Production of oil palm under phosphorus, potassium and magnesium fertilization[1]

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ABSTRACT

Oil palm production is strategic in the Amazon with high productive potential, but information on its fertilization is still relatively scarce for the region. The objective of this work was to evaluate the effects of phosphorus, potassium and magnesium fertilizations on oil palm production in different years in the state of Pará, Brazil. The study was conducted in Tailândia, Northeastern of Pará, Eastern Amazon, Brazil. A randomized block design was used in a 4 x 2 x 3 x 2 factorial scheme, with four levels of phosphorus, two sources of phosphorus, three levels of potassium and two levels of magnesium. Oil palm production responded positively to the increase in phosphorus levels, and until the eighth year of age of the plants, there was greater production when triple superphosphate was applied. From the ninth year onwards, fertilization with phosphine provided a production equal to the supply of phosphorus with triple superphosphate. The application of potassium chloride increased the number, weight and production of the bunches from the sixth year. The supply of magnesium sulfate increased the average weight of the bunches. Thus, phosphorus, potassium and magnesium fertilizations become essential to increase oil palm production in the Northeast of Pará.

Keywords: *Elaeis guineensis* Jacq.; Amazon; oilseed; fertilizers.

INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) is widely cultivated in the Eastern Amazon with high productive potential. The crop has an economically viable exploitation period of 25 years, reaching a maximum productivity of 25 t ha^{-1} year^{-1} of bunches to the eighth year of cultivation, resulting in 4 to 6 t ha^{-1} year^{-1} of oil (Franzini & Silva, 2012).

In tropical regions, soils with low natural chemical fertility are generally found (Lopes & Guilherme, 2007), however, increasing productivity requires higher nutrient extraction rates (Matos *et al.*, 2016). The nutrients available in the solution of tropical soils are insufficient to supply the oil palm's nutritional demands, requiring fertilization and correction practices to overcome such limitations (Priyandari *et al.*, 2017). Fertilization provides nutrients in sufficient levels to stimulate vegetative growth and make it possible to achieve maximum crop productivity (Budiargo *et al.*, 2015). Fertilization practices are important in decision making in commercial oil palm plantations, being responsible for 40 to 60% of maintenance costs (Priyandari *et al.*, 2017).

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The fertilization efficiency is an essential parameter to observe, since it will determine the percentage of fertilization that is actually used by plants (Budiargo *et al.*, 2015). The nutritional demand of oil palm changes according to the phenology of the plant, changing the amount of fertilizers in the different growth phases (Franzini & Silva, 2012), indicating the importance of crop long-term research. Pacheco *et al.* (1985) developed pioneering work in Pará state on the effects of fertilization on oil palm cultivation. However, the knowledge of fertilizer efficiency is still limited, requiring studies that enable greater understanding to achieve better fertilization plans, capable of guaranteeing higher yields for oil palm (Nunyai *et al.*, 2016).

The efficiency of phosphorus fertilization is essential to oil palm, since the P deficiency is able to decrease the crown, produces smaller bunches, trunks with smaller diameters and decreases the crop production (Uexkull & Fairhust, 1991). Also, the source of the fertilizer is a strategic factor for the management of phosphorus fertilization, mainly for its solubility and efficiency, capable of altering the availability of P and the cost of fertilization (Chien & Menon, 1995). In this sense, there are soluble phosphates, such as triple superphosphate, and natural phosphates (Ferreira *et al.*, 2020), such as phosphine, which need to be evaluated for their efficiency in meeting the nutritional demands of P and increasing long-term productivity of the oil palm harvest.

Potassium fertilization is essential for oil palm, mainly because of its relationship with fruit formation, since greater availability of K is able to increase the oil content and decrease the water content in the fruits' mesocarp (Mirande Ney *et al.*, 2019). For magnesium fertilization, there is an increase in the production of bunches of oil palm due to the application of higher levels of Mg (Oliveira *et al.*, 2019).

The aim of the current research was to evaluate the effects of phosphorus, potassium and magnesium fertilizations on oil palm production in the edaphoclimatic conditions of Tailândia, Pará state, Brazil.

MATERIAL AND METHOD

The experiment was conducted in the municipality of Tailândia, Pará state, Brazil, at the company AGROPALMA (2 ° 56 ‘50’ ‘S and 48 ° 57’ 12 ‘’ W) for a period of 12 years. The municipality has a rainy tropical climate without seasonal variation (type Am) according to the Köppen classification (Köppen, 1918). Temperatures during the study period ranged from 21 to 32.5 ºC and the average annual rainfall was 2,463 mm. During the experimental period, rainfall (Figure 1) was measured using a rain gauge installed at AGROPALMA.

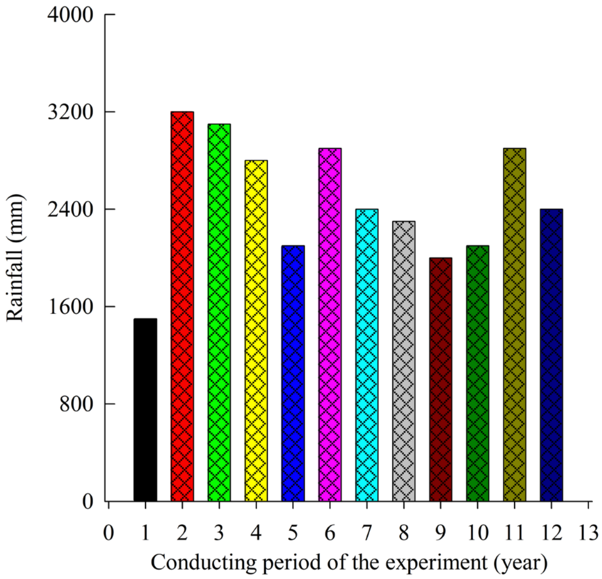

Figure 1: Rainfall (mm) occurred during the period of conducting the experiment at AGROPALMA.

In Tailândia, the dystrophic Yellow Latosol, acid and with low natural chemical fertility predominates (Rodrigues *et al.*, 2005). Before the installation of the experiment, soil granulometry (610 g kg^{-1} of sand, 150 g kg^{-1} of silt and 240 g kg^{-1} of clay) was evaluated (layer 0 - 0.2 m), classifying it as of loamy sandy texture. The chemical characteristics of the soil were measured in a composite soil sample (at 0.3 m depth) obtained of 30 simple samples (Table 1), characterized by low natural fertility (Brasil & Cravo, 2020). Chemical and granulometric analyzes of the soil were carried out in the laboratory of the Institut de Recherches pour les Huiles et Oléagineux.

Table 1: Chemical characteristics of the soil (0 - 0.3 m) of the area before the installation of the experiment

pH	SOM**	$P_{available}$*	P_{total}	K*	Ca^{+2}*	Mg^{+2}*	Al^{+3}
(H_2O)	g kg^{-1}		---------- mg dm^{-3} ----------			----- cmol$_c$ dm^{-3} -----	
5.20	16.4	12	89	15.6	2.38	0.50	0.02

*extracted with ion exchange resin. ** colorimetric method. SOM - Soil organic matter.

The preparation of the area included the removal of natural vegetation and the burning of plant residues. The swath was mechanized, forming a windrow for every six rows of the oil palm plantation. The soil cover was performed at the beginning of the experiment with the planting between the lines of the oil palm with the legumes *Pueraria phaseoloides* (Roxb.) Benth., *Calopogonium mucunoides* Desv. and *Centrosema pubescens* Benth.

The experimental design used was in randomized blocks, in a 4 x 2 x 3 x 2 factorial scheme, with four levels of P, two sources of P, three levels of K and two levels of Mg. The sources of P, K and Mg used were, respectively, triple superphosphate (45% P_2O_5 and 10% OCa) and phosphine (natural phosphate; 33% P_2O_5 and 42% OCa), potassium chloride (60% K_2O) and magnesium sulfate (18% Mg) (Table 2). Before applying the treatments, a uniform fertilization was carried out throughout the experimental area, with 300 kg ha^{-1} of partially acidulated natural phosphate (27% total P_2O_5). The nitrogen mineral fertilization was carried out from the application of 150, 300 and 500 g plant^{-1} in the form of urea between the first and the third year of cultivation, respectively, while the boric fertilization was carried out with 100 g plant^{-1} of borax to the fifth year of cultivation. Nitrogen fertilization was carried out only in the first three years of vegetative growth of the plants (young phase), later the N supply was carried out only by green fertilization (intercropping with legumes), while B and increasing doses of P, K and Mg was up to the first year of the reproductive phase (5th year old) (Table 2).

Table 2: Levels, sources and years of application of fertilizers used in the treatments of the experiment

Year	Sources of P ** (g plant^{-1})								KCl (g plant^{-1})			$MgSO_4$ (g plant^{-1})	
	F0				F1								
	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	K_0	K_1	K_2	Mg_0	Mg_1
0*	250	500	700	1000	200	400	600	800	0	300	450	0	300
1	250	500	750	1000	200	400	600	800	0	500	750	0	500
2	250	500	750	1000	200	400	750	800	0	1000	1500	0	1000
3	250	500	750	1000	200	400	600	800	0	1500	2250	0	1000
4	250	500	750	1000	200	400	600	800	0	2000	3000	0	1000
5	250	625	1000	1375	200	500	800	1100	0	1500	3000	0	1000
6 to 12	250	750	1250	1750	200	600	1000	1400	0	1600	3200	0	1200

*Another 300 kg/ha of acidulated natural phosphate throughout the area; ** F_o = Phosphine (33% P_2O_5 and 42% OCa) and F_1 = Triple superphosphate (45% P_2O_5 and 10% OCa).

The genetic material used was the hybrid DELI x La Mé (Category C), from the La Mé research station of the Institut de Recherches pour les Huiles et Oléagineux. The oil palm seedlings remained for a period of six months in pre- nursery and three months in the nursery. The pre-nursery was characterized by transplanting the germinated seed to a small plastic bag (0.023 m³), while the nursery was characterized by transplanting the seedling to a large plastic bag (0.16 m³). The experiment used spacing in an equilateral triangle of nine meters in quincunx (9 m between plants and 7.80 m between lines), totaling 143 plants ha^{-1}. The experimental plots were composed of six lines with nine plants each, evaluating only the twelve central plants.

Plant responses to fertilization were evaluated based on the average number of fresh fruit bunches per plant (NB), average weight of fresh fruit bunch (WB) and production of fresh fruit bunches (PB) (t^{-1} ha^{-1} year^{-1}). The results obtained were subjected to analysis of variance and, when significant, compared by the Tukey test ($p < 0.05$) for the factors of P sources and the levels of K and Mg. For P levels, regression models were adjusted using the statistical software Sisvar (Ferreira, 2011).

RESULTS AND DISCUSSIONS

For the average number of fresh fruit bunches per plant (NB), there were quadratic responses to the increase in P levels (Figure 2). The estimated P levels that provided greater increases in NB for young oil palm plants were 580 and 679 g plant^{-1} at the third and fifth year of age, reaching 6.25 and 16.55 bunches, respectively. In the production phase, the maximum increase in NB was estimated by the level of 620 g plant^{-1} of P_2O_5 (average from the sixth to the twelfth year).

A study carried out with oil palm in the municipality of Tailândia (Pará state) indicated that there was also a higher NB with phosphate fertilization (Viégas *et al.*, 2019). These authors found NB similar to the current study, with a variation in NB from 9.8 to 17.1 up to the sixth year and, from 5.5 to 10.5, between the seventh and twelfth year of age of the plants. The low levels of available P in Amazon soils make this nutrient the main limiting factor for oil palm cultivation in the region, and its low availability is able to promote the reduction of bunches production (Rodrigues *et al.*, 2010).

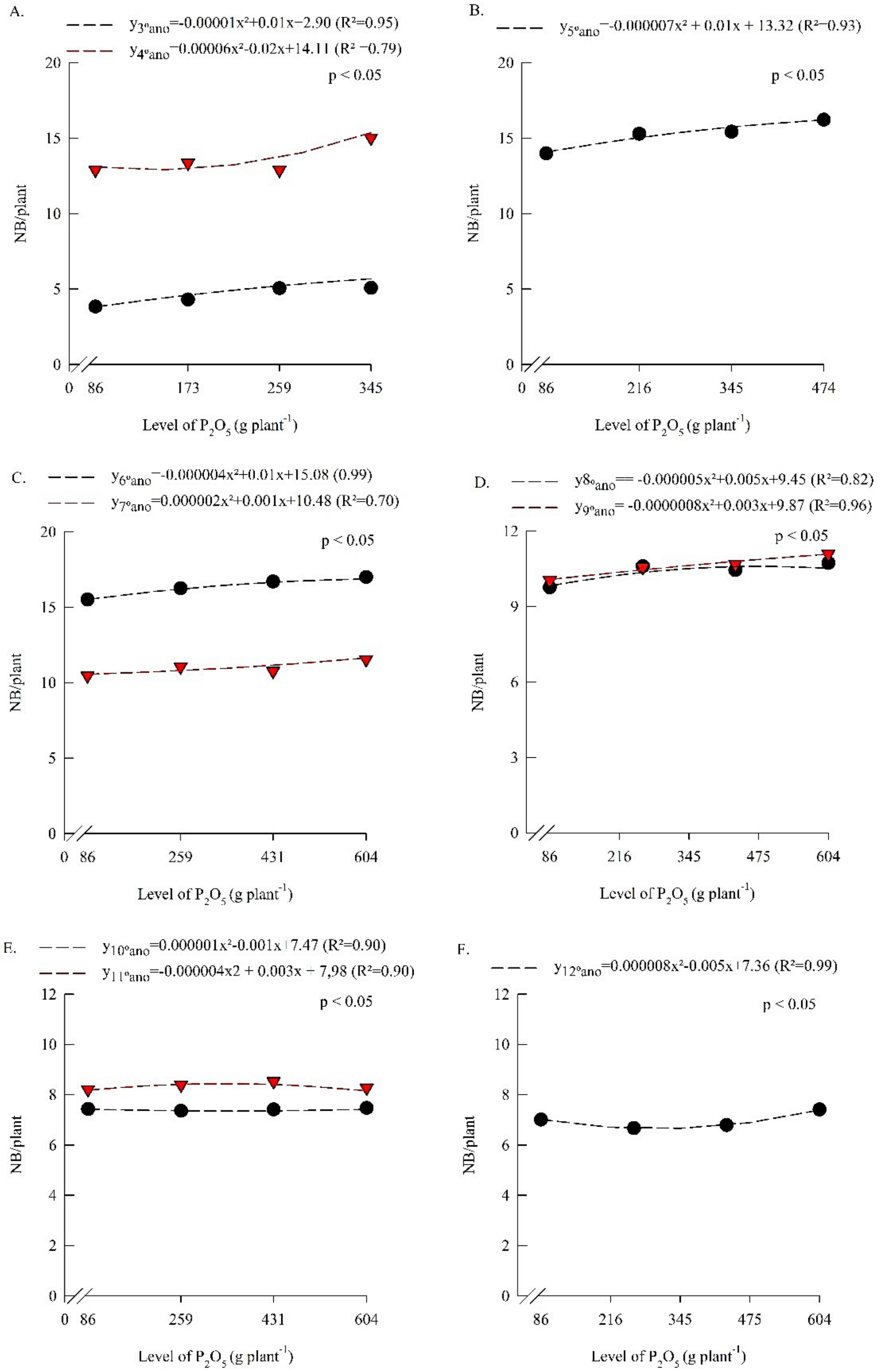

Figure 2: Effect of P levels on the average number of fresh fruit bunches (NB) $plant^{-1}$ in the third and fourth (a), in the fifth (b), in the sixth and seventh (c), in the eighth and ninth (d), in the tenth and eleventh (e) and twelfth (f) years of age of the oil palm.

A study carried out in oil palm plantations estimated the nutritional demand for P at 12.4 kg ha^{-1} year^{-1}, 3.1 kg ha^{-1} year^{-1} for losses of P through leaching, erosion and runoff and in 3.2 kg ha^{-1} year^{-1} of immobilized P (Tarmizi & Mohd Tayeb, 2006). According to Franzini & Silva (2012), applications of adequate levels of P are essential to oil palm cultivation, especially in the Amazon region, which has soils with high capacity of fixation this nutrient and that P has a synergistic effect with other nutrients, mainly with N. This fact indicates the need for fertilization with higher levels of P in tropical soils, corroborating the positive results of applying higher levels of the nutrient in this research. In addition, phosphorus nutritional management is essential for higher NB yields, as P performs functions related to the structural aspect and to the energy transfer and storage process, in its deficiency, it results in the accumulation of potential chemical energy, resulting in a lack of energy via adenosine triphosphate (Prado, 2021). In this scenario, phosphate fertilization increases the energy efficiency of plants, resulting in an increase in the biosynthesis of photoassimilates and, consequently, directing the gain of photoassimilates to produce clusters. The effects of P supply on plant nutrition and productivity increase are more evident in weathered tropical soils, since these soils naturally have low availability of the nutrient due to its high adsorption to Fe and Al oxides (Novais *et al.*, 2007).

The NB of oil palm submitted to different sources of P in the third, fifth and sixth year was higher with the application of triple superphosphate (F1). However, in the other years of evaluation (seventh to twelfth year of age of the plants), there was no difference in the NB between the sources of P applied (Figure 3a).

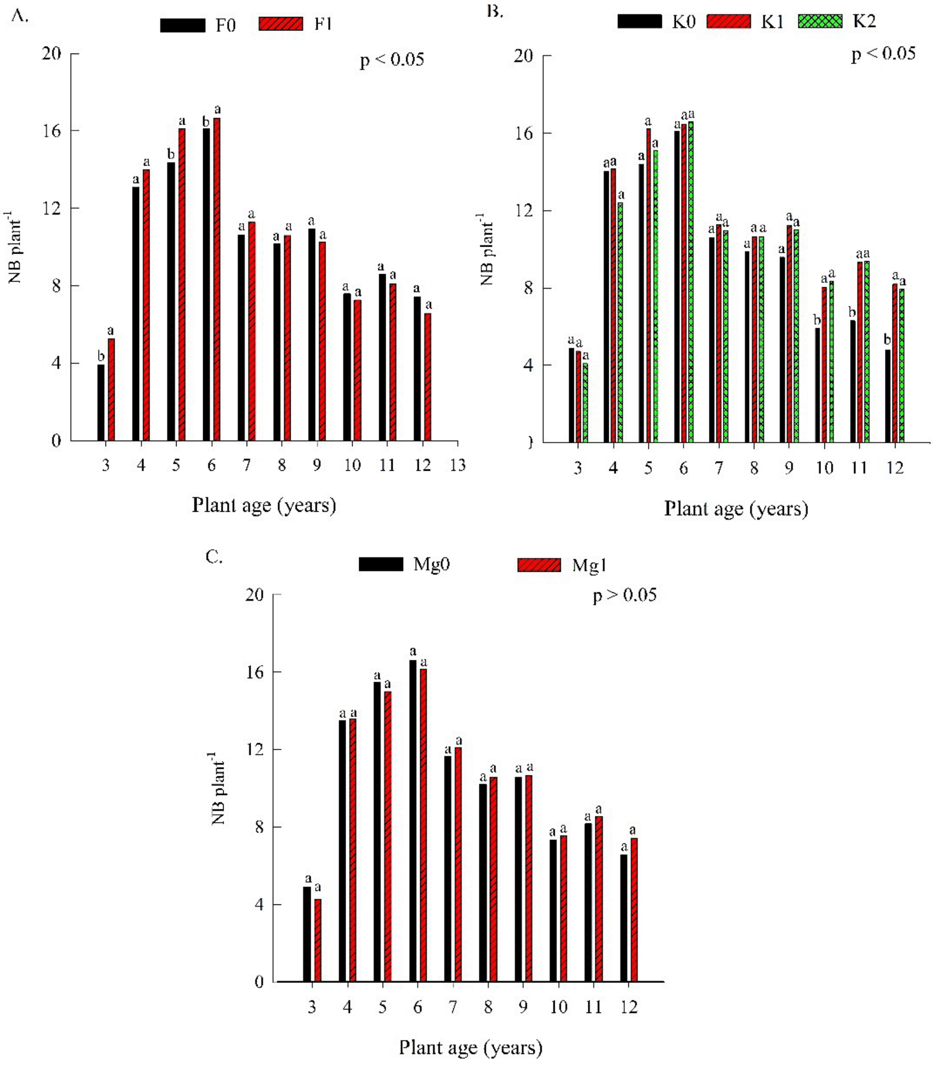

Figure 3: Effect of P sources, FO-phosphine and F1- triple superphosphate (a), and of K (b) and Mg (c) levels on the average number of fresh fruit bunches (NB) plant^{-1} among the third and the twelfth year of the oil palm. Equal letters in the columns, comparing fertilization sources and levels at each age of the plants, are considered statistically equal by the Tukey test ($p > 0.05$).

The results of the current study corroborate with the literature; higher NB production is observed in the first years of production, when F1 is used, since it presents faster P release compared to phosphine (F0) (Franzini & Silva, 2012). Natural phosphate (phosphine), due to its slower release of P, provided an increase in the production of NB in the later years of cultivation, equaling the production of NB with the application of triple superphosphate. The results obtained with the application of phosphine, which is a non-reactive natural phosphate, igneous, crystalline and of low quality, indicate the viability of using a reactive natural phosphate of high agronomic efficiency with success in commercial oil palm plantations in acidic soils of the Amazon. The acidic soil (Table 1) also favored the dissolution and release of P from natural phosphate and thus the production of NB (Figure 3a).

For the effect of K levels on NB, only in the tenth, eleventh and twelfth year of age of the plants there were higher values with potassium fertilization (K1 and K2) (Figure 3b). Research conducted in Pará state also found a difference in NB only in older plants of oil palm (ninth year of age), but not differing between K levels (Viégas *et al.*, 2019). Thus, the results of the present study corroborate with the literature, indicating the importance of supplying K to oil palm at older ages of production. However, as there was no difference in NB, at this stage of production, between K1 and K2 levels, it is recommended, economically, to apply 1600 g plant^{-1} of KCl (K1). In Pará, the recommendation for potassium fertilization for oil palm in the production phase is based on the export of the nutrient; 2378 g plant^{-1} of KCl (60% K_2O) (Franzini *et al.*, 2020) for the state's average productivity (17 t ha^{-1}) (Homma & Rebello, 2020), considering the planting density of the present study (143 plants ha^{-1}). In other words, the current state fertilization manual recommends a 33% higher K level compared to the current research.

Additionally, the management of K fertilization in oil palm plantations is essential, mainly due to its functionality in plant metabolism, as it is an important enzyme activator, promoting changes in the conformation of molecules to increase the exposure of active sites of binding with the substrate, resulting in an increase in of catalytic reactions and improving substrate affinity (Prado, 2021). In this sense, oil palm plants supplied with K are more efficient in increasing NB (Figure 3b), so they need an adequate K supply.

For Mg fertilization, there was no response on NB (Figure 3c). Similar NB results were obtained by Viégas *et al.* (2019); the supply of Mg in the oil palm cultivation also did not alter the NB. On the other hand, magnesium fertilization in oil palm plants in Garrafão do Norte (PA) provided a positive response on NB in a situation of low concentration of Mg (0.1 cmol$_c$ dm^{-3}) in the soil (Oliveira *et al.*, 2019). In Pará, Mg concentrations in the soil of 0.5 to 1.5 cmol$_c$ dm^{-3} are considered as the average range and values below this range are considered low (Brasil & Cravo, 2020). Thus, the average Mg concentration in the soil (Table 1) explains the lack of response in the NB of oil palm plants to magnesium fertilization (Figure 3c). In acidic tropical soils, Mg is not so strongly adsorbed by clays and organic matter, in addition to the frequent competition in its absorption with H^+, Al^{3+} and Ca^{2+} and, also, its leaching can occur in regions with high rainfall (Lima *et al.*, 2018), such as those verified at the location of the present study (Figure 1). The high rainfall index can decrease the efficiency of nutrient absorption, mainly due to the increase in runoff and the greater leaching of nutrients (Tarmizi & Mohd Tayeb, 2006).

In relation to the average weight of fresh fruit bunch (WB), the application of P provided quadratic responses from third to the eleventh year of age of the plants (Figure 4). For the WB, the maximum increase in young oil palm trees (3 to 5 years old) was reached with the estimated levels of 198, 385 and 336 g plant^{-1} of P_2O_5, reaching 2.11, 5.06 and 4.66 kg bunch^{-1}, respectively. In adult oil palm plants (sixth to twelfth year) the maximum mean increase (11.47 kg bunch^{-1}) in WB was achieved with the estimated level of 584 g plant^{-1} of P_2O_5.

Viégas *et al.* (2019) found that this variable the oil palm responded proportionally to the increase in P levels. The export of P in oil palm plantations was determined at 0.39 and 0.44 kg t^{-1} of Tenera and Dura fruits, respectively (Tarmizi & Mohd Tayeb, 2006). In Pará, the average yield of oil palm fruits is 11.76 t ha^{-1} (IBGE, 2017), promoting an export of 4.59 and 5.17 kg of P through the Tenera and Dura fruits, respectively. In this sense, phosphorus fertilization needs to supply the demand for the nutrient export by the fruits, the immobilization in the vegetal tissues and the fixed P by the soil, besides the losses by runoff.

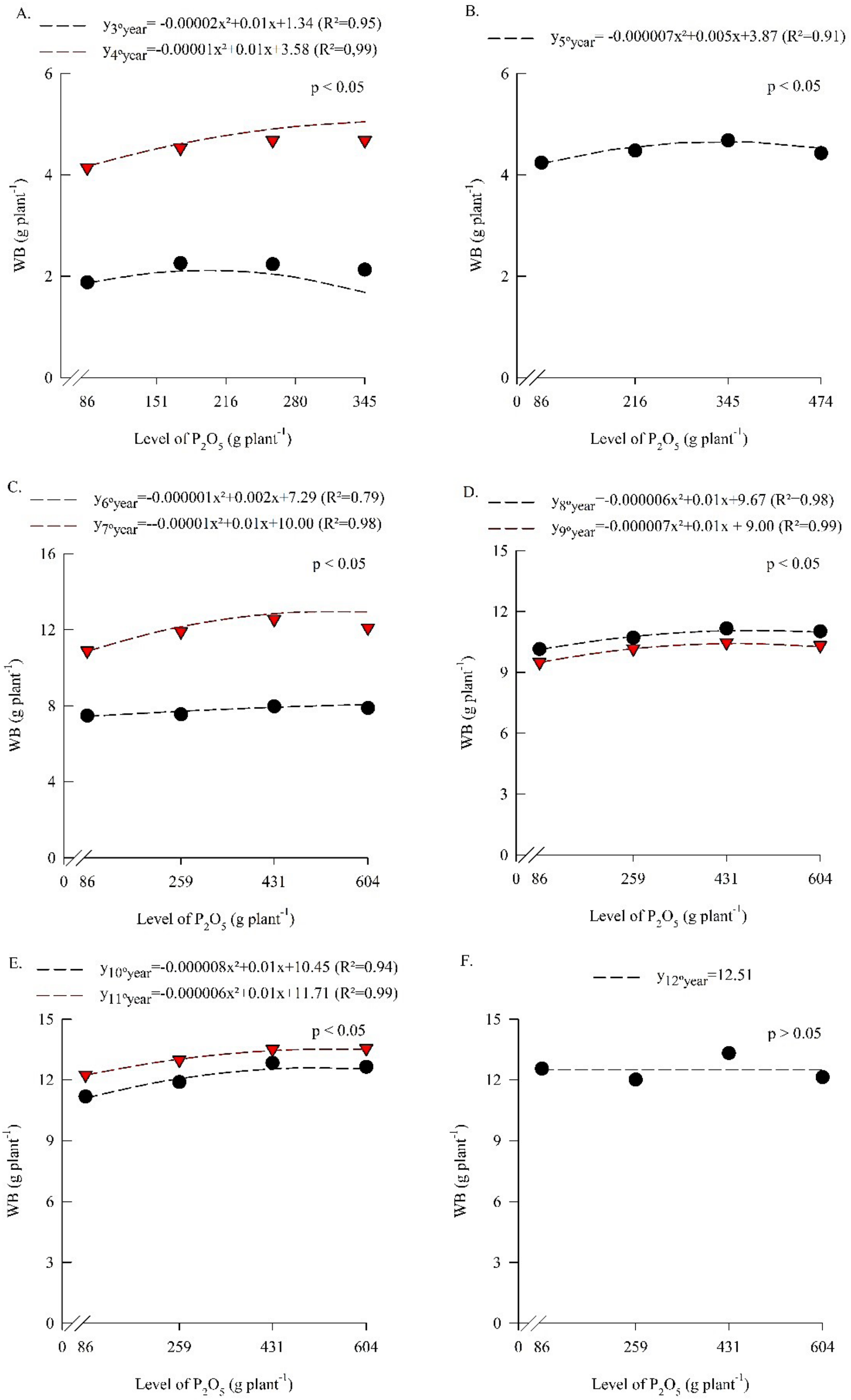

Figure 4: Effect of P levels on the average weight of fresh fruit bunch (WB) in the third and fourth (a), in the fifth (b), in the sixth and seventh (c), in the eighth and ninth (d), in the tenth and eleventh (e) and twelfth (f) years of age of the oil palm.

Regarding the effect of P sources on WB, there were higher values with phosphorus fertilization via F1 between the fourth and ninth year of age of the plants. In later years, there was no difference on the WB between the sources of P evaluated (Figure 5a). The older plants fertilized with phosphine reached similar WB to those fertilized with triple superphosphate (Figure 5a). Reactive natural phosphate is commonly used in commercial oil palm plantations, mainly due to the lower cost compared to acidulated phosphates. However, the efficiency of natural phosphate is influenced by its origin, particle size, application way and plant species, in addition to the soil texture, the P retention capacity and the acidity of the soil (Franzini & Silva, 2012). In this perspective, the soil of the current study has 240 g kg^{-1} of clay and medium acidity, conditions conducive to the application of natural phosphates. Moreover, younger roots are more efficient in absorbing P than older roots (Prado, 2021), decreasing the efficiency of plants in absorbing nutrients as a function of the age of cultivation.

For the effect of K on the WB, from the sixth year of age of the plants there were responses to its fertilization (Figure 5b). In relation to K effect on the WB of oil palm, a study found positive response but there was no significant difference between the K levels (Viégas *et al.*, 2019), as also observed in the current research (Figure 5b). K fertilization is essential in oil palm nutrition, since this nutrient is capable of influencing the number and weight of bunches, and can decrease the oil content of the fruit in deficient conditions (Naqiuddin *et al.*, 2020). The Mg fertilization, in most of years, provided greater WB of plants (Figure 5c). The WB was higher when the plants received magnesium fertilization at the ages of the fifth, seventh, eighth, ninth, eleventh and twelfth year. Positive results were found with increased levels of Mg in young oil palm plants (3 and 4 years old), providing gains in the WB (Oliveira *et al.*, 2019). To achieve maximum oil palm productivity, it is recommended to replace the Mg exported by the fruits, needing to supply 4 kg t^{-1} of bunches (Franzini *et al.*, 2020).

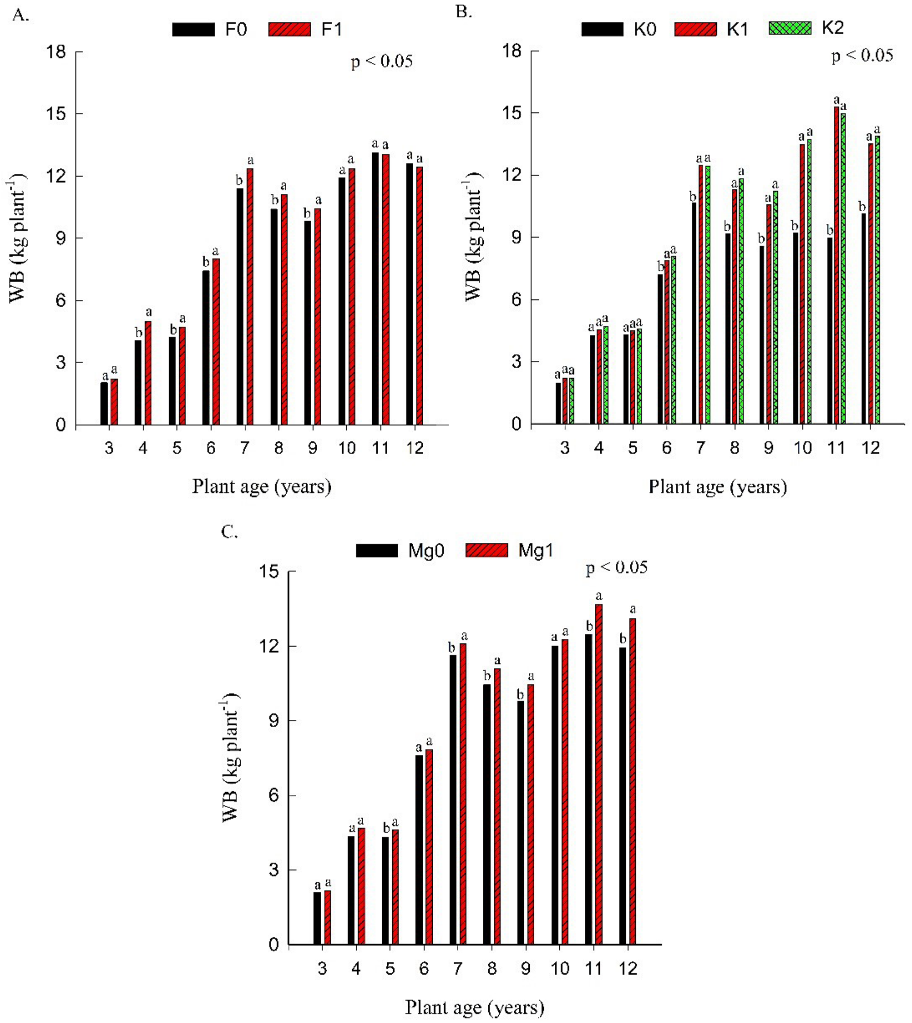

Figure 5: Effect of P sources, F0-phosphine and F1- triple superphosphate (a), and of K (b) and Mg (c) levels on the average weight of fresh fruit bunches (WB) plant^{-1} among the third and the twelfth year of the oil palm. Equal letters in the columns, comparing fertilization sources and levels at each age of the plants, are considered statistically equal by the Tukey test ($p > 0.05$).

The greatest effect of Mg fertilization on older oil palm plants is expected, as the soil had initially greater Mg availability (Table 1), but this reserve was enough to supply the plants that did not receive Mg only in the first years, promoting WB losses in the first consecutive years. These results demonstrate the essentiality of the nutritional management of Mg and its ability to increase WB (Figure 5c), as it participates in the structure of chlorophyll (central atom) and, also, plays a role in enzymatic activation (Lima *et al.*, 2018).

For the production of fresh fruit bunches (PB, t ha^{-1}), there were quadratic responses to the increase in P levels in the different years of age of the plants (Figure 6). The maximum PB, in relation to phosphorus fertilization, was estimated with levels of 365 and 390 g plant^{-1} of P_2O_5 for young plants at the third (1.76 t ha^{-1} PB) and the fifth year of age (9.87 t ha^{-1} of PB), while for adult plants (sixth to twelfth) the average level of 693 g plant^{-1} of P_2O_5 was estimated, for an average PB of 15.84 t ha^{-1} (Figure 6).

A study evaluating the effect of P levels also found a positive response to the nutrient (Viégas *et al.*, 2019), consistent with cultivation in a soil with 240 g kg^{-1} of clay and low availability of P (Table 1). In addition, it was found that phosphorus fertilization doubled the production of young oil palm plants and quadrupled the production of plants over fifteen years old (Pacheco *et al.*, 1985). The recommendation of P fertilization for oil palm in Pará is 608 g plant^{-1} of P_2O_5 for plants in production with 17 t ha^{-1} of expected productivity (Franzini *et al.*, 2020), considering 143 plants ha^{-1}. Thus, the P level estimated (693 g plant^{-1} of P_2O_5) to reach the maximum PB of the current study is close to that recommended by the literature (608 g plant^{-1} of P_2O_5) for oil palm in the state (Franzini *et al.*, 2020).

Comparing the effect of P sources, there was a higher PB with the supply of F1 between the third and eighth year of age of the plants. After this age, no differences on PB were observed between the sources of applied P (Figure 7a). Oil palm is considered tolerant to acidity and is predominantly cultivated in acidic soils in the Amazon, which allows producers to use natural reactive phosphate to supply P, since under conditions of greater acidity this source presents greater dissolution (Franzini & Silva, 2012). On the other hand, one must take into account the increase in P availability promoted by corrective practices, with a consequent increase in fertilizer efficiency (Franzini & Silva, 2012). Despite the greater dissolution of F0 in acidic soils, it is observed that there were similar responses on production to triple superphosphate only after the ninth year of plant age (Figure 7a). Thus, in the early years of oil palm cultivation, one should opt for the application of soluble sources of P, such as triple superphosphate. And, at a more advanced age of plants, the application of natural phosphate will be beneficial to oil palm production.

For K fertilization, there was a positive response in relation to PB, from the sixth year of age of the plants, but without difference between the K1 and K2 levels (Figure 7b). Viégas *et al.* (2019) evaluating K effect on PB of oil palm observed that its supply positively changes this variable, but also without difference between the levels of K evaluated in the different years of age of the plants. Thus, the lowest level of K applied (K1; 1600 g plant^{-1} KCl) from the sixth year onwards is recommended for oil palm plantations, since the evaluated K levels did not differ in the present study (Figure 7b), the example also occurred for the variables NB (Figure 3b) and WB (Figure 5b). The availability of K in the soil influences the response of PB, considering the average class of availability of this nutrient from 41 to 60 mg dm^{-3} in soils from Pará (Brasil & Cravo, 2020).

For the effect of Mg fertilization, a higher PB was observed only in the eleventh and twelfth year of age of the plants (Figure 7c). The Mg fertilization, in another research conducted in Tailândia (PA), also provided no response on PB of palm oil plants (Viégas *et al.*, 2019). The lack of response on PB of the oil palm by the supply of Mg can also be explained by the presence of legumes, as soil cover, in the orchards of culture in the Amazon. This practice makes it possible to contribute to the organic matter concentration of plant residues generated by cover crops, with greater Mg mineralization (Viégas *et al.*, 2019), favored by the climate (Figure 1), and consequent lack of response to its application (Figure 7c). Evaluation of *Pueraria phaseoloides* L. in oil palm plantation showed an average cycling of 20.6 kg ha^{-1} year^{-1} of Mg (Viégas *et al.*, 2021), indicating the relevance of using this cover plant in the supply of the nutrient.

It is also important to note that the oil palm produces 20 to 30 leaves plant^{-1} annually, which are removed during harvest and deposited in the planting area, promoting nutrient cycling and providing up to 90 kg ha^{-1} of Mg (Botelho *et al.*, 2020), higher than the recommended level of 34 kg ha^{-1} of Mg for an expected productivity of 17 t ha^{-1} in Pará (Franzini *et al.*, 2020). However, it is estimated that in oil palm orchards on tropical soils there is a loss of 23 kg ha^{-1} year^{-1} of Mg by leaching, erosion and runoff and the demand for Mg by oil palm plants is 22 kg ha^{-1} year^{-1} (Tarmizi & Mohd Tayeb, 2006). Thus, the use of legumes as soil cover plants, the Mg concentration in the soil and the nutrient cycling through the leaves may have influenced the lack of positive response to Mg supply in the production of oil palm bunches in the current study.

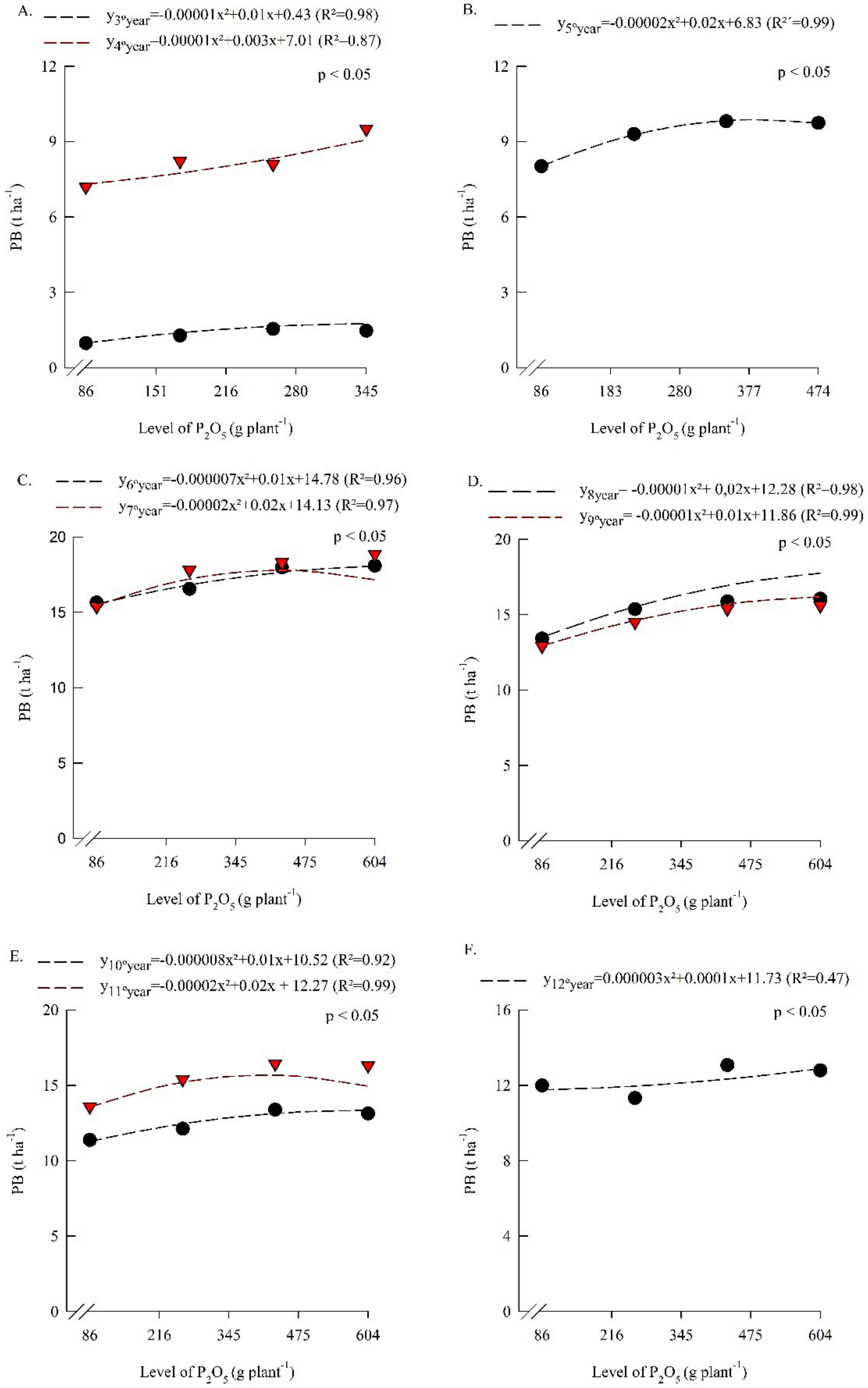

Figure 6: Effect of P levels on the production of fresh fruit bunches (PB) plant^{-1} in the third and fourth (a), in the fifth (b), in the sixth and seventh (c), in the eighth and ninth (d), in the tenth and eleventh (e) and twelfth (f) years of age of the oil palm.

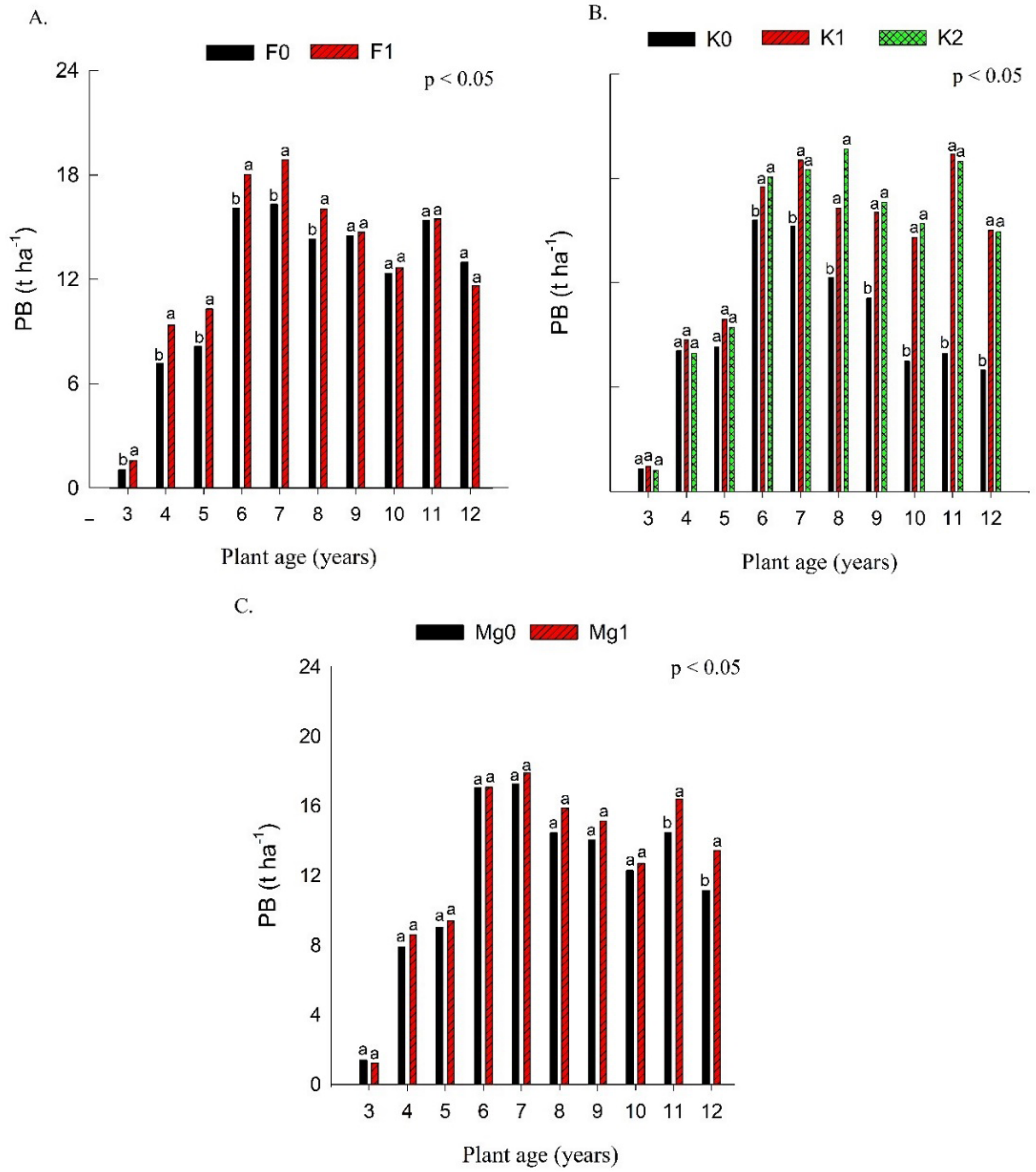

Figure 7: Effect of P sources, FO-phosphine and F1- triple superphosphate (a), and of K (b) and Mg (c) levels on the production of fresh fruit bunches (PB) plant^{-1} between the third and the twelfth year of the oil palm. Equal letters in the columns, comparing fertilization sources and levels at each age of the plants, are considered statistically equal by the Tukey test ($p > 0.05$).

CONCLUSIONS

- The oil palm production increase with the supply of P, with the level of 693 g plant^{-1} of P_2O_5 recommended for plants in production with expected productivity of 17 t ha^{-1};
- The P source directly influences oil palm production in the first years of cultivation (< 8 years of age), with emphasis on the use of the faster release source (triple superphosphate), however natural phosphate is viable to use, mainly through a reactive source of high agronomic efficiency;
- Potassium fertilization increases the oil palm production, recommending, in the production phase, the lowest evaluated level (1600 g plant^{-1} of KCl);
- Magnesium fertilization increases the weight of bunch of oil palm.

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