties in a red-yellow ultisol.

Material and Methods

The experiment was conducted at the experimental area of the Campus of Aquidauana, belonging to the Department of Crop Production, State University of Mato Grosso do Sul - UEMS, in the period from August to December 2009 in greenhouse conditions, geographical coordinates of 40° 28' S, 35° 40' W to 207 meters altitude.

The soil used in the experiment was an Acrisol. The soil chemical analysis showed pH (H_2O) = 4.7; O.M=1.2%; P: 4.4 mg/dm^3; K: 0.24 mg/dm^3; Ca: 1.1 mg/dm^3; Mg: 1.2 mg/dm^3, Al: 0.4 mg/dm^3; H+Al: 2.7 mg/dm^3, EC [Electrical Conductivity]: 2.54 mg/dm^3 and CEC [Cation exchange capacity]: 5.24 mg/dm^3, respectively and SB [Base saturation] (%): 48.47.

The design used was completely randomized in a 5x2x5 factorial. The factors consisted of five nitrogen rates (0, 250, 500, 750 and 1000 mg dm^{-3} of soil), two cotton varieties (FiberMax 910 and FiberMax 966) and five repetitions, using urea as N source (45% N). Pots with capacity of 5 dm^3 were used, which received 5 kg of sieved soil 0-20 cm layer (2mm mesh). Each pot was lined with thick plastic bags to prevent leaks. Five seeds pot^{-1} were sown and after the establishment of plants, they were thinned to two seedlings pot^{-1}. Irrigation was carried out whenever necessary to maintain 70% of maximum water-holding capacity.

Nitrogen fertilization was performed half at the sowing period as urea, and the rest 30 days after planting, also as urea. Nutrients phosphorus (P) and potassium (K) were provided for all treatments in the same quantity according to soil analysis, using triple superphosphate and potassium chloride. At 120 days after emergence, the tops of plants were removed, which were weighed, washed in distilled water, and dried in an oven with forced air at 65°C for 72 hours, weighed, ground in a Wiley type mill (sieve with mesh diameter of 1 mm) and submitted to determinations of the nitrogen concentration using the Kjeldahl method (Malavolta *et al.*, 1997), i.e., sulfuric acid digestion followed by distillation and titration.

The following variables were determined, as described by Baligar and Fageria (1999): Nitrogen use efficiency (NUE): total dry matter produced (g) / total nutrient content in plant (mg). Physiological efficiency (PE): $(BP_f - BP_{nf}) / (AN_f - AN_{nf})$ was given in kg kg^{-1}, in which BP_f is the biological production (straw and grain) with nitrogen fertilizer; BP_{nf} is the biological production (straw and grains), without nitrogen fertilizer; (AN_f is the accumulation of N in plant top and grains, with nitrogen fertilizer, and AN_{nf} is the accumulation of N in plant top and grains, without nitrogen fertilizer. Agro-physiologic efficiency (APE): (GP_f - GP_{nf}) / (AN_f - AN_{nf}) was given in kg kg^{-1}, in which GP_f is the grain production, with nitrogen fertilizer; GP_{nf} is the grain production without nitrogen fertilizer; AN_f is the accumulation of N in plant top and grains with nitrogen fertilizer, and AN_{nf} is the accumulation of N in plant top and grains without nitrogen fertilizer. Applied nitrogen efficiency: plant nitrogen content (mg) / dose of fertilizer multiplied by 100 and multiplied by the N use efficiency. Recovery efficiency (RE): 100 (AN_f - AN_{nf} / AN_a) was given in percentage, in which AN_f is the accumulation of N in plant top and grains with nitrogen fertilizer; AN_{nf} is the accumulation of N in plant top and grain without fertilizer, and AN_a is the amount of N applied in kg.

The data were submitted to the W test for normality and in case of normal distribution, the analysis of variance was performed using the Statistical Analysis System [SAS] software. After descriptive analysis, the data were used to establish linear conditions (Pearson, $p \leq 0.05$).

Results and discussion

There was a significant response ($p<0.05$) to rates of nitrogen of dry mass of shoots, nitrogen content, accumulated nitrogen, nitrogen use efficiency, efficiency agro-physiological of nitrogen and nitrogen efficiency applied (Table 1). Only nitrogen physiological efficiency was not affected by doses of nitrogen for both varieties of cotton (Table 1).

The dry mass of top was influenced by rate of nitrogen, so that the largest rates of N provided greater accumulation of dry mass of cotton varieties (Figure 1). However, there was a tendency for higher production by varied FiberMax 910. Estimated by the equation, the maximum dry mass production was 36.54 g per pot for FiberMax 910 and 35.72 g per pot for FiberMax 966, obtained at a dose of 1000 mg dm ^{3}, and this must have occurred due to the increased availability of this nutrient. This variation is related to the absorption capacity and nutrient use by the varieties; however, this does not indicate that they are more or less efficient in absorbing soil N.

The content and the accumulated N in the shoots were influenced by the rate of N (Figure 2a and 2b). The amount of N in the tissue of the plant was greater than the amount of N applied. This result was expected because plants can obtain nitrogen from atmospheric deposition, biological nitrogen fixation or soil organic matter. Foliar nitrogen varied from 20.51 g kg^{-1} in FiberMax 910 to 15.38 g kg^{-1} in FiberMax 966, being lower at rates 0 and 250 mg dm^{-3} N. The findings are contrary to those found by other authors, with N contents outside the range of suitable levels (35-43 g kg^{-1}), according to criteria established by Silva *et al.* (1999). Figure 2 shows that the N content in cotton leaves increased linearly with the nitrogen doses applied. Zhao *et al.* (2005) reported that foliar N was closely linked with the consequent increase in the nitrogen levels applied to soil. Ibrahim *et al.* (2010) found that the nitrogen content in cotton shoots of three varieties increased significantly with increasing levels of nitrogen added without any indication of the variety x interaction of nitrogen. Nakayama *et al.* (2004) tested increasing nitrogen doses in IAC 23 cultivar and found significant foliar N values from 48.05 to 52.92 g kg^{-1}. Camacho *et al.* (2009), obtained foliar nitrogen values between 30.923 and 54.045 g kg-^{1} and the highest seed cotton yields were associated with levels of 42 and 44 g kg^{-1}, with a productivity peak at 47 g kg $^{-1}$ of foliar nitrogen.

Table 1 - Summary of the analysis of variance: coefficient of variation and probability of F for dry mass of shoots, nitrogen content and accumulated, nitrogen use efficiency, physiological efficiency nitrogen, agro physiological efficiency, recovery efficiency of nitrogen and nitrogen use efficiency applied by cotton varieties on nitrogen dose responses.

Parameters	CV (%)		Pr>F	
	F910	F966	F910	F966
Dry mass of shoots	11,53	12,09	0,0001*	0,0001*
Nitrogen content	28,72	16,47	0,0002*	0,0001*
Nitrogen accumulated	25,43	18,16	0,0001*	0,0001*
Nitrogen use efficiency	32,42	26,64	0,0001*	0,0001*
Physiological efficiency nitrogen	54,61	46,35	0,0527	0,0632
Agro-physiological efficiency nitrogen	31,21	29,28	0,0001*	0,0001*
Recovery efficiency of nitrogen	36,67	31,59	0,0072*	0,0077*
Nitrogen efficiency applied	30,60	48,55	0,0002*	0,0001*

CV: coefficient of variation. * Significant at 5% probability for the F-test.

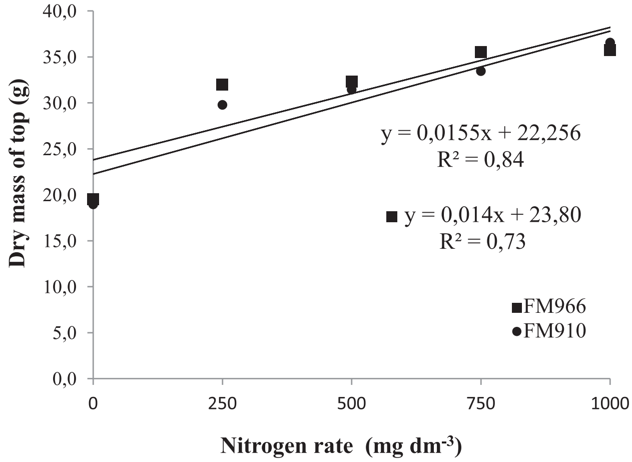

Figure 1 - Dry mass of shoots produced by cotton plants in response to the rates of nitrogen.

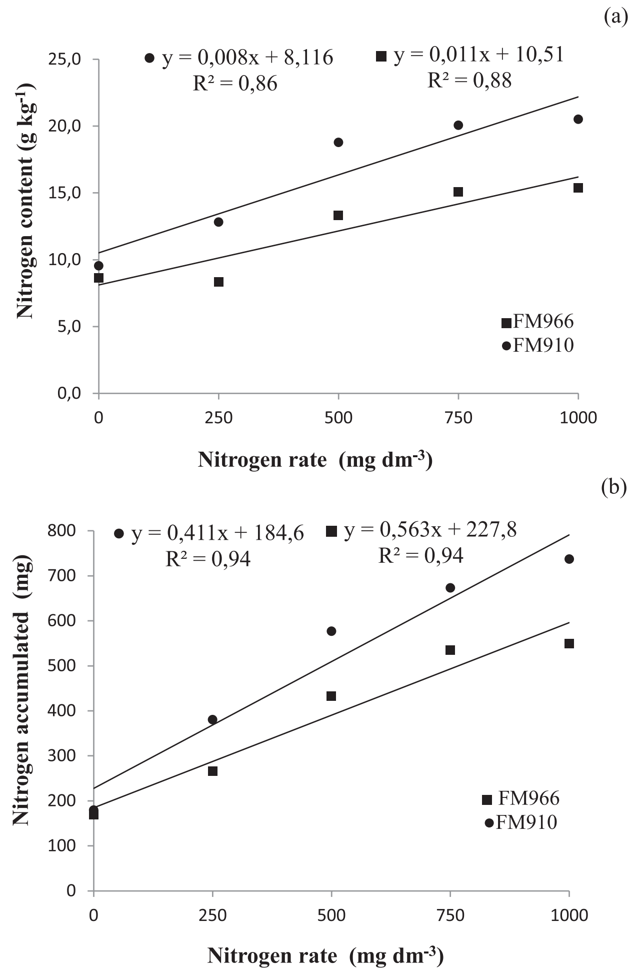

Figure 2 - Content (a) and accumulated (b) nitrogen in shoots of plants cotton in response the rates of nitrogen.

The varieties showed a linear negative and significant ($p<0.05$) behavior of the nitrogen use efficiency in function of N rate (Figure 3). Variety FiberMax 910 showed better performance in the nitrogen use efficiency when compared to variety FiberMax 966; however, this efficiency decreased with increasing nitrogen doses, not responding to the high level of this nutrient. The efficiency of N ranged from 4,7 a 5,5 g mg^{-1} dry weight per milligram of absorbed nitrogen. Similar results were obtained by Nedel *et al.* (1997), who observed that the N use efficiency in barley genotypes decreased with increasing rate of N. There are several mechanisms related to morphological and physiological characteristics of the plant, which contribute to the efficient use of nutrients, including a high ratio between plant top and roots. Thus, there should be a direct correlation for this attribute, i.e., the higher the top / root ratio, the greater the nutritional efficiency of the cultivar (Fageria and Baligar, 1993).

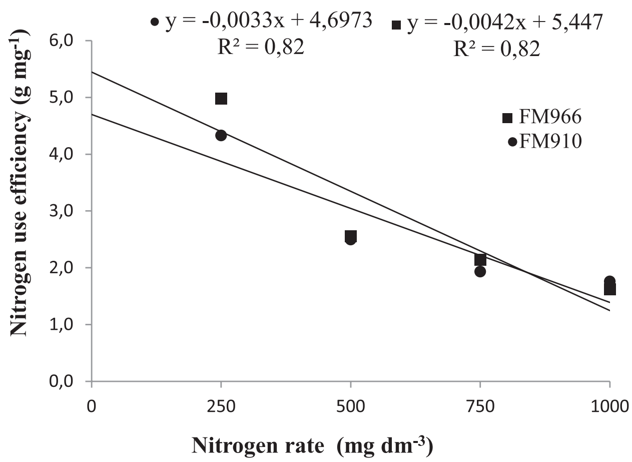

Figure 3 - Nitrogen use efficiency of cotton genotypes in response to nitrogen rates.

The efficiency of use of the nitrogen applied was reduced with increasing rate of fertilizer, with being variety FiberMax 910 superior to variety FiberMax 966 (Figure 4). Similar results were obtained by Cruz *et al.*, 2008, who found high N use efficiency for all corn cultivars. Ceretta (1998), using 30, 60 and 90 kg ha^{-1} of N in pre-seeding, providing an increase of 10, 13 and 18 kg grain kg $^{-1}$ of applied N. Oliveira and Caires (2003) found an average production increase of 15.59 ha^{-1} of grain for each kg of N applied as top dressing with rates of 30, 60, 90 and 120 kg ha^{-1} N in no-tillage system.

The N agro-physiological efficiency by cotton varieties presented negative linear effects in response to the rate of nitrogen, with variation of 0.016 to 0.050 mg of grain produced per gram of N accumulated (Figure 5). Fageria *et al.* (2003b) reported that accumulation of 1 kg of N in rice plant top and grains produced 146 kg of dry matter.

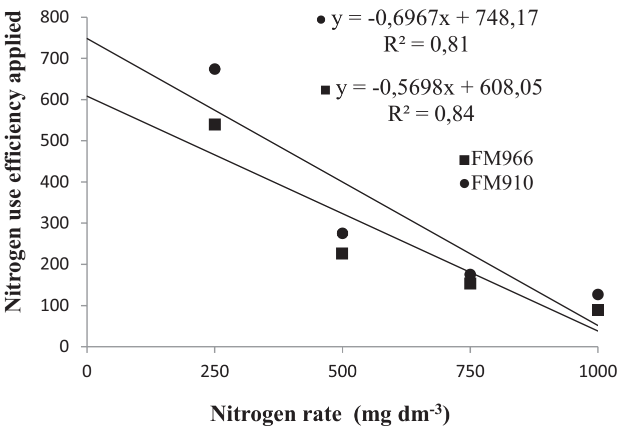

Figure 4 - Nitrogen efficiency applied of cotton plants in response to nitrogen rate.

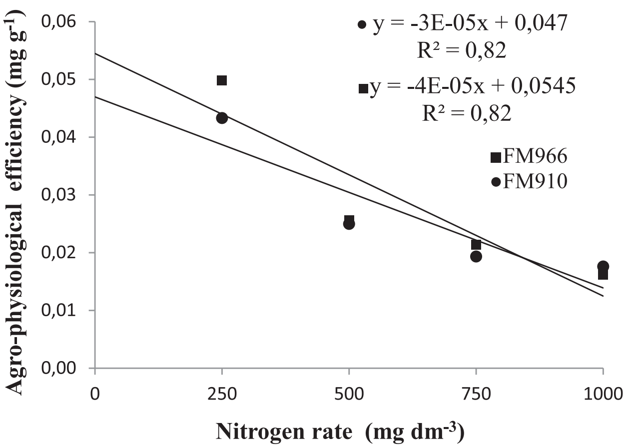

Figure 5 - Agro-physiological efficiency of nitrogen absorbed by cotton plants in response to nitrogen rate.

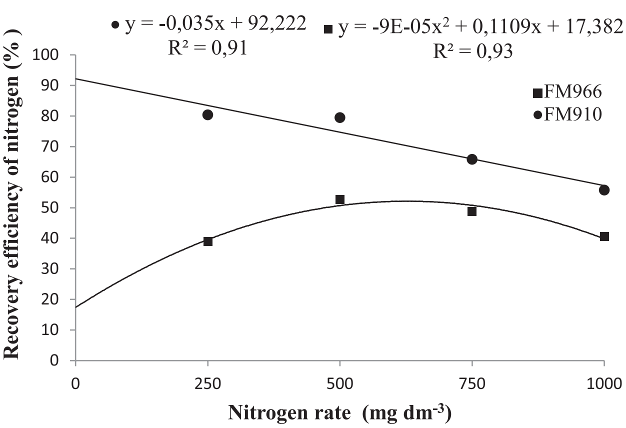

Figure 6 - Recovery efficiency of nitrogen absorbed by cotton plants in response to nitrogen rate.

The recovery efficiency of N applied to cotton responded significantly ($p<0.05$) to the rate of nitrogen (Figure 6). It was found that the recovery of applied N ranged from 40 to 80% between genotypes, with an average value of 57%. With increasing doses of N, less N was usually recovered by plants. The results observed here, with an average recovery of 57%, occurred possibly due to the lower N immobilization, and also because at lower N doses, the fertilizer recovery tends to be higher (Gava *et al.*, 2006; Silva *et al.*, 2006). However, the recovery of a nutrient is dependent on the time elapsed after application and the dose applied. Besides the aspects discussed above on the volatilization of ammonia resulting from the enzymatic hydrolysis of urea, it should be considered that the fall of leaves also contributes to losses of N.

Conclusions

1. Dry matter production, the content and accumulated nitrogen in cotton plants are influenced by the rate of nitrogen.
2. The nitrogen use efficiency varies with the genotypes and the type of the efficiency calculated, and with increasing rate of N, less N was recovered by cotton plants.

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