

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

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ABSTRACT

Aims: The objective of this study was to evaluate the efficiency of the use of different nitrogen (N) doses applied in installments to sesame growth and production.

Study design: The design used was in random blocks, arranged in a 9 × 3 factor 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 of nine rates of nitrogen (0; 10; 20; 30; 40; 50; 100; 150 and 200 kg ha⁻¹) and three forms of division (P1 = 50% in foundation and 50% in coverage thirty days after sowing (DAS); P2 = 33.3% in foundation, 33.3% to fifteen DAS and 33.3% in coverage; P3 = 25% in foundation, 25% to fifteen DAS, 25% in coverage and 25% to 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 function of the increase in N doses. The doses of N applied only in 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 forms of division, 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% in foundation and 50% in coverage, provides higher productivity of sesame grains (1541.3 kg ha⁻¹).

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Keywords: Functional food; urea; parceling; productivity.

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1. INTRODUCTION

The sesame (*Sesamum indicum* L.) is an oleaginous of African origin belonging to the family Pedaliaceae. 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's production and increase the status of the world's most produced ninth oleaginous [2, 3].

In Brazil, sesame is traditionally grown in most of the northeastern states and in the Center-West region of the country, which holds 70% of the national production, especially in the

24 states of Mato Grosso and Goiás [4, 5]. The culture has been gaining prominence among
25 Brazilians due to the growing demand for functional foods. In the last decades, the
26 consumption of this oilseed in the country increased from 1,000 t year⁻¹ to 10,500 t year⁻¹,
27 due to the in natura use of its grains by fast food chains, that increased its demand by 550%
28 [5].

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

37 The crop presents wide adaptability to the most diverse soil and climate conditions,
38 especially the hot climate and water deficit, due to its high stomatal resistance, which gives
39 lower transpiration in critical periods. However, in spite of this rusticity, its productivity under
40 field conditions is still considered low when compared to other oleaginous species, mainly
41 due to its need for good fertility soils, which entails greater need for fertilization and limits the
42 expansion of cultivation [2, 8, 9].

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

47
48 Among the essential mineral elements, nitrogen (N) most often limits the growth and
49 production of sesame. The requirement of the plant for this nutrient grows rapidly and
50 reaches the maximum demand at 74 days after emergence, requiring the use of 30 kg ha⁻¹
51 of N for the production of 500 kg of seeds [5]. However, when N is applied in excess, there is
52 greater growth of the plants, which increases the risk of anomalies and decrease in
53 production. The deficiency, in turn, causes nutritional disturbance with subsequent reduction
54 in the oil content of the grains [14, 15].

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

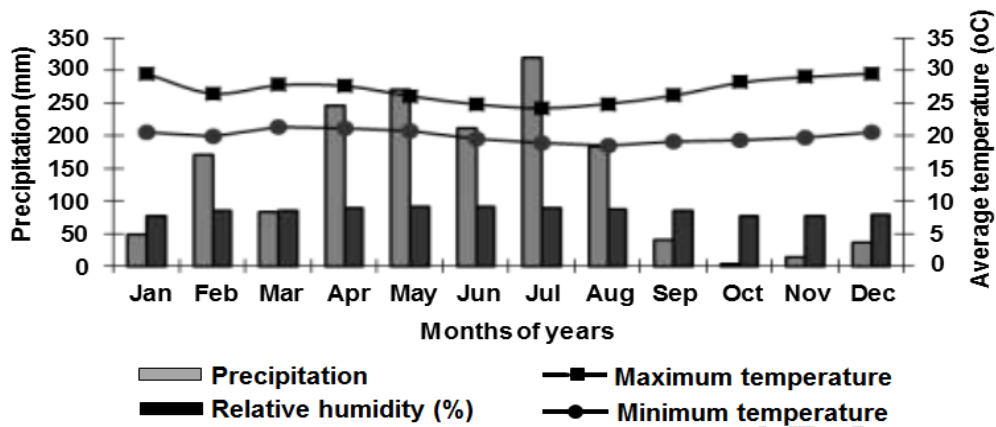
61 In this sense, the objective of this work was to evaluate the efficiency of the use of different
62 doses of nitrogen (N) applied in a fragmented way in the growth and production of sesame.

63 64 **2. MATERIAL AND METHODS**

65 66 **2.1 Location of Study Area**

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

72 The local climate according to Köppen is type A, hot and humid, with autumn and winter
 73 rains, characterized by annual averages of precipitation, relative humidity and ambient
 74 temperature around 1,300 mm, 80% and 26 °C, respectively.
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76
 77 **Figure 1. Average monthly data of precipitation, relative humidity and temperature in**
 78 **year 2018, obtained from a meteorological station located at the Experimental Chã-de-**
 79 **Jardim Farm, Areia, Paraíba, Brazil.**
 80

81 The soil of the study area was classified as a dystrophic YELLOW LATOSOL (LAdx), with
 82 sandy clay texture, which presented the following physico-chemical characterization in the 0
 83 to 20 cm layer (Table 1).
 84

85 **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 |
|--------------------------------|--------------------|---------------------|---|------|--|------|------|
| (water) | g kg ⁻¹ | mg dm ⁻³ | ----- (cmol _c dm ⁻³) ----- | | | | |
| 5.50 | 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 |

86 *Analysis performed according to EMBRAPA methodology [17]. O.M. = Organic Matter; V = Base*
 87 *Saturation; M = Saturation by Al³⁺; CEC = Cation Exchange Capacity; BS = Base Sum.*
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89 2.2 Study design

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 91 The experimental design was in randomized blocks arranged in a 9 × 3 factorial scheme,
 92 with five replications and ten plants per experimental unit. The treatments consisted of nine
 93 nitrogen doses (0, 10, 20, 30, 40, 50, 100, 150 and 200 kg ha⁻¹) applied in the form of urea in
 94 three forms of installmentation (P1 = 50% in the foundation and 50% covering 30 days after
 95 sowing (DAS); (P2 = 33.3% in foundation, 33.3% in fifteen DAS and 33.3% in coverage, P3
 96 = 25% in foundation, 25% in fifteen DAS , 25% in coverage and 25% in the case of 45 DAS).
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98 The experimental plot consisted of 6 lines of 5 m in length with spacing of 0.5 m between
 99 rows and 0.10 m between plants, totaling 30.0 m², of which 16.0 m² were used as a useful
 100 area and remaining as edge.
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102 Soil preparation was performed 30 days before sowing and a plowing at 20 cm depth two
103 harrowing levelers and application of 0.45 t ha⁻¹ of dolomitic limestone (90% PRNT) to
104 provide 70% base saturation %) recommended for the cultivation of sesame.

105
106 Fertilization was carried out in the sowing phase and included 60 kg ha⁻¹ of P₂O₅, 40 kg ha⁻¹
107 of K₂O and 25 kg ha⁻¹ of micronutrients, applied as single superphosphate, potassium
108 chloride and FTE BR 12 respectively. Nitrogen fertilization was used according to previously
109 established treatments.

110
111 The cultivar used was the BRS Silk, which presents a medium-sized and 90 days cycle,
112 indicated for the dryland cultivation in the Northeast of Brazil. The sowing was done directly
113 in the field, placing five seeds per pit, where at ten days after emergence the thinning was
114 done leaving only one plant.

115
116 The cultural treatments during the crop cycle consisted of manual weeding among the ranks.
117 Pest control was performed 45 days after emergence and consisted of 400 ml of p.c. ha⁻¹
118 from Decis 25 CE® to control the screwing caterpillar (*Antigastra catalaunalis*).

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120 **2.3 Data Collection**

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

130 **2.4 Data Analysis**

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

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139 **3. RESULTS AND DISCUSSION**

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141 The N doses together with the splitting forms promoted significant effects on plant height
142 (PH), stem diameter (SD), number of capsules (NC) and productivity of grain (PG). The
143 sheet number (SN) was influenced in an isolated way by the doses of N and by the forms of
144 parceling, whereas the mass of 1000 grains (M1000) was not influenced by the treatments
145 used.

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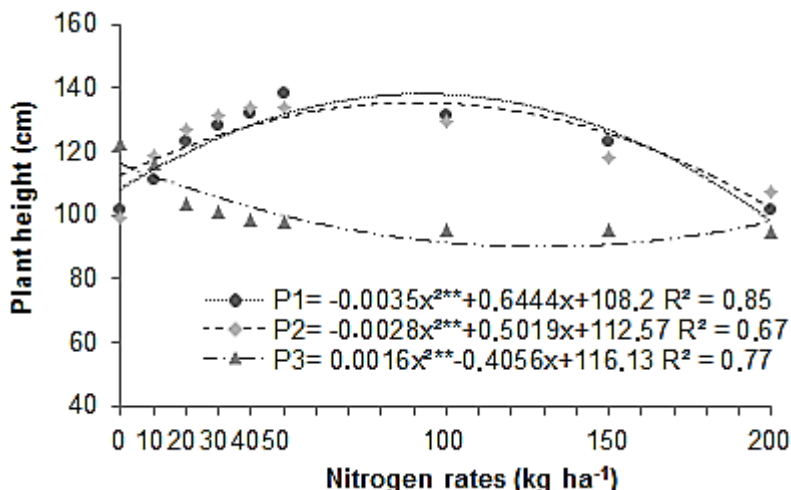
147 **3.1 Plant height**

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

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154 Souza et al. (2014) [11] evaluating the initial development of sesame, cultivar IAC ouro,
 155 submitted to nitrogen fertilization, obtained plant height similar to that found in this work with
 156 the conventional application of 85.6 kg ha⁻¹ of N. According to Grilo Júnior et al. (2015) [18]
 157 plant height is directly related to sesame productivity, therefore, it is expected to reach
 158 satisfactory production results in higher plants.
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160 **Figure 2. Height of sesame plants (*Sesamum indicum* L.) as a function of the rates**
 161 **and the nitrogen fertilization.**
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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 smaller amount of N applied in the initial stage, to the detriment of the greater parceling, resulted in a decrease in the growth of the culture, possibly due to the deficiency of N suffered by the plants in the period before the flowering, since the cultivar BRS Seda begins flowering 30 days after emergence. However, the opposite result 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 at 74 days after germination. Such behavior suggests that it is important to study studies of this nature to determine precisely the effect of the interaction between the amount of N applied and the correct time of application.

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During the sowing period of the crop, a high rainfall regime was observed in the region, which possibly resulted in higher losses of nitrogen by 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.

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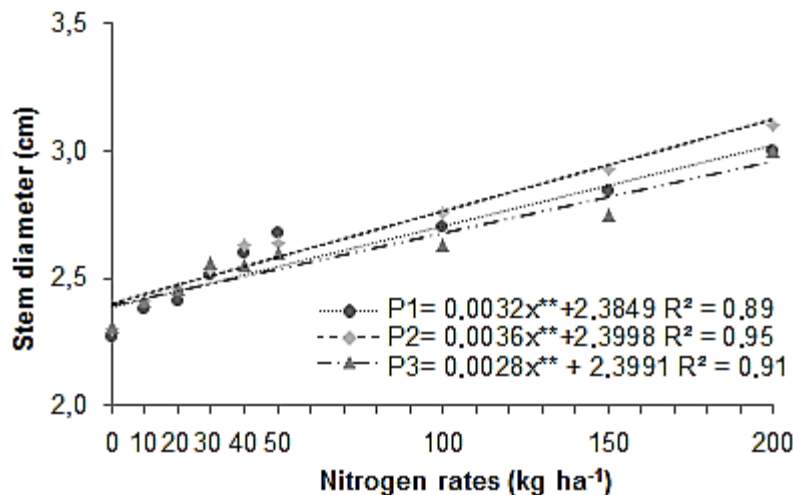
It is known that N is part of components of the protein, RNA, DNA, ATP, chlorophyll among other molecules. In this sense, its deficiency considerably reduced the plant's growth capacity. As N losses occurred during sowing, there was also a reduction in the amount offered in the later stages, a fact that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

187 **3.2 Stem diameter**

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The stem diameter (SD) increased linearly as a function 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

192 to the production of branches, leaves, fruits and avoid the fall of the plants in the adult phase
 193 by the action of the winds. However, it is worth noting that not only fertilization and land
 194 parceling affect the to soak diameter of this species, but also factors such as water quantity
 195 and population density [21].
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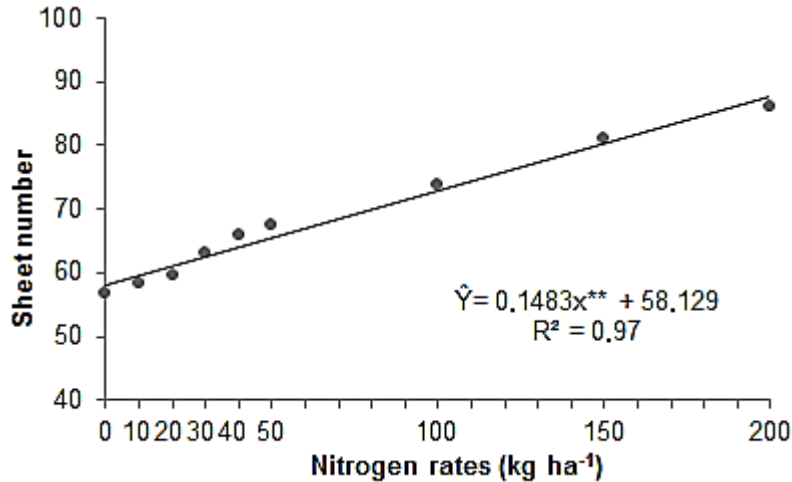
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 198 **Figure 3. Stem diameter of sesame plants (*Sesamum indicum* L.) as a function of the**
 199 **rates and the nitrogen fertilization.**
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When evaluating the effects of the different dosages of nitrogen fertilization on the initial development of the "IAC Ouro" sesame, Souza et al. (2014) [1] found that the application of increasing doses of N at 53 days after emergence (DAE) provided a better trunk 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 way, since in this study the last application occurred at 45 DAS, which allowed greater absorption by the plants.

3.3 Sheet number

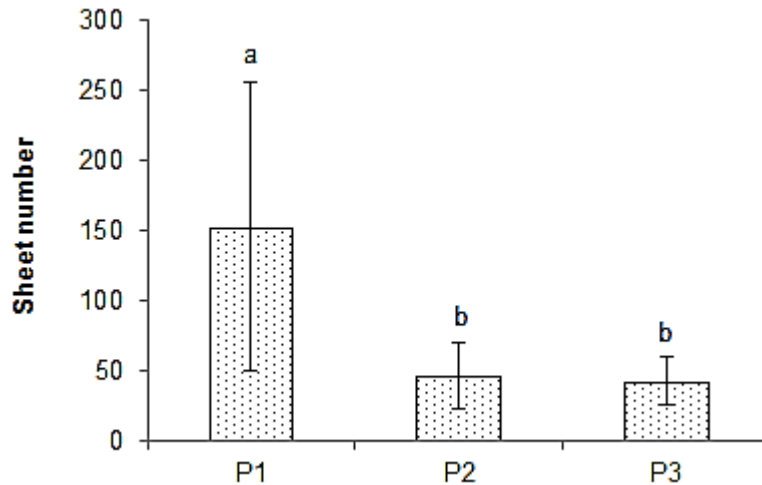
The sheet number (SN), as well as the stem diameter, increased with the addition of nitrogen fertilization (Figure 4), with the maximum value obtained (86.13 sheets) with the application of 200 kg ha⁻¹. O N is an element that is closely linked to the process of cell division and expansion in plants, 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.



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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 higher, differing from other forms of application (Figure 5). Probably this answer was due to higher 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.



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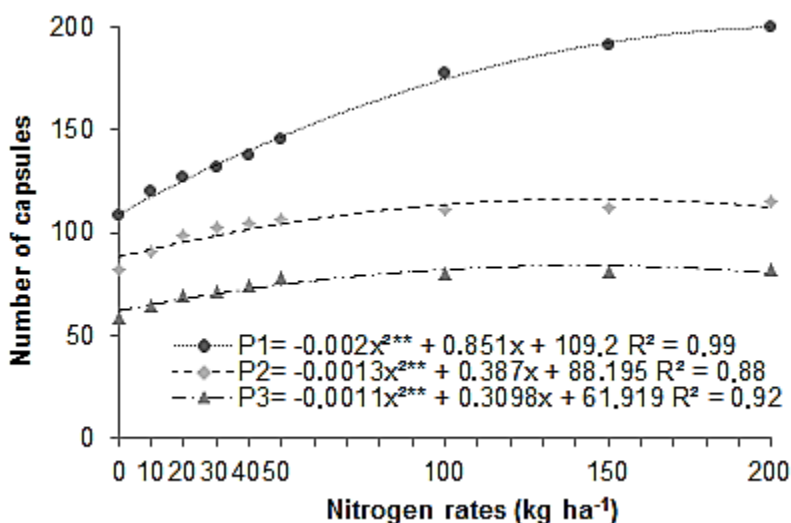
Figure 5. Mean and standard deviation of the sheet number per sesame (*Sesamum indicum* L.) as a function of nitrogen fertilization. Columns followed by the same letter do not differ by the Tukey test at 5% probability.

The sheet number is a characteristic that expresses little the nutritional state 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 nutrientes 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

242 For the number of capsules (NC) a larger quantity was verified as the nitrogen fertilization
243 was reduced, mainly for the application of P1.

244 It was also observed that in the other forms of application (P2 and P3) there was a small
245 increase in the number of capsules due to the increase of N doses, with a consequent
246 stabilization tendency (Figure 6). The doses of N applied only to the foundation (50%) and
247 the cover (50%) (P1) promoted increase in the number of capsules, with maximum value
248 (199.7 capsules per plant) obtained with the application of 212,75 kg ha⁻¹ of N. This result is
249 in agreement with Lima et al. (2013) [23] when working with the application of organic
250 fertilizer in sesame, which is a rich source of N, with an average of 192.0 capsules per plant.
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253 **Figure 6. Number of capsules of sesame plants (*Sesamum indicum* L.) as a function of**
254 **the rates and the nitrogen fertilization.**
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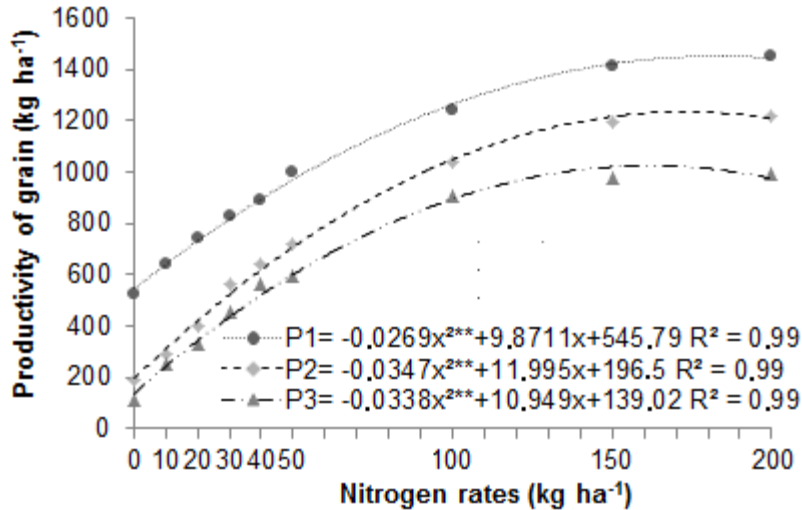
256 Again, the most likely cause of plant response, expressed in the capsule increase, may have
257 been the greater availability of N in the initial stage of plant growth, due to the greater
258 amount of fertilizer applied (100%) up to 30 DAS. The number of capsules per plant is
259 extremely important because, according to Jadhav et al. (2015) [20], is directly related to
260 crop productivity, since the greater quantity of capsules corresponds to the greater quantity
261 of seeds and consequently the higher productivity. As in this result, Bharathi et al. (2014)
262 [24], studying the effects of different types of fertilizers on sesame yield and productivity,
263 showed increases in the number of capsules per plant, and attributed this result to increase
264 height and stem diameter, leaf area and increase of production of flowers, which are
265 responsible for the formation of fruits.
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267 3.5 Productivity of grain

268 Grain productivity was increased with increasing application of N up to a maximum efficiency
269 dose, subsequent to a decrease, for the three forms of subdivision studied. The application
270 of 183.5 kg ha⁻¹ of N, divided in 50% in foundation and 50% in cover (P1) provided higher
271 grain yield (1541.3 kg ha⁻¹) when compared to other forms of 7). It was also observed that
272 the higher nitrogen fertilization (P3) resulted in lower grains weight gain, even at higher N
273 doses.
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276 The sesame cultivar BRS Seda began to bloom 30 days after emergence, if added to the
277 four day speed of sowing emergence, the fertilization of the cover was provided exactly four

278 days before the beginning of the flowering of the plants. At the moment, the plants begin to
 279 require a greater amount of N for pod formation and grain filling, which may explain the fact
 280 that the application, 50% in the foundation and 50% in the coverage (P1) results in higher
 281 productivity, since the amount of N applied in cover in this installment was higher than the
 282 others.
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284 **Figura 7. Productivity of grain of sesame plants (*Sesamum indicum* L.) as a function**
 285 **of the rates and the nitrogen fertilization.**
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288 The productivity of grain reached in this study under drought conditions is close to that
 289 obtained by Grilo and Azevedo (2013) [25] when evaluating the growth, development and
 290 productivity of "BRS Seda" sesame irrigated at Agrovila de Canudos, Ceará Mirim (RN),
 291 which obtained 1600 kg ha⁻¹. According to Beltrão et al. (2013) [8], the yield of the "BRS
 292 Seda" sesame is 1000 kg ha⁻¹, with the potential to reach higher levels, provided the
 293 irrigated cultivation system is adopted and the fertilizer is correctly handled. In this sense,
 294 the productivity obtained in the present study was significantly higher than the average cited
 295 by these authors.
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297 3.6 Pearson correlation

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 299 Table 2 shows the Pearson correlation matrix between the sesame PG and the other growth
 300 and yield components (PH, SD, SN e NC). Significance was verified for the pairs: PG × NC
 301 ($r = 0,994^{**}$) and PG × SD ($r = 0,977^{**}$). For these, the correlations were direct, indicating
 302 that with the increase of the number of capsules and the diameter of the stem, also occurred
 303 the increase of grain productivity. It was also observed that the number of capsules was the
 304 production component that contributed most to the productivity increase ($r = 0,994^{**}$). This
 305 result corroborates those observed by Laurentin et al. (2004) [26] and Grilo and Azevedo
 306 (2013) [25] who mention that there is a great correlation between the number of capsules
 307 per plant and the yield of the sesame crop, suggesting that the increase in the number of
 308 capsules contributes to the increase productivity.
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310 In general, significant correlations between the pairs, when analyzed for any two
 311 components (Table 2), presented with positive sign (direct correlation) or negative (indirect
 312 correlation). Correlations with correlation coefficient values were found between: SN × NC
 313 ($0,825^{**}$), SD × NC ($0,970^{**}$) e SD × SN ($0,870^{**}$). The only indirect correlation was obtained

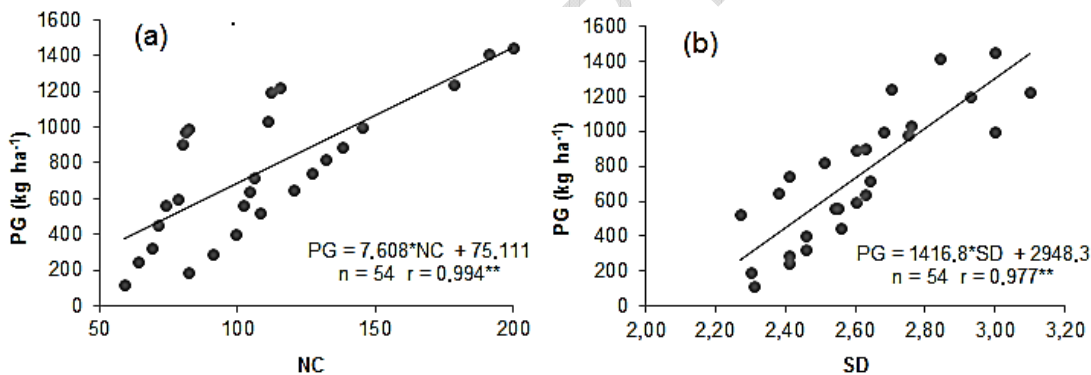
314 between AP × NF ($r = -0.720^*$), indicating that with increasing plant height there will be a
 315 decrease in the number of sheet.
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317 **Table 2. Simple linear correlation matrix between sesame grain yield (*Sesamum***
 318 ***indicum* L.) and its other growth and yield components.**
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| 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} |

320 PG, NC, SN, SD e PH, are respectively, productivity of grain, number of capsules, sheet number, stem
 321 diameter and plant height. **, * and ns: significant and 1%, 5% e not significant.
 322

323 The simple linear regression equations between PG × NC and between PG × SD, as well as
 324 the multiple linear regression adjusted to estimate PG (dependent variable) as a function of
 325 NC e do SD (independent variables) are presented in figure 8. It was verified that the PG
 326 presented a direct linear variation with the NC (Figure 8a) and with the SD (Figura 8b).
 327 Therefore, when the maximum values of the capsule number and the stem diameter,
 328 maximum values of grain productivity will occur in the sesame crop. It was also observed
 329 that by the model attested that approximately 57.7% of the sedame grain productivity
 330 variation is influenced by the number of capsules and stem diameter ($R^2 = 0.577^{**}$).
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332
 333 **Figure 8. Regression equations of sesame grain yield (*Sesamum indicum* L.) as a**
 334 **function of the number of capsules per plant (a) and stem diameter (b).**
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336 4. CONCLUSION

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

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 341 The application of 183.5 kg ha⁻¹ of N, 50% in base and 50% in cover, provides higher
 342 productivity of sesame grains (1541.3 kg ha⁻¹)
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344 COMPETING INTERESTS

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 346 Authors have declared that no competing interests exist.
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REFERENCES

1. Hwang LS. Sesame oil. In: Shahidi F. (Ed.) Bailey's Industrial Oil & Fat Products. 6 th ed. Wiley-Interscience. 2005:537-75. English.
2. Silva JCA, Fernandes PD, Bezerra JRC, Arriel NHC, Cardoso GD. Growth and production of sesame genotypes as a function of irrigation slides. Brazilian Journal of Agricultural and Environmental Engineering. 2014;18(4):408-416. English.
Available: <http://dx.doi.org/10.1590/S1415-43662014000400008>.
3. Cruz NFFS, Nascimento LFJ, Santos RF, Zanão Júnior LA, Cunha E, Rocha EO. Characteristics and cultural practices of sesame (*Sesamum indicum* L.). Brazilian Magazine of Renewable Energies. 2019;8(4):665-675. English.
Available: <http://dx.doi.org/10.5380/rber.v8i4.65757>.
4. Arriel NH, Beltrão NEM, Firmino PT. Sesame: the producer asks, Embrapa responds. Brasília - DF: Embrapa Information Technology. 2009;209. English.
5. Brazilian Agricultural Research Corporation (EMBRAPA). Sesame Growing. Embrapa Cotton. 2° Ed, Londrina, 2014;164. English.
6. Furtado GF, Souza AS, Sousa Júnior JR, Sousa JRM, Lacerda RRA, Silva SS. Yield and correlations of the mixed castor bean with cowpea and sesame seeds in the semi-arid region of. Brazilian Journal of Agricultural and Environmental Engineering. 2014;18(9):892-898. English.
Available: <http://dx.doi.org/10.1590/1807-1929/agriambi.v18n09p892-898>.
7. Pathack N, Rai AK, Kumari R, Thapa A, Bhat KV. Sesame Crop: An underexploited Oilseed Holds Tremendous Potential for Enhanced Food Value. Agriculture Sciences. 2014;5(6):519-529. English.
Available: <https://doi:10.4236/as.2014.56054>.
8. Beltrão NEM, Ferreira LL, Queiroz NL, Tavares MS, Rocha MS, Alencar RD, Porto VCN. Sesame and its cultivation in the Brazilian semiarid. Natal-RN: IFRN. 2013;225. English.
9. Araújo FS, Borges SRS, Silva GZ, Araújo LHB, Torres EJM. Doses of phosphorus on the initial growth of sesame seeds grown in nutrient solution. Agropecuária Tecnologia & Ciência Magazine. 2014;8(2):41-47. English.
10. Perin A, Cruvinel DJ, Silva JW. Performance of sesame as a function of NPK fertilization and soil fertility level. Acta Scientiarum Agronomy. 2010;32(1):93-98. English.
Available: <http://dx.doi.org/10.4025/actasciagron.v32i1.252110.4025>.
11. Souza AP, Russo L, Ferreira DSP, Yada MM, Jardim CA, Franco CF. Initial development of sesame with nitrogen fertilization. Science & Technology: Fatec-JB. 2014;6(1):6-10. English.
12. Carneiro JSS, Silva PSS, Freitas GA, Santos AC, Silva RR. Response of sesame to manure with bovine manure and doses of phosphorus in southern Tocantins. Revista scientia agraria. 2016;17(2):41-48. English.
Available: <http://dx.doi.org/10.5380/rsa.v17i2.48531>.
13. Euba Neto M, Pereira WE, Souto JS, Arriel NHC. Growth and productivity of sesame in Flossic Neosolum due to organic and mineral fertilization. Ceres Journal. 2016;63(4):568-575. English.
Available: <http://dx.doi.org/10.1590/0034-737X201663040018>.
14. Biscaro GA, Machado JR, Tosta MS, Mendonça V, Soratto RP, Carvalho LA. Nitrogen fertilization on cover in irrigated sunflower under conditions of Cassilândia - MS. Science and agrotechnology. 2008;32(5):1366-1373. English.
Available: <http://dx.doi.org/10.1590/S1413-70542008000500002>.
15. Jakusko B B, Usman BD. Effects of NPK fertilizer and plant population density on productivity of sesame (*Sesamum indicum* L.). Research Journal of Agricultural and Environmental Management. 2013;2(5):121-126. English.

- 402 16. Teixeira Filho MCMT, Buzetti S, Andreotti M, Arf O, Benett CGS. Doses, sources and
403 times of application of nitrogen in irrigated wheat under no-tillage. Brazilian Agricultural
404 Research. 2010;45(8):797-804. English.
405 Available: <http://dx.doi.org/10.1590/S0100-204X2010000800004>.
- 406 17. Brazilian Agricultural Research Corporation (EMBRAPA). Brazilian system of soil
407 classification. 5th Ed. Rio de Janeiro: Embrapa Solos. 2018;590. English.
- 408 18. Grilo Júnior R JAS, Azevedo PV, Vale MB, Saraiva VM. Growth, development and
409 productivity of sesame irrigated with pisciculture water and groundwater. Agriculture
410 Science and Technology. 2015;9(1):45-50. English.
- 411 19. Arriel NHC, Araújo AE, Soares JJ, Beltrão NEM, Firmino PT. Sesame Culture.
412 Campina Grande – PB: Embrapa Production system. 2006;6. English.
- 413 20. Jadhav SR, Naiknaware MD, Pawar GR. Effect of nitrogen, phosphorus and
414 biofertilizers on growth, yield and quality of summer sesame (*Sesamum indicum* L.).
415 International Journal of Tropical Agriculture. 2015;33(2):475-480. English.
416 Available: <https://doi.org/10.4236/oje.2017.72008>.
- 417 21. Cruz RN, Azevedo CAV, Fernandes JD, Monteiro Filho AF, Wanderley JAC. Residual
418 organic fertilization on the growth and production of sesame irrigated with waste water.
419 Green Magazine. 2013;8(1):257- 263. English.
- 420 22. Queiroga VP, Firmino PT, Silva AC, Kojima AY, Queiroga DAN. Quality of sesame
421 seeds produced in three locations in the semiarid region. Agricultural Technology and
422 Science. 2014;8(2):9-14. English.
- 423 23. Lima FA, Sousa G G, Viana TVA, Pinheiro Neto LG, Azevedo BM, Carvalho CM. DE.
424 Irrigation of sesame crop in soil with bovine biofertilizer. Brazilian Journal of Irrigated
425 Agriculture. 2013;7(2):102-111. English.
426 Available: <https://doi:10.7127/rbai.v7n200007>.
- 427 24. Bharathi K, Panneerselvam P, Bhagya HP. Effect of clipping and plant growth regulator
428 along with different kinds of fertilizers on yield and yield parameters in sesame
429 (*sesamum indicum* L.) during monsoon period. Indian Journal of Agricultural Research.
430 2014;48(3):232-236. English.
431 Available: <http://dx.doi.org/10.5958/j.0976-058X.48.3.039>.
- 432 25. Grilo Júnior JAS, Azevedo PV. Growth, development and productivity of 'BRS Silk'
433 sesame in Canudos agrovillage, in Ceará Mirim (RN). Holos Magazine. 2013;29(2):19-
434 33. English.
435 Available: <https://doi.org/10.15628/holos.2013.1223>.
- 436 26. Laurentin H, Montilla D, Garcia V. Relationship between the yield of eight genotypes of
437 sesame (*Sesamum indicum* L.) and its components: Comparison of methodologies.
438 Bioagro, 2004;16(3):152-162. English.
439