Management of Nitrogenous Fertilization in Sesame (*Sesamum indicum* L.) Growth and Production

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ABSTRACT

Aims: The objective of present study was to evaluate the efficiency of the use of different doses of nitrogen (N) applied in part to the growth and production of sesame.
Study design: The design used was in random blocks, arranged in factor 9 × 3 scheme, with five repetitions and ten plants per experimental unit.
Place and Duration of Study: The study was conducted from June to September 2018 at Experimental Chã-de-Jardim Farm, Center of Agrarian Sciences of the Federal University of Paraíba, municipality of Areia, Paraíba, Brazil.
Methodology: The treatments consisted nine doses of nitrogen (0; 10; 20; 30; 40; 50; 100; 150 and 200 kg ha^{-1}) and three forms of installment (P1 = 50% in foundation and 50% in cover thirty days after sowing (DAS); P2 = 33.3% on foundation, 33.3% for fifteen DAS and 33.3% for coverage; P3 = 25% for foundation, 25% for fifteen DAS, 25% for coverage and 25% for 45 DAS). The parameters were evaluated: plant height (PH), stem diameter (SD), sheet number (SN), number of capsules (NC), productivity of grain (PG) and mass of 1000 grains (M1000).
Results: There was an increase in plant height when N was less fragmented, with a maximum height of 137.7 cm at a dose of 92.05 kg ha^{-1} of N. The diameter of the stem and the number of leaves increased linearly as a result of the increase in N doses. The doses of N applied only on foundation (50%) and coverage (50%) promoted an increase in the number of capsules, with a maximum of 199.7 units referring to the application of 212.75 kg ha^{-1} of N. Grain productivity was increased with an increase in the application of N, for the three splitting forms, up to a dose of maximum efficiency, followed by a subsequent decrease.
Conclusion: The increase in the portioning of nitrogen fertilization promotes lower growth of sesame plants. The application of 183.5 kg ha^{-1} of N, 50% on foundation and 50% on coverage, provides higher productivity of sesame grains (1541.3 kg ha^{-1}).

Keywords: Functional food; urea; parceling; productivity.

1. INTRODUCTION

The sesame (*Sesamum indicum* L.) is an oleaginous of African origin belonging to the Pedaliaceae family. It is considered one of the oldest cultures produced in the world, with records of cultivation in Babylon and Assyria 4,000 years ago [1]. Currently, sesame is grown in 65 countries, especially in Asia, mainly in India, Myanmar and China, which together account for 60% of the world production and increase the status of the world is most produced ninth oleaginous [2, 3].

In Brazil, sesame is traditionally grown in most of the northeastern states and in the midwestern region of the country, which holds 70% of the national production, especially in the states of Mato Grosso and Goiás [4, 5]. The culture has been gaining prominence among Brazilians due to the growing demand for functional foods. In the recent decades, the consumption of this oilseed in the country increased from 1,000 t year^{-1} to 10,500 t year^{-1}, due to the use in natura of its grains by fast food chains, which increased its demand by 550% [5].

The value of sesame is mainly due to its grains, rich in vitamin B, minerals (calcium, phosphorus, magnesium, sodium and zinc), antioxidants (sesamin, sesamoline and tocopherol) and oil, composed of unsaturated fatty acids and linoleic which give higher grades and qualities to other oilseeds such as soybean (*Glycine max*) and sunflower (*Helianthus annuus*) [3]. In addition to the use in human foods, sesame is used for various purposes such as industrial, pharmaceutical, medicinal and in the production of renewable energy through biofuel [6, 7].

The crop has ample adaptability to the most diverse soil and climate conditions, especially the hot climate and water deficit, due to its high stomatal resistance, provides less transpiration in critical periods [2, 8]. However, despite this rusticity, your productivity field conditions is still considered low when compared to other oleaginous species, mainly due to its need for good fertility soils, which entails greater need for fertilization and limits crop expansion [9].

One of the most debated subjects in the literature despite this oleaginous is the fertilization [10, 11]. The use of fertilizers has shown satisfactory productivity gains in some studies, in which the authors report that the increase in sesame productivity is directly related to the increase of nutrients in the soil through fertilization [12, 13].

Among the essential mineral elements, nitrogen (N) most often limits the growth and production of sesame. The requirement of the plant for this nutrient grows rapidly and reaches the maximum demand at 74 days after emergence, requiring the use of 30 kg ha^{-1} of N for the production of 500 kg of seeds [5]. However, when N is applied in excess, there is greater growth of the plants, which increases the risk of anomalies and decrease in production. The deficiency, in turn, causes nutritional disturbance with subsequent reduction in the oil content of the grains [14, 15].

The use of N is necessary due to the insufficient amount that the soil provides for the growth and development of the plants throughout its cycle, and its application in the form of fertilizer is necessary. Traditionally, annual crops receive two applications of N during the cycle, a small fraction at sowing and the remainder in single application coverage [16]. However, it is known that increased nitrogen fertilization at the appropriate time increases plant efficiency, increases grain yield and reduces leaching, volatilization and denitrification losses [10,11].

In this sense, the objective of this work was to evaluate the efficiency of the use of different doses of nitrogen (N) applied in part to the growth and production of sesame.

2. MATERIAL AND METHODS

2.1 Location of Study Area

The study was carried out from June to September 2018 at the Experimental Chã-de-Jardim Farm, Agricultural Sciences Center of the Federal University of Paraíba, Areia municipality, located in the Geographical Microregion of Brejo Paraibano at 6º 58 '12 "S e 35º 42 '15 "W, with an average elevation of 534 m.

The local climate according to Köppen is type A, hot and humid, with autumn and winter rains, characterized by annual averages of precipitation, relative humidity and ambient temperature around 1,300 mm, 80% and 26 ° C, respectively.

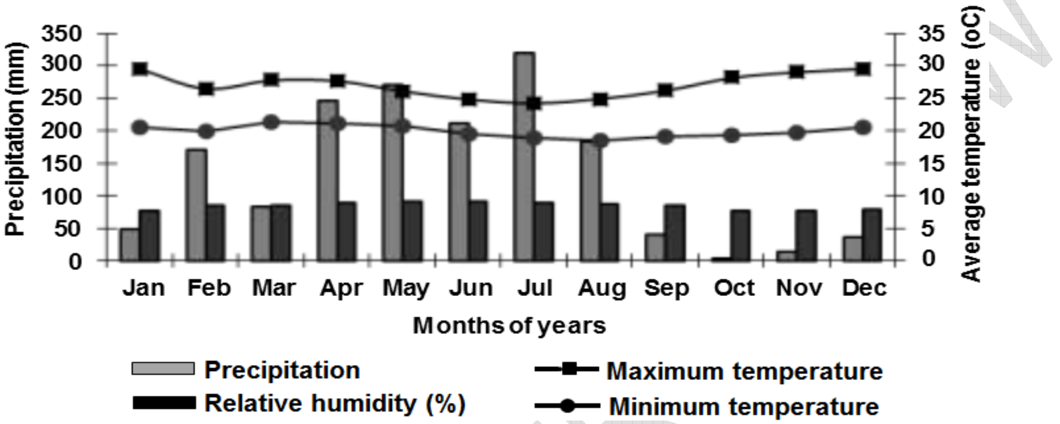

Figure 1. Average monthly data of precipitation, relative humidity and temperature in year 2018, obtained from a meteorological station located at the Experimental Chã-de-Jardim Farm, Areia, Paraíba, Brazil.

The soil of the study area was classified as a dystrophic YELLOW LATOSOL (LAdx), with Sandy Clay Texture, which presented the following physico-chemical characterization in the 0 to 20 cm layer (Table 1).

Table 1. Chemical and physical characteristics of the soil at the 0-20 cm depth layer.

pH	OM	P	Ca	Mg	Al	H+Al	K
($CaCl_2$ 10 mmol L^{-1})	g kg^{-1}	mg dm^{-3}	----------------- ($cmol_c dm^{-3}$) ---------------				
4.90	30.7	11.6	1.66	0.47	0.03	1.93	0.05
Sand	Silt	Clay	V	m	CEC	BS	Na
------------ g kg^{-1} -------------			-------%--------		-------- $cmol_c$ dm^{-3} -------		
525.0	41.0	434.0	49.0	2.0	1.86	2.23	0.05

Analysis performed according to EMBRAPA methodology [17]. O.M. = Organic Matter; V = Base Saturation; m = Saturation by Al^{3+}; CEC = Cation Exchange Capacity; BS = Base Sum.

2.2 Study design

The experimental design was in randomized blocks arranged in factor 9 × 3 scheme, with five replications and ten plants per experimental unit. The treatments consisted of nine doses of nitrogen (0, 10, 20, 30, 40, 50, 100, 150 and 200 kg ha^{-1}) applied as urea in three forms of installmentation (P1 = 50% on foundation and 50% covering 30 days after sowing

(DAS); (P2 = 33.3% on foundation, 33.3% on fifteen DAS and 33.3% on coverage, P3 = 25% on foundation, 25% on fifteen DAS , 25% on coverage and 25% on 45 DAS).

The experimental plot consisted of 6 lines of 5 m length with spacing of 0.5 m between lines and 0.10 m between plants, totaling 30.0 m^2, of which 16.0 m^2 were used as a useful area and remaining as edge.

Soil preparation was carried 30 days before sowing and a crop at 20 cm depth two harrowing levelers and application of 0.45 t ha^{-1} of dolomitic limestone (90% PRNT) to provide 70% base saturation %) recommended for growing of sesame.

Fertilization was carried out in the sowing phase and included 60 kg ha^{-1} of P_2O_5, 40 kg ha^{-1} of K_2O and 25 kg ha^{-1} of micronutrients (Sulfur: 3.9%, Boron: 1.8%, Copper: 0.85%, Manganese: 2.0% e Zinc: 9.0%), applied as single superphosphate, potassium chloride and FTE BR 12 respectively. Nitrogen fertilization was used according to previously established treatments.

The cultivar used was the BRS Silk, which presents a medium-sized and 90 days cycle, indicated for the dryland cultivation in the northeast of Brazil. The sowing was done directly in the field, placing five seeds per pit, where ten days after emergence the thinning was done leaving only one plant.

The cultural treatments during the crop cycle consisted of manual weeding between rows. The pest control was performed 45 days after emergence and consisted of 400 ml of p.c. ha^{-1} from Decis 25 CE® to control the screw track (*Antigastra catalaunalis*).

2.3 Data Collection

At 90 days after emergence, at the time of harvest, the following variables were evaluated: plant height (PH), base measurement at the apex of the stem with the aid of a tape measure; stem diameter (SD), measured in the lap of the plant with the aid of a digital parking meter; sheet number (SN), determined by the count of fully expanded leaves in each plant; number of capsules (NC), determined by counting the total number of capsules per plant; productivity of grain (PG), determined by weighing the grains of the plot area, expressed in kg ha^{-1} and 1000 grains (M1000), determined by counting and weighing the seeds using a precision digital scale.

2.4 Data Analysis

The data were submitted to analysis of variance completed by the F test ($p \leq 0.05$). The effect of nitrogen doses was verified by regression analysis. The Tukey test ($p \leq 0.05$) was used to compare the subdivision forms. The correlation between sesame grains yield and the other growth and productivity components was performed by Pearson's linear correlation analysis ($p \leq 0.05$) using statistical software SPSS (Statistical Package for the Social Science) version 20.0.

3. RESULTS AND DISCUSSION

The N doses together with the division forms promoted significant effects on plant height (PH), stem diameter (SD), number of capsules (NC) and productivity of grain (PG). The sheet number (SN) was influenced in isolation by the doses of N and by the forms of parceling, while the mass of 1000 grains (M1000) was not influenced by the treatments used.

3.1 Plant height

There was an increase in plant height (PH) when the N was divided into two (P1) and three (P2) equal applications, with averages of 137.7 and 135.1 cm, obtained with the optimal doses of 92.05 and 89.62 kg. ha^{-1} of N, respectively (Figure 2). In addition, the decrease in plant growth was observed when these doses were exceeded in both divisional forms.

Souza et al. (2014) [11] evaluating the initial development of the cultivar IAC Ouro, submitted to nitrogen fertilization, obtained plant height similar to that found in this work with the conventional application of 85.6 kg ha^{-1} of N. According to Grilo Júnior et al. (2015) [18] the plant height is directly related to the sesame productivity; therefore, it is expected to achieve satisfactory production results in higher plants.

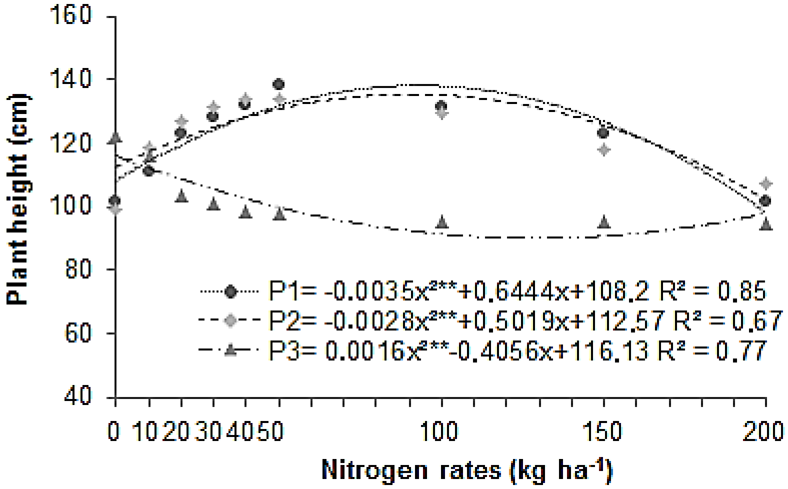

Figure 2. Height of sesame plants (*Sesamum indicum* L.) as a function of the rates and the nitrogen fertilization.

When N was divided into four equal applications (P3), there was a marked decrease in plant height as nutrient doses increased. It was also verified that the lower amount of N applied in the initial phase, due to the higher number of plots, resulted in a decrease in the crop growth, possibly due to the deficiency of N suffered by the plants in the period before the flowering, since the BRS Seda cultivar begins flowering 30 days after emergence.

Contrary to the present study for plant height was observed by Arriel et al. (2006) [19] mention that up to the thirtieth day N is not very required by sesame, but from that period, plant requirements for this nutrient grow rapidly, reaching maximum demand in 74 days after germination. Such behavior suggests that it is important to study studies of this nature to accurately determine the effect of the interaction between the amount of N applied and the correct time of application.

During the sowing period of the crop, a high rainfall regime was observed in the region, possibly resulting in higher losses of nitrogen from leaching, leading to a reduction in the efficiency of N separation in four equal applications (P3), which received only 25% of the total to be applied.

It is known that N is part of the components of protein, RNA, DNA, ATP, chlorophyll among other molecules. In this sense, its deficiency has considerably reduced the plant is growth capacity. As N losses occurred during sowing, there was also a reduction in the amount offered in the later stages, a fact that reflected in the reduction of growth. This result is similar to that obtained by Jadhav et al. (2015) [20] who mention that N deficiency in the early growth phase of the crop results in lower plant height at the end of the cycle.

3.2 Stem diameter

The stem diameter (SD) increased linearly as a result of the increase of N doses for all forms of splitting (Figure 3), especially when it was divided into three equal applications (P2), reaching 3.1 cm. The increase of the diameter of the stem is important to give better support to the production of branches, leaves, fruits and avoid the fall of the plants in the adult phase by the action of the winds. However, it is worth noting that not only fertilization and land parceling affect the to soak diameter of this species, but also factors such as water quantity and population density [21].

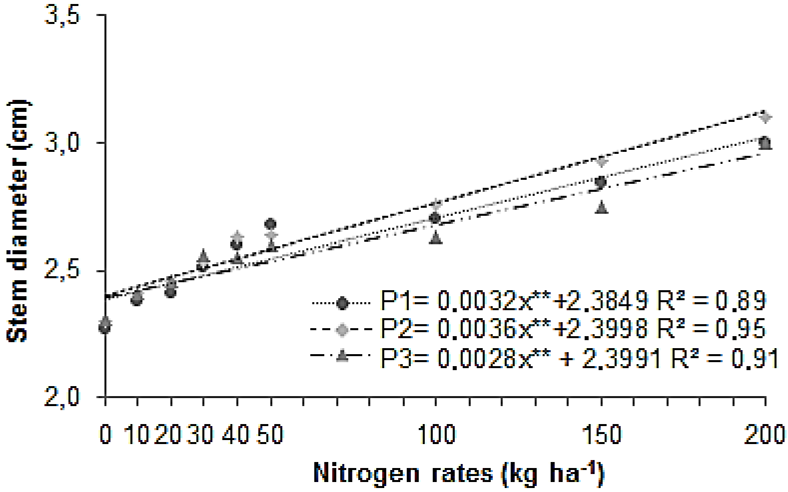

Figure 3. Stem diameter of sesame plants (*Sesamum indicum* L.) as a function of the rates and the nitrogen fertilization.

When evaluating the effects of different nitrogen fertilization dosages on the initial development of the "IAC Gold" sesame, Souza et al. (2014) [1] found that the application of increasing doses of N at 53 days after emergence (DAE) provided a better steem diameter, corroborating with the response obtained in the present study, however, the same authors mention that stem diameter fertilization. Possibly this response occurred due to the different times of application of N in a fragmented form, since in this study the last application occurred at 45 DAS, which allowed greater absorption by the plants.

3.3 Sheet number

The sheet number (SN), as well as the stem diameter, increased with the addition of nitrogen fertilization (Figure 4), with the maximum value obtained (86.13 sheets) with the application of 200 kg ha^{-1}. O N is an element that is closely linked to the process of cell division and expansion of the plants, in this sense, the greater the availability of this macronutrient, the greater the plant growth, especially the stem and the number of leaves, provided availability is below the toxic limits. This fact is evidenced by the increase in the number of sheet in the present study, which confirms those obtained by Sousa et al. (2014) [11], mentioning that the increase in the number of sheet in sesame plants is a result of the positive action of nitrogen fertilization.

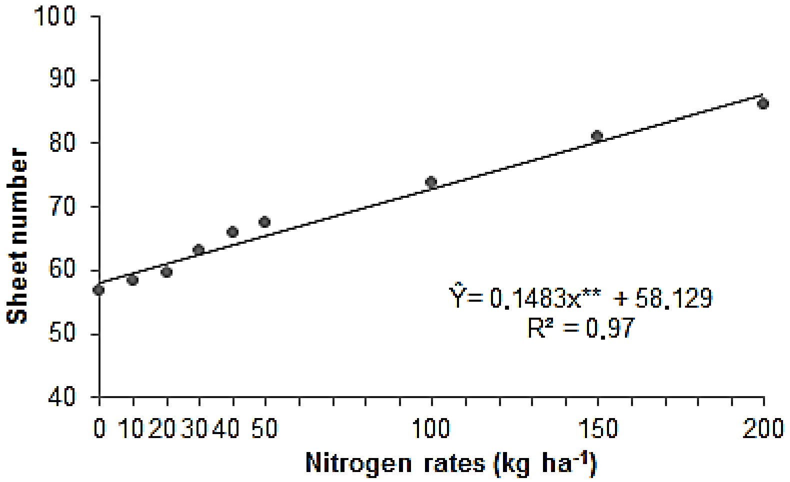

Figure 4. Sheet number of sesame plants (*Sesamum indicum* L.) as a function of the rates and the nitrogen fertilization.

When comparing the nitrogen fertilization forms in the sheet number in sesame plants, we found that the fertilization provided in two equal applications (P1) was much larger, differing from other forms of application (Figure 5). Probably this response was due to increased availability of N and greater leaf production in the initial phase of crop growth due to the amount of fertilizer applied (100%) up to 30 DAS, which lasted until harvest.

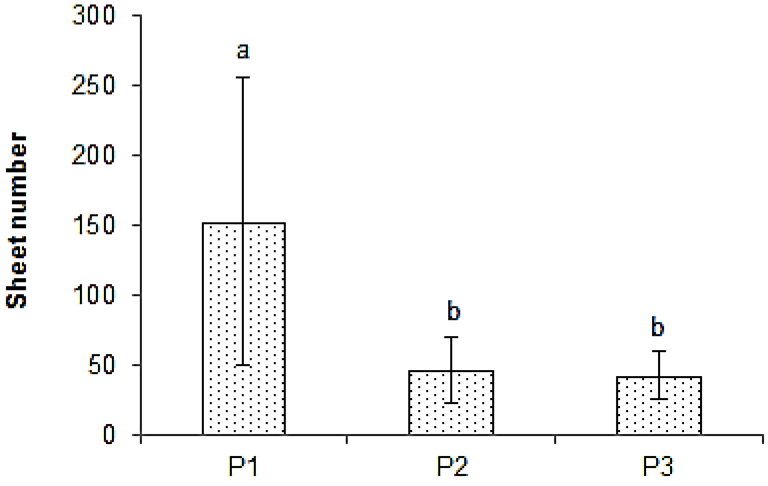

Figure 5. Mean and standard deviation of the sheet number per sesame (*Sesamum indicum* L.) as a function of nitrogen fertilization. Columns followed by the same letter do not differ by the Tukey test at 5% probability.

The sheet number is a characteristic that expresses little the nutritional status of the sesame at the end of its cycle. This is because there is a reduction in the sheet number cause the crop undergoes foliar senescence, directing the absorbed nutrients for the production of capsules (fruits). According to Queiroga et al. (2014) [22] in some sesame varieties, the grains are only completely filled when all the leaves fall from the plant.

3.4 Number of capsules

For the number of capsules (NC) a greater amount was verified as the nitrogen fertilization was reduced, mainly for the application of P1.

It was also observed that in the other forms of application (P2 and P3) there was a small increase in the number of capsules due to the increase of N doses, with a consequent stabilization tendency (Figure 6). The N doses applied only to the foundation (50%) and the cover (50%) (P1) increased in the number of capsules, with maximum value (199.7 capsules per plant) obtained with the application of 212,75 kg ha $^{-1}$ of N. This result is in accordance with Lima et al. (2013) [23] when working with the application of organic fertilizer in sesame, which is a rich source of N, with an average of 192.0 capsules per plant.

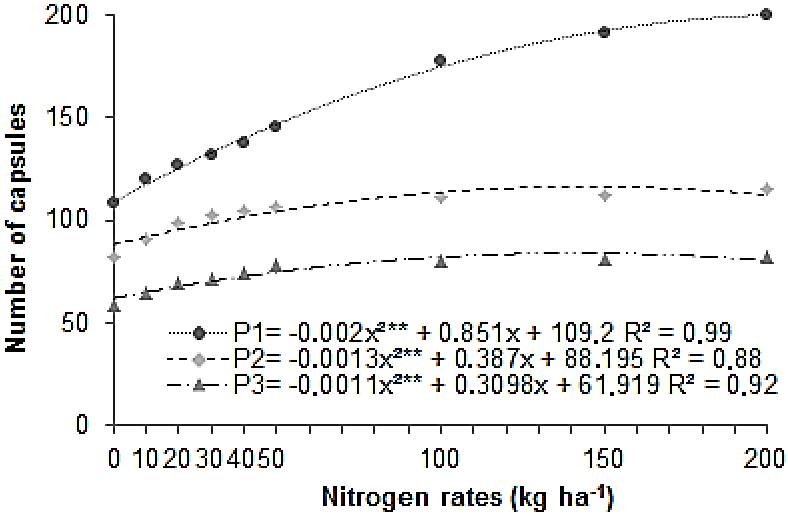

Figure 6. Number of capsules of sesame plants (*Sesamum indicum* L.) as a function of the rates and the nitrogen fertilization.

Again, the most likely cause of plant response, expressed in increase the capsule, may have been the greater availability of N in the initial stage of plant growth, due to the greater amount of fertilizer applied (100%) up to 30 DAS. The number of capsules per plant is extremely important because, according to Jadhav et al. (2015) [20], is directly related to crop productivity, since the largest amount of capsules corresponds to the greater quantity of seeds and consequently, the higher productivity. As in this result, Bharathi et al. (2014) [24], studying the effects of different types of fertilizers on sesame yield and productivity, showed increases in the number of capsules per plant, and attributed this result to increase in the height and stem diameter, leaf area and increase of production of flowers, which are responsible for the formation of fruits.

3.5 Productivity of grain

Grain productivity was increased with increase of the application of N up to a maximum efficiency dose, subsequent to a decrease, for the three forms of subdivision studied. The application of 183.5 kg ha^{-1} of N, divided into 50% of foundation and 50% of cover (P1) provided higher grain yield (1541.3 kg ha^{-1}) when compared to other forms of installment (Figure 7). It was also observed that the higher nitrogen fertilization (P3) resulted in lower grains weight gain, even at higher N doses.

The sesame cultivar BRS Seda began to bloom 30 days after emergence, if added to the four day speed of sowing emergence, the fertilization of the cover was provided exactly four days before the beginning of the flowering of the plants. At the moment, the plants begin to require a greater amount of N for pod formation and grain filling [25, 26], which may explain the fact that the application, 50% in the foundation and 50% in the cover (P1) results in higher productivity, since the amount of N applied in cover in this installment was higher than of the others.

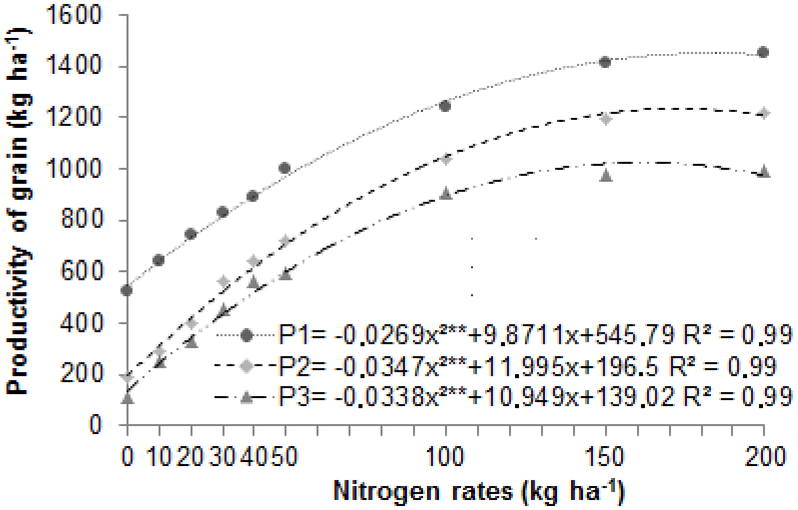

Figure 7. Productivity of grain of sesame plants (*Sesamum indicum* L.) as a function of the rates and the nitrogen fertilization.

The productivity of grain achieved in this study in dry conditions is close to that obtained by Grilo and Azevedo (2013) [27] when evaluating the growth, development and productivity of "BRS Seda" sesame irrigated at Agrovila of Canudos, Ceará Mirim (RN), which obtained 1600 kg ha^{-1}. According to Beltrão et al. (2013) [8], the yield of the "BRS Seda" sesame is 1000 kg ha^{-1}, with the potential to reach higher levels, provided that the irrigated crop system is adopted and the fertilizer handled correctly. In this sense, the productivity obtained in the present study was significantly higher than the average reported by these authors.

3.6 Pearson correlation

Table 2 shows the Pearson correlation matrix between the sesame PG and the other growth and yield components (PH, SD, SN e NC). It was found to be significant for the pairs: PG × NC (r = 0,994**) and PG × SD (r = 0,977**). For these, the correlations were direct, indicating that with the increase of the number of capsules and the diameter of the stem, there was also to increase of grain productivity. It was also observed that the number of capsules was the production component that contributed most to the productivity increase (r = 0,994**). This result corroborates those observed by Laurentin et al. (2004) [28] and Grilo and Azevedo (2013) [27] who mention that there is a great correlation between the number of capsules per plant and the yield of the sesame culture, suggesting that the increasing the number of capsules contributes to the increased productivity.

In general, significant correlations between the pairs, when analyzed for any two components (Table 2), presented positive signal (direct correlation) or negative (indirect correlation). Correlations were found with correlation coefficient values between: SN × NC (0,825**), SD × NC (0,970**) e SD × SN (0,870**). The only indirect correlation was obtained between AP × NF (r = -0.720*), indicating that with increasing plant height there will be a decrease in the number of sheet.

Table 2. Simple linear correlation matrix between sesame grain yield **(*Sesamum indicum* L.) and its other growth and yield components.**

Attributes	**Correlation coefficients**			
	PG	**NC**	**SN**	**SD**
NC	0.994**	-	-	-
SN	0.032^{ns}	0.825**	-	-
SD	0.977**	0.970**	0.870**	-
PH	-0.318^{ns}	-0.239^{ns}	-0.720*	-0.356^{ns}

PG, NC, SN, SD e PH, are respectively, productivity of grain, number of capsules, sheet number, stem diameter and plant height. **, * and ns: significant and 1%, 5% e not significant.

The simple linear regression equations between PG x NC and between PG x SD, as well as the multiple linear regression adjusted to estimate PG (dependent variable) as a function of NC e do SD (independent variables) are presented in figure 8. It was verified that the PG presented a direct linear variation with the NC (Figure 8a) and with the SD (Figura 8b). Therefore, when the maximum values of the capsule number and the stem diameter, maximum values of grain productivity will occur in the sesame crop. It was also observed that the model attested that approximately 57.7% of the sedate grain productivity variation is influenced by the number of capsules and stem diameter (R^2 = 0.577**).

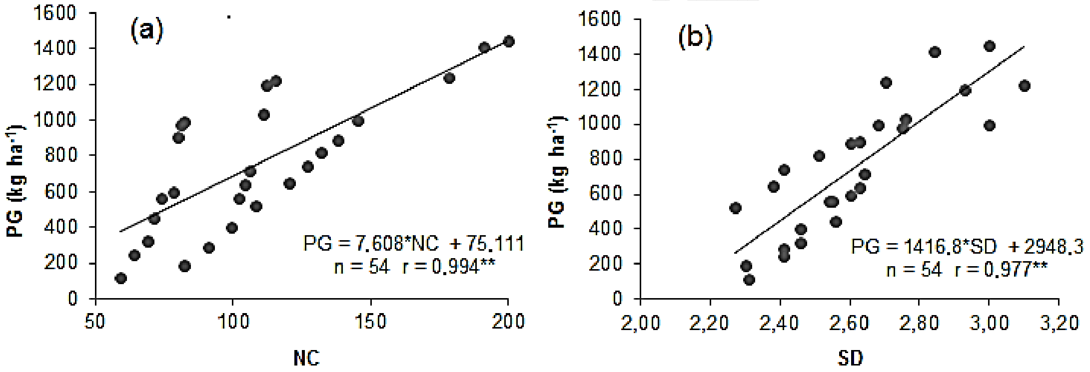

Figure 8. Regression equations of sesame grain yield (*Sesamum indicum* L.) as a function of the number of capsules per plant (a) and stem diameter (b).

4. CONCLUSION

The increase in the nitrogen fertilization scheme promotes lower growth of the sesame plants.

The application of 183.5 kg ha^{-1} of N, 50% on base and 50% on cover, provides higher productivity of sesame grains (1541.3 kg ha^{-1})

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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