La Granja: Revista de Ciencias de la Vida
pISSN:1390-3799; eISSN:1390-8596

Scientific paper/ Artículo científico
Agronomy

Fertilization with magnesium in 'Barraganete' plantain (*Musa* AAB) Ecuador

Fertilización con magnesio en plátano 'Barraganete' (*Musa* AAB) Ecuador

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Abstract

Plantain is an important crop for Ecuador due to its contribution in socio-economy and food security of this country, supplying rich-energy food to most of the population; in addition, it is necessary to carry out fertilization management that allows a better use of this resource and increase the yield. Magnesium fertilization in 'Barraganete' (*Musa* AAB) plantain was evaluated in El Carmen, Manabí, Ecuador. The research was conducted in the Experimental Farm "Rio Suma", Universidad Laica Eloy Alfaro de Manabí, Extension El Carmen, located at 260 masl, average temperature of 24 °C, annual rainfall of 2 684 mm. Six levels of MgO (0, 25, 50, 75, 100, 125 kg·ha^{-1}) were applied to know its effect on morpho-physiology and plant yield. A completely randomized block design with six treatments and three replications was used; the sowing was carried out with a distance of 2.50 m × 1.80 m (2 222 plants·ha^{-1}), and the variables of vegetative growth were evaluated as repeated measures over time. The results demonstrated significant differences in all the morpho-physiological variables, which showed that fertilization with 30% MgO affected the growth of the plants; however, the reproductive variables were not affected by the applied doses; the 25 kg·ha^{-1} dose generated the best yields, agronomic efficiency and partial productivity factor.

Keywords: Morpho-physiology, yield, photosynthesis, agronomic efficiency.

Resumen

El cultivo de plátano es importante por el aporte que genera en la socio-economía y seguridad alimentaria de Ecuador, pues suministra alimentos ricos en energía a la mayor parte de la población. Además, se hace necesario realizar manejos de la fertilización que permitan una mejor utilización de este recurso e incrementar los rendimientos. Por ello, se evaluó la fertilización con magnesio en plátano 'Barraganete' (*Musa* AAB) en El Carmen, Manabí, Ecuador. La investigación se condujo en la Granja Experimental "Rio Suma", Universidad Laica Eloy Alfaro de Manabí, extensión en El Carmen, ubicada a 260 msnm, temperatura promedio de 24 °C, precipitación anual de 2 684 mm. Se aplicaron seis niveles de MgO (0, 25, 50, 75, 100, 125 kg·ha^{-1}) para conocer su efecto sobre la morfo-fisiología y el rendimiento de las plantas. Se utilizó un diseño de bloques completos al azar con seis tratamientos y tres repeticiones; la siembra se realizó con un distanciamiento de 2,50 m × 1,80 m (2 222 plantas·ha^{-1}), y las variables de crecimiento vegetativo se evaluaron como medidas repetidas en el tiempo. Los resultados demostraron diferencias en todas las variables morfo-fisiológicas, lo que demostró que la fertilización con 30% de MgO afectó el crecimiento de las plantas; no obstante, las variables reproductivas no fueron afectadas por las dosis aplicadas; la dosis de 25 kg·ha^{-1} generó los mejores rendimientos, eficiencia agronómica y factor parcial de productividad.
Palabras clave: Morfo-fisiología, rendimiento, fotosíntesis, eficiencia agronómica.

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1 Introduction

World plantain production (*Musa* sp.) during 2012-2017 was distributed in Africa (60.60 %), America (26.50 %), Asia (12.80 %) and Oceania (0.10 %), indicating the economic and nutritional importance of this crop to the population (FAOSTAT, 2018). High temperatures and relative humidity predominate in America, Asia and Africa, as well as in the subtropical and tropical areas of these continents, and plantain represents an important crop by the planted area that it represents (Ramos et al., 2016).

According to the Research Center on Sustainable Rural Development and Food Sovereignty (CEDRSSA, 2019) India is the main platain producing country with 30 477000 t, 2.67 times larger than China (11 422956 t), which is its closest competitor. In addition, six countries in Latin America stand out by their plantain production, such as Brazil (6 675100 t), Ecuador (6 282105 t), Guatemala (3 887439 t), Colombia (3 786672 t), Costa Rica (2 552822 t) and Mexico (2 229519 t).

Plantains in Ecuador represent an export item and a source of employment. Because of the importance of this crop, it is necessary to generate reliable tools for the farmer to manage the crop in an appropriate and cost-effective way (Tumbaco et al., 2015). In addition, it is important by its contribution for socio-economy and agri-food security, providing direct employment (fixed labor) and indirect employment (occasional labor and added value of products), and food to the population. According to the National Statistics and Census Institute (INEC, 2020) in 2019 there were 115069 ha planted with plantain in Ecuador as monoculture and 45 194 ha associated with other crops, and the production corresponded to 582706 and 166745 Tm, equivalent to 5064 and 3690 $kg{\cdot}ha^{-1}$, respectively. Banana and plantain exports in Ecuador accounted for $3.27 billion, representing 17.5 % of total non-oil exports (OEC, 2017; Álvarez et al., 2020); however, the Central Bank of Ecuador (**?**) noted that the export of plantain in Ecuador during 2019 was 211732.6 Tm.

A research carried out by Molero et al. (2008), showed that the extraction of nutrients using cv. Hartón at the time of harvest was approximately N: 150; P: 60; Ca: 215; Mg: 140; Mn: 12; Fe: 5; Zn: 1.5; B: 1.25 and Cu: 0.5 $kg{\cdot}ha^{-1}{\cdot}yr^{-1}$; therefore, it was important to use restitution doses to maintain soil fertility and ensure high production. These same authors have pointed out that nitrogen, potassium and to a lesser extent magnesium in banana cultivation are the most important elements for its growth and production.

Cobeña et al. (2020) found that the nutritional elements were extracted in higher amount in plantain 'Barraganete' were K, CA, N, P and Mg, when N and K_2O were fertilized. Regarding the content of P and Mg, there was no sustained extraction behavior. Avellán et al. (2020) evaluated the export of P in 'Barraganete' plantain, finding that it presented low mobility in the soil, for this reason it was absorbing the one found around the roots, indicating that P was available and in a soluble form when fertilizing, but was fixed almost immediately, hence it was non usable for the plant; thus, P fractionning was suggested as an alternative for increasing its efficiency.

On the other hand, Mg is very important for plants. The amount of Mg contained in leaves (75 %) participated in protein synthesis and 15 to 20 % of the total Mg was found to be associated with chlorophyll pigments (White and Broadley, 2009), acting as a cofactor of enzymes involved in the metabolism and fixation of photosynthetic carbon (Hermans et al., 2013).

Between 90 and 98 % of the Mg present in soil is not available for plant absorption but it is incorporated into the crystalline structure of minerals (Senbayram et al., 2015). The usable form of Mg to be absorbed by plants is as ion Mg^{2+}, which has the smallest ionic radius, but the largest hydrated radius among cations (Maguire and Cowan, 2002). This causes a weak attachment to the negatively charged soil colloids and root cell walls, causing Mg to be easily lost (Grzebisz, 2011). At the same time, excessive fertilization with K^+ and NH_4^+ has been reported to be antagonistic with the absorption of Mg, increasing its deficiency. The deficiency of Mg increases in acid soils saturated with H^+, Al^{3+} and Mn^{2+} cations where intensive leaching occurs, especially in areas with high rainfall (Gransee and Führs, 2013).

Despite the importance of Mg^{2+} in the plant growth and development, the molecular mechanism of plant cells regulating homeostasis in Mg^{2+}, as well as the molecular mechanisms related to magnesium transport are little known. Mg^{2+} is required for adequate functioning of the many cellular activities related to chlorophyll synthesis, as the main component of chlorophyll, membrane stability and enzymatic activation (Guo et al., 2016).

On the other hand, nutrition with Mg in plants must be considered a major global problem, not only in terms of food security but also in terms of human health, since Mg is an essential nutrient in human and animal nutrition, and plants are the main source of daily intake of this element. In this regard, experiments have been carried out evaluating the effects of magnesium in plants; however, this information in plantain is scarce, particularly in Ecuador. Therefore, the aim of this research is to evaluate the response to magnesium fertilization in the plantain crop 'Barraganete' (*Musa* AAB), in El Carmen canton, Manabí, Ecuador.

2 Materials and Methods

The research was carried out from 2018 to 2019, at the Experimental Farm Rio Suma, Lay University "Eloy Alfaro" of Manabí, campus El Carmen, geographically located in the Province of Manabí, Canton El Carmen, coordinates UTM (−0.259503 S; −79.427558 0), in a humid tropical climate. The agro-ecological characteristics corresponded to altitude 260 masl, temperature of 24.15 °C, annual precipitation of 2 600 mm, relative humidity 85.6%, sunlight 553 hours·light^{-1}·year^{-1} and evaporation 1 064 mm·year^{-1} (Climate-data.org, 2019).

The soil analysis of the study area indicated mean levels of MO (4.48%), non-saline C.E. (0.08 ds·m^{-1}), pH of 5.7 (moderately acid). Low contents of NH_4 (11.61 ppm), P (4.56 ppm), S (2.14 ppm), Mg (0.90 meq·100 g^{-1}), base sum 8.40 meq·100 g^{-1}, Mn (9.70 ppm), and mg/K ratio (1.80), Ca mg/K (15.80). High levels of K (0.50 meq·100 g^{-1}), Ca (7.00 meq·100 g^{-1}), Cu (5.80 ppm), Fe (123.10 ppm), Zn (23.20 ppm) and Ca/mg ratio (7.78). The texture is sandy loamy (62% sand, 28% silt and 10% clay) (Avellán et al., 2020). Once the culture reached the average age, soil and leaf area samples were obtained; it was also done at the end of the crop cycle. Soil samples were analyzed at the Agrolab Laboratory, located in the Water and Soil Laboratory Network of Ecuador (Relase).

The reasearch was evaluated in a first-cycle plantation of 'Barraganete' plantain (*Musa* sp. AAB), with a planting distance of 2.5 m between rows x 1.8 m between plants (4.5 m^2), for a total of 2 222 plants·ha^{-1}, corresponding to a high density management of plants. 288 plants were included in the research and were distributed in three blocks. Three-dose fractionated fertilizer applications (N-P-K and MgO) were performed. The treatments followed an experimental design in totally random blocks, with three repetitions.

Treatments were MgO fertilization at six levels (0, 25, 50, 75, 100 and 125 kg·ha^{-1}) and a standard dose of 80 kg·ha^{-1} of N, 40 kg·ha^{-1} of P_2O_5 and 150 kg·ha^{-1} de K_2O, divided into three equal parts and applied to the soil when the plant emitted leaves 12, 16 and 20. The commercial fertilizers used were urea with 46% of N, diammonium phosphate (DAP) with 18% of N and 46% of P_2O_5, potassium muriate with 60% of K_2O and magnesium oxide with 30% of MgO.

The experimental unit consisted of 16 plants, from which four plants were selected from the central part to avoid the embroidery effect. Plants were transplanted when leaf five was obtained. The mean of the treatments were compared using Tukey test ($P<0.05$). The GLM procedure of the SAS® program, version 15.1 (Statistical Analysis System, 2020) was used for processing the data.

The morpho-physiological variables (plant height, pseudostem perimeter, number of leaves, length and width of leaf 3 and leaf area) were evaluated over time with measurements every 8 days, using the time-repeated measurement methodology through MIXED procedure (Statistical Analysis System, 2020); second-degree polynomic models were selected because these were the ones that best explained the behavior over time of the growth variables. The graphical representation of the variables was made using the SigmaPlot software.

In addition, variables related to yield were measured (number of bunches, number of fruits, length of fruits, diameter of exportable fruits, biomass of fruit and bunch, yield per hectare, soil and foliar concentration of Mg, concentration of Mg in the fruit, export of Mg in the fruit, agronomic efficiency and partial productivity factor). The leaf area was determined by the measurements obtained from the length and width of the third leaf and was calculated with the following formula:

$Leaf\ area = length \times width \times 0{,}8$ (Martínez, 1984).

Regarding the variables related to fertilization efficiency, the export of Mg was determined considering the dry biomass percentage of the fruit multiplied by the yield of the crop per hectare and multiplied by the percentage of magnesium concentration, in this way, the amount of magnesium that left the crop was calculated through the fruit, and the response was obtained in kg·ha^{-1}. Agronomic efficiency (AE) was defined as the increase in yield from fertilization per unit of the nutrient applied (Dobermann, 2007) and was calculated by considering the yield of the fertilized plots (YFP) minus the yield of the control plot (YCP), divided by the applied dose (AD), and expressed in kg of fruit·kg^{-1} of applied nutrient.

$$AE = \frac{YFP - YCP}{AD}$$

The partial productivity factor allows to evaluate the efficiency of a nutrient for the production (Bruulsema et al., 2011), and it was calculated using the formula $FPP = \frac{Y}{D}$ in which Y= yield of harvested plots (kg·ha^{-1}) and D= dose of nutrient applied (kg·ha^{-1}) (Dobermann, 2007).

3 Results and Discussion

3.1 Height of the plant and perimeter of the pseudostem

Significant differences (P<0.01) were found for this variable by the effect of treatments for sampling at week 10 (T25-T50; T75-T125 and T100-T125) and from week 11 to week 53 differences were between T0-T75, T0-T100, T0-T125, T50-T75 and T50-T100. In the weeks mentioned, T25 was the one that presented the highest height of the plant, reaching 3.47 m at week 53 after planting; T0 was higher than T75 and T100.

The height of plants had the same tendency for all treatments over time, adjusting to a second polynomial degree (Y= a + bx + cx^2), indicating that fertilization with magnesium increased the length of 'Barraganete' plantain plants with T50, T125 and T0 when compared with T75 and T100; the latter two showed similar values to T25 until week 46, and then it increased to similar values to T0, T50 and T125 (Figure 1). This second-order polynomial behavior suggests that as the emergence of the inflorescence approaches, the growth of the plant slows down until it reaches its final height.

The average height obtained in this research at 53 weeks was 3.47 m, similar to that reported by Cayón et al. (2004) which was between 3.2-3.4 m when evaluating densities and planting arrangements in a range of 1 500 to 3 000 plants·ha^{-1}, with no statistical differences between them.

Significant differences (P<0.01) were found for the pseudostem perimeter by effect of treatments during all the weeks where the assessments were performed. There were differences in week 10 between T0-T25; T0-T50 and T100-T125, and between weeks 11 to 53 in T0-T75, T0-T100, T0-T125, T25-T100, T25-T125, T50-T100 and T50-T125. This variable over time was adjusted to a second polynomial order (Y= a + bx + cx^2). There was a similar trend between treatments over time, indicating that fertilization with MgO affected the diameter of the pseudostem of 'Barraganete' plantain (Figure 2).

In this sense, it is recognized the importance of Mg in various metabolic processes and reactions in plants, particularly photosynthesis and chlorophyll content. Therefore, Cakmak and Yazici (2010) noted that plants with Mg deficiencies accumulated up to four times more sucrose when compared with those with an adequate Mg content, generating a severe inhibition of the sucrose transport in leaves to other plant-receiving organs (roots, stems, among others). Adequate nutrition with Mg during periods of carbohydrate transport from leaves to cells at other sites in the plant ensures maximum transport of carbohydrates to the recipient organs, thus promoting growth and high yields.

The overall average perimeter of the pseudostem was 52.23 cm, similar to that indicated by Barrera et al. (2011), with 52.23 cm on average for the first production cycle and 48.15 cm for the second cycle in Hartón plantain with a density of 1 111 plants·ha^{-1}; however, when applying mycorrhizae + earthworms it was 60.08 and 41.5 cm, for each production cycle, respectively, i.e., less than that obtained by Pinchao (2018) when evaluating the effect of different levels of K_2O and MgO in 'Barraganete' plantain, obtaining on average 70 cm in this same variable with a density of 2 222 plants·ha^{-1}.

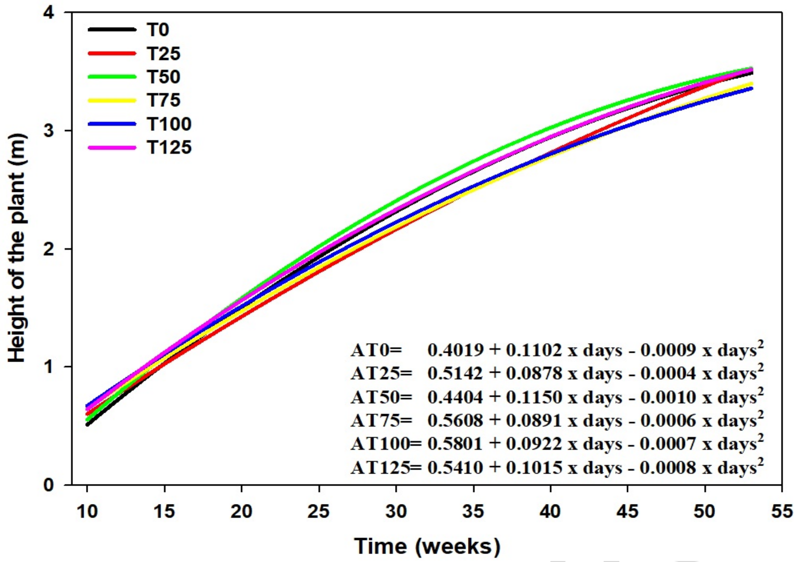

Figure 1. Height of 'Barraganete' plantain plants (*Musa* ABB), under different fertilization doses with MgO, in El Carmen, Ecuador. Data were collected every 8 days. The estimated values are presented. T0= witness (0 kg·ha^{-1} of MgO, black), T25= 25 kg·ha^{-1} of MgO (red), T50= 50 kg·ha^{-1} of MgO (green), T75= 75 kg·ha^{-1} of MgO (yellow), T100= 100 kg·ha^{-1} of MgO (blue), and T125= 125 kg·ha^{-1} of MgO (magenta).

3.2 Width, lenght and leaf area

Significant differences ($P<0.01$) were found for leaf width at week 10 (T0-T25, T0-T75, T0-T100, T0-T125, T25-T50, T25-T125, T50-T75, T50-T100, T50-T125, and T75-T100; for week 11 (T0-T25, T0-T100, T25-T50, T25-T75, T25-T125, T50-T100, T75-T100 and T100-125; and from week 12 to week 53 between T0-T25, T0-T100, T25-T50, T25-T75, T25-T150, T50-T100, T75-T100 and T100-T125 for the effect of treatments. There also statistical differences ($P<0.01$) for the leaf lenght during the entire evaluated period between T0-T25, T25-T50, T25-T75, T25-T125, T50-T100, T75-T100 and T75-T125. The foliar area showed statistical differences in week 10 between T0-T25, T0-T50, T0-T100, T50-T100, T75-T100 and T75-T125; and between T0-T25 from week 11 to week 53 and between T25 with T50, T75, T100 and T125.

The results indicated that fertilization with MgO influenced leaf development. Both the width of leaves and the leaf area over time presented a similar trend, where T0 had the least development of leaves (Figure 3). Treatments had a second polynomial behavior degree ($Y= a + bx + cx^2$) for these variables, where from approximately week 30 of the development of the crop there was a tendency to increase the width of leaves between the different treatments except for T0, which maintained over time.

There was an increase in leaf width in week 53 of 1.12 with the doses 125 kg·ha^{-1} compared to T0. On average, T0 had a width of 0.68 m, while T50 and T125 had an average of 0.72 m. The development of leaves had similar behavior to that indicated by Aristizábal (2008), who mentioned that terminal leaves decreased in size during the last weeks before the emission of the inflorescence (acorn); in this investigation was observed on leaf 3 of the plant.

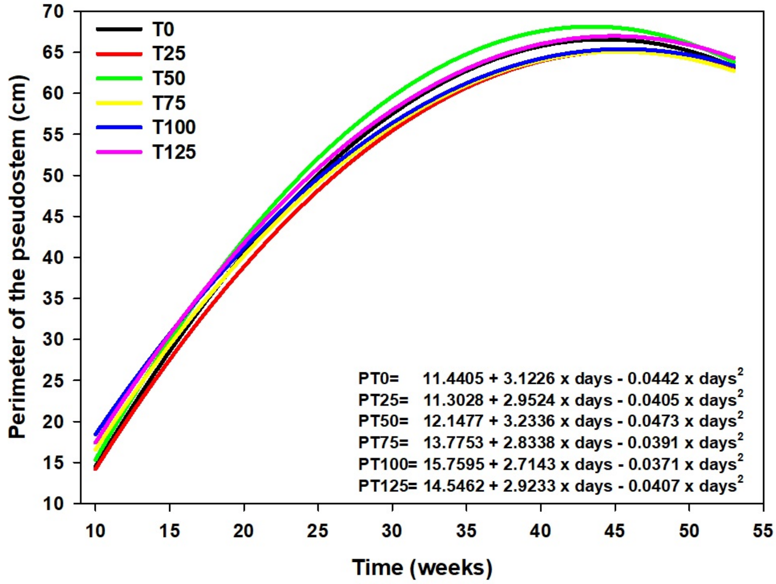

Figure 2. Perimeter of the pseudostem in 'Barraganete' plantain (*Musa* ABB), under different fertilization doses with MgO, in El Carmen, Ecuador. Data were obtained every 8 days. The estimated values are presented. T0= witness (0 kg·ha^{-1} of MgO, black), T25= 25 kg·ha^{-1} of MgO (red), T50= 50 kg·ha^{-1} of MgO (green), T75= 75 kg·ha^{-1} of MgO (yellow), T100= 100 kg·ha^{-1} of MgO (blue), and T125= 125 kg·ha^{-1} of MgO (magenta).

Regarding the length in the leaf area, it was observed in Figure 3 that from week 15 until week 30 there was a more accelerated leaf growth, on average it was 1.88 times higher in the indicated range. From week 30 to week 53, leaf growth was slower (increase of 1.04 times), showing that the length of leaves in the last weeks had a smaller slope, growth being almost horizontal. Both the width and length of leaves were evaluated on leaf 3, which has been used as a reference leaf in the crop.

According to Martínez and Cayón (2011), the logarithmic phase (vegetative phase) had a slow growth, followed by a progressive change in its speed rate, evidenced by the slope of the curve, and with exponential increase in the width and length of leaves; likewise, differentiation marked the completion of this phase. The linear phase (vegetative-reproductive phase) continued, and the plant presented accelerated and constant growth, thus stability of the curve´s slope. In this phase, the development and elongation of the floral stem was noted, and it finished with the emergence of inflorescence (flowering). The cultivation cycle completed at the beginning of the senescence phase (reproductive-productive phase), with flowering and subsequent development of the cluster; the growth rate of the plant decreased since leaves and pseudostem (sources) moved to the fruit (sump).

Leaf area dynamics over time suggested that it tended to decrease as the plant got close to inflorescence emission, which could be due to a lower leaf emission rate; reduction of leaf size, lower longevity of the last leaves emitted or the combined effect of these facts.

Figure 3 shows that T0 performed more evenly than fertilized plants with the smallest leaf area at the end of the investigation period, which was 1.19 times less than T125. This is because the lack of Mg inhibits plant growth, accelerates the aging process and generates losses in both production and crop quality (Verbruggen and Hermans, 2013), since it is involved in the photosynthesis process, so its deficiency decreased the photosynthetic rate and blocked the carbohydrate rate to the demanding organs, leading to the growth inhibition of the demanding organs and thus low productivity in many plant species (Chen et al., 2018; He et al., 2020).

Martínez and Cayón (2011) indicated that the total foliar area produced by plantain plants lose approximately 8 m^2 when they reach flowering and an additional 4 m^2 until the harvest; these losses, however, may be higher if there is not adequate management of foliar diseases or if the plant experiences water stress conditions. This means that from the dry biomass destined for the formation of leaves throughout the cycle, the plant loses 60% in the form of non-recoverable dried leaves.

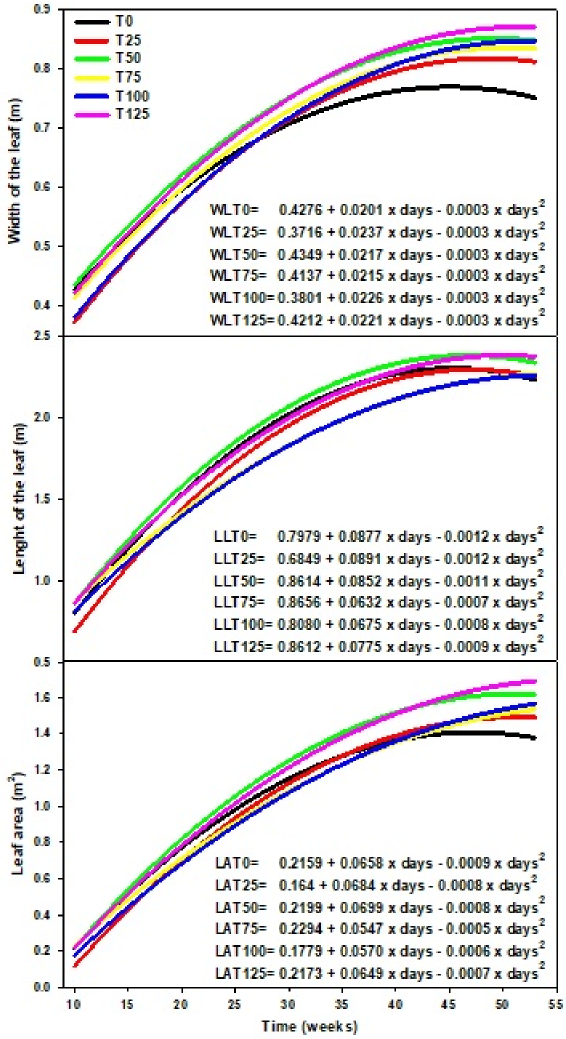

Figure 3. Width, length and leaf area of 'Barraganete' plantain (*Musa* ABB) under different fertilization doses with MgO in El Carmen, Ecuador. Data were obtained every 8 days. The estimated values are presented. T0= witness (0 kg·ha^{-1} of MgO, black), T25= 25 kg·ha^{-1} of MgO (red), T50= 50 kg·ha^{-1} of MgO (green), T75= 75 kg·ha^{-1} of MgO (yellow), T100= 100 kg·ha^{-1} of MgO (blue), and T125= 125 kg·ha^{-1} of MgO (magenta).

3.3 Number of leaves

On the other hand, there were no statistical differences ($P>0.05$) for the number of emerged leaves·$plant^{-1}$ due to the effect of the evaluated treatments. The averages reached for the number of total leaves (38.33 leaves), the number of leaves emerging the inflorescence (12.33 functional leaves) and the time of harvest (5.67 leaves), suggest that fertilization with magnesium did not have any influence on this variable. These results were similar to those obtained by Pinchao (2018) who reported 5 leaves during the crop and 38 to 40 leaves throughout the crop cycle. Similar results were reported by Herrera and Aristizábal (2003) and Jaramillo and Aristizábal (2004) in other plantain cultivars.

According to Martínez and Cayón (2011) the plant must maintain a minimum of 8 leaves to guarantee the filling of the cluster from the emergence of the inflorescence. Aristizábal (2008) stated that while the number of functional leaves present is important, their position in the plant is much more important, since it determines their contribution to the filling of the bunch. In this regard, they observed that the foliar emission rate in Honduran Dwarf and Dominico Hartón plantain tended to decrease linearly over time, until the plant emitted the inflorescence.

3.4 Number of bunches and fruits, length and perimeter of fruits, biomass of fruits and bunches and yield·ha^{-1}

The variables number of bunches and fruits, length and perimeter of fruits, biomass of fruits and bunches and yield·ha^{-1}, all related to yield components, did not show statistical differences ($P>0.05$) with the doses of MgO applied. However, mean values were 5.44 fruits·bunch^{-1}; 26.33 exportable fruits·bunch^{-1}; fruit length of 31.44 cm; fruit perimeter of 47.17 mm; fruit biomass of 350 g; bunch biomass between 10.28 and 11.49 kg and yield between 22.98 and 25.88 t·ha^{-1}.

3.5 Agronomic efficiency (AE) and partial productivity factor (PPF)

Doses of 50 to 125 kg·ha^{-1} generated negative AE from −3.33 to −30.67 kg·ha^{-1}, while doses of 25 kg·ha^{-1} resulted in 23.95 kg·ha^{-1} (Figure 4). Negative AEs were the result of T0 (witness without MgO; 25 277.78 kg·ha^{-1}), having a higher yield than fertilized plots except for T25 (25 876.54).

The intersection of lines is considered the optimal point, where the fertilizer was mostly used by the plant to increase production. It was higher than 25 kg·ha^{-1}, with an agronomic efficiency lower than 20 kg of fruit·kg·ha^{-1} of MgO applied, suggesting the conduction of research with smaller doses and in intervals between 20 and 30 kg·ha^{-1} to determine the appropriate dose to be applied to increase the yield of the crop (Figure 4). Doses higher than 50 kg·ha^{-1} of MgO decreased agronomic efficiency under experimental conditions.

According to Avellán et al. (2020) and Cobeña et al. (2020) this could be because the absorption of nutrients, due to excess of fertilization, was higher than the one required by plants, generating a negative effect since it prevented the absorption of other nutrients that could have been present in the soil solution. This suggests a nutritional imbalance; in other words, the absorption of more MgO and the lower absorption of other nutrients, especially N and P, could contribute to lower yields.

Statistical differences ($P<0.01$) for PPF were found due to the effect of the MgO doses applied. The reported values were between 1 035.06 and 184.73 kg of fruit·kg·ha^{-1} with MgO doses 25 and 125 kg·ha^{-1} of MgO, respectively (Figure 5). In this regard, Boaretto et al. (2007) noted that as the fertilizer dose increased, the productive efficiency of the crops was lower; in other words, with low fertilization doses, the efficiency of the nutrient applied was higher.

Karley and White (2009), and White (2012) indicated that antagonisms and synergies between nutrients affecting yield are common in perennial crops such as bananas and plantains, noting that the antagonistic relationship between K, Ca and Mg has been the most studied, and concluding that when any of these nutrients is high, the content of the others decrease, thus generating a decrease in the growth and yield of plants.

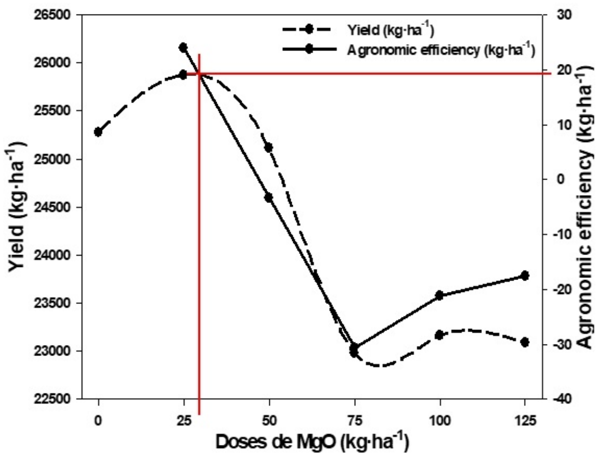

Figure 4. Yield and agronomic efficiency in 'Barraganete' plantain (*Musa* ABB), under different fertilization doses with MgO, in El Carmen, Ecuador.

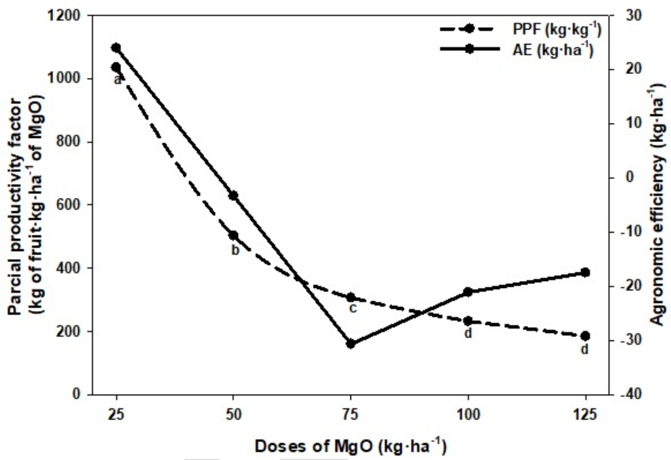

Figure 5. Partial productivity and agronomic efficiency factors in 'Barraganete' plantain (*Musa* ABB), under different fertilization doses with MgO, in El Carmen, Ecuador.

4 Conclusions

Productive variables were not influenced by the applied doses, even though the higher yield, agronomic efficiency and partial production factor were reached with 25 kg·ha^{-1} of MgO or close o it, which suggests conducting research with doses close to that value. The dynamics of the morphophysiological variables evaluated over time conform to second polynomial order equations, where the application of MgO generates differences between the doses used in 'Barraganete' plantain. The dose 50 kg·ha^{-1} of MgO showed the greatest differences between fertilization treatments with MgO.

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