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EFFICIENCY OF NITROGEN USE BY SESAME GENOTYPES UNDER BRAZILIAN SEMI-ARID CONDITIONS

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Abstract

Nitrogen (N) is an essential macronutrient for plant growth and rate applications can influence the performance of sesame, and when applied in excess can cause nitrogen loss in the environment, and consequently make the cost of production more costly to the producer. Therefore, the objective of this work was to evaluate the efficiency of nitrogen use by different cultivars of irrigated sesame seeds under the edaphoclimatic conditions of the northeastern semi-arid region in two harvests. The experiments were carried out from February to May (1st harvest) and from July to October (2nd harvest) in 2016. The treatments were arranged in a split plot scheme, in which the plots were the five nitrogen doses (0, 30, 60, 90 and 120 kg ha^{-1}), and in the subplots, the four sesame genotypes (CNPA G2, CNPA G3, CNPA G4 and BRS Seda), the design was in randomized complete blocks with four replications. The nitrogen use efficiency assessments evaluated were: agronomic efficiency (AE), physiological efficiency (PE), agrophysiological efficiency (APE), recovery efficiency (RE) and efficiency of use (EU). The rate that provided the greatest efficiency of use was 30 kg ha^{-1} of N applied. The cultivar BRS Seda had greater efficiency of use in relation to the other cultivars studied. The crop that had better efficiency of use was the 2nd agricultural harvest.

Keywords: Agronomic Efficiency. Edaphoclimatic Conditions. Nutritional Efficiency. *Sesamum indicum* L.

1. Introduction

Nitrogen (N) is one of the nutrients most demanded by plants, as it is constituent of several compounds, especially amino acids, nucleic acids and chlorophyll. Thus, the main biochemical reactions involve the presence of N, which makes one of the elements absorbed in greater quantity (Cantarella 2007). Part of the amount of nutrient required can be supplied by the soil, however on many occasions the soil is unable to meet all the demand, thus making nitrogen fertilization necessary (Abranches et al. 2016). Being then, the N used in large quantities in modern agriculture in the form of fertilizer. Thus, for most crops, it represents the costliest nutrient (Cantarella 2007). In this way, the adequate supply of N is a preponderant factor in the good nutrition of most crops and in the achievement of high yields (Abranches et al. 2016).

When the N is used in excessive amounts or in adverse conditions, it can be lost, and when transported to other places may be pollutants of water and atmosphere. The N losses in the soil-plant system can occur by nitrate leaching, which occurs due to the low chemical interaction with the soil minerals, the amount of water, and also the soil texture (Cantarella 2007). Another form of N loss in the system is through the volatilization of ammonia in soil, which is influenced by pH, buffering power, urease activity, soil moisture, and soil temperature (Cantarella 2007). Therefore, the understanding of the behavior of N in the soil-plant system is fundamental for the adequate agricultural management.

The plant has a use efficiency that is inherently complex, since each stage, including N uptake, translocation, assimilation and remobilization, is governed by multiple genetic and environmental factors that interact (Xu et al. 2012). The productive performance of crops depends on good management of N fertilization, in which case of excess is harmful to the environment, and also to the rural producer due to the cost of fertilization. Therefore, increasing the efficiency of N use of the plant is fundamental for the development of more sustainable agriculture (Xu et al. 2012).

The recovery capacity of N by the cultures in general is bottom than 50% of the applied fertilization (Baligar and Bennett 1986). The low capacity for N recovery by plants is associated with the dynamics of the nutrient in the soil-plant system, through the loss of leaching and volatilization (Baligar and Bennett 1986). This low recovery of N directly influences the higher production cost as well as affects the environment through pollution. Given this, it is important to improve the efficiency of the use of N to provide greater performance of the crops, reducing the production cost and also reducing the environmental damage. So it is necessary to adopt managements that improve the efficiency of N use by crops, such as improved fertilizers, soil and crop management (Fageria and Baligar 2005).

Fertilization is one of the most studied subjects in the sesame crop, presenting different responses when evaluating locations and growing seasons, or even cultivars (Mahdi 2008; Shehu et al. 2010; Ali and Jan 2014; Shehu 2014; Karavaye and Shkoffar 2015). Research on sesame nutrition in Tanzania, India and Pakistan has shown significant increases in productivity due to nitrogen fertilization (Taylor et al. 1986; Kalaiselvan et al. 2002; Malik et al. 2003; Ali and Jan 2014). Also, studies conducted evaluating rates in Nigeria and Iran has identified different responses of the nitrogen use efficiency by the sesame crop (Jouyban et al. 2011; Shehu 2014). This proves that the crop's response varies according to the management adopted and that it is not so simple to understand the soil-plant-atmosphere relations in the agricultural environment (Santos et al. 2018).

Amount of organic matter, soil texture, characteristics of fertilizers, timing and method of application are some of the factors that interfere with fertilization (Arriel et al. 2007). Another point to highlight is the genotypes, which may defer when the efficiency with which the plant nutrients are used to produce, in this case would be the efficiency of use, and/or may differ in its effectiveness in the absorption of nutrients from the soil (Sattelmacher et al. 1994).

Fertilization increases crop productivity and profitability, but it raises the cost of agricultural production. One of the main factors for the high costs is fertilizer prices, which reduce the profit margin of the agricultural activity, causing greater demand for adequate practices for fertilization, which becomes essential to obtain profits (Nobre 2007; Baldi 2008).

To know the efficiency of the use of N in different genotypes is of fundamental importance, due to several edaphoclimatic factors influencing the nutrient dynamics in the soil. With this, it allows the proper management of fertilization in order to obtain greater efficiency in the use of N, and consequently reduce the environmental and economic damages, which could have occurred with the incorrect handling of the fertilization.

In view of the above, the present work had the objective of evaluating the efficiency of nitrogen use by different cultivars of irrigated sesame in the soil and climatic conditions of the northeastern semi-arid region in two agricultural harvests.

2. Material and Methods

The tests were conducted in the experimental field of the Federal Rural University of the Semi-Arid (UFERSA) which is located at the following coordinates: latitude 5°03'37” S and longitude 37°23'50” W Gr, with an approximate altitude of 72 m, in the municipality of Mossoró - RN, Brazil. The experiments were carried out in two harvests, from February to May (1st harvest) and from June to October (2nd harvest) in 2016. The climate of the place according to Thornthwaite is DdAa, that is, semi-arid, megathermic and with little or no excess water throughout the year, and according to Köppen it is BSwh', dry and very hot (Carmo Filho et al. 1991).

The average meteorological data from the period of the experiments were two agricultural harvests are presented in Figure 1. The chemical characteristics of the soil in the depth of 0-0.20m, 1st and 2nd harvest crop, respectively, were: pH = 6.50 and 5.63; electrical conductivity = 0.58 and 0.75 dS m^{-1}; N = 0.14 and 0.42 g kg^{-1}; organic matter = 7.23 and 12.78 g kg^{-1}; K = 52.01 and 58.8 mg dm^{-3}; P = 4.47 and 3.0 mg dm^{-3}; Na = 8.1 and 4.8 mg dm^{-3}; Ca = 2.10 and 1.00 cmolc dm^{-3}; and Mg = 0.55 and 1.80 cmolc dm^{-3}. The soil type of the experimental area is classified as Typical Dystrophic Red Argisol (Rêgo et al. 2016), sand free texture.

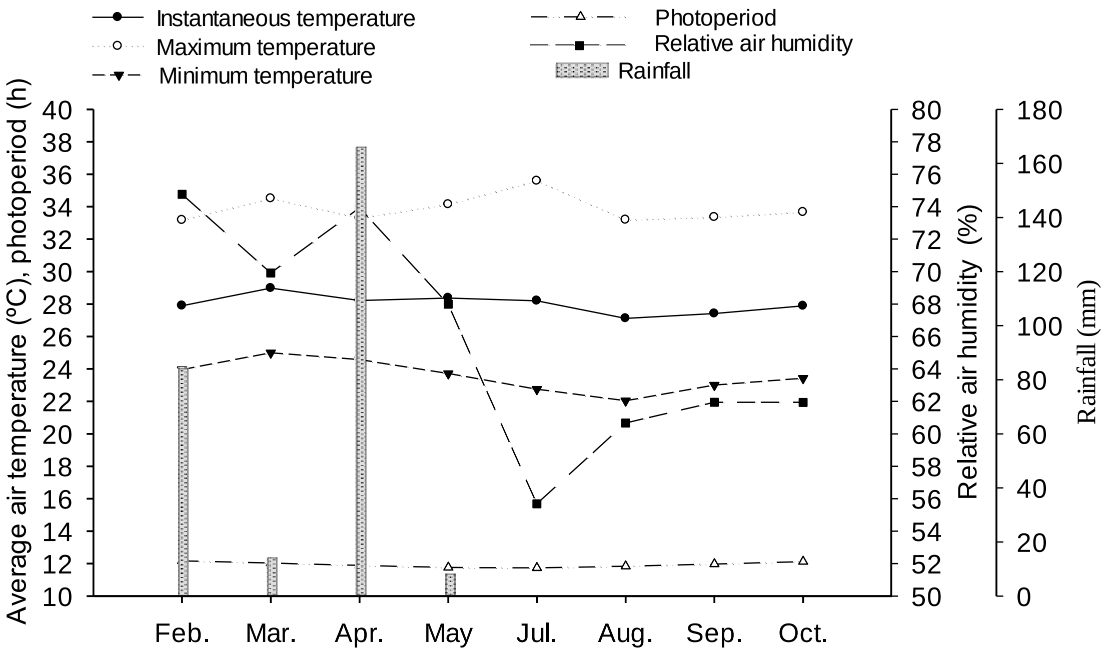


Figure 1. Mean values of instantaneous, maximum and minimum air temperatures, photoperiod (h), relative air humidity (%) and rainfall (mm) in the two agricultural harvests of sesame.

The experimental design used in each experiment was a randomized block, with four replications, where five doses of N (0, 30, 60, 90 and 120 kg ha^{-1}) were allocated in the plots, and the four sesame cultivars (CNPA G2, CNPA G3, CNPA G4 and BRS Seda) in the subplots. The experimental plot contained four rows of sesame, occupying an area of 7.2 m^2 (3.0 x 2.4 m). The spacing between pits adopted was 0.30 x 0.60 m, with two sesame plants per pit, which totaled 32 plants in the useful area of each experimental plot (2.88 m^2). The planting of sesame in the 1st harvest was carried out on February 14, 2016, and in the 2nd harvest was held on July 19 of the same year. A direct seeding, 2 cm deep, was planted with 8 to 10 seeds per well. After ten days of emergence, thinning occurred, leaving two plants per pit.

The irrigation used was by drip (drippers every 0.30 m), and the hoses were spaced apart each 0.60 m. Irrigations were made based on the sesame ETc daily (Amaral and Silva 2008). Fertilizers were applied following the fertilization recommendation manual for the state of Pernambuco (Gomes and Coutinho 2008), with the exception of nitrogen fertilization, which was carried out according to each treatment. Urea was the source of N used, applied according to the treatments, with 25% applied at planting, 50% at the eight-leaf stage and the other 25% at the beginning of flowering (Kamravaie and Shokohfar 2015). The fertilizers were distributed by fertigation with the aid of the bypass tank. In accordance with the need for sesame, cultural treatments and other phytosanitary controls were carried out.

The crop of sesame in the 1st and 2nd agricultural harvest was carried out at 110 and 105 days after sowing, respectively. Productivity (kg ha^{-1}) was determined by weighing the grains of all the plants of the useful area, with 6% water content in the seeds (Grilo Júnior and Azevedo 2013; Santos et al. 2018).

On the occasion of the harvest, 4 plants of the useful area were collected, fractionated in stem, leaf and capsule and carried out the washing process; after drying the vegetable material in the oven at 65ºC for approximately 48 hours or until the constant mass was obtained and finally weighed to obtain the dry mass of the material in grams. The total dry mass of the plant was obtained by the sum of the dry mass of the leaf, stem and capsules. Subsequently the results were converted to g ha^{-1}, multiplying the result by the plant population and then to kg ha^{-1}. The total dry mass of the shoot was the result of the sum of the dry mass of all constituent parts of the plant, expressed in kg ha^{-1} (Ribeiro et al. 2019).

The dry mass of each vegetable component was milled in Wiley electric mill, equipped with a stainless steel sieve, until the material became homogeneous. The material was then packed in plastic bags for further chemical analysis of the nutrient content. To determine the accumulation of N, sulfuric digestion was performed, using the Kjeldahl method for quantification (Tedesco et al. 1995; Ribeiro et al. 2019). In order to determine the amount accumulated in each fraction of the plant, the concentration will be multiplied by the dry mass of said fraction.

The evaluation of the efficiency of N use was performed following the formulas described: agronomic efficiency (AE) = $(GY_{with}N - GY_{without}N)/(AN_a)$, given in kg kg^{-1}, where $GY_{with}N$ is grain yield with N fertilizer; $GY_{without}N$ is grain yield without N fertilizer; and AN_a is the amount of N applied, in kg. The physiological efficiency (PE) = $(BP_{witht}N - BP_{without}N)/(AN_{witht}N - AN_{without}N)$ was given in kg kg^{-1}, where $BP_{witht}N$ is the biological production (total aerial part) with N fertilizer; $BP_{without}N$ is the biological production (total aerial part) without N fertilizer; $AN_{witht}N$ is the accumulation of N in the total aerial part with application of N fertilizer; and $AN_{without}N$ is the accumulation of N in the total aerial part without application of N fertilizer; Agrophysiological efficiency (APE) = $(GY_{with}N - GY_{without}N)/(AN_{witht}N - AN_{without}N)$ was given in kg kg^{-1}, where $GY_{with}N$ is grain yield with N fertilizer; $GY_{without}N$ is grain yield without N fertilizer; $AN_{witht}N$ is the accumulation of N in the total aerial part with application of N fertilizer; and $AN_{without}N$ is the accumulation of N in the total aerial part without application of N fertilizer. The recovery efficiency (RE) = $(AN_{witht}N - AN_{without}N/AN_a) \times 100$ was given in percentage, where $AN_{witht}N$ is the accumulation of N in the total aerial part with N fertilizer; $AN_{without}N$ is the accumulation of N in the total aerial part without N fertilizer; and ANa is the amount of N applied in kg. The efficiency of use (EU) = PE x RE, given in kg kg^{-1} (Fageria 1998; Fageria and Baligar 2005; Fageria et al. 2007).

Through the statistical program SISVAR 5.6, analyzes of variances of agricultural harvests were made in isolation for the variables evaluated (Ferreira 2011). The joint analysis of the evaluated variables was carried out after analyzing the homogeneity of the variances in agricultural harvests (Ferreira 2000). To adjust the response curves, the Table Curve 2D program (Systat Software 2002) was used; the graphics were prepared using SigmaPlot 12.0 (Systat Software 2011). Tukey's test at 5% probability was used to compare the averages between cultivars and agricultural harvests.

3. Results

The homogeneity of the variances was accepted for the variables of agronomic efficiency (AE), agrophysiological efficiency (APE) and efficiency of use (EU), thus enabling the joint analysis of the experiments, in which, for all these characteristics, interaction between rates, cultivars and agricultural harvests. For the variables, physiological efficiency (PE) and recovery efficiency (RE) were evaluated separately (univariate analyzes) for each harvest, and there was a double interaction between rates and cultivars.

In AE, it was observed that different responses of the cultivars evaluated in the different rates and agricultural harvests occurred (Figure 2). The maximum values obtained at the rate 120 kg ha^{-1} of N in the EA were 9.07 kg kg^{-1} (CNPA G3) and 4.61 kg kg^{-1} (CNPA G4), and at the rate of 112.79 kg ha^{-1} of N was 8.09 kg kg^{-1} (BRS Seda), there was no equation adjustment for cultivar CNPA G2 that obtained the mean value of efficiency 4.88 kg kg^{-1} in the 1st harvest season (Figure 2A). In the second harvest, the maximum values were 50.45 and 30 kg ha^{-1} of N, where the agronomic efficiency was 14.99 (CNPA G3) and 9.63 kg kg^{-1} (BRS Seda), respectively (Figure 2B). There was no equation adjustment for the cultivars CNPA G2 and CNPA G4; however their mean values were 2.62 and 2.04 kg kg^{-1}, respectively.

In the 1st harvest, it was observed that at the rate 30 kg ha^{-1} of N the cultivar CNPA G2 was superior to the other cultivars evaluated, at the rate 60 kg ha^{-1} was the cultivar CNPA G3 at the rate of 90 kg ha^{-1} of N were the cultivars CNPA G2 and CNPA G3. At the rate of 120 kg ha^{-1} of N, the cultivar CNPA G3 was superior to the other cultivars when agronomic efficiency (Figure 2A). In the second harvest, the cultivar BRS Seda was superior to the other cultivars at the rate of 30 kg ha^{-1} of N at the rate of 60 kg ha^{-1} of N to CNPA G3 at the rate of 90 kg ha^{-1} of N to cultivar BRS Seda. At the rate of 120 kg ha^{-1} of N, the cultivars CNPA G2 and BRS

Seda were superior to the other cultivars in the agronomic efficiency (Figure 2B). The second agricultural harvest had the best agronomic efficiency (Figure 2).

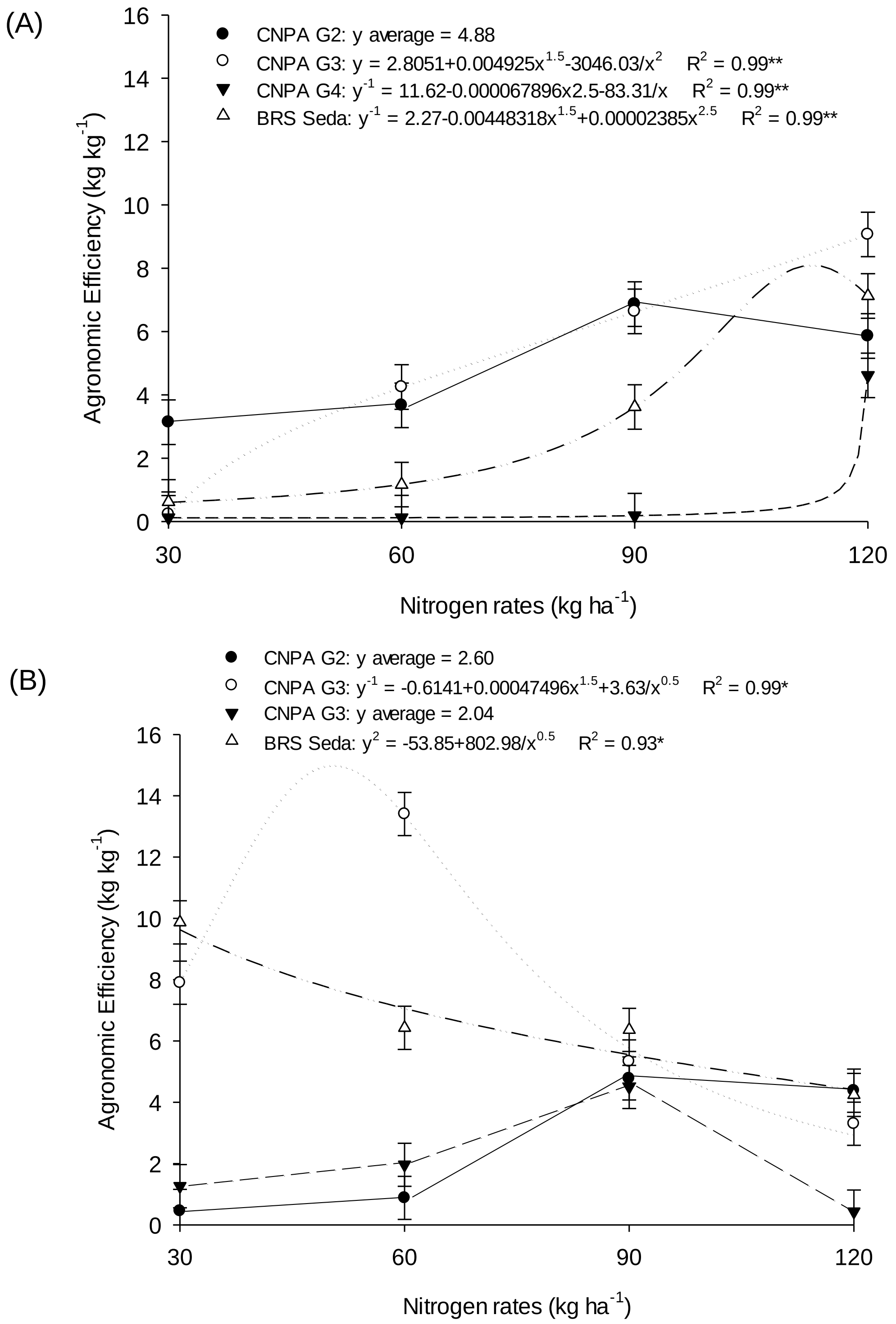


Figure 2. Agronomic efficiency as a function of nitrogen rates and sesame cultivars in the 1st harvest (A) and 2nd harvest (B).

It was generally observed in the first harvest that the cultivars responded positively with the increase of the rates of N applied. Since the second harvest did not observe the same behavior of the cultivars studied, in which rates lower than 60 kg ha^{-1} had the highest agronomic efficiency.

In the PE, different responses of the cultivars occurred under the interactions with the N rates applied in the 1st harvest. The maximum values obtained by the cultivars varied between the rates of 30; 39.07 and 88.87 kg ha^{-1} of N, the PE of 21.26 kg kg^{-1} (CNPA G2), 17.82 kg kg^{-1} (CNPA G3) and 16.55 kg kg^{-1} (BRS Seda), respectively. There was no equation adjustment for the CNPA G4 cultivar, where the mean PE was 16.72 kg kg^{-1} (Figure 3). The cultivar CNPA G2 was superior to the other cultivars when the PE in the rates of 30 and 90 kg ha^{-1} of N applied. At the rates of 60 and 120 kg ha^{-1} of N applied were cultivars CNPA G4 and CNPA G3, respectively (Figure 3).

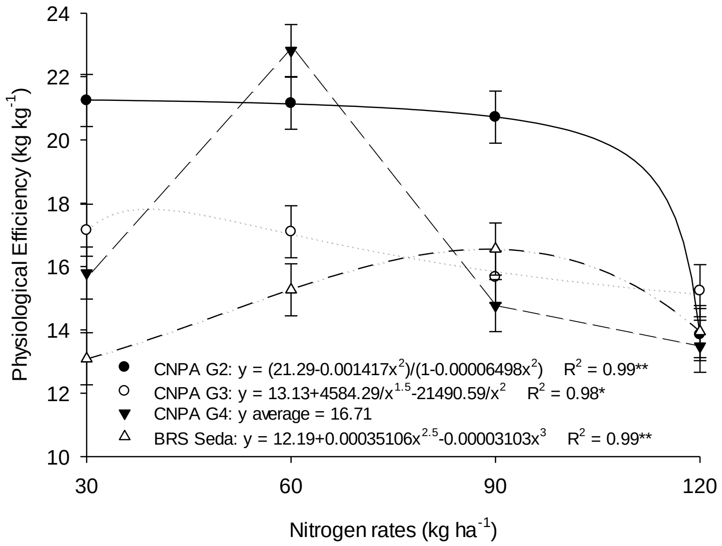


Figure 3. Physiological efficiency as a function of nitrogen and sesame cultivars in the 1st harvest.

In the 2nd harvest season, maximum PE values were obtained at the rate of 30 kg ha^{-1} of N (Figure 4). The PE obtained were 94.35 kg kg^{-1} (CNPA G2), 73.19 kg kg^{-1} (CNPA G3), 64.96 kg kg^{-1} (CNPA G4) and 88.95 kg kg^{-1} (BRS Seda). The cultivar CNPA G2 was superior to the other cultivars at the rate of 30 kg ha^{-1} of N, already at the rate of 60 and 90 kg ha^{-1} was the cultivar CNPA G3, and at the rate of 120 kg ha^{-1} of N was cultivar BRS Seda superior to the other evaluated cultivars (Figure 4).

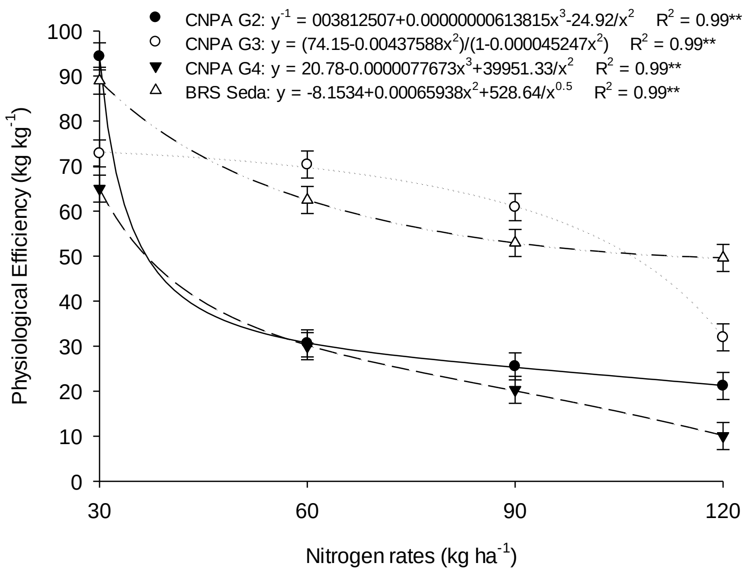
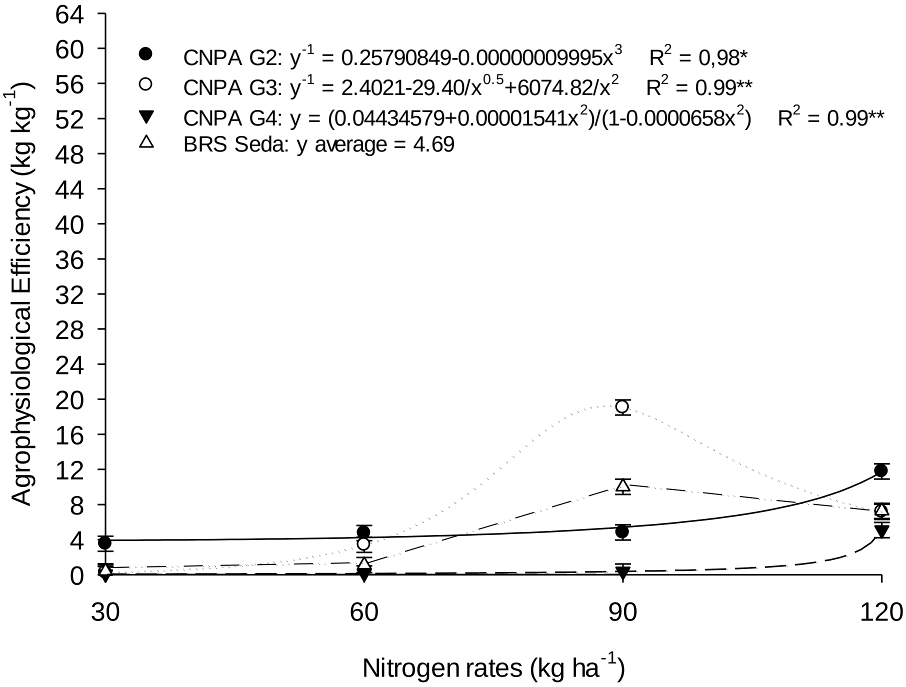


Figure 4. Physiological efficiency as a function of nitrogen and sesame cultivars in the 2nd harvest.

The maximum values for APE were obtained at the rate of 120 kg ha^{-1} and 88.06 kg ha^{-1} in the 1st harvest, in the 2nd harvest, there was no equation adjustment for the evaluated cultivars, except the cultivar BRS Seda, which obtained maximum value of EAF at the rate of 53.31 kg ha^{-1} of N (Figure 5). Agrophysiological efficiency was 11.74 kg kg^{-1} (CNPA G2) and 5.09 kg kg^{-1} (CNPA G4) at the rate of 120 kg ha^{-1} of N, the cultivar CNPA G3 at APE was 19.26 kg kg^{-1} kg kg^{-1} at the rate of 88.06 kg ha^{-1} of N. For the cultivar BRS Seda, no equation adjustment occurred; it had an average APE value of 4.69 kg kg^{-1} in the 1st harvest season (Figure 5A). Regarding the 2nd harvest, the maximum value obtained was 43 kg kg^{-1} (BRS Seda) at the rate of 53.31 kg ha^{-1} of N (Figure 5B). There was no equation adjustment for cultivars CNPA G2, CNPA G3 and CNPA G4, in which the average APE obtained by cultivars was 21.04; 23.15; 4.45 kg kg^{-1}, respectively.

(A)



(B)

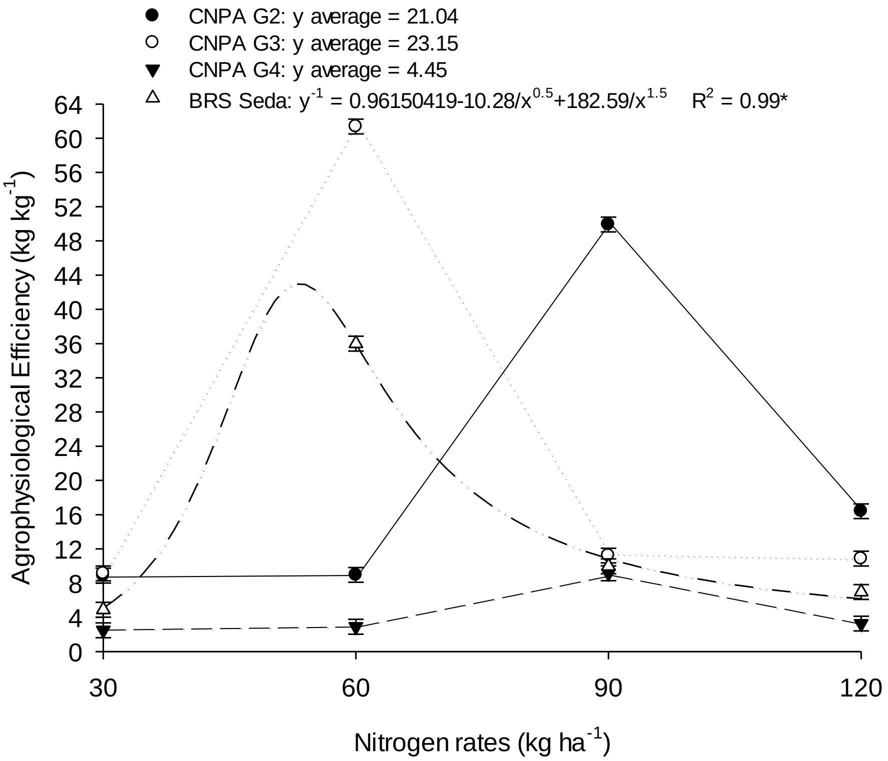


Figure 5. Agrophysiological efficiency as a function of the nitrogen and sesame cultivars rates in the 1st harvest (A) and 2nd harvest (B).

The CNPA G2 cultivar was superior to the other cultivars at rates of 30, 60 and 120 kg ha^{-1} of N, while the cultivar CNPA G3 obtained better APE at 60 kg ha^{-1} of N in the 1st harvest (Figure 5A). The cultivars CNPA G2 and CNPA G3 did not differ statistically between and is and were superior to the other cultivars at the rate of 30 kg ha^{-1} of N, at the rate of 60 kg ha^{-1} was the cultivar CNPA G3, already for the rates of 90 and 120 kg ha^{-1} of N, the CNPA G2 cultivar obtained higher agrophysiological efficiency in the 2nd harvest season (Figure 5B). The second harvest was generally the best agrophysiological efficiency (Figure 5).

For the recovery efficiency the maximum values were obtained in the rate of 30 kg ha^{-1} in the 1st harvest season (Figure 6). The RE was 137.50% (CNPA G2), 120.04% (CNPA G3), 206.47% (CNPA G4) and 171.55% (BRS Seda). The cultivar CNPA G4 obtained higher recovery efficiency at the rate of 30 kg ha^{-1}, already the cultivar BRS Seda (60 kg ha^{-1}). At 90 kg ha^{-1} the cultivars CNPA G3, CNPA G4 and BRS Seda did not differ statistically, being superior to CNPA G2. At 120 kg ha^{-1}, the cultivars CNPA G2 and CNPA G3 did not differ among themselves, being superior to the other cultivars in the 1st harvest (Figure 6).

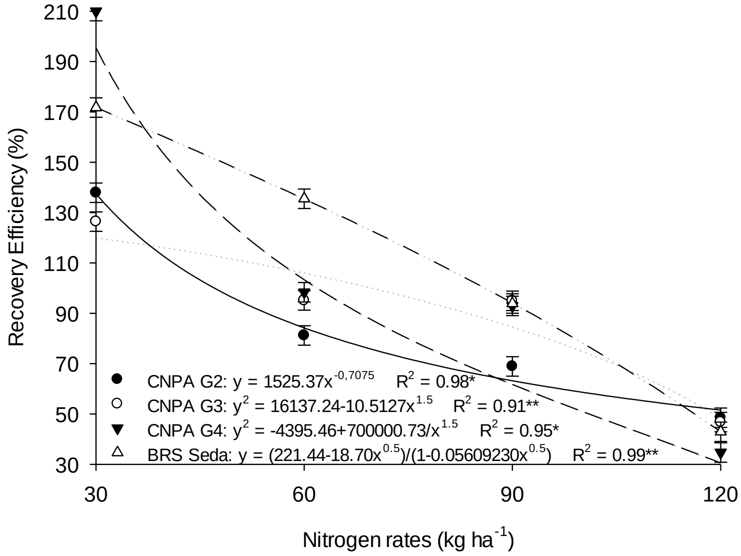


Figure 6. Recovery efficiency of as a function of nitrogen and sesame cultivars in the 1st harvest.

Regarding the RE of the 2nd harvest, different responses of the cultivars occurred under the interactions with the applied N rates (Figure 7). The maximum recovery efficiency values obtained were: at the rate of 65.25 kg ha^{-1} of N of 50.14% (CNPA G2) at the rate 30 kg ha^{-1} of N of 90.98% (CNPA G3) and 70.38% (CNPA G4), and at the rate 65.41 kg ha^{-1} of N of 115.11% RE (BRS Seda). The cultivar CNPA G3 obtained higher efficiency of recovery at the rate of 30 kg ha^{-1} of N, already at the rates of 60, 90 and 120 kg ha^{-1} the cultivar BRS Seda was superior to the other cultivars in the recovery efficiency in the 2nd agricultural harvest (Figure 7).

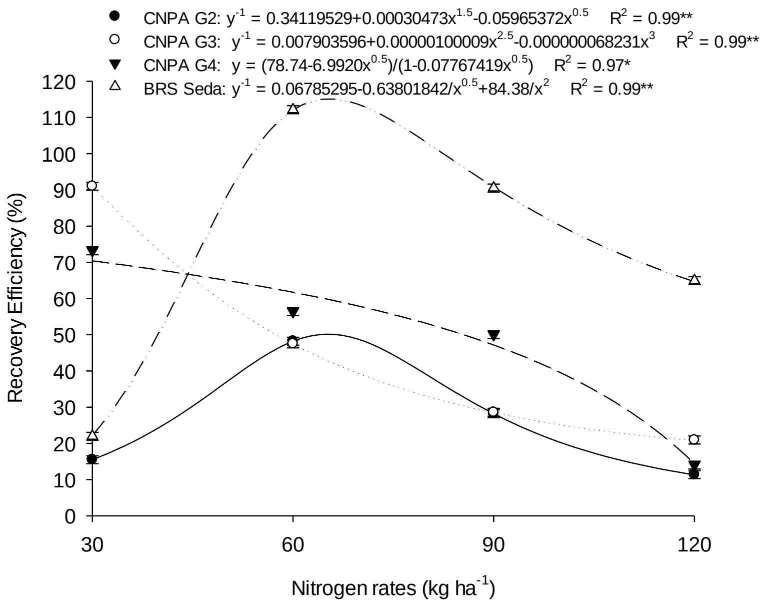


Figure 7. Recovery efficiency as a function of nitrogen rates and sesame cultivars in the 2nd harvest.

The highest efficiency of N utilization was obtained 30 kg ha^{-1} in both crops, except CNPA G2 (39.74 kg ha^{-1}) and BRS Seda (48.24 kg ha^{-1}) in the 2nd harvest (Figure 8). The maximum values obtained in the 1st

harvest was: 29.31 kg kg^{-1} (CNPA G2), 20.99 kg kg^{-1} (CNPA G3), 33.16 kg kg^{-1} (CNPA G4) and 22.47 kg kg^{-1} BRS Seda) (Figure 8A). In the second harvest, the maximum values were: 19.63 kg kg^{-1} (CNPA G2), 66.25 kg kg^{-1} (CNPA G3), 47.48 kg kg^{-1} (CNPA G4) and 75 Kg kg^{-1} (BRS Seda) (Figure 8B).

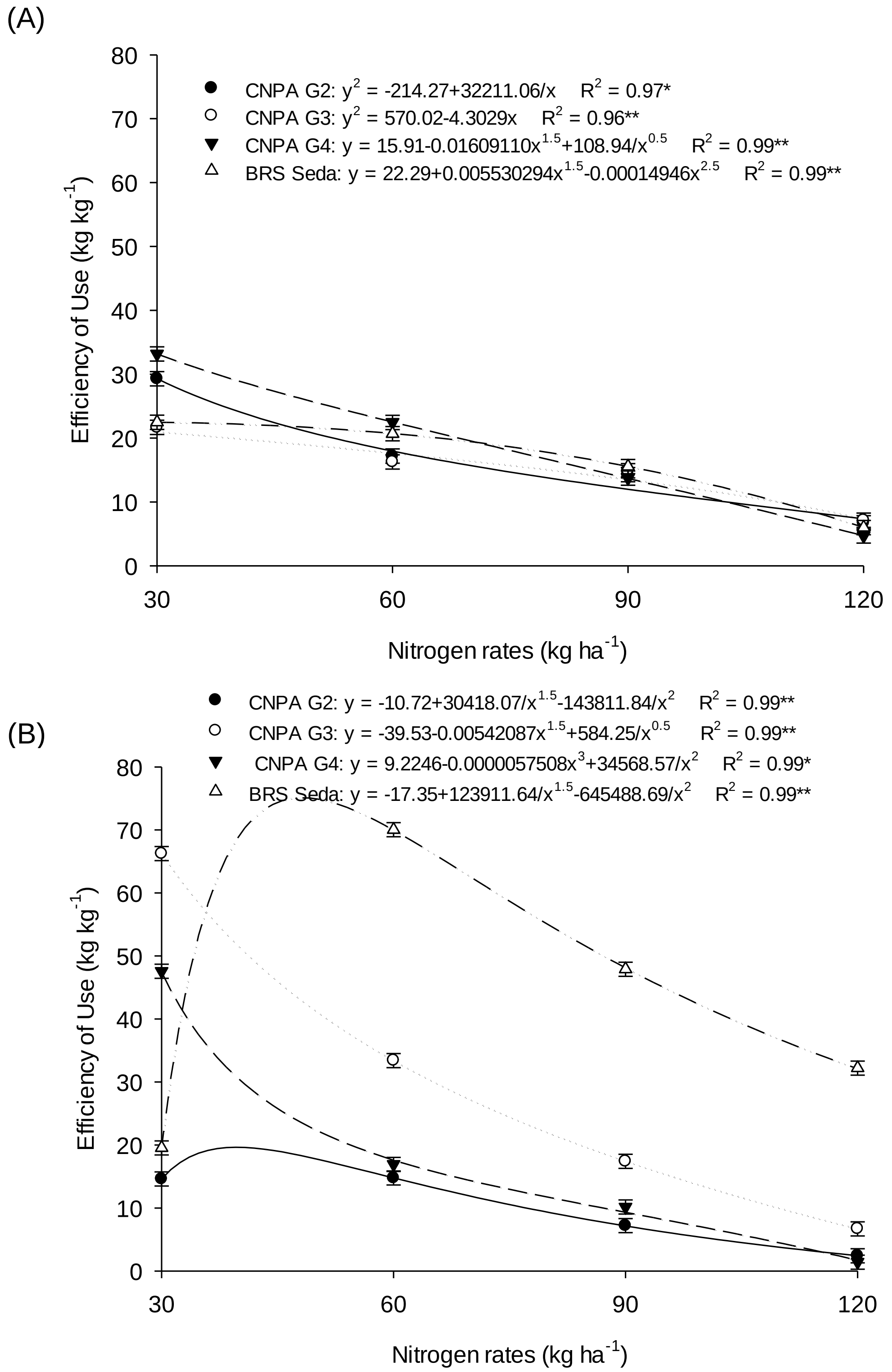


Figure 8. Efficiency of use as a function of the rates of nitrogen and sesame cultivars in the 1st harvest (A) and 2nd harvest (B).

The cultivar CNPA G4 obtained better efficiency of N utilization in the rates of 30 and 60 kg ha^{-1} of N, already in the rate of 90 kg ha^{-1} of N the cultivar BRS Seda was similar to cultivar CNPA G3 and superior to the other cultivars when the EU of N. At the rate of 120 kg ha^{-1} of N the cultivar CNPA G3 was similar to CNPA G2 and superior to the other cultivars in the 1st agricultural harvest (Figure 8A). In the second harvest, the cultivar CNPA G3 was more efficient than the other cultivars evaluated, at the rates of 60, 90 and 120 kg ha-

[1] the cultivar BRS Seda obtained higher efficiency of N utilization (Figure 8B). The second harvest yielded higher values of efficiency of use of N (Figure 8).

4. Discussion

Shehu (2014), evaluating the agronomic and recovery efficiency of N, phosphorus and potassium in the sesame in Mubi, Nigeria, obtained that the agronomic and recovery efficiency of N was 2.26 kg kg^{-1} and 17.80% at the applied dose of 75 kg ha^{-1} of N, respectively. The values found in the present study were higher than those seen by Shehu (2014), where they were obtained at a dose of 120 kg ha^{-1} of N for agronomic efficiency regardless of cultivars, whereas for recovery efficiency it was the dose of 60 kg ha^{-1} of N, indicating that the difference in fertilizer management through the greater availability of N can affect the response of sesame.

The present study also found a better efficiency in the use of N by sesame cultivars with N fertilization with the lowest doses of N applied in relation to those seen by Joyaban et al. (2011) in the city of Birjand, Iran. In their study, they concluded that the use of the 6-day irrigation interval with the application of 100 kg ha^{-1} of N, obtained an efficiency of use of 7.04 kg of seeds per kg of N applied (Joyaban et al. 2011).

The different responses found in the present study are possibly linked to factors of the soil-plant-atmosphere relationship, indicating that it is not so simple to understand this relationship in the agricultural environment (Santos et al. 2018). It is possible to emphasize this due to the variation in soil characteristics, mainly the organic matter of the soil between the two agricultural harvests. The other important factor to be highlighted is that genotypes can differ when their efficiency in absorbing nutrients from the soil (Sattelmacher et al. 1994). Furthermore, probably the climatic conditions such as relative humidity, temperature and precipitation (Figure 1) affected the availability of N for sesame, directly affecting the efficiency of absorption of N by sesame due to the losses of N through leaching and volatilization of the applied N (Fageria 1998).

The greatest physiological efficiency occurred in the second harvest, probably due to the fact that the soil of the second growing season had a higher content of organic matter in the soil (12.78 g kg^{-1}). In the soil, organic matter directly affects the physical, chemical and biological characteristics of the soil, thereby influencing the nutritional efficiency of crops (Fageria 1998). Soil organic matter increases the capacity of the soil to absorb cations, provides energy for the activities of soil microorganisms, regulates the temperature of the soil, affects the physical and chemical characteristics of the soil that favors the development of roots and increases the retention capacity of water in the soil (Fageria 1998). It is also noted that in the second agricultural season, in general, the levels of nutrients in the soil were higher and there was no record of rainfall. In contrast to the edaphoclimatic conditions of the first harvest in which the rains in the first harvest may have favored the leaching of nutrients (Figure 1).

The recovery capacity of N by the cultures in general is less than 50% of the applied fertilization (Baligar and Bennett 1986). The low recovery of N by plants is linked to the loss of N through leaching and volatilization. This low recovery of N causes a higher production cost to the producer and also affects the environment through environmental pollution (Fageria and Baligar 2005).

When N is used in excessive amounts or in adverse conditions, it can be lost. N losses in the soil-plant system can occur due to nitrate leaching, which occurs due to the low chemical interaction with soil minerals, the amount of water and also the texture of the soil (Cantarella 2007). Another form of N loss in the system is through the volatilization of ammonia in the soil, which is influenced by pH, buffering power, urease activity, soil moisture and soil temperature (Cantarella 2007). Therefore, the understanding of the main reactions that govern the behavior of N in the soil-plant system is, therefore, fundamental for the adequate management of agricultural production (Cantarella 2007).

Improving the efficiency of the use of N is desirable to improve the productive performance of the crops, thus reducing production costs and decreasing possible environmental damage. So it is necessary to adopt managements that improve the efficiency of N use by crops, such as improved fertilizers, soil and crop management (Fageria and Baligar 2005).

Knowledge of the efficiency of N utilization in different genotypes of sesame in the (semi-arid) edaphoclimatic conditions is of fundamental importance, due to the fact that several soil-plant-atmosphere factors influence soil nutrient dynamics. With this, it allows the proper management of the fertilization in which the N fertilizer is more efficient, and consequently reduces the environmental and economic damages, which could have occurred with the incorrect management of the fertilization.

5. Conclusions

There was interaction between the factors studied (rates, cultivars and agricultural harvests) in the evaluated variables, having an effect on the efficiency of use by sesame cultivars. Increase in agronomic efficiency (second harvest), physiological efficiency (second harvest), recovery efficiency and utilization efficiency were generally achieved by decreasing nitrogen rates applied to different sesame cultivars and agricultural harvest under the conditions of soil and climate of the semiarid. For physiological efficiency (first harvest) and agrophysiological efficiency slightly increased as nitrogen rates increased, and later there was a decrease in the efficiency of different sesame cultivars in agricultural harvests.

Different answers were obtained from the nutritional efficiency of sesame cultivars in view of the different nitrogen rates applied in the two harvests. Nitrogen rates directly influenced the utilization efficiency, where in general the 30 kg ha^{-1} N rate provided the highest utilization efficiency of N. The cultivar BRS Seda had the maximum utilization efficiency in relation to the other cultivars studied in 60 kg ha^{-1} rate of N applied. The second agricultural harvest had better utilization efficiency.

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