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Scientific Article

Growth and seed yield of K3 sesame crops in a typic hapludox with potassium fertilization

Desenvolvimento e produtividade de gergelim (cultivar k3) em latossolo amarelo em função da adubação potássica

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ABSTRACT – Sesame (*Sesamum indicum* L.) is an oilseed crop species valued for its nutritional properties. Sesame production has been a strategic alternative for expanding agricultural diversification in Mato Grosso, Brazil. In this context, the objective of this study was to assess growth and seed yield of sesame plants (cultivar K3) grown in a Typic Hapludox soil under potassium (K) fertilizer application. The experiment was conducted in a randomized block design with four replications, using a 6×4 factorial arrangement consisting of six K_2O rates (0, 30, 50, 70, 90, and 120 kg ha^{-1}) and four application times (0, 20, 30, and 40 days after sowing). Agronomic parameters were evaluated, including plant height, first capsule height, numbers of branches and capsules per plant, capsule weight, 1000-seed weight, and seed yield. Soil samples were chemically analyzed after harvest. Individual factors (K_2O rates and application times) and the interaction between factors had no significant effects on plant height, first capsule height, number of branches per plant, and capsule and 1000-seed weights. The timing of fertilizer application did not significantly affect plant growth and seed yield. However, K fertilizer application increased soil K contents, number of capsules per plant, and seed yield. The highest seed yield was found for the K_2O rate of 90 kg ha^{-1}.

Keywords: *Sesamum indicum* L.. Fertilizer. Oilseed Production.

RESUMO – O cultivo do gergelim destaca-se como uma cultura oleaginosa apreciada por suas propriedades nutritivas. No Mato Grosso, a produção de gergelim está sendo impulsionada como uma opção estratégica para ampliar a diversificação agrícola. Nesse contexto, objetivo deste trabalho foi avaliar o desenvolvimento e produtividade do gergelim em latossolo amarelo em função da adubação potássica. O experimento adotou um arranjo fatorial 6x4, envolvendo seis doses de K_2O (0, 30, 50, 70, 90 e 120 kg/ha^{-1}) e quatro épocas de aplicação (0, 20, 30 e 40 dias após a semeadura). O delineamento experimental foi inteiramente casualizado, com quatro repetições. Foram avaliados diversos parâmetros agronômicos, incluindo altura da planta, altura da inserção da primeira cápsula, número de ramos, número de cápsulas, massa das cápsulas, massa de mil grãos e produtividade. Foi realizada também a análise química do solo após a colheita. Não foram identificadas variações significativas para variáveis altura da planta, altura de inserção da primeira cápsula, número de ramos, massa de cápsulas e massa de mil grãos em para interação doses e épocas de aplicação. A época de aplicação não influenciou no desenvolvimento e produtividade do gergelim. No entanto, a adubação potássica promoveu aumento nos níveis de potássio no solo e proporcionou incremento no número de cápsulas por planta e na produtividade. A dose que maximizou a produção foi 90 k.ha^{-1} de K_2O.

Palavras-chave: Sessamum indicum L. Fertilizante. Rendimento de grãos.

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INTRODUCTION

Sesame (*Sesamum indicum* L.), an oilseed species in the family Pedaliaceae, is native to Africa and Asia and has been grown in 75 countries worldwide (ZHANG; MIAO, JU, 2019).

Global sesame production has significantly increased in recent decades, mainly due to the growing demand for its seeds and derivatives driven by their high nutritional value, as they are rich in oil (44% to 58%), proteins (18% to 25%), and carbohydrates (up to 13%) (TENYANG et al., 2017; MA et al., 2022).

Brazil is still a small sesame-producing country globally; however, recent trends have indicated a significant potential growth in the production of this crop. Sesame seed production in Brazil has increased approximately 20-fold over the last decade compared to 2010, accounted for 110,900 Mg of seeds on a total area of 213,900 hectares in the 2021/2022 crop season, with a seed yield of 519 60-kg bags per hectare (CONAB, 2023).

Mato Grosso, Goiás, São Paulo, and Minas Gerais are the largest sesame-producing states in Brazil, with Mato Grosso standing out, mainly represented by the municipalities of Canarana and Água Boa. In 2020, Canarana accounted for the largest national production in 2020, with approximately 100,000 hectares planted with sesame crops, significantly contributing to the 40,000 Mg of seeds harvested in the state (BOTELHO et al., 2022).

In this context, growing sesame crops is an important alternative for agricultural diversification, boosting economic, agronomic, and social benefits. The crop's tolerance to drought, ease of management, and adaptability to diverse production systems make it an attractive option for effective integration into various agricultural practices (BARROS; SANTOS, 2002; PERIN; CRUVINEL; SILVA, 2010).

The scarcity of technical information on sesame crop management in Brazil can limit the growth of its production. Therefore, expanding scientific knowledge about this crop is necessary to explore its production potential. The management of fertilizer applications should be considered an important strategy to meet the plants' nutritional needs, improve nutrient absorption, and contribute to the sustainable and effective management of sesame crops (ALVES et al., 2019).

Therefore, considering that potassium (K) is one of the most required macronutrients for sesame plants, that the use of fertilizers accounts for a significant portion of the seed production costs, and that the K3 sesame cultivar is the most widely grown in Mato Grosso, the objective of this study was to evaluate the growth and seed yield of sesame plants of the cultivar K3 grown in a Typic Hapludox under different K fertilizer application rates.

MATERIAL AND METHODS

The experiment was conducted at the experimental field of the Xingu Pesquisa e Consultoria Agronômica company, in Confresa, northeastern region of the state of Mato Grosso, Brazil. The region has an average altitude of 230 meters; its climate was classified as Aw, humid tropical, according to the Köppen classification, characterized by a rainy summer and a dry winter. The mean air temperature and total rainfall depth during the experiment were 25 ºC and 587.4 mm, respectively (Figure 1).

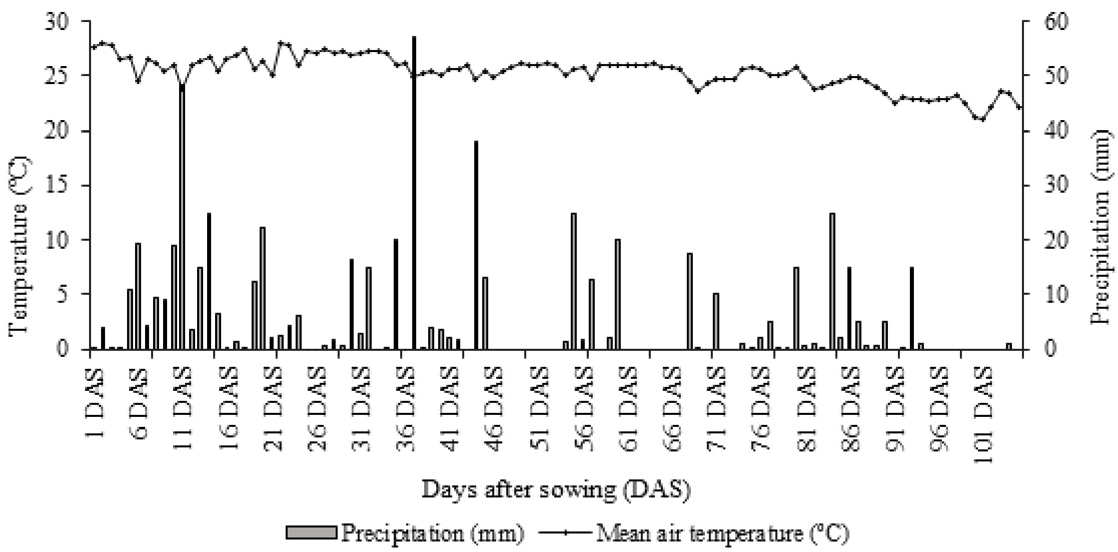

Figure 1. Meteorological data on rainfall depths and mean air temperatures between sesame planting and harvesting. Confresa, MT, Brazil, 2022/2023 crop season.

The soil of the experimental area was classified as Typic Hapludox (Latossolo Amarelo; Santos et al. (2018) of medium texture and flat relief; the soil chemical and physical characteristics before implementing the experiment are shown in Table 1.

Table 1. Chemical and physical characterization of the soil of the experimental area before the implementation of the experiment with sesame crops. Confresa, MT, Brazil, 2022/2023 crop season.

pH $CaCl_2$	P	K	Ca	Mg	Al	H	OM	SB	CEC	BS	Sand	Silt	Clay
	mg dm^{-3}		---------- cmolc dm^{-3} ----------				g kg^{-1}	cmolc dm^{-3}		%	---------- % ----------		
5.44	10.35	48.25	2.41	1.05	0.00	5.94	11.32	3.29	5.06	58.46	68.93	4.00	27.07

OM = organic matter; SB = sum of bases; CEC = cation exchange capacity; and BS = base saturation.

A randomized block experimental design with four replications was used, in a 6×4 factorial arrangement consisting of six potassium (K_2O) fertilizer rates (0, 30, 50, 70, 90, and 120 kg ha^{-1}) applied at four different times (10, 20, 30, and 40 days after sowing), totaling 24 treatments. The experimental unit consisted of an area of 74.25 m² with 11 planting rows spaced 45 cm apart, with 15 plants per meter, totaling a length of 15 meters.

The sesame cultivar K3 was used; it is currently the most widely grown cultivar in the state of Mato Grosso. Complementary fertilizer application consisted of basal dressing using 50 kg ha^{-1} of phosphorus (P), and two nitrogen (N) foliar applications of 60 kg ha^{-1}, at 20 and 30 days after plant emergence.

Soil samples were collected before harvest for chemical analysis to asses pH, cation exchange capacity (CEC), and contents of potassium (K), calcium (Ca), magnesium (Mg), hydrogen + aluminum (H+Al), and organic matter.

Biometric parameters of sesame plants were assessed 90 days after sowing (DAS) on 10 plants collected per plot. Plant height (cm) and first capsule height (cm) were measured using a tape measure for determining the means of each replication. Additionally, number of branches and capsules per plant were counted.

Thousand-seed weight was determined by separating eight 100-seed subsamples per plot, which were weighed on an analytical balance, following the procedures established by the Seed Analysis Rules (BRASIL, 2009).

Harvest was done manually when the fruits at the base of the sesame plants began to open (dehiscence), corresponding to 100 DAS. Six five-meter rows from the four replications of each treatment were harvested by cutting the plants at ground level. Subsequently, the harvested material was taken for threshing (separation of seeds) and weighing. Moisture content was determined using a Motomco 999-CP meter and adjusted to 5%. Seed yield (kg ha^{-1}) was determined based on the evaluation area of the plots.

The obtained data were subjected to normality analysis using the Shapiro-Wilk test (SCOTT; KNOTT, 1974). The application timing data were subjected cluster analysis using the Scott-Knott test, whereas K rate data were subjected to regression analysis. The choice between a linear or quadratic model for regression analysis was based on the significance of the coefficients (F-test) and the coefficient of determination (R^2). In the case of quadratic regression analysis, the point of maximum technical efficiency (identification of the economic fertilizer rate) was determined using the equation $x = b / 2a$, assuming normally distributed coefficients. Statistical analyses were performed using the ASSISTAT 7.6 beta software developed by the Federal University of Campina Grande (SILVA; AZEVEDO, 2002).

RESULTS AND DISCUSSION

The results of pH, K, Ca, Mg, H+Al, organic matter (OM), and cation exchange capacity (CEC) in the soil before harvesting sesame plants are shown in Table 2.

Table 2. Analysis of variance for pH, potassium (K), calcium (Ca), magnesium (Mg), hydrogen + aluminum (H+Al), organic matter (OM), cation exchange capacity (CEC) in the soil of treatments as a function of K_2O rates (R) and application times (T) before harvesting sesame crops. Confresa, MT, Brazil, 2022/2023 crop season.

Source of variation	Mean square							
	DF	pH	K	Ca	Mg	H+Al	OM	CEC
R	5	092^{ns}	069**	0.161^{ns}	0.064^{ns}	0.356^{ns}	10.74^{ns}	0.918^{ns}
T	3	0.536^{ns}	0.0003^{ns}	0.801^{ns}	0.032^{ns}	0.260^{ns}	14.51^{ns}	1.000^{ns}
R×T	15	0.226^{ns}	0.0006^{ns}	0.281^{ns}	0.043^{ns}	0.210^{ns}	14.63^{ns}	0.369^{ns}
Residue	72	0.176	0.0012	0.621	0.056	0.226	19.49	0.745
CV(%)	-	7.92	16.33	27.3	23.23	22.14	27.17	13.76
Mean	-	5.30	0.21	2.88	1.02	2.14	16.24	6.27

CV = coefficient of variation; DF = degrees of freedom; ** and ^{ns} = significant at 1% level and not significant by the F-test.

The evaluated soil chemical properties were not significantly affected by the interaction between the factors (K_2O rates and application times) or by the application time factor.

Soil K contents were significantly affected by the K_2O rate factor, showing a linear increasing response as the K_2O rate was increased, as the highest K content was found for the K_2O rate of 120 kg ha^{-1} (Figure 2).

The soil K content can be a positive factor for crop rotation systems, as the subsequent crop can benefit from residual K content in the soil, resulting in reduced production costs.

Plant height, first capsule height, and number of branches per plant were not significantly affected by K_2O rates, regardless of the application time and the interaction between the factors (Table 3).

These results are consistent with those reported by Costa et al. (2012), who evaluated sesame crops under fertigation with different K sources and rates and found that K rates did not significantly affect pant height, stem diameter, and leaf area. They attributed the observed variability to the K sources and sesame cultivar used.

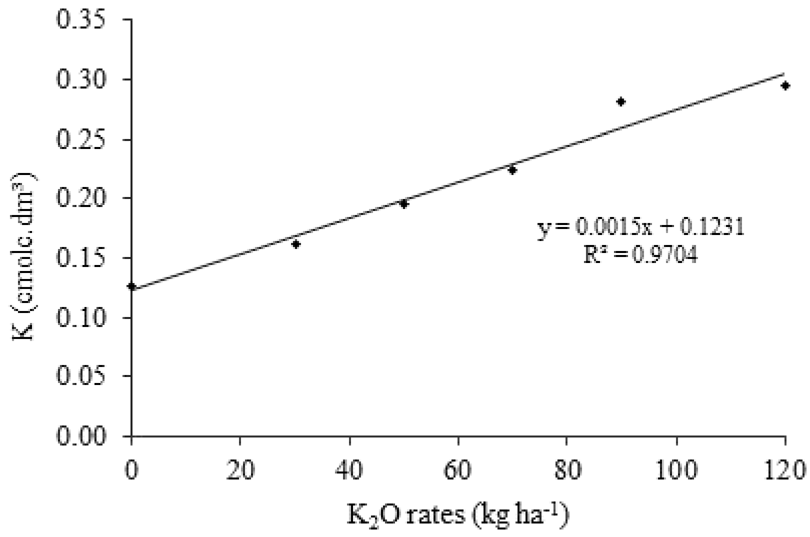

Figure 2. Soil K content at pre-harvest of sesame crops as a function of application of K_2O rates. Confresa, MT, Brazil, 2022/2023 crop season.

Table 3. Summary of the analysis of variance for plant height (PH), first capsule height (FCH), and number of branches per plant (NB) of sesame crops as a function of K_2O rates and application times. Confresa, MT, Brazil, 2022/2023 crop season.

Source of variation	Mean square			
	DF	PH	FCH	NB
K_2O rates (R)	5	0.02^{ns}	26.53^{ns}	0.31^{ns}
Application times (T)	3	0.015^{ns}	19.34^{ns}	0.67^{ns}
R×T	15	0.07^{ns}	9.23^{ns}	0.31^{ns}
Residue	72	0.01	7.72	0.28
CV(%)	-	26.55	13.39	19.36
Mean	-	1.33	20.76	2.74

CV = coefficient of variation; DF = degrees of freedom; ^{ns} = not significant by the F-test.

Ahmad et al. (2018) investigated the effects of sulfur (S) and K rates on seed yield and other yield parameters of sesame plants and found effect of K fertilizer application on vegetative growth parameters. Abdel-Rahman (2014) reported similar results when evaluating the effects of K rates on soil physicochemical properties and sesame seed yield.

K uptake in plants can be affected by several factors, including the soil K availability, root absorption capacity, and environmental conditions during plant growth. The meteorological data recorded throughout the experimental period (Figure 1) showed a more significant rainfall distribution during the vegetative development stage (from sowing to 45 DAS), totaling a rainfall depth of 348.4 mm, which may have favored a uniform plant growth.

The interaction between the factors and the individual factors had no significant effects on number of capsules per plant, capsule weight, thousand-seed weight, and seed yield (Table 4).

Applications of K rates increase enzymatic activity and the translocation of assimilates from leaves to fruits, improving crop yield components, such as number of fruits and seed weight, as found by Salim, Abd El-Gawad and Abou El-Yazied (2014), who reported significant effects of K_2O rates on number of capsules and seed yield of sesame plants. However, no significant difference in capsule weight and 1000-seed weight was found among the treatments evaluated in the present study.

Low rainfall depths were recorded during the capsule development and seed filling stages, totaling 184 mm from 45 to 100 DAS (Figure 1), which may have hindered the adequate uptake of nutrients, including K, by the sesame plants. According to Brady and Weil (2013) and Cavalli and Lange (2018), well-distributed and adequate rainfall favors efficient absorption and utilization of soil K by plants. Moreover, many crops need a greater amount of water during the flowering and fruiting stages, which makes them more sensitive to water deficit conditions. According to Lourenço et al. (2018), water consumption of sesame plants of the cultivar BRS Anahi is approximately 500 mm per cycle, with more than 50% (268.5 mm) during fruit formation and ripening stages.

Table 4. Analysis of variance for number of capsules per plant (NCP), capsule weight (CW), 1000-seed weight (TSW), and seed yield (SY) of sesame crops as a function of K_2O rates and application times. Confresa, MT, Brazil, 2022/2023 crop season.

Source of variation	Mean square				
	DF	NCP	CW	SY	TSW
K_2O rates (R)	5	936.83^{**}	5.150^{ns}	221890.08^{**}	0.9848^{ns}
Application times (T)	3	32.37^{ns}	1.72^{ns}	848.89^{ns}	0.085^{ns}
R×T	15	42.51^{ns}	3.96^{ns}	1087.39^{ns}	0.4124^{ns}
Residue	72	26.10	2.69	4540.69	0.486
CV(%)	-	9.50	34.85	10.43	17.66
Mean	-	53.30	4.70	646.11	3.95

CV = coefficient of variation; DF = degrees of freedom; ** and ns = significant at 1% level and not significant by the F-test.

Number of capsules per plant showed a significant quadratic response to K_2O rates (Figure 3); the highest technical efficiency was found for the application of 80 kg ha^{-1} of K_2O, resulting in an increase of 53.85% in number of capsules per plant. This result denotes a direct correlation between this K_2O rate and increased capsule production of sesame plants.

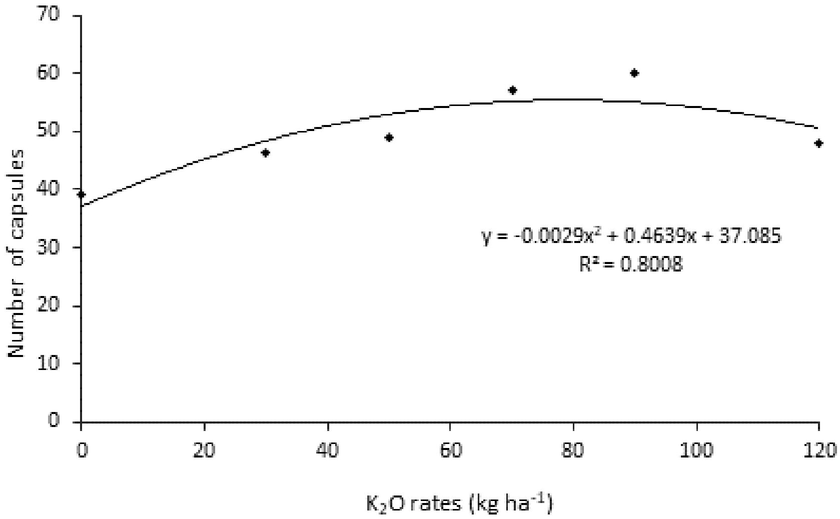

Figure 3. Number of capsules per plant as a function of application of K_2O rates for growing sesame crops. Confresa, MT, Brazil, 2022/2023 crop season.

K is a nutrient significantly involved in enzyme activation, contributing to various metabolic activities in plants, including the efficient transport of photosynthetic products to fruits and their subsequent conversion into oil. This indicates that this nutrient can promote higher flower and pod retention in plants (JAT et al., 2017; YOUNIS et al., 2020).

Kale et al. (2019) evaluated the responses of sesame plants to application of N and K fertilizers and found a significant increase in number of capsules per plant with increasing the K rate from 0 to 20 kg ha^{-1}, reaching the highest mean (55.56) for a K rate of 30 kg ha^{-1}.

The highest sesame seed yield (775.68 kg ha^{-1}) was found for the K_2O of 90 kg ha^{-1}. The application of higher K_2O rates did not result in increased seed yield (Figure 4).

Sesame plants present a seed yield potential from 1,500 to 2,000 kg ha^{-1} when grown under irrigation and adequate fertilizer application management (EUBA NETO et al., 2016; CRUZ et al., 2019).

Ahmad et al. (2018) reported a positive response of sesame plants to K fertilizer application, with an increase in number of seeds per capsule when applying a K rate of 50 kg ha^{-1}, reaching the highest seed yield of 617 kg ha^{-1}. Kale et al. (2019) evaluated sesame plants under application of N and K fertilizers and found increases in seed yield when applying K_2O rates, with the highest mean (1,207.92 kg ha^{-1}) obtained with the application of 30 kg ha^{-1}.

Overall, the results showed that the K3 sesame cultivar exhibit a significant response in seed yield to K fertilizer application, which may be attributed mainly to the increase in number of capsules per plant. However, water deficit conditions during the crop cycle may limited increases in seed and capsule weight, as plants use stomatal closure as a protective strategy against water loss through transpiration, resulting in reduced water loss and photosynthetic rate (TAIZ; ZEIGER, 2009). Therefore, a more significant increase in seed yield is expected for sesame plants grown under more favorable climate conditions.

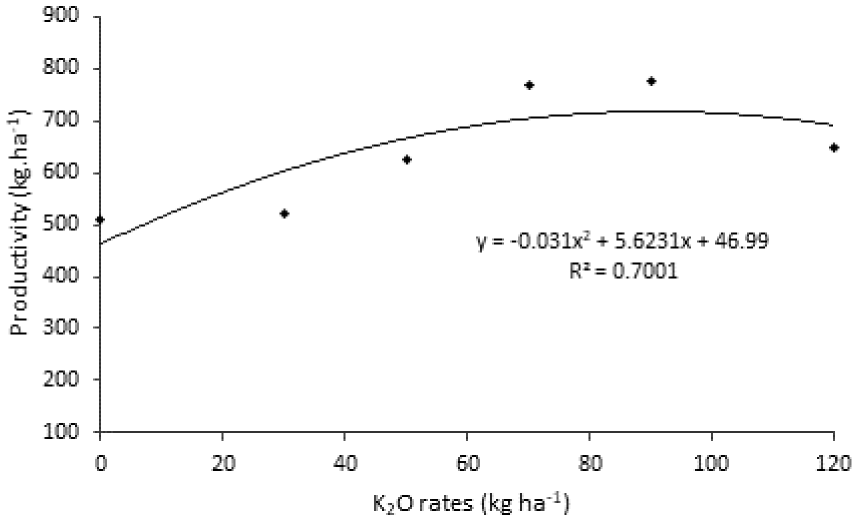

Figure 4. Sesame seed yield as a function of application of K_2O rates. Confresa, MT, Brazil, 2022/2023 crop season.

In the context of Mato Grosso, sesame crops are grown mainly as a second crop in small and medium-sized agricultural areas in which growing maize crops is not viable due to the planting window. Approximately 90% of the total sesame seed production in the state is destined for export, mainly to Arab countries and regions in Asia and the Middle East. indicates the potential of sesame as a significant commercial crop for the state's economy, contributing to the growers' profitability and the diversification of agricultural production in the region.

Total production cost of sesame crops ranges from US$ 202 to US$ 303 ha^{-1} (BLR 1,000 to BLR 1,500 ha^{-1}) depending on management practices and the level of technology adopted. The cost of potassium fertilizer applications can account for 20% to 30% of the total production cost. Thus, the information provided in the present study serve as a reference for sesame crop management by assisting in choosing the planting window to optimize the effectiveness of fertilizer applications and enabling a more accurate analysis of production costs according to the specific reality of each agricultural enterprise.

CONCLUSION

Potassium fertilizer application significantly affected the number of capsules per plant and seed yield of sesame crops. The highest seed yield (775,68 kg ha^{-1}) was found for the K_2O rate of 90 kg ha^{-1}.

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