

Original Research Article

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

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).

Keywords: Functional food; urea; parceling; productivity.

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].
29

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, sesamol 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].

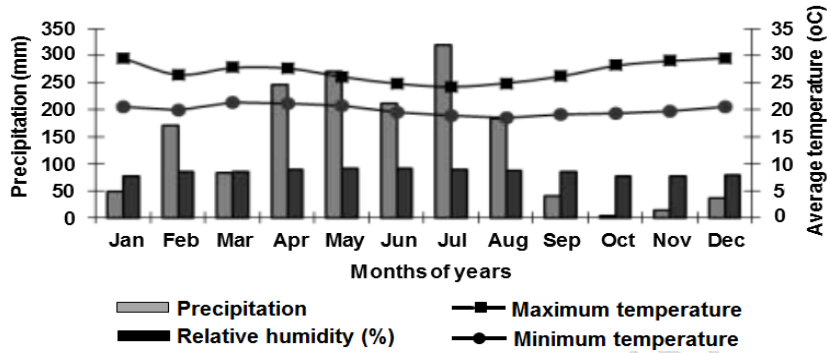
61 In this sense, the objective of this work was to evaluate the efficiency of the use of different
62 doses of nitrogen (N) applied in a fragmented way in the growth and production of sesame.
63

64 2. MATERIAL AND METHODS

65 2.1 Location of Study Area

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

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.
 75



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.*
 88

89 2.2 Study design

90
 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).
 97

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.
 101

Comment [HP1]: Write the soil and water ration. Suspension ration

Comment [HP2]: Is this OM?

Comment [HP3]:

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.

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mention

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*).

119 120 2.3 Data Collection

121
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

131
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.

138 139 3. RESULTS AND DISCUSSION

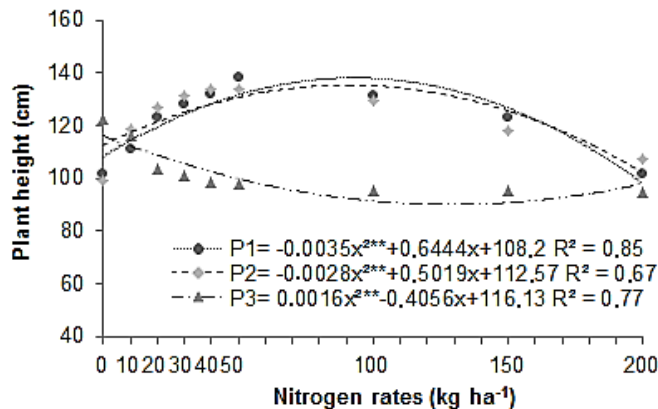
140
141 The N doses together with the splitting forms promoted significant effects on plant height
142 (PH), stem diameter (SD), number of capsules (NC) and productivity of grain (PG). The
143 sheet number (SN) was influenced in an isolated way by the doses of N and by the forms of
144 parceling, whereas the mass of 1000 grains (M1000) was not influenced by the treatments
145 used.

146 147 3.1 Plant height

148
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.

153

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.
 159



160 **Figure 2. Height of sesame plants (*Sesamum indicum* L.) as a function of the rates**
 161 **and the nitrogen fertilization.**
 162
 163

164 When N was divided into four equal applications (P3), there was a marked decrease in plant
 165 height as nutrient doses increased. It was also verified that the smaller amount of N applied
 166 in the initial stage, to the detriment of the greater parceling, resulted in a decrease in the
 167 growth of the culture, possibly due to the deficiency of N suffered by the plants in the period
 168 before the flowering, since the cultivar BRS Seda begins flowering 30 days after emergence.
 169 However, the opposite result was observed by Arriel et al. (2006) [19] mention that up to the
 170 thirtieth day N is not very required by sesame, but from that period, plant requirements for
 171 this nutrient grow rapidly, reaching maximum demand at 74 days after germination. Such
 172 behavior suggests that it is important to study studies of this nature to determine precisely
 173 the effect of the interaction between the amount of N applied and the correct time of
 174 application.
 175

176 During the sowing period of the crop, a high rainfall regime was observed in the region,
 177 which possibly resulted in higher losses of nitrogen by leaching, leading to a reduction in the
 178 efficiency of N separation in four equal applications (P3), which received only 25% of the
 179 total to be applied.
 180

181 It is known that N is part of components of the protein, RNA, DNA, ATP, chlorophyll among
 182 other molecules. In this sense, its deficiency considerably reduced the plant's growth
 183 capacity. As N losses occurred during sowing, there was also a reduction in the amount
 184 offered in the later stages, a fact that reflected in the reduction of growth. This result
 185 resembles that obtained by Jadhav et al. (2015) [20] who mention that N deficiency at the
 186 initial stage of crop growth results in lower plant height at the end of the cycle.
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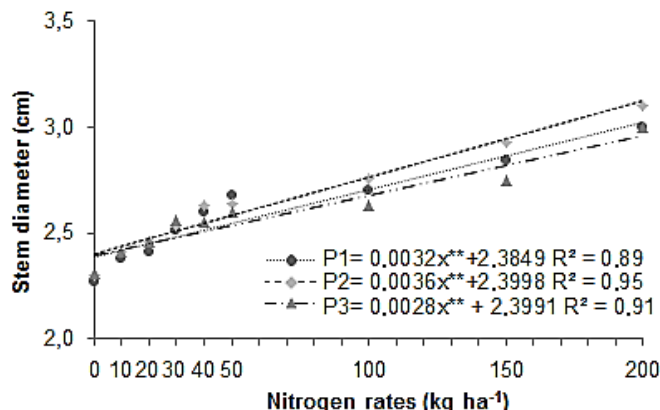
187 3.2 Stem diameter

188 The stem diameter (SD) increased linearly as a function of the increase of N doses for all
 189 forms of splitting (Figure 3), especially when it was divided into three equal applications (P2),
 190 reaching 3.1 cm. The increase of the diameter of the stem is important to give better support
 191

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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 stem diameter of this species, but also factors such as water quantity
195 and population density [21].
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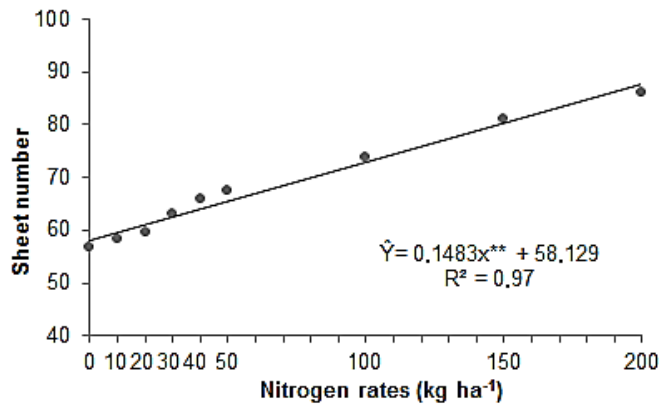


197
198 **Figure 3. Stem diameter of sesame plants (*Sesamum indicum* L.) as a function of the**
199 **rates and the nitrogen fertilization.**
200

201 When evaluating the effects of the different dosages of nitrogen fertilization on the initial
202 development of the "IAC Ouro" sesame, Souza et al. (2014) [1] found that the application of
203 increasing doses of N at 53 days after emergence (DAE) provided a better trunk diameter,
204 corroborating with the response obtained in the present study, however, the same authors
205 mention that stem diameter fertilization. Possibly this response occurred due to the different
206 times of application of N in a fragmented way, since in this study the last application
207 occurred at 45 DAS, which allowed greater absorption by the plants.
208

209 3.3 Sheet number

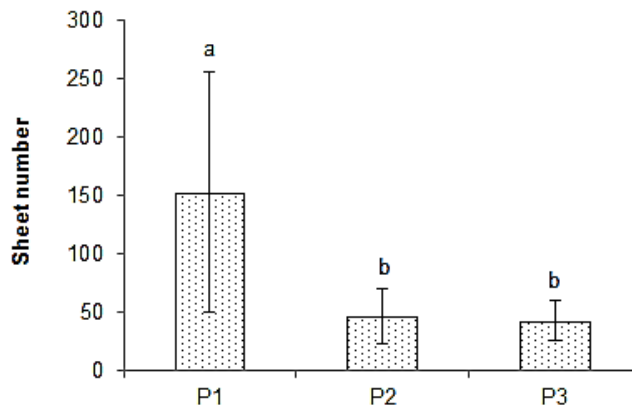
210
211 The sheet number (SN), as well as the stem diameter, increased with the addition of
212 nitrogen fertilization (Figure 4), with the maximum value obtained (86.13 sheets) with the
213 application of 200 kg ha⁻¹. O N is an element that is closely linked to the process of cell
214 division and expansion in plants, in this sense, the greater the availability of this
215 macronutrient, the greater the plant growth, especially the stem and the number of leaves,
216 provided availability is below the toxic limits. This fact is evidenced by the increase in the
217 number of sheet in the present study, which confirms those obtained by Sousa et al. (2014)
218 [11], mentioning that the increase in the number of sheet in sesame plants is a result of the
219 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.

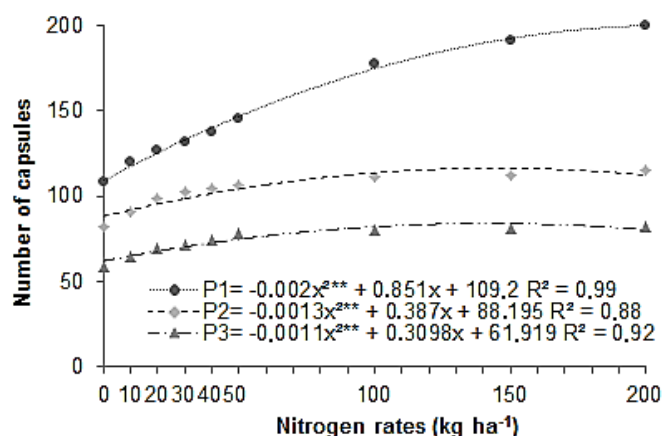
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The sheet number is a characteristic that expresses little the nutritional state of the sesame at the end of its cycle. This is because there is a reduction in the sheet number cause the crop undergoes foliar senescence, directing the absorbed nutrients 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

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.
251



252 **Figure 6. Number of capsules of sesame plants (*Sesamum indicum* L.) as a function of**
253 **the rates and the nitrogen fertilization.**
254
255

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

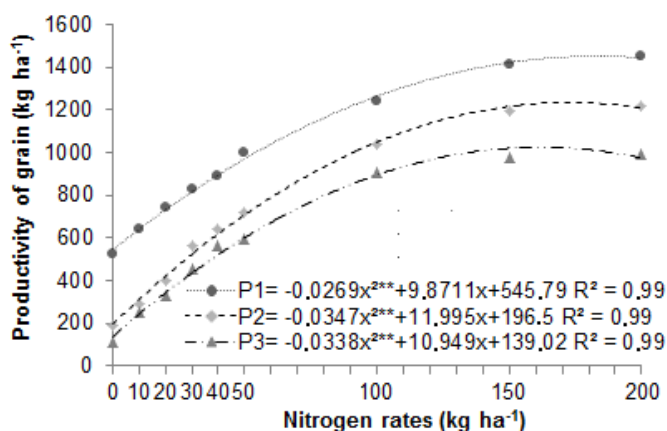
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269 Grain productivity was increased with increasing application of N up to a maximum efficiency
270 dose, subsequent to a decrease, for the three forms of subdivision studied. The application
271 of 183.5 kg ha⁻¹ of N, divided in 50% in foundation and 50% in cover (P1) provided higher
272 grain yield (1541.3 kg ha⁻¹) when compared to other forms of [7]. It was also observed that
273 the higher nitrogen fertilization (P3) resulted in lower grains weight gain, even at higher N
274 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

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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.
 283



284 **Figura 7. Productivity of grain of sesame plants (*Sesamum indicum* L.) as a function**
 285 **of the rates and the nitrogen fertilization.**
 286
 287

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.
 296

297 3.6 Pearson correlation

298 Table 2 shows the Pearson correlation matrix between the sesame PG and the other growth
 299 and yield components (PH, SD, SN e NC). Significance was verified for the pairs: PG × NC
 300 ($r = 0,994^{**}$) and PG × SD ($r = 0,977^{**}$). For these, the correlations were direct, indicating
 301 that with the increase of the number of capsules and the diameter of the stem, also occurred
 302 the increase of grain productivity. It was also observed that the number of capsules was the
 303 production component that contributed most to the productivity increase ($r = 0,994^{**}$). This
 304 result corroborates those observed by Laurentin et al. (2004) [26] and Grilo and Azevedo
 305 (2013) [25] who mention that there is a great correlation between the number of capsules
 306 per plant and the yield of the sesame crop, suggesting that the increase in the number of
 307 capsules contributes to the increase productivity.
 308
 309

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

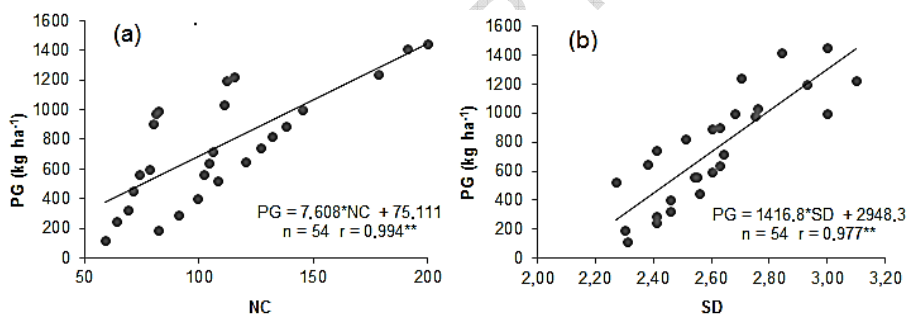
314 between AP × NF ($r = -0.720^*$), indicating that with increasing plant height there will be a
 315 decrease in the number of sheet.
 316

317 **Table 2. Simple linear correlation matrix between sesame grain yield (*Sesamum*
 318 *indicum* L.) and its other growth and yield components.**
 319

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 ($R^2 = 0.577^{**}$).
 331



332 **Figure 8. Regression equations of sesame grain yield (*Sesamum indicum* L.) as a
 333 function of the number of capsules per plant (a) and stem diameter (b).**
 334

335 4. CONCLUSION

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

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

342 COMPETING INTERESTS

343 Authors have declared that no competing interests exist.
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