



# Initial Growth of Sesame under Nutrient Omission

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## **Authors' contributions**

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

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## **ABSTRACT**

Sesame is an oilseed, nutritionally important in the world, for its seeds are rich sources of protein and calcium. Fertilizer management is fundamental for the development of this crop and consequently to increase its productivity. In this context, this research aimed to evaluate the initial development of sesame under nutrient omission in the Cerrado of Mato Grosso, Brazil. The

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experiment was conducted under controlled conditions in a greenhouse, at the Federal University of Rondonópolis. The soil used was Oxisol and the crop used was black sesame. The design was in randomized blocks, with five treatments (absence of nitrogen, absence of phosphorus, absence of potassium, complete fertilization and control (absence of nutrients)) and four repetitions. The variables analyzed were pH, chlorophyll index, plant height, number of leaves, stem diameter, leaf area, aboveground dry mass, root volume, and root dry mass. The pH variable showed a statistical difference 45 days after emergence. The chlorophyll index showed a difference between 30 and 45 days after emergence. The stem diameter, leaf area, plant height, number of leaves, aboveground dry mass, root volume, and dry mass showed a difference among treatments. The absence of nitrogen, phosphorus, and potassium significantly affects the initial development of sesame.

**Keywords:** *Sesamum indicum*; nitrogen fertilization; phosphate fertilization; potassium fertilization.

## 1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is an annual, oleaginous plant belonging to the Pedaliaceae family that has high oil content and quality, and the seeds are rich sources of protein and calcium [1,2]. It is an economically and nutritionally important crop, so it is increasing its demand in the global market [3].

This oilseed grows well in different seasons under different cropping systems [4]. One of the limitations in sesame production is the lack of information about the nutritional aspects of the crop, and nutrient deficiency can affect its development. There are some studies showing plant response to fertilization with specific nutrients. Zenawi G and Mizan A [5] observed the effects of nitrogen fertilization on sesame growth and found that yield is greatly influenced by nitrogen application. Research on the influence of nitrogen fertilizer management on sesame has found that nitrogen influences the phytometric and yield characteristics of sesame [6].

Bhavana T et al. [7] explain that phosphate fertilization in sesame significantly increases sesame growth and seed yield, even recording a yield of 770kg/ha<sup>-1</sup>. Ahmad F et al. [8] studying the influence of potassium and phosphate fertilization on sesame cultivation, observed that fertilization significantly influences the

phytometric characteristics of the crop. Bijarnia A et al. [9] explain in their research on the influence of potassium fertilization on sesame development that the application of this nutrient influences the growth and production of the crop.

In this context, soil fertility management in sesame cultivation can influence its growth. Considering the nutritional importance of the crop, this research aimed to evaluate the initial development of sesame under nutrient omission in the Cerrado of Mato Grosso, Brazil.

## 2. MATERIALS AND METHODS

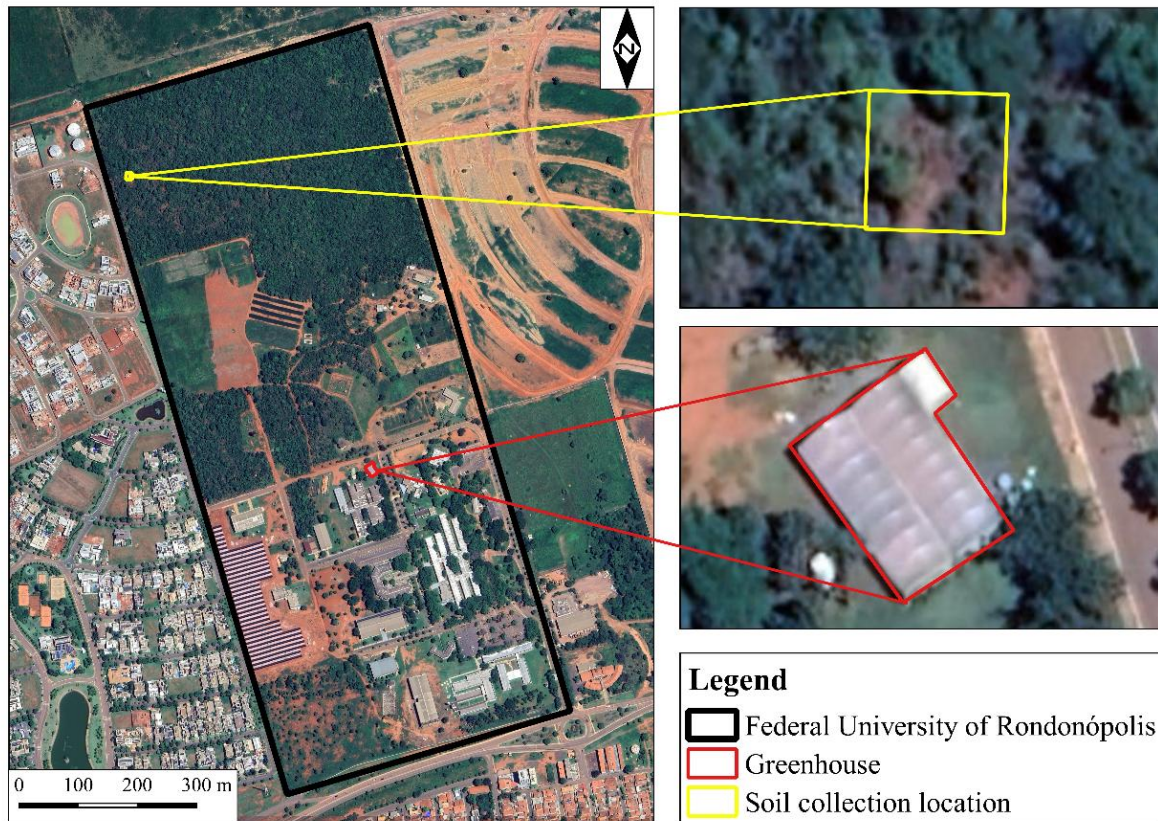
The experiment was conducted in a greenhouse at the Federal University of Rondonópolis in Mato Grosso, Brazil, located at the geographical coordinates 16° 27' 50" S, 54° 34' 49" W. The region's climate is of type Aw [10]. In addition, it is characterized by a tropical climate, rainy in summer and dry in winter [11].

The soil used in the experiment was Oxisol, according to Embrapa's classification [12]. The soil was collected at a depth of 0 to 0.20m under Cerrado vegetation, whose geographic coordinates are 16° 27' 35" S, 54° 35' 00" W (Fig. 1). After the collection, it was sieved in a 4mm mesh for the composition of the experimental units and 2mm mesh for chemical and granulometric characteristics of the soil [13] (Table 1).

**Table 1. Chemical and granulometric characteristics of oxisol collected in the 0 to 0.20m depth layer**

pH	P	K	S	Ca	Mg	Al	H+Al	CEC	SB	OM	V	m
CaCl <sub>2</sub>	.....mg dm <sup>-3</sup>		.....	..... cmol <sub>c</sub> dm <sup>-3</sup>		.....		cmol <sub>c</sub> dm <sup>-3</sup>	g kg	..... %		.....
4.3	1.5	18	2	0.5	0.2	0.6	4.8	5.6	0.8	21.3	13.5	44.4
Zn	Mn	Cu		Fe	B		Clay	Silt	Sand			
..... mg dm <sup>-3</sup>		.....		.....		..... g kg <sup>-1</sup>		.....				
0.7	21.8	0.2		64	0.15		475	100	425			

CEC: Cations Exchange Capacity, SB: Sum of bases, OM: Organic matter, V: Base saturation, m: Aluminum saturation



**Fig. 1. Geographic location of the greenhouse and the soil collection location, at the Federal University of Rondonópolis, Rondonópolis – MT**

The design was a randomized block, with 5 treatments: absence of nitrogen, absence of phosphorus, absence of potassium, complete (complete fertilization of nutrients) and control (absence of nutrients), and four repetitions totaling 20 experimental units (Fig. 2). The black sesame crop was used and pots with a capacity of 1.5 dm<sup>3</sup>. Sowing took place on April 5, 2022, when 10 seeds were sown per pot, and later thinning was performed, leaving only 3 plants per pot.

The base saturation (V%) was raised to 70% in the experimental units according to the recommendation [14]. The soil was incubated with liming 30 days before sowing and the moisture was adjusted to 60% of the maximum water-holding capacity according to field capacity determination methodology [15]. Irrigation during the experimental period was done by the gravimetric method [16].

The nitrogen recommendation was 40 mg dm<sup>-3</sup> [14], using urea as a source. The nitrogen fertilization was done in two applications, the first 10 days after sowing and the second 7 days after

the first application. The potassium recommendation was 60 mg dm<sup>-3</sup> [14], using simple superphosphate as the source. The phosphorus recommendation was 80 mg dm<sup>-3</sup> [14], and the source used was potassium chloride. The recommendation for FTE (Fritted Trace Elements. Composition: Boron 1.8%, Copper 0.8%, Iron: 3.0%, Manganese 2.0%, Molybdenum 0.1% and Zinc 9.0%) was 50 mg dm<sup>-3</sup>.

Soil pH was determined at sowing and 45 days after emergence, using CaCl<sub>2</sub> solution (concentration 0,01 mol L<sup>-1</sup>) and pH meter equipment (Fig. 3). The chlorophyll index was measured at 30 and 45 days after emergence using a Minolta portable Chlorophyll meter SPAD-502 (Soil Plant Analysis Development). The height of plants was determined with a graduated ruler, which was measured from the ground to the apex of the highest leaf. The number of leaves was counted manually, and the diameter of the stem was determined with a digital pachymeter. Plant height, number of leaves, and stem diameter were measured at 15, 30, and 45 days.



**Fig. 2. 3D sketch of the isometric view of the nutrient omission experiment on sesame cultivation at the Federal University of Rondonópolis**



**Fig. 3. Determination of oxisol pH in the soil laboratory of the Federal University of Rondonópolis, Rondonópolis-MT**

For leaf area, the leaf area integrator model LI 3100 was used to measure the total leaf area of each plot (pot). The determination of the dry mass of the aerial part of the sesame was performed at the moment of cutting, placing the aerial part in a closed circulation oven at 65°C, for 72 hours to dry them and later weighing them on a semi-analytical scale [17]. The root volume was determined with a 500mL graduated cylinder, in which the root of each plant was placed inside the cylinder with a known volume of water, and the excess volume difference observed after placing the root equals its volume [17].

The data were submitted to variance analysis by the F test, and when significant, to the Tukey test, at a 5% error probability. For the statistical analyses, the SISVAR software was used [18].

### **3. RESULTS AND DISCUSSION**

#### **3.1 pH do Solo**

For the pH variable, it was observed that at the time of sowing there was no significant difference (Table 2). The soil acidity was corrected, increasing the base saturation (V%) to 70% in all treatments, so that all had the same condition at

the time of application of the treatments and sesame sowing. This justifies the fact that initially no difference in pH was observed among the treatments.

**Table 2. Oxisol pH at the time of sesame sowing (initial) and 45 days after emergence as a function of nutrient omission**

Treatments	pH	
	Initial <sup>n.s.</sup>	45 DAE
Absence of N	5.4	5.21bc
Absence of P	5.28	4.83d
Absence of K	5.27	5.45ab
Complete	5.26	5.57a
Control	5.43	5.07cd
CV (%) <sup>(a)</sup>	3.91	2.99

N: nitrogen; P: phosphorus; K: potassium; DAE: days after emergency; <sup>(a)</sup> coefficient of variation; n.s.: not statistically significant. Means followed by equal letters do not differ statistically by the Tukey test ( $P = .05$ )

At 45 days after crop emergence, a difference was noted among the treatments (Table 2). There was a reduction in pH at 45 days after emergence concerning the initial pH in most treatments. Some factors may have influenced the acidification of the soil during the

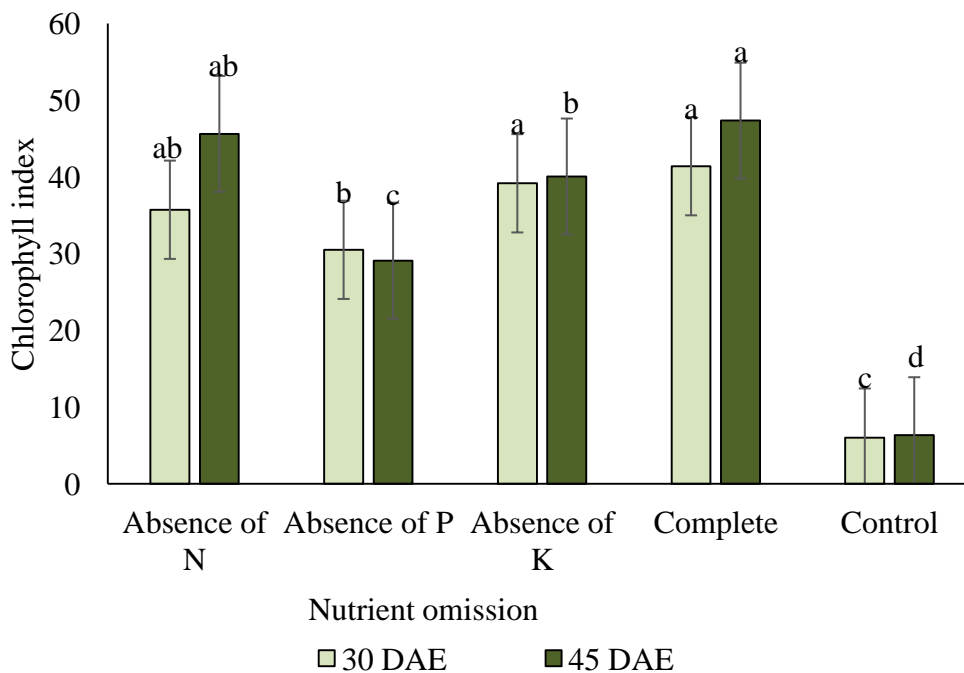
experiment, such as nitrogen fertilization in some treatments.

Bhella HS and Wilcox GE [19] observed in their studies on the influence of liming and doses of nitrogen on soil pH that as the dose of N increased, the greater the acidification of the soil, i.e. nitrogen fertilization acidifies the soil lowering the pH.

During crop growth, the plant needs to absorb nutrients through the roots to develop properly, and the process of releasing  $H^+$  ions by the roots also occurs, so the soil acidifies and consequently lowers the pH.

### 3.2 Chlorophyll Index

For the chlorophyll index, a significant difference was observed at 30 and 45 days after sesame emergence (Fig. 4). At 30 days, the treatments with nitrogen omission, potassium omission, and complete were those with the highest chlorophyll index, 35.72, 39.17, and 41.40, respectively. At 45 days, in the treatments with complete and omission of nitrogen the highest chlorophyll indices were observed, 47.45 and 45.62, respectively.



**Fig. 4. Chlorophyll index as a function of nutrient omission at 30 and 45 days after emergence of black sesame. DAE: Days After Emergence; N: Nitrogen; P: Phosphorus; K: Potassium**  
The vertical bars are the confidence interval for the mean ( $P = .05$ )

Ahmad I et al. [20] studying the effects of nitrogen, phosphorus, and potassium on cotton leaves found that the combined application of nitrogen, phosphorus, and potassium significantly increased the chlorophyll index compared to treatments that had no application of phosphorus and potassium. This explains why the complete treatment obtained the highest chlorophyll values at 30 and 45 days after emergence. Furthermore, the control treatment obtained the lowest chlorophyll indexes in both evaluations.

The treatment with phosphorus omission was the one that showed the lowest chlorophyll index after the control. The supply of phosphorus provides greater nitrogen uptake by the crop, for having as one of its functions the formation of ATP, which releases energy for nitrogen uptake by the crop, in addition, nitrogen has a high correlation with the chlorophyll index, for acting directly in the photosynthesis process [21,22]. This explains why the treatment with phosphorus omission provided low chlorophyll index values even with the application of nitrogen in this treatment.

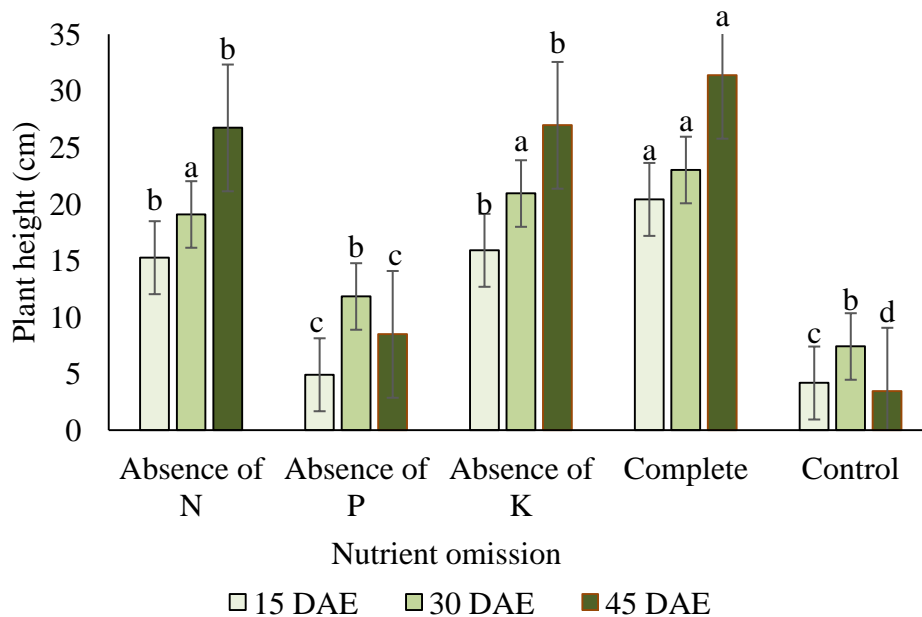
At 30 days after sesame emergence, the treatment with nitrogen and potassium omission had no significant difference in chlorophyll index compared to the treatment with complete

fertilization. At 45 days after emergence, the treatment with the absence of potassium had a lower chlorophyll index than the treatments with nitrogen omission and complete fertilization. Studies on the influence of potassium fertilization on the chlorophyll index of arugula plants observed that increased potassium availability favors nitrogen assimilation and consequently elevates photosynthetic activity [23]. Therefore, potassium omission influenced the decrease in chlorophyll index as sesame developed.

### 3.3 Plant Height

For the variable plant height there was a significant difference at 15, 30, and 45 days after emergence (Fig. 5). Initially, at 15 days, the complete treatment showed the greatest plant height (20.40 cm). In addition, the control and the absence of phosphorus showed the lowest values of height, 4.17, and 4.90 cm, respectively.

Thus, the importance of phosphorus in the initial development of sesame can be seen. The height of the plant in this treatment without application of phosphorus was statistically equal to the treatment without application of any nutrient (control) at 15 and 30 days after emergence (Fig. 5).



**Fig. 5. Plant height (cm) as a function of nutrient omission at 15, 30, and 45 days after emergence of black sesame. DAE: Days After Emergence; N: Nitrogen; P: Phosphorus; K: Potassium.**

Vertical bars are the confidence interval for the mean ( $P = .05$ )

At 30 and 45 days after crop emergence, it was observed that the treatments with phosphorus omission and control presented the lowest values of plant height, while the complete treatment presented the highest values (Fig. 5). At 30 days, the treatment with absence of nitrogen and potassium were statistically equal to the complete treatment, but at 45 days, the complete treatment presented the highest plant height (Fig. 5).

Research on the effects of nitrogen and phosphorus on sesame plant height on vertisol observes that nitrogen and phosphorus influence the growth parameters of the crop; moreover, the interaction of the nutrients significantly increases plant height concerning the control treatment, without the application of nitrogen and phosphate fertilizer [24].

Kale PD et al. [25] studying the influence of nitrogen and potassium fertilization on sesame development, noted that nitrogen fertilization significantly influenced plant height at 30 days

after sowing, furthermore, in the initial development of sesame, they also observed increased plant height with the application of potassium doses.

Nitrogen plays a role in several physiological processes, and potassium also performs functions such as enzyme activation therefore the availability of these nutrients directly influences the vegetative growth of crops. [25]. This shows the importance of nitrogen and potassium fertilization for the vegetative development of plants. This justifies that the treatments with the absence of nitrogen, phosphorus, and potassium did not develop adequately as the treatment with a complete fertilization.

Therefore, the importance of complete fertilization of the nutrient nitrogen, phosphorus and potassium for the initial development of the sesame can be seen. The difference in plant height between treatments at 15 (Fig. 6A), 30 (Fig. 6B) and 45 (Fig. 6C) days after emergence is visible.



**Fig. 6. Plant height as a function of nutrient omission at (A) 15; (B) 30; and (C) 45 days after emergence of black sesame. -N: Absence of nitrogen; -P: Absence of phosphorus; -K: Absence of potassium; C: Complete; T: Control**

The soil pH at 45 days after emergence in the treatment with absence of phosphorus was below the adequate range for crop development, 4.8 (Table 2). This may have also influenced the development of plant height in the treatment with phosphate fertilizer omission.

### 3.4 Stem Diameter

For stem diameter, there was a statistical difference at 30 and 45 days after sesame emergence. At 30 and 45 days, the treatments with absence of nitrogen, absence of potassium and complete showed the largest stem diameters, while in the treatments with absence of phosphorus and control were observed the lowest values (Fig. 7).

Silva OMC et al. [26] in their studies on the influence of phosphate fertilization on the initial growth of seven different crops, observed that the application of phosphorus influenced the initial growth of the crops, distinctly. Research with nutrient omission in early sesame development observed a 70% reduction in stem diameter of plants submitted to phosphorus omission in comparison with plants submitted to complete fertilization [27].

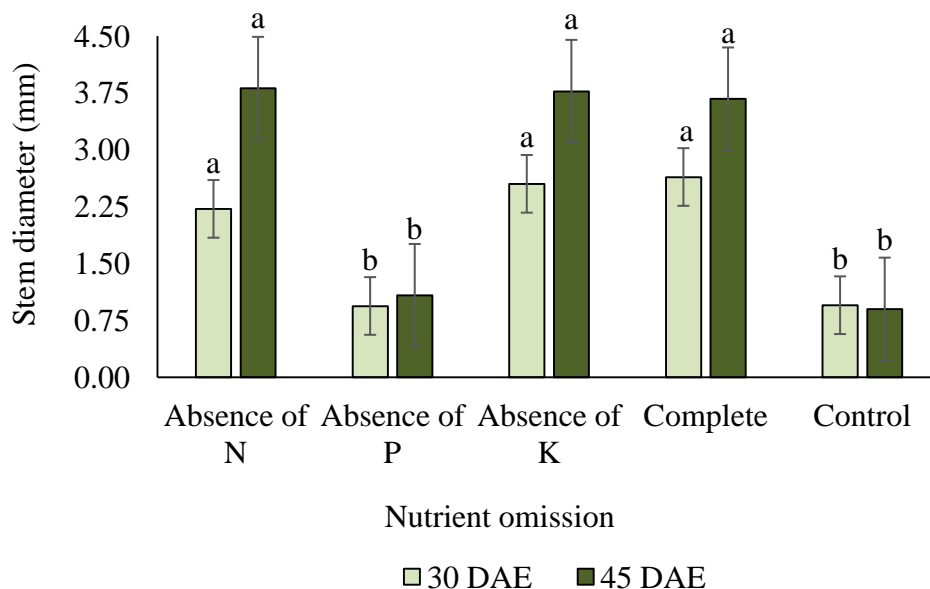
Phosphorus omission significantly affected sesame stem diameter at 30 and 45 days after emergence, with up to a 71% reduction

compared with the complete fertilization treatment (Fig. 7). Thus, the importance of phosphate fertilization in the initial development of sesame can be observed because the treatment with the absence of this macronutrient showed low values for plant height and stem diameter (Fig. 5 and Fig. 7).

### 3.5 Number of Leaves

For the variable number of leaves there was a statistical difference for 30 and 45 days after emergence (Fig. 8). At 30 days, the absence of phosphorus and the control showed the lowest values for number of leaves, while the absence of potassium and the complete treatment showed the highest number. At 45 days, the highest number of leaves was observed in the treatments absence of nitrogen, absence of potassium and complete. Thus, for plant height and stem diameter, phosphorus was the nutrient that most significantly affected sesame development.

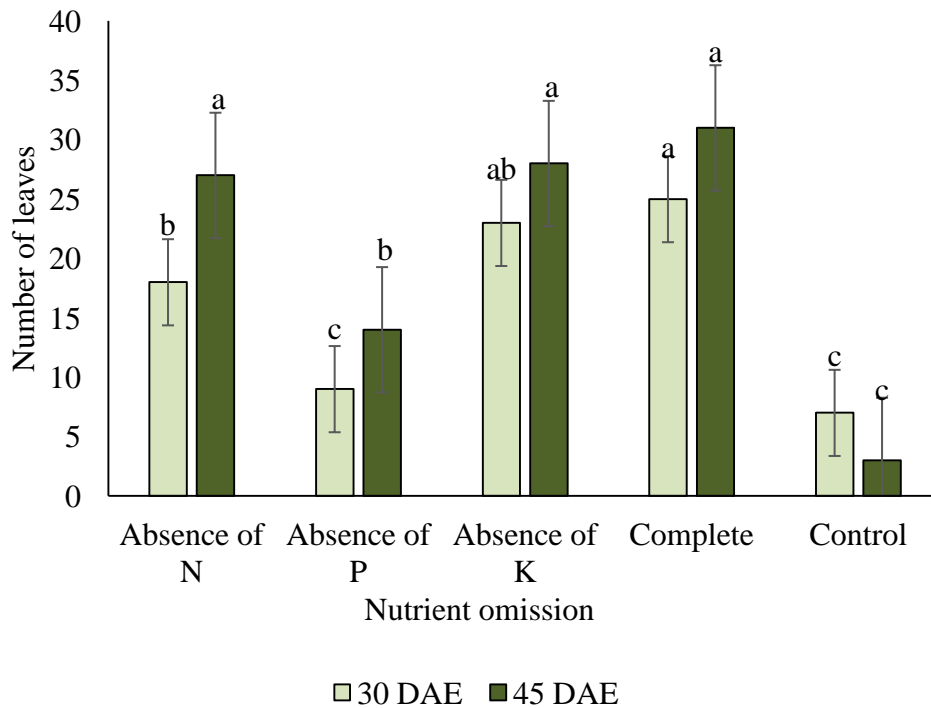
A study with cotton under the omission of macronutrients such as nitrogen, phosphorus, and potassium, observed a significant reduction in the number of leaves in the treatments with nitrogen, phosphorus, and potassium omission, in which the plants with nitrogen and phosphorus deficiency showed a reduction of up to 65% at 50 days after sowing, compared to the treatment with a complete fertilization [27].



**Fig. 7. Stem diameter (mm) as a function of nutrient omission at 30 and 45 days after emergence of black sesame. DAE: Days after emergence; N: Nitrogen; P: Phosphorus; K: Potassium.**

Vertical bars are the confidence interval for the mean ( $P = .05$ )





**Fig. 8. Number of leaves as a function of nutrient omission at 30 and 45 days after emergence of black sesame. DAE: Days After Emergence; N: Nitrogen; P: Phosphorus; K: Potassium**  
*Vertical bars are the confidence interval for the mean (P = .05)*

Sesame plants were significantly affected by the treatments with nitrogen and phosphorus omission 30 days after emergence, reaching a reduction in the number of leaves of up to 64% compared with the plants submitted to complete fertilization. At 45 days, the treatment with phosphorus omission showed a 55% reduction in the number of leaves compared to the complete treatment.

### 3.6 Leaf Area

For the variable leaf area, there was a significant difference between the treatments. Note that the absence of nitrogen and potassium did not differ statistically from the complete treatment, so these treatments obtained the largest leaf areas. The absence of phosphorus did not differ from the control, obtaining the smallest leaf areas (Fig. 9). The leaf area of sesame was significantly affected by the absence of phosphorus compared to the complete fertilizer treatment.

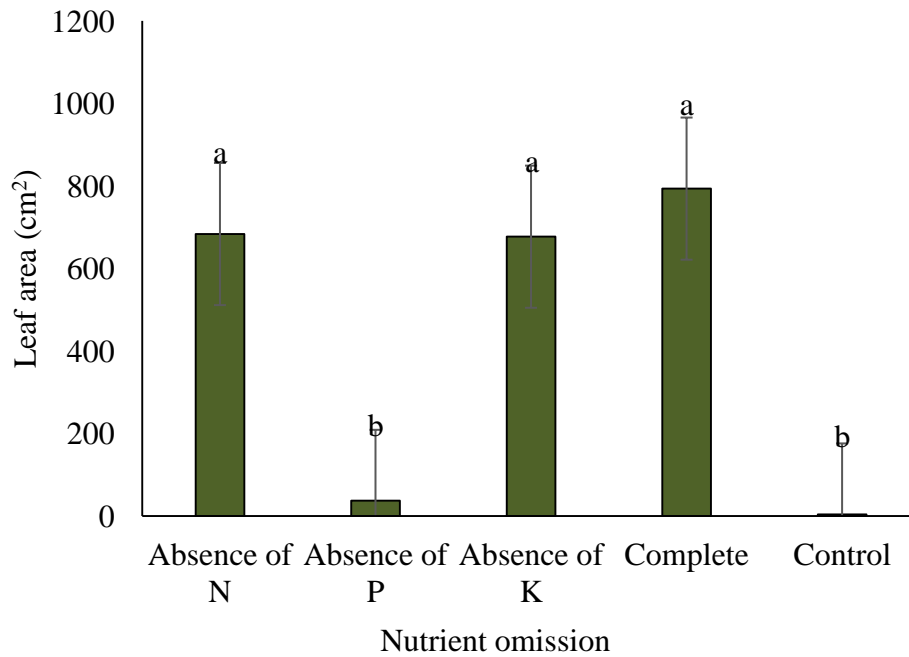
Zenawi G and Mizan, A [5] in their studies with sesame under the influence of nitrogen fertilization, found that nitrogen greatly influences the growth and production of sesame, moreover, they observed that fertilization with nitrogen,

phosphorus, and potassium significantly increased the production of the crop. [28] in their research on the initial development of quinoa under the influence of phosphate fertilization, explained that phosphorus fertilization influences the initial growth of the crop.

In this context, it is observed that for sesame, the nutrient that most influenced the initial development of the crop as a function of the response variable leaf area was phosphorus, in which the plant statistically obtained the same behavior as the treatment with the absence of nutrients (Fig. 9).

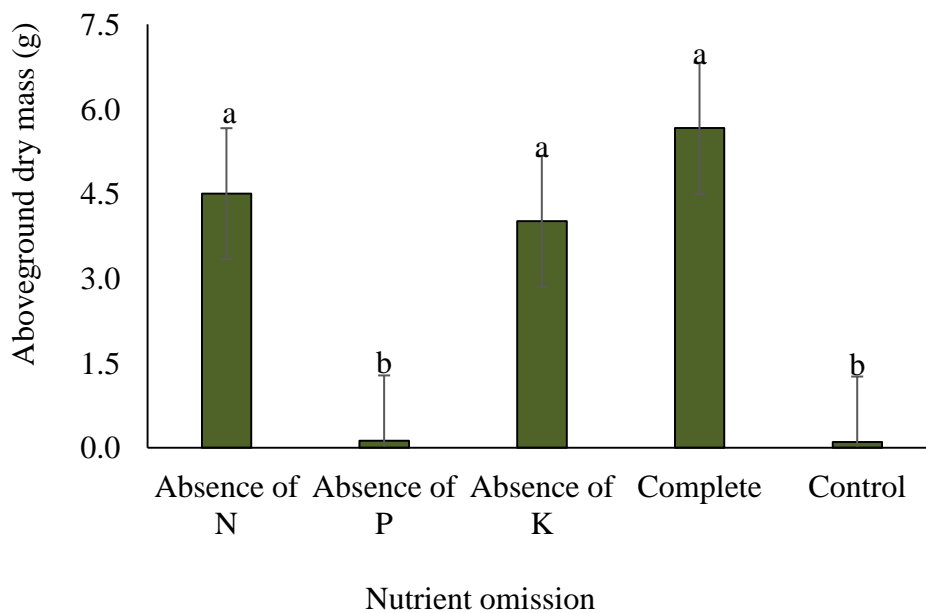
### 3.7 Aboveground Dry Mass

For the aboveground dry mass, there was a statistical difference between the treatments (Fig. 10). The highest masses were found in the treatments without nitrogen, without potassium, and complete, 4.50, 4.01, and 5.66, respectively. The lowest masses were observed in the treatments with the absence of phosphorus and control. The aboveground dry mass of sesame was significantly affected by the absence of phosphorus compared to the complete fertilizer treatment.



**Fig. 9. Leaf area (cm<sup>2</sup>) as a function of nutrient omission in black sesame cultivation. N: Nitrogen; P: Phosphorus; K: Potassium.**

Vertical bars are the confidence interval for the mean ( $P = .05$ )



**Fig. 10. Aboveground dry mass (g) as a function of nutrient omission in black sesame cultivation. N: Nitrogen; P: Phosphorus; K: Potassium.**

Vertical bars are the confidence interval for the mean ( $P = .05$ )

Bhavana T et al. [7] in their studies with phosphate fertilization in sesame cultivation, explain that the application of superphosphate in the adequate dose significantly increases plant height, leaf area index, and consequently the dry

matter of the crop. This justifies that the treatment of phosphorus omission presented low values of plant height (Fig. 6), leaf area index (Fig. 9), and dry mass of the aerial part (Fig. 10).

An almost 98% reduction in aboveground dry mass is observed in the treatments with phosphorus omission in comparison with the treatment with a complete fertilization. Thus, it is observed that phosphorus is the macronutrient that most interferes with the dry mass of the aboveground part in the initial development of sesame.

### 3.8 Root Volume

For the root volume variable, there was a statistical difference among treatments, in which the treatments without potassium and complete showed the highest volumes, 47.50 and 58.75, respectively (Fig. 11). The lowest root volume values were observed in the control and the absence of phosphorus.

In the treatments absence of potassium and the complete treatment, nitrogen was Applied. [29] in their research on nitrogen fertilization, explain that the application of this fertilizer to the soil increases the mineralization of organic matter in the soil. This may have influenced these treatments to have greater root development and consequently greater volume.

The absence of phosphorus inhibited the initial development of sesame roots. This nutrient is very much required by sesame culture because it stimulates root growth, thus obtaining better root development. Moreover, the application of phosphate fertilization results in

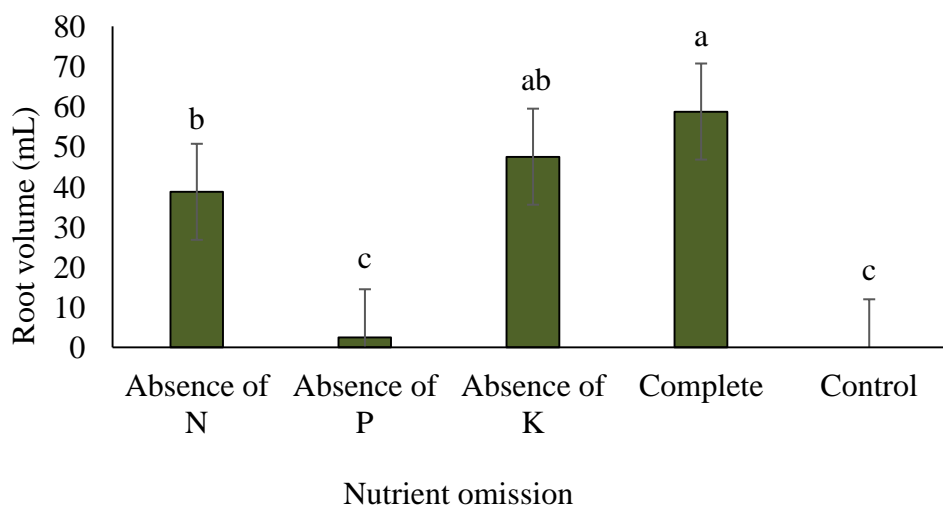
significant improvements in sesame growth and yield [30].

The difference in root volume in the treatments is visibly observed, especially when comparing the absence of phosphorus and the control with the other treatments (Fig. 12). Note that complete fertilization is fundamental for adequate root development; moreover, when there is an absence of any nutrient, deficiency occurs in the sesame, affecting its growth.

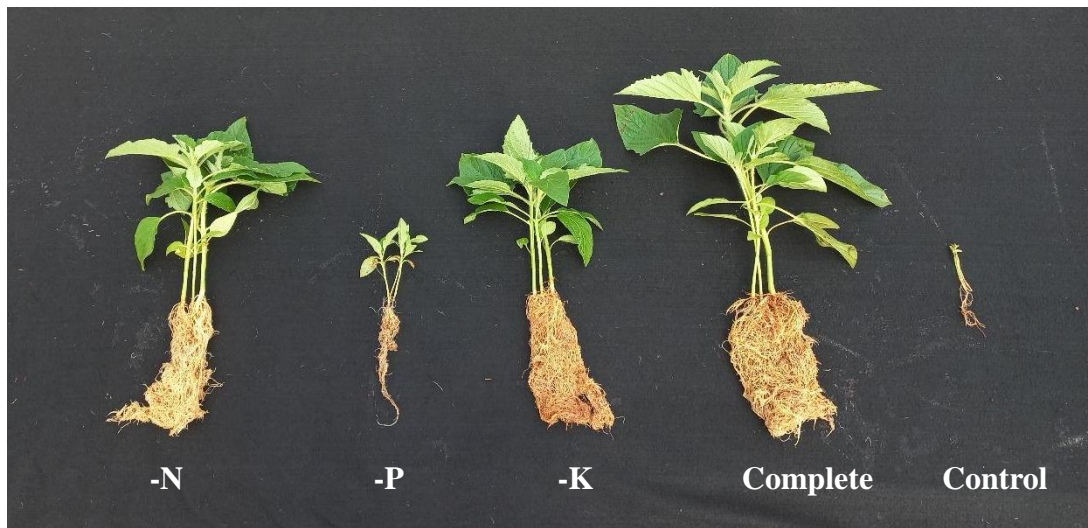
The absence of phosphorus and nitrogen significantly affected root volume in early sesame development when compared to the complete fertilization treatment. The absence of nitrogen provided up to a 35% reduction in root volume, while the absence of phosphorus provided up to a 96% reduction in root volume. Thus, the importance of complete fertilization for the initial root growth of sesame is noted.

### 3.9 Root Dry Mass

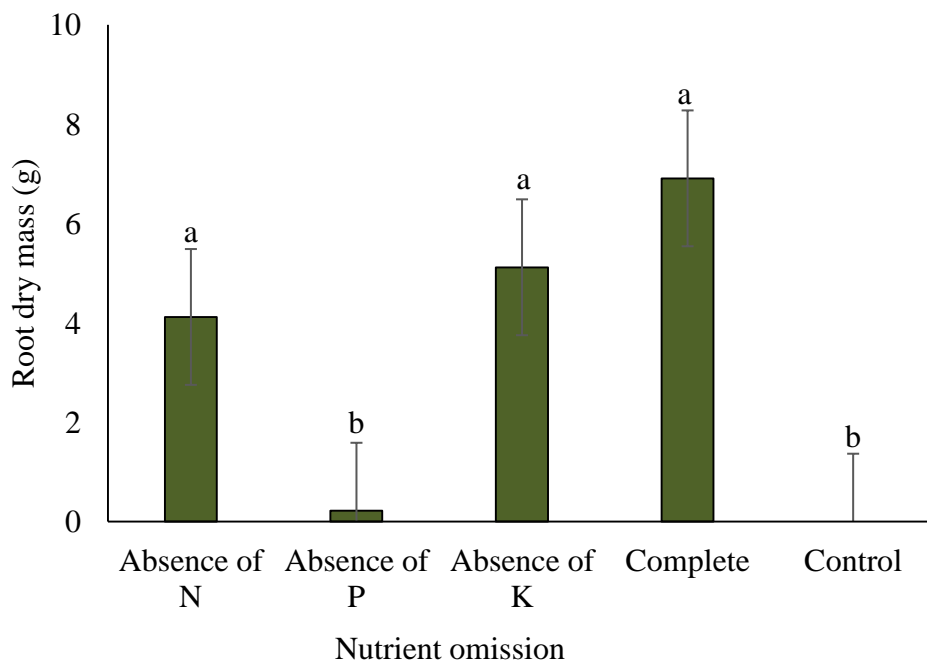
For the root dry mass, statistically, there was a significant difference between treatments (Fig. 13). In the complete treatments, the absence of nitrogen and potassium, the largest dry masses were observed, thus, it is noted that nitrogen and potassium fertilizers do not interfere initially in sesame root development, in relation to dry mass. On the other hand, the absence of phosphorus and the control showed the lowest dry masses.



**Fig. 11. Root volume (mL) as a function of nutrient omission in black sesame cultivation. N: Nitrogen; P: Phosphorus; K: Potassium. Vertical bars are the confidence interval for the mean ( $P = .05$ )**



**Fig. 12. Root volume (mL) as a function of nutrient omission in black sesame cultivation. -N: Absence of nitrogen; -P: Absence of phosphorus; -K: Absence of potassium**



**Fig. 13. Root dry mass (g) as a function of nutrient omission in black sesame cultivation. N: Nitrogen; P: Phosphorus; K: Potassium.**

*Vertical bars are the confidence interval for the mean (P = .05)*

Jesus FQ, Gomes MB and Silva VL [31] in their studies on the morphological response of radish as a function of phosphate fertilization, observed the influence of phosphorus on the variables root length and root dry mass. This explains why the treatment with no phosphorus showed low values for root volume and root dry mass of the sesame in relation to the other treatments.

The absence of phosphorus significantly affected root dry mass in early sesame development when compared to the complete fertilization treatment. The absence of phosphorus provided up to a 97% reduction in root dry mass when compared to the complete fertilization treatment.

#### 4. CONCLUSION

The omission of nitrogen, phosphorus and potassium in sesame fertilization affects the initial development of the crop, phosphorus being the most limiting nutrient in the Brazilian Cerrado Oxisol.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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