



RESEARCH ARTICLE

PRODUCTIVITY AND QUALITY OF SESAME OIL AS A FUNCTION OF ORGANIC AND MINERAL FERTILIZATION

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ABSTRACT

Several studies have demonstrated the effect of fertilizer on different crops; however, few contemplate the low yield of sesame obtained in most growing areas by production constraints associated with low-income cultivars or, because of non-application of fertilizers. The objective of this experiment was to verify the yield and quality of oil in two sesame varieties as a function of organic and mineral fertilization. To this effect, a field experiment in a randomized complete block in factorial (2 x 5) + 2, corresponding to the 'BRS Seda' and 'CNPA G4', five organic sources (cotton cake and mammon cake, cattle manure and goat; without fertilization), two relative controls, fertilized with ammonium sulfate was performed with four replications. Productivity were determined, the oil content, acid value and peroxide value. Submitted the results of analysis of variance, Pearson's correlation, Tukey test, F test and analysis of principal components and grouping. The sources of fertilization influence on yield and oil content, especially goat manure; while the cultivars showed significance for oil content extracted by solvent. The high oil content, 0.698 t/ha, obtained in this experiment is indicative of the viability of commercial extraction.

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INTRODUCTION

The world demand for vegetable oils, especially sesame oil (*Sesamum indicum* L.), for both food and industrial purposes has increased sharply. Many countries face shortages of edible oil, because their production is very low relative to the level of consumption and consequently, a large part of foreign exchange is spent on oil imports, which increase each year (Ali & Ullah, 2012). Sesame oil is considered to be of high quality and often referred to as the "queen" of vegetable oils, because of its stability, high conservation and resistance to rancid. However, in soil without fertilization, the average yield of sesame is small, and, around 300 kg of seeds per hectare (Haruna & Abimiku, 2012), it has been used for salad, cooking oil, margarine production, among others, because they have no cholesterol in their composition. In oilseed crops, quality criteria are the fatty acid composition of seed oil, such as oleic acid (a monounsaturated fatty acid) with important implications for human health (Ali & Ullah, 2012).

The use of fertilizers is considered one of the most important factors to increase sesame production per unit area (Gao *et al.*, 2012; Hasanpour *et al.*, 2012). However, for its applicability requires a better understanding of the relationship between crop yield, fertilizer doses and plant requirements (Gao *et al.*, 2012). The application of nitrogen in the sesame crop increases the biological productivity and the oil content (Sharar *et al.*, 2000). Malik *et al.* (2003) reported that between nitrogen levels (0, 40, 80 kg N ha⁻¹), the treatment with 80 kg N/ha yielded maximum seed yield (0.79 t ha⁻¹) and maximum seed oil in the sesame seeds, corresponding to 45.88% of the productivity in t ha⁻¹. Combining sources of organic nutrients and mineral fertilizers have resulted in synergistic effects and improved synchronization, release and uptake of nutrients by crops leading to higher yields (Mbah & Onweremadu, 2009). Research in the tropics with plant mineral nutrition has shown that sesame crop performs well with organic or inorganic fertilizer applications (Okpara *et al.*, 2007; Jooyban & Moosavi, 2012). The sesame crop responds significantly to fertilization with manure, increasing its productivity. This type of fertilization serves as a soil conditioner, due to the addition of organic matter, besides raising soil fertility, previously limited by the absence or low input of agricultural inputs (Haruna & Abimiku, 2012).

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Considering the low sesame yield obtained in most of the growing areas because of the non-application of fertilizers and the low fertility of the cerrado soils, the objective of this research was to evaluate the performance of sesame using different organic and inorganic fertilizers, and verify their influence on the productivity and quality of the oil.

MATERIALS AND METHODS

The experiment was carried out in the village Rosario, in the city of Caxias, Maranhão, between the coordinates of the 04°55'62" south latitude and 043°16'65" west longitude, with a mean altitude of 92 m and climate according to the classification of Thornwaite type C₁dA'a' (dry sub-humid with annual average rainfall between 1,300 and 1,500 mm). The Fluvisol of the experimental area presented sandy texture and the following chemical attributes: pH (1:2.5) = 5.5; OM = 10.8 g kg⁻¹; P = 2.1 mg kg⁻¹; K⁺ = 0.9 cmol_c kg⁻¹; Na⁺ = 0.1 cmol_c kg⁻¹; Ca⁺² = 1.9 cmol_c kg⁻¹; Mg⁺² = 0.2 cmol_c kg⁻¹; Al⁺³ = 0.0 cmol_c kg⁻¹ and H⁺ = 3.0 cmol_c kg⁻¹. Analysis of soil, as well as to the chemical composition of the organic materials used in the experiment (Table 1), were determined according to EMBRAPA (2011).

The treatments, T3 and T9, were fertilized with 31.0 kg of cattle manure (CM); T4 and T10, treatments fertilized with 14.0 kg of goat manure (GM); T5 and T11, treatments fertilized with 5.01 kg of mammon cake (MC), and, T6 and T12, treatments fertilized with 3.4 kg of cotton cake (CC). Each plot consisted of a total area of 28.8 m² (8.0 m x 3.6 m) and useful area of 19.2 m² (8.0 m x 2.4 m). The spacing was 0.6 m x 0.1 m between rows and plants, respectively. For the calculation of productivity, the seed mass (g/plant) was divided by the final density of plants/ha of the useful area of each plot, and the value obtained in kg plot⁻¹ was transformed to kg ha⁻¹. The oil content of the seeds was determined in low field nuclear magnetic resonance (NMR) equipment, and the moisture content of the seeds was determined according to EMBRAPA (2011). The extraction of the oil from the seeds and the determination of the acidity, the peroxide indices and the saponification of the oil followed the methodology of the Adolfo Lutz Institute (1985). The results were submitted to analysis of variance and Pearson's correlation. The means of the fertilization sources were compared by the Tukey test at 5% probability. The varieties and additional treatments were submitted to the F test. Subsequently, principal and cluster components were analyzed.

Table 1. Chemical composition of the organic materials used in the experiment in Caxias, Maranhão, 2013

	N	P	K	Ca	Mg	C	S	OM
Manure				%				
Cattle	1.68	0.07	0.20	0.09	0.03	0.55	-	0.95
Goat	2.11	0.04	0.08	0.13	0.09	3.00	-	5.18
Oil cake				%				
Cotton	6.77	1.26	1.13	0.45	0.40	-	0.22	86.73
Mammon	4.60	1.20	0.57	0.83	0.38	-	0.19	83.80

Table 2. Summary of the variance analysis of content (%) extracted oil by solvent (EOS), oil content estimated by nuclear magnetic resonance (ORMN), moisture content (%) (MC) and productivity (PROD) (t ha⁻¹) in sesame culture in Caxias, Maranhão, 2013

Sources of Variation	Degrees of freedom	Mean square			
		EOS	ORMN	MC	PROD
Blocks	3	16.6292**	19.9462**	0.3347**	0.3452**
Sources (S)	5	11.2693**	11.2091**	0.1121 ^{ns}	0.1984*
Cultivar (C)	1	11.9002**	5.5216 ^{ns}	0.0120 ^{ns}	0.0242 ^{ns}
S x C	5	1.6655 ^{ns}	1.2706 ^{ns}	0.0222 ^{ns}	0.0490 ^{ns}
Residue	33	1.4197	1.8255	0.05	0.0626
Total	47				
CV(%)		2.34	2.75	3.80	21.58

^{ns}, ** and *: not significant, significant at 0.01 and 0.05 probability level, respectively.

The experimental design was a randomized complete block, with 12 treatments, in a factorial scheme (5 x 2) + 2, with five sources of organic matter (cattle manure, goat manure, cotton cake, mammon cake and absence of organic fertilizer), Two cultivars: 'BRS Seda' and 'CNPA G4', plus two relative controls, fertilized with ammonium sulfate, in four replications, totaling 48 plots. For the calculation of the fertilizer quantities used in fertilization with the organic sources (N), the equivalence of 80 kg of N/ha was considered. In addition, in relation to phosphorus, 80 kg of P₂O₅/ha. The sources of N and P₂O₅ used were ammonium sulfate [(NH₄)₂SO₄] and the simple superphosphate [Ca(H₂PO₄)₂.H₂O + CaSO₄.2H₂O], respectively. All treatments received 1.52 kg of single superphosphate at the foundation, except the absolute control. The treatments designated T1 to T6 included the cultivar 'BRS Seda' and, from T7 to T12 the cultivar 'CNPA G4'; being T1 and T7 the absolute control (AC), without fertilization; T2 and T8, the relative controls (RC), fertilized with 1.52 kg of ammonium sulphate (ASU).

RESULTS AND DISCUSSION

Fertilizer sources were significant for oil content and yield and cultivars had a significant effect only on oil content. No interaction effect was observed for any variable (Table 2). In an experiment with nitrogen fertilization Hasanpour *et al.* (2012), with respect to the oil content in the seeds, obtained divergent results for the source of fertilization and concordant results for cultivars and the source interaction of fertilization and cultivars. While, Haruna and Abimiku (2012), using manure, obtained concordant results regarding productivity. For the moisture content of the seeds Queiroga *et al.* (2010) found divergent results; While, statistically equal results were observed by Antoniassi *et al.* (2013) who cultivated sesame genotypes in soil class similar to the present study. Regarding productivity, Jooyban and Moosavi (2012), in an experiment with nitrogen fertilization levels, obtained significant results at the 1% level (Table 2). Already, Pereira *et al.* (2002), using cattle manure as a nitrogen source, obtained non-significant

Table 3. Oil content (%) extracted by solvent (EOS), oil content estimated by nuclear magnetic resonance (ORMN), moisture content (%) (MC) and productivity (PROD) of grains (t ha⁻¹) sesame cultivated in Fluvic Entisol in Caxias, Maranhão, 2013

Sources of fertilization	EOS	ORMN	MC	PROD
Cattle manure	51.24abc	49.37ab	5.67ab	1.20ab
Goat manure	51.72ab	49.94ab	5.68ab	1.35a
Mammon cake	50.45bc	48.51b	5.84a	1.29ab
Cotton cake	49.96bc	48.35b	5.81ab	1.05ab
Ammonium sulfate	49.72c	47.90b	5.76ab	1.16ab
Absolute control	52.86a	51.09a	5.51b	0.92b
MSD	1.80	2.04	0.33	0.38

Means (n = 8) followed by the same letter in the column do not differ by Tukey test at 0.05 probability level.

Table 4. Principal components obtained from analysis of eight productivity characteristics and quality of sesame oil valued at Caxias, Maranhão, 2013

	PC1	PC2
Eigenvalue	3.170	2.358
Variance (%)	39.62	29.47
Cumulative variance	39.62	69.09
Variables	Eigenvectors	
EOS	0.532	-0.143
ORMN	0.532	-0.046
PROD	-0.211	-0.220
AV	0.039	0.592
OAV	0.031	0.591
PV	-0.062	-0.363
SV	-0.307	0.278
MC	-0.537	-0.139

EOS = oil content extracted by solvent; ORMN = oil content estimated by nuclear magnetic resonance; PROD = productivity; AV = acid value; OAV = oleic acid value; PV = peroxide value; SV = saponification value; MC = moisture content.

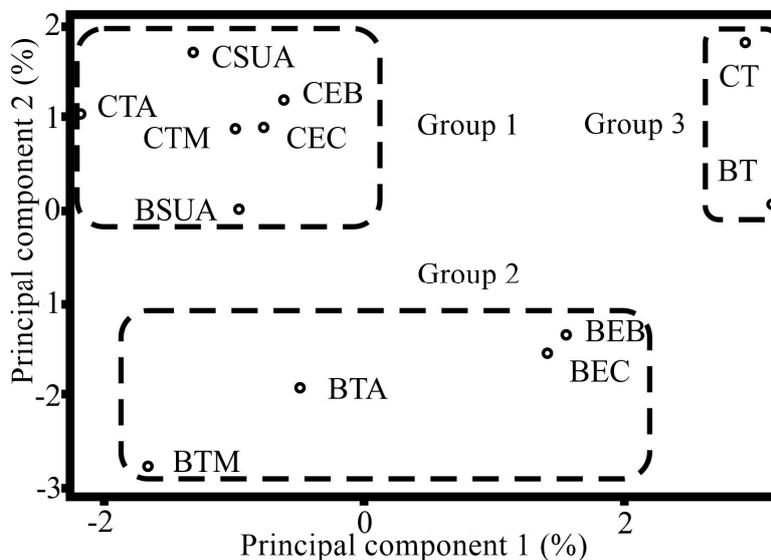


Figure 1. Groups of the treatments based on the scores of the first and second principal component, the experiment with the sesame culture Caxias, Maranhão, 2013. Means (n = 12). 'BRS Seda' (bovine manure = BEB, goat manure = BEC; control = BT; cotton cake = BTA; mammon cake = BTM; ammonium sulfate = BSUA); 'CNPA G4' (bovine manure = CEB, goat manure = CEC; control = CT; cotton cake = CTA; mammon cake = CTM; ammonium sulfate = CSUA)

results for productivity. The divergences between the highlighted researches may be due to differences in the responses of the cultivars to the application of nitrogen or to differences in climatic conditions. By both methods of determination of the oil content, the plants cultivated without fertilization were superior to the others, producing the highest averages of oil content in the seeds, while the plants fertilized with ammonium sulfate had the lowest oil content in the seeds (Table 3). Considering the sources of fertilization, the average oil content in the seeds was higher when extracted by solvent (Table 3).

The superiority of this method, too, was found by Nzikou *et al.* (2009) and Queiroga *et al.* (2010), and diverge from the results found by Antoniassi *et al.* (2013). The observed averages are among the variations verified by Queiroga *et al.* (2010) and Silva *et al.* (2014) for the 'BRS Seda' and 'CNPA G4' varieties, respectively. The sesame plants fertilized with mammon cake and the controls produced seeds with higher and lower moisture content, respectively, while the other fertilization sources were statistically the same. Silva *et al.* (2014) verified moisture contents similar and equal to 5.31 and 5.37% with the same varieties.

Sesame plants fertilized with goat manure showed the highest average productivity, while those fertilized with the other fertilization sources reached a statistically average productivity equal to each other and higher than the control (Table 3). Mesquita *et al.* (2013), with NPK fertilization and 'BRS Seda' variety, obtained a mean yield of sesame grains of only 0.68 t/ha, a value below that obtained with the absolute and relative controls of this study. With respect to oil yield, the results of this study ranged from 0.486 to 0.698 t/ha; While Hasanpour *et al.* (2012), using equivalent nitrogen fertilization, obtained 0.362 tons of oil/ha. The increase in oil yield may be due to cultivars, appropriate time of harvest, among others. The analysis by the principal components method, applied to the correlation matrix of the eigenvalues related to the productivity and oil quality characteristics, allowed to identify two eigenvalues, PC1 and PC2, greater than 2 (Table 4).

In the interpretation of the results, the two components were used, since they captured a significant proportion of 69.09% of the total variance of the original variables. The first component, PC1, which corresponds to the linear combination of the original variables and which can explain individually the largest portion of the variance, captured 39.62%, and the second component, PC2, in order of contribution to the total variance, captured 29.47% (Table 4). Yol & Uzun (2012) obtained similar results. For the interpretation of each of the principal components, absolute values higher than 0.38 and 0.41 were considered for the eigenvectors of components 1 and 2, respectively. The first component is positive and strongly correlated with oil content, productivity, saponification index and moisture content. With the exception of the ORMN, all the characters contributed a lot to the second principal component, highlighting AV and OAV that were strongly correlated. AV, OAV and PV were the characteristics that best explained the principal component 2, with scores in the order of 0.592; 0.591 and 0.363, respectively; while, moisture content and oil contents better explained PC1, with scores of 0.537 and 0.532 (Table 4). Lower results regarding oil contents (-0.315; 0.28) and higher in relation to productivity (0.377; -0.41) were obtained by Menzir (2012).

Positive correlations and homogeneity regarding the productivity and oil quality characteristics were observed between the sesame cultivars and the experimental treatments, which were distributed in three groups (Figure 1). In groups 1 and 3, treatments of cotton cake (TA), bovine manure (EB), goat manure (EC), mammon cake (TM), ammonium sulphate (SUA) and controls (T) applied to the sesame variety 'CNPA G4' and 'BRS Seda' present the highest values of the variables related to the second principal component, i.e., AV, OAV and PV. Group 2, which includes the 'BRS Seda' variety, showed similarity between the BTM, BTA, BEB and BEC treatments, with the lowest scores in the second principal component and the highest scores in the first principal component (Figure 1). Maia Filho *et al.* (2013) using bovine manure obtained similar results.

Conclusions

- The sources of organic fertilizers used in the experiment may be indicated for the sesame crop, especially goat manure.
- The quality of the seeds and the sesame oil are inversely related to the moisture content and the acidity presented, respectively.

- The high oil content obtained in this experiment is indicative of the feasibility of commercial extraction.

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