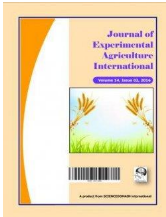

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Effect of Different Doses of Magnesium Sulphate Monohydrate on Productivity of Oil Palm

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Authors' contributions

This work was carried out in collaboration between all the authors. Authors SSO, ECMS and MRSS designed, performed a statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NKC, HGAR, JLSA and GMA were able to analyze the study. The author WTSL managed the bibliographic research. All authors read and approved the final manuscript.

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ABSTRACT

Objectives: The objective of this work was to evaluate the effect of doses of magnesium sulphate monohydrate for increased productivity in the cultivation of oil palm.
Location and Duration of Study: The experiment was conducted in the Company Marborges, located in the municipality of Garrafão do Norte, State of Pará, Brazil, during 2014 to 2015.

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Methodology: The experiment was laid out in randomized block design, consisting of five treatments *viz*., magnesium sulphate monohydrate @ 0 g plant^{-1}, 500 g plant^{-1}, 1000 g plant^{-1},1500 g plant^{-1} and 2000 g plant^{-1} with three replications. Soil samples were collected from two depths i.e., 20 and 40 cm before the treatments imposition for laboratory analysis. After soil sample collection, treatments were applied manually twice, with an interval of 6 months. The harvests of fresh fruit bunches were manually performed every fifteen days within a period of two years being evaluated the sum of the number of bunches of fresh fruits produced by treatment; bunch weight of fresh fruit (Kg) and productivity (t/ha/year). Performed analysis of variance year level of 5% probability and for variables whose F was significant regression analysis.

Results: The superficial application of magnesium sulphate monohydrate to the root zone of the treated plants promoted a significant increase in the level (P<0.05) probability of error, the dose of 1500 g plant^{-1} provided an increase of 12% for the variable number of bunches of fresh fruit. With respect to the variable weight of fresh fruit, bunches were unable to calculate the best dose for the increase in weight was 1370 g plant^{-1}.The dose of 1000 g plant^{-1} provided a 15% gain for the variable fresh fruit weight when compared to the control. For the variable productivity, this dose had a significant effect ($P<0.05$), when compared to dose 0.

Conclusion: This study showed that the superficial application of $MgSO_4$ had a significant positive effect on the oil palm crop, improving nutrition in Mg and S, allowing an increase in the number and weight of fresh fruit bunch, which increased crop productivity. In the conditions studied, the ideal dose obtained by means of the derivative of the first equation was 1333 g plant^{-1} being between 1000 and 1500 g plant^{-1}.

Keywords: Fertilisation; oil palm; magnesium; oleaginous plant.

1. INTRODUCTION

The oil palm (*Elaeis guineensis*) has its centre of origin of the African continent, but has been cultivated in the Amazon region because of its similar climatic characteristics. According to Gomes et al. [1] the fruits of the palm oil are used to extract the oil from their mesocarp and core, palm oil and palm tree kernel oil, both of which have great potential for the food, cosmetics and more recently efficiency, which is arousing great interest cost by culture in the internal and external market. In this context it is emphasised the importance of the cultivation of this commodity in agro-industrial sector, because it is considered the largest oilseed production of oil per area planted, reaching a productive potential ten times greater than the productivity of soybean, main raw material for the production of biodiesel in Brazil in the same planted area [2].

According to Foong et al. [3] oil palm is one of the most important oil palm trees in the world, considering that, compared to other crops such as sunflower and soybeans, the yield in vegetable oil for the same area planted is 10 times higher in oil palm [4]. This commodity is responsible for about 30% of vegetable oil produced worldwide [3].

Brazil has a large area with an agricultural aptitude for the cultivation of oil palm, approximately 70 million hectares where the planting of this oilseed has been carried out. [5]. In the year 2016, the Brazilian production was 340 thousand tons of palm oil, which shows the Brazilian potential for the increase of production of this commodity [6].

However one of the limiting factors for the cultivation of oil palm is low natural fertility of the soils of the region, since they present characteristics of acid reaction, with low values of pH and high levels of aluminium which limits directly the absorption of nutrients by the plant, being needed higher doses of fertilisers with the objective of ensuring the vegetative development of oil palm tree and adequate productivity of clusters [7]. In addition, the continuous use of fertilisers with formulations of N-P-K (nitrogen, phosphorus and potassium), which does not contain Mg in their formulations and not performing the practice of liming has aggravated problems of nutritional deficiency with magnesium in oil palm plantations in the region.

According to Cakmak and Iazici [8] Mg deficiency is considered a worrisome factor since Mg plays important roles in photosynthetic reactions in the plant as an example of the metabolic processes and the particular reactions influenced by Mg, among which we can mention photophosphorylation (such as the formation of ATP in chloroplasts); the photosynthetic fixation of carbon dioxide (CO_2); protein synthesis; chlorophyll formation; loading of phloem; separation and use of photoassimilates; generation of reactive oxygen species and photooxidation in leaf tissues [9]. For all these important functions within the plant, Mg is considered as one of the nutrients most required by the crop for a better vegetative development and gains in productivity even under conditions of low soil fertility [10].

For the conversion of sunlight into carbohydrates, the oil palm needs a large amount of Mg^{+2} so that these photosassilates are mobilised to the fruit bunches and are converted into oil by the plant. Admit that an efficient supply of Mg^{+2} in a wide variety of deficient soils can ensure an adequate root development and by consequence, improve the uptake of water and nutrients and here is its productive productive [11]. Thus, the objective of this work was to evaluate the effects of rates of magnesium sulphate monohydrateon weight and number of fresh fruit bunches, and yield of oil palm.

2. MATERIALS AND METHODS

The experiment was conducted in the municipality of Garrafão of North, State of Pará, Brazil, west between the coordinates of latitude 1°55'59'' S and longitude 47°2'59'' W at an altitude of 56 meters [12]. According to the classification of Köppen, the climate of the region is tropical of altitude (AMI), the local soil characteristic of an alic Yellow Latosols [13]. The site chosen for the implementation of the experiment was in an area of commercial plantations belonging to company Marborges (01°57'42'' S and 47°00'53'' W) with plants already in productive age (3 years of age) cultivar BRS C 2501, type Tenera.

2.1 Product Used

The fertiliser used in the experiment was magnesium sulphate monohydrate (kieserite granular) with chemical formulation ($MgSO_4H_2O$) originated in the deposits of salt from Germany, purchased from company K+S Kali Brasileira. According to Carvalho et al. [14] the magnesium sulphate monohydrate granular form, is an excellent product with 25% of Mg and 20% of S are soluble in water, with excellent properties of spread because of their characteristic shape and hardness of the granules.

2.2 Experimental Design, Treatments and Variables Studied

The experiment was selected in field conditions in area of cultivation of three years of age with an area of approximately 2.6 ha^{-1}. The spacing between two adjacent plants was 7.8 m, and between plants 9 m in the form of an equilateral triangle, and planting density of 143 plants ha^{-1}.

The treatments were composed by the control (without application of $MgSO_4$) and 4 doses of magnesium sulphate monohydrate soil application. Description of the treatments used in the palm tree oil area, where: T1 = $MgSO_4$ (g $plant^{-1}$) 0, Mg (g $plant^{-1}$) 0, S (g $plant^{-1}$) 0; T2 = $MgSO_4$ (g $plant^{-1}$) 500, Mg (g $plant^{-1}$) 125, S (g $plant^{-1}$) 100; T3 = $MgSO_4$ (g $plant^{-1}$) 1000, Mg (g $plant^{-1}$) 250, S (g $plant^{-1}$) 200; T4 = $MgSO_4$ (g $plant^{-1}$) 1500, Mg (g $plant^{-1}$) 325, S (g $plant^{-1}$) 300; T5 = $MgSO_4$ (g $plant^{-1}$) 2000, Mg (g $plant^{-1}$) 500, S (g $plant^{-1}$) 400, magnesium sulphate monohydrate ($MgSO_4$ H_2O - 25% Mg and 20% S).

The treatments were applied in plots, the first application being on June 22 and the second on July 22, 2014. The applications were carried out with the objective of manually and uniformly transporting the fertiliser distribution on the root growth zone of the plants palm oil. Thirty days before the application of treatments of the experiment, soil sampling was done to analyse the layers 0-20 and 20-40 cm) for the determination of the chemical attributes (Table 1). These collections at random in line with the projection of planting (CUP) and in the middle of the Inter-rows. Procedures for the withdrawal of soil samples were carried out in accordance with Cloves et al. [15] and the samples sent to the laboratory for analysis of soil.

During the conduct of the experiment, the cultural and phytosanitary treatment were made by the Company in accordance with the necessity of culture, having been performed the fertilisation recommendation for all evaluated treatments: MAP (12-54-00) 500 g $plant^{-1}$ (188 Kg); potassium chloride (KCl) 700 g $plant^{-1}$ (263 Kg); boric acid (10% (B)100 g $plant^{-1}$ (38 Kg).With the objective of evaluating the annual income, harvests were carried out manually, every fifteen days, being evaluated the sum of the number of bunches of fresh fruits produced by treatment; bunch weight of fresh fruit CFF (Kg) and productivity (t ha^{-1} $year^{-1}$).

Table 1. Chemical characteristics of samples of soils (Yellow Latosol (Oxisol) at 0-20 and 20-40 cm depths before the installation of the experiment

Feature	Unity	Depth of soil layer (cm)			
		Cup projection(1)		Interline(2)	
		00 -20	20 -40	00 -20	20 -40
pH (1)	cmolc dm^{-3}	3,7	3,8	3,8	3,9
Al (2)	cmolc dm^{-3}	0,6	0,4	0,3	0,5
H+ Al (3)	cmolc dm^{-3}	3,4	3,8	3,4	3,8
Ca (2)	cmolc dm^{-3}	0,2	0,2	0,2	0,2
Mg (2)	cmolc dm^{-3}	0,1	0,1	0,1	0,1
K(4)	cmolc dm^{-3}	0,07	0,05	0,07	0,07
Cátion exchange capacity pH 7,0	cmolc dm^{-3}	3,8	4,2	3,8	4,2
Base saturation	%	10	8	10	9
Saturation by Al	%	62	53	45	57
P (4)	mg dm^{-3}	1	1	2	1

(1)pH in $CaCl_2$; relationship 1:2.5. (2)Extractor KCl 1 mol $^{L-1}$. (3)Extractoracetate Ca 0,5 mol $^{L-1}$ pH 7,0. (4) Extractor Mechilch $^{-1}$

Projection of the copa: Collect held in the middle of the area of projection of the canopy[1]; Collect held in the middle of rows of crops[2]

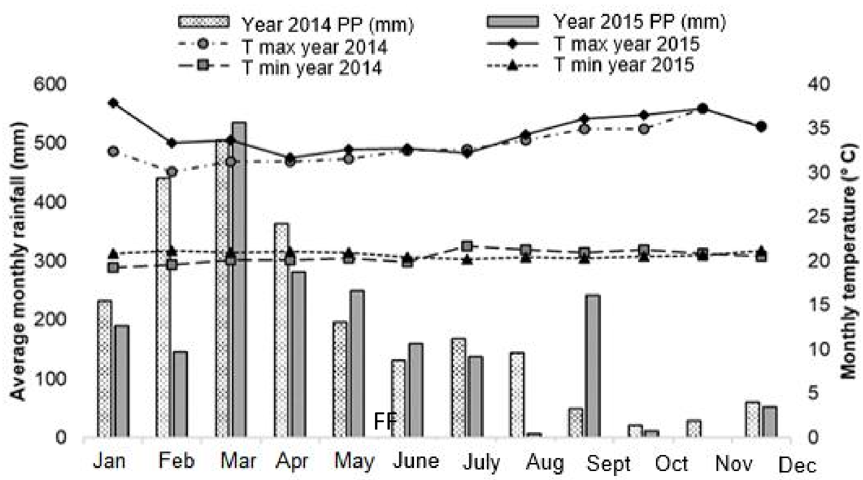

Fig. 1. Averagemonthly temperature and precipitation during 2014 and 2015 in Garrafão of north-PA, Brazil

Source: Marborges, 2014

The climatic data during the period of the experiment was collected from the Marborges company. The maximum and minimum temperatures were measured with the aid of a Digital Thermo-Hygrometerand rainfall, with the aid of the Tank Class A. The data obtained were made available by the company and are presented in Fig. 1.

2.3 Statistical Analysis

The results were submitted to analysis of variance, and when F was significant, we carried out regression, at 5% of probability to evaluate the effect of doses magnesium sulphate monohydrate on productivity of oil palm. The analyses were performed using the statistical program Assistat [16].

3. RESULTS AND DISCUSSION

We can observe that the municipality of Garrafão of North presents little variation in ambient temperature, while that in terms of rainfall, there is variability in the rainy period with periods of high rainfall and others with little rainfall. For the period assessed, it could be inferred that there was no limitation with respect to temperature for the culture, since the minimum value found was not less than 20°C and 37°C. With regard to rainfall, it was observed that in the year 2014 the months of June, August, September, October, November and December had less than 150 mm rainfall per month. However, the annual sum for the same year was 2,341 mm, being in the range adequate for the crop. With respect to the year 2015 this rainfall variation was even greater for the second half of 2015, except for the month of September, the annual sum was equivalent to 2,003 mm.

It emerged as the soil analysis, before the application of $MgSO_4$, for the interpretation of the results, was taken as base the data offered by Carvalho et al. [14] used in the state of Pará, Brazil it was possible to observe that in general the soil where the experiment characterised by acidic pH values below 5.0, i.e., soils with high acidity in both depths evaluated, besides presenting nutritional content of nitrogen, phosphorus, potassium and magnesium mainly far below the ideal in soil exchangeable phase (<0.2 cmolc/dm^{-3}). Another characteristic of the utmost importance in plant nutrition is the base saturation (V%) which must be in the range of 45% for the cultivation of oil palm and the cation exchange capacity of the soil (CEC), which to the area of the experiment were far below the desired for culture.

3.1 Income Productive Harvest Year 2015

The improvement in the chemical characteristics of the soil in the experimental area harvest year 2015, with the superficial application of $MgSO_4$, promoted a significant increase ($P<0.05$) for the number of bunches of fresh fruits per plant in relation to the control treatment. As the weight of the bunches has increased, the productivity consequently increases because they are interconnected the two. Furthermore, it was observed an increase in the number of bunches of fresh fruit produced by the plant for all doses of $MgSO_4$, but the dosage of 1500 g plant^{-1} allowed an increase of 12% in the harvest year of 2015 in relation to the control treatment. The addition of fertilisers thermophosphate contributed to the income of the number of bunches in the cultivation of oil palm, in this study, it was observed a correlation coefficient of 0.79, adjusting the linear equation, it is possible to determine the optimal dose for this variable (Fig. 2).

The regression analysis, performed with the doses (0, 500, 1000, 1500 and 2000 g plant^{-1}) of magnesium sulphate monohydrateenabled a quadratic adjustment for the variable weight of bunch of fresh fruit for the cultivation of oil palm tree (Fig. 3). By means of the parameters of the equation shown in Fig. 3 it was possible to calculate the maximum dose by the method of the derived from the first equation for the variable weight of bunch of fresh fruit. The ideal dose was 1370 g $MgSO_4$ plant^{-1} (342 g plant^{-1} Mg and 274 g plant^{-1} S), for the conditions observed in this experiment, the ideal dose remained in the range of 1000 to 1500 g plant^{-1}. With respect to the increment for the weight variable bunch of fresh fruit, it was observed that the dose of 1000 g plant^{-1} allowed an increase of 15% for the variable weight of bunches of fresh fruits produced by Palm tree. These doses provided 250 to 325 g plant^{-1} Mg and 200 to 300 g plant^{-1} of S, therefore catering for the cultivation of oil palm.

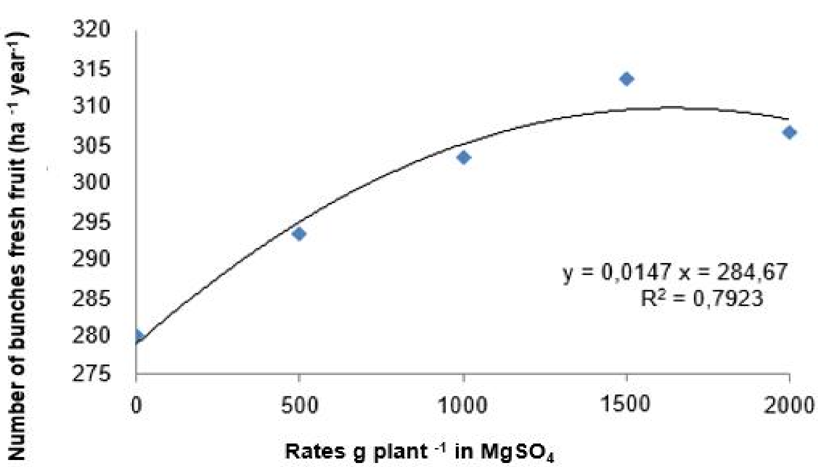

Fig. 2. The number of bunches of fresh fruit in function of the superficial application of dosageof magnesium sulphate monohydratein the cultivation of oil palm tree

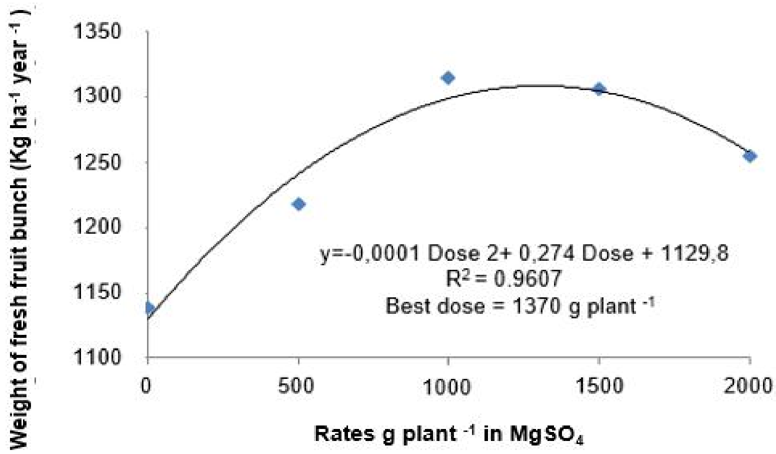

Fig. 3. Weight of bunch of fresh fruit in function of the superficial application of dosage of magnesium sulphate monohydratein the cultivation of oil palm tree

The use of magnesium sulphate monohydrate also provided increment in other cultures among which we can mention the maize [17], potatoes and sugar beet [18]. According to Wang et al. [19] evaluating areas of coffee production in Africa observed increases in production of arabica coffee in relation to the increase in the Mg content in the soil, and consequent increase in the production of coffee to provide greater dose of magnesium plants.

The application of magnesium sulphate monohydrate granulated was positive in productivity of oil palm tree, presenting statistically significant (*P<0.05*), with a high correlation coefficient of 0.96, which allows us to affirm that the yield obtained in the oil palm harvest year 2015, was influenced by the supply of Mg and S in the soil and consequently in the plant. The model was adjusted by the quadratic regression was, since it was observed a linear increase of absorption by the plant until the dose of 1000 g $plant^{-1}$ $MgSO_4$ (equivalent to 250 g $plant^{-1}$ Mg and 200 g $plant^{-1}$ of S), but the journey this dose, there was a decrease of absorption of the plant with the application of higher quantities, possibly due to the occurrence of interactions of Mg and S with other nutrients in the soil solution and in the plant. For obtaining the ideal dose obtained was necessary to the achievement of the derivative of the first equation, which allowed to describe the behaviour of the variable, up to a maximum dose of adsorption of 1333 g $plant^{-1}$ (equivalent to 333 g $plant^{-1}$ Mg and 267 g $plant^{-1}$ of S). The ideal dose remained between the doses of 1000 and 1500 g $plant^{-1}$. Equivalent to 143 and 214.5 kg ha^{-1}.

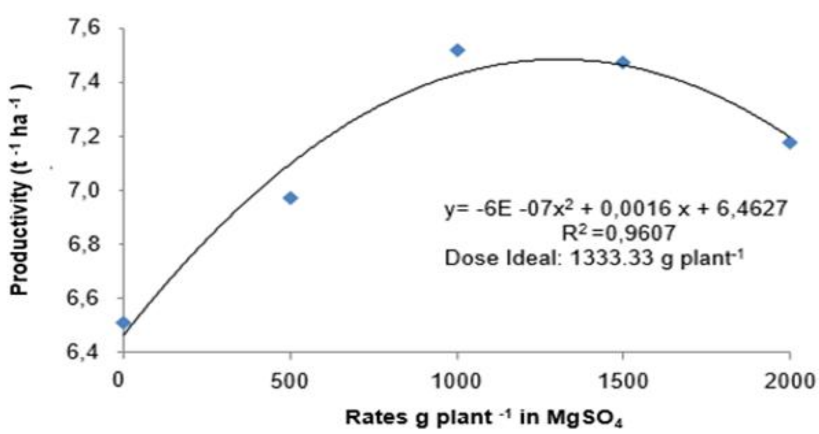

Fig. 4. Productivity in function of the superficial application of dosage of magnesium sulphate monohydrate in the cultivation of oil palm tree

Similar results were found by Carvalho et al. [14]. In an experiment with the cultivation of cotton, obtained answers with high significant correlation 0.97, for the number of pit and feathers in function of the application of $MgSO_4$. According to Taiz and Zeiger [20] the increase of the doses of $MgSO_4$ in soybean cultivars provided high production of total dry matter on the plants, and also an increase in leaf area, volume of roots, the contents of chlorophyll and total carotenoids. It is worth noting that there was an increase in productivity of the order of 15 and 14% for the doses 1000 and 1500 g $plant^{-1}$ respectively, with the application of magnesium sulphate monohydrate. It is observed that the magnesium fertilisation has increased the productivity of plantations, in the experimental area of the company in the municipality of Marborges Garrafão of North -PA, which translates into an important tool in conducting the management of fertilisation of plantations of oil palm in the region, assigning gains to the producer.

The Mg directly influences the productive yield of the plants, because its deficiency reduces the distribution of carbohydrates to the roots, damaging them, which leads to a disproportionate increase in the dry mass ratio of the area and root [8]. This causes the increase of the sucrose in the leaves and reduction of the flow and export of photoassimilates in the aerial and root direction. This hinders the vegetative growth and productive yield as it directly changes the photosynthetic rate by reducing the use of light energy by the plant.

The Mg is central constituent of the molecule of chlorophyll, the photosynthetic pigment responsible for the capture of incident solar energy, needed for photosynthesis. The ions free of Mg^{2+} stabilise the membranes and also play role of enzyme activator of important enzymes as ATPases and ribulose-1,5-bisphosphate carboxylase/oxygenase (RUBISCO) [21,22]. In addition, this nutrient is important in the stacking of granas in chloroplasts [23,24]. These functions in the plant exerted by Mg may adversely affect the photosynthetic performance of plants [25]. The Mg also affects the nodulation of activities of ribulose 1-5- bisphosphate-carboxylase oxygenase in the stroma of the chloroplast, and in this case the activation of enzymes dependent on Mg and pH. The connection of the mg with the enzyme increases affinity for CO_2 and doubles the rate of maximum speed of reaction, interfering directly in the photosynthesis performed by plant [22].

When the plant is properly nourished, in addition to expressing its genetic yield potential, can also be more efficient in the absorption and use of water from the soil'and the absorption of nutrients [23]. Gomes and Bars [24] reported that when the soil is naturally acidic, it has a high content of Al^{3+} exchangeable in subsurface layers, thus contributing to the reduction of root depth. According to Gomes et al. [1] in the palm, the roots responsible for the absorption of nutrients and water, concentrate in layers of 0-20 and 20-40 cm of soil, these characteristics are important for the handling of mineral fertilisers, the magnesium sulfate, is a source that contains Mg and S are soluble in water, the sulfateion SO_4^{2-} form ion pairs in the soil, thus have the reduction of Ca^{2+} by the formation $AlSO_4$ less toxic to the plants [25].

The results observed in this study for the number of fresh fruit bunches, bunch weight and productivity in response to $MgSO_4$ application is due to the fact that African palm oil has a high demand for Mg, since the mobilisation of carbohydrates to the bunches and its conversion into lipids in fruits is highly dependent on this nutrient. In addition, Mg plays an important role in the root growth of plants, therefore in unfavourable environments, as in soils of low natural fertility, the root growth of this crop can improve the assimilation of water and nutrients [25].

4. CONCLUSION

This study showed that the superficial application of $MgSO_4$ had a significant positive effect on the oil palm crop, improving nutrition in Mg and S, allowing an increase in the number and weight of fresh fruit bunch, which increased crop productivity. In the conditions studied, the ideal dose obtained by means of the derivative of the first equation was 1333 g $plant^{-1}$ being between 1000 and 1500 g $plant^{-1}$.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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