Effect of fertilizer insertion in the harvested mother banana plant pseudostem (*Musa* AAA Simmonds)

Efecto de la inserción de fertilizante en el seudotallo de la planta madre cosechada de banano (*Musa* AAA Simmonds)

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ABSTRACT

The need for more efficient nutrient use in adverse conditions, such as droughts, facilitated the development of new alternatives for fertilizer application, such as direct insertion into the vascular system of the pseudostem of harvested banana plants (*Musa* AAA Simmonds), considering the plant interconnection between the mother plant and the sucker in succession. The objective of this study was to evaluate the effect of fertilizer insertion into the pseudostem of banana plants compared to the conventional soil fertilization system. The study was conducted at two locations (north and center of Urabá region), setting different rates of fertilizer treatments (75, 100 and 125% of the commercial rate) inserted at different heights (0.6 m and 0.9 m) with a soil application of fertilizers as a control treatment. Biometric (height, pseudostem diameter, number of leaves), physiological (specific leaf area and specific leaf weight), and production variables were evaluated in the plants. According to the results, it was evident that the 0.9 m insertion height of the fertilizer was better than 0.6 m and the soil application. Although no significant differences were found between doses of fertilizer, we observed a trend of better performance for plants in treatments of 75% and 100% fertilizer dose inserted at 0.9 m.

Key words: fertilization, macronutrients, growth, production.

RESUMEN

La necesidad de hacer más eficiente el uso nutrientes en condiciones adversas como la sequía ha permitido el desarrollo de nuevas alternativas de aplicación de fertilizantes como la inserción directa al sistema vascular del seudotallo o "troncón" de la planta cosechada del banano (*Musa* AAA Simmonds), teniendo en cuenta la intercomunicación que existe entre la planta madre y el hijo en sucesión. El objetivo del ensayo fue evaluar la eficiencia de inserción del fertilizante al troncón comparado con la fertilización edáfica convencional. El ensayo se realizó en dos localidades (zona norte y centro) de Urabá (Colombia), con cuatro dosis de fertilizante (75, 100 y 125% de la dosis comercial y fertilización edáfica) insertadas en el seudotallo a 0,9 y 0,6 m. Se tomaron variables de crecimiento (altura, diámetro del seudotallo, número de hojas), fisiológicas (área foliar específica, peso foliar especifico) y producción. La inserción del fertilizante a 0,9 m fue más efectiva que a 0,6 m y que la fertilización al suelo. Aunque no se evidenciaron diferencias significativas entre las dosis de fertilizante, se pudo observar una tendencia de mejor comportamiento de las plantas en los tratamientos de 75 y 100% de la dosis comercial insertados a 0,9 m.

Palabras clave: fertilización, macronutrientes, crecimiento, producción.

Introduction

In Colombia, the banana (*Musa* AAA Simmonds) is one of the most important crops of agricultural production and is one of the largest export products, after coffee and flowers. The province of Antioquia, specifically the banana region of Urabá, has the largest production of banana in the country (Díaz, 2005), where fertilizers are applied via foliar and soil applications according to soil and climatic conditions that may eventually limit the form and efficiency of application (Flores and López, 1991).

The need to search for alternative forms of fertilizer applications in periods of drought or extreme rainfall facilitated the emergence of new methods that permit the effective application of fertilizers that can function in any climate condition without relying on environmental factors or affecting yields. López and Espinoza (1995) evaluated different forms of fertilizer placement in the banana and found no significant differences among the techniques used, as compared to the control (semicircle in front of the sucker in succession), while there was a slight tendency to increase bunch weight, return, and production volume (number of boxes/ha/year) when the fertilizer was placed in a hole in front of the sucker. It is worth noting that, in economic terms, the gain in weight and number of boxes is not worth the cost of the new methodology, so the cost/benefit ratio was less than when compared to other evaluated techniques (López and Espinoza, 1995).

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The study of Flores and López (1991) suggests that a viable alternative in terms of costs and maximization of fertilizer use may be the insertion of fertilizer into the pseudostem of freshly harvested plants. This also obtained certain savings by reducing fertilizer losses due to leaching, volatilization of the product and fixing by soil colloids (Shand, 1975). This technique involves direct insertion of the fertilizer into the vascular system of the pseudostem (*topiban* practice), where water is responsible for fertilizer solubilization and its further translocation to the sucker in succession due to intercommunication between the mother plant and the sucker plant that was proved by Keshava and Iyengar (1994), Díaz (2005), Cavalcante *et al.* (2005), and Rodríguez *et al.* (2006). This technique provides the opportunity to apply different types of treatments to trees, such as injection of fertilizers and growth regulators, but must meet certain technical conditions to ensure that the application is effective, fast and without causing injury to the tree (Ardila, 2010). The results of these applications were observed after two and four weeks and have been proven effective for three to five years after the application (Rivas, 2006).

Considering the above, the objectives of this study were to analyze the effect of fertilizer inserted in a banana pseudostem as compared with a soil fertilization system, and identify the advantages and disadvantages of each of the application modes in terms of plant growth and production, and thus, sought to standardize this new alternative methodology of fertilization.

Materials and methods

The experiment was conducted in an area of the Golf of Urabá located at 28 m a.s.l., with an average temperature of 28°C, relative humidity of 81.8%, average annual rainfall of 2,896 mm and annual evaporation of 1,303 mm. The experiment was located on two farms belonging to Comercializadora Internacional Banacol, the Rita Maria farm (north region) and the Retiro farm (central region), located in the municipalities of Apartado and Carepa, respectively. The plant material from banana (*Musa* AAA Simmonds) plants of the cultivar Valery was used on the Rita María farm, and the cultivar Grand Naine was employed on the Retiro farm. In each location, 84 freshly harvested plants were selected, having suckers in succession ranging between 1.80 m (for Grand Naine) and 2.00 m (for Valery), ensuring the highest possible uniformity in terms of vigor.

In order to determine the effect of fertilizer insertion into mother plant pseudostem on sucker growth and production, different treatments were established taking into account the insertion heights on the pseudostem and doses, since no clear methodology exists for the implementation of this technique in the banana. In order to set the insertion height, the results obtained by Labarca *et al.* (2005) were taken into account and insertion heights of 0.9 and 0.6 m of the pseudostem were established. In the case of the fertilizer dose, it was determined from the basal dose (conventional edaphic, 100%), where the losses produced by different factors (leaching, volatilization, retention in the soil, etc.) and representing approximately 25% were eliminated. Likewise, the basal dose was changed by the same percentage, *i.e.* a 25% increase and a 25% reduction in the basal dose were done, resulting in three different doses 75, 100 and 125% corresponding to 90, 120 and 150 g of fertilizers, respectively. The fertilizers used in the study were YaraVera Amidas™ (Yara), potassium chloride Nutrimon™ (Monómeros Colombo Venezolanos), Mezclas Nórdicas™ (Yara), Abocol Nitrofer Calcio™ (Abocol Abonos Colombianos), and ammonium sulphate Nutrimon™ (Monómeros Colombo Venezolanos). After setting different combinations and dose heights, the following seven treatments were established: 25% Fert. +0.9 m; 25% Fert. + 0.6 m; 100% Fert. + 0.9 m; 100% Fert. + 0.6 m; 75% Fert. + 0.9 m; 75% Fert. + 0.6 m; 100% Fert. (control).

For the experiment, 12 freshly harvested mother plants per treatment were selected that had a pseudostem of 1.80 m in height and were distributed randomly in lots of each farm. On each farm, 84 plants in total (12 replicates x seven treatments) were taken that were subjected to different treatments that consisted of drilling the mother plant pseudostem at different heights (0.9 and 0.6 m), where the fertilizers, at the different established doses (75, 100 and 125% or 90, 120 and 150 g), were inserted according to the fertilization plan established at each farm (same moment of application and product applied).

The sampling was conducted on a weekly basis on the sucker plants; the following data were recorded and quantified:

Height and diameter of the plant (m). The height was measured from soil surface or pseudostem base to the apex of the insertion of the cigar leaf or the last leaf in sequence to open, whereas the pseudostem diameter was determined at 30 cm from the soil surface.

Emerged leaves (No). We counted the number of emerged leaves after application of treatments and the leaf emission rate was determined.

Leaf area, specific leaf area and specific leaf weight were determined in banana leaf area using the calculation proposed by Martinez (1987):

Leaf area = length x width x 0.8   (1)

Specific leaf area (SLA) was obtained by dividing a rectangular section of 50 cm^2 of the middle part of the third leaf of each of the plants subjected to various treatments by the dry weight of the same section:

Specific leaf area = 50 cm^2/dry weight   (2)

Specific leaf weight (SLW) was determined following the methodology of Reyes et al., (2000), who used the specific leaf area:

Specific leaf weight = dry weight (mg)/leaf area (cm^2) (3)

Production (kg). The bunch weight was an estimate because the plants were not suitable for harvest until the last observation. For that reason, the fingers located on the apical and subasal hands of the bunch were counted and the average weight of the fingers was determined.

For statistical analysis of the data, the specific periods of agronomic importance in the banana, such as floral differentiation (Stage 1) and flowering (Stage 2), which occur after 2 to 4 weeks and 18 and 22 weeks after harvest, respectively, were taken. For the experiment, data for week 11 of floral differentiation and week 30 of bloom were taken, where over 70% of the plant population was in this period. These data were analyzed using a 3 x 2 + 1 factorial design, with three being the fertilizer dose factor (75, 100 and 125%), two being insertion height (0.6 and 0.9 m) and one being the control treatment. Additionally, a Duncan test was carried out using the statistical software SAS® (SAS Institute, 1985).

Results and discussion

Plant height

Figs. 1A and 1B demonstrate the dynamics of height during the experiment, where the plants subjected to different treatments showed no significant differences in any of the stages evaluated on both farms. However, by week 30 or bloom (Stage 2), the highest values were recorded for treatments 75% Fert. + 0.9 m (1.32 m), 25% Fert. + 0.9 m (1.29 m), and 25% Fert. + 0.6 m (1.28 m), while the control had a value of 1.20 m on the Rita María farm, obtaining a 0.12 m gain when comparing 75% Fert. + 0.9 m and the

control. On the Retiro farm, the best treatments were 75% Fert. + 0.6 m (1.18 m), 25% Fert. + 0.9 m (1.16 m) and 75% Fert. + 0.9 m (1, 12 m) and the control was 1.09 m, with a height gain of 0.09 m when comparing 75% Fert. + 0.6 m and the control. The tendency of height changes over time suggested that the gain in height in all treatments decreased as emergence or inflorescence approached, as reported by Vuylskete et al. (1996), who considered Musa sp. as plants of a determinate growth habit, where the vegetative growth stops once flowering occurs.

These data indicate that the methodology of fertilizer insertion in the pseudostem presents results similar or superior to the control in terms of height. These results agree with the study of Flores and López (1991), who found no difference when the fertilizer was applied to the soil in a semicircle around the sucker in succession. When the fertilizer was inserted directly into the pseudostem, apparently it was more easily absorbed by the plant and translocated to the suckers more quickly than when applied to the soil (Labarca et al., 2005). Likewise, the best results were seen when applying 75, 100 or 125% doses at a height of 0.9 m, while the lowest values were evident when the insertion was done at 0.6 m regardless of the dose, except for treatment 75% dose inserted at 0.6 m.This may be due to the water content in the pseudostem that exists below the insertion point and facilitates solubilization of the fertilizer, i.e. a higher water content exists at this point that allows a better dilution of the fertilizer as it is moving in the pseudostem by gravity force, approaching the corm. Also, it can be inferred that there was more efficient translocation of dissolved fertilizer in the pseudostem to the sucker at a height of 0.9 m due to the pressure that that height exerted: considering the Pascal law, the height, liquid density, and gravity determine the pressure value, therefore, the treatments at 0.6 m should have lower pressure values compared to the treatments at 0.9 m for the same dose. Likewise, it could be that, when inserted at a height under 0.6 m, it is more difficult or inefficient for the flow of the fertilizer because the cell size becomes smaller as it approaches the ground or corm, thus preventing fertilizer translocation. Since nitrogen is considered an element involved in the growth, development and production of dry matter within the plants (Finol et al., 2004), the growth in height can be attributed to efficiency of translocation of this element, which is consistent with the results of Lahav and Turner, quoted by Borges et al., (1997), who showed a positive correlation ($r = 0.79$) between the production of dry matter and N absorbed resulting in a greater height in some treatments.
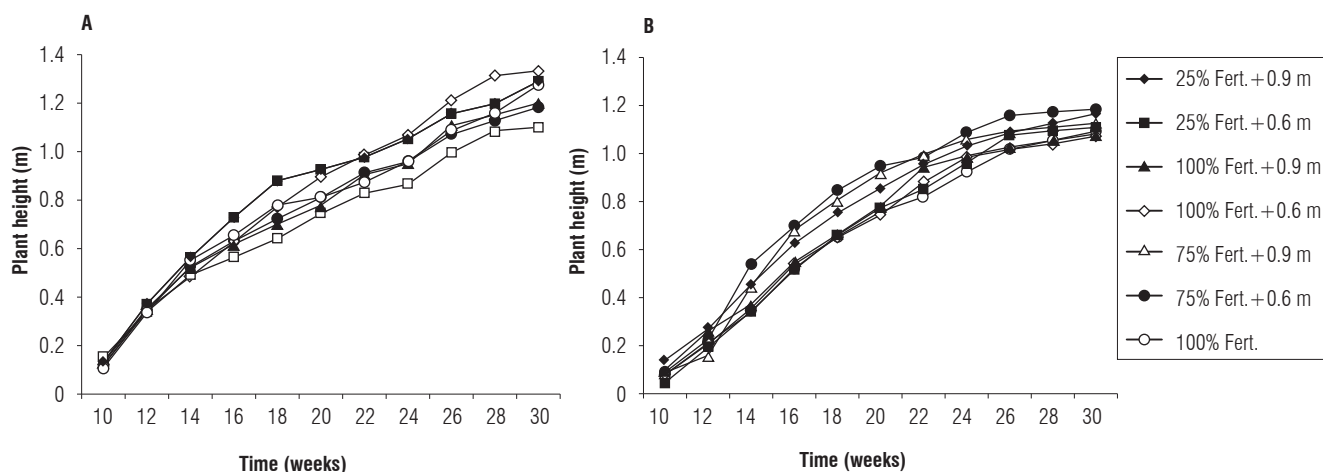
FIGURE 1. Dynamics of plant height in banana plants subjected to the different treatments on the Rita María farm (A) and on the Retiro farm (B) located in the municipalities of Apartado and Carepa (Colombia), respectively.

Plant diameter

In Figs. 2A and 2B, perimeter dynamics during the experiment may be evidenced, where the plants subjected to different treatments showed no significant differences at any of the developmental stages evaluated on both farms. Towards Stage 2, the higher values of pseudostem diameter were observed in treatments 25% Fert. + 0.9 m (0.38 m), 25%Fert. + 0.6 m (0.38 m), 75% Fert. + 0.9 m (0.38 m), and 100% Fert. + 0.9 m (0.36 m) while the control had a value of 0.33 m, with a gain of 0.06 m when comparing 25% Fert. + 0.9 m, 25% Fert. + 0.6 m, and 75% Fert. + 0.9 m with the control for the Rita María farm. On the Retiro farm, the best treatments were 25% Fert. + 0.9 m (0.33 m), 75% Fert. + 0.9 m (0.33 m) and 25% Fert. + 0.6 m (0.32 m), while the control had 0.31 m, with a gain of 0.02 m in diameter for

25% Fert. + 0.9 m and 75% Fert. + 0.9 m as compared with the control. The absence of significant differences in the perimeters among the different treatments and the control match reports by Flores and López (1991), who showed that the values of thickness of pseudostem were very similar when inserting fertilizer to the trunk of the recently harvested mother plant and applying it in a semicircle around the sucker in succession. The visual differences observed for plant diameter among the different treatments in our experiment were due to a better performance in treatments 25% Fert. + 0.9 m, 25% Fert. + 0.6 m, 100% Fert. + 0.9 m and 75% Fert. + 0.9 m, where three of these treatments involved the fertilizer insertion height of 0.9 m and were possibly due to the same explanation given for the plant height in terms of fertilizer insertion.
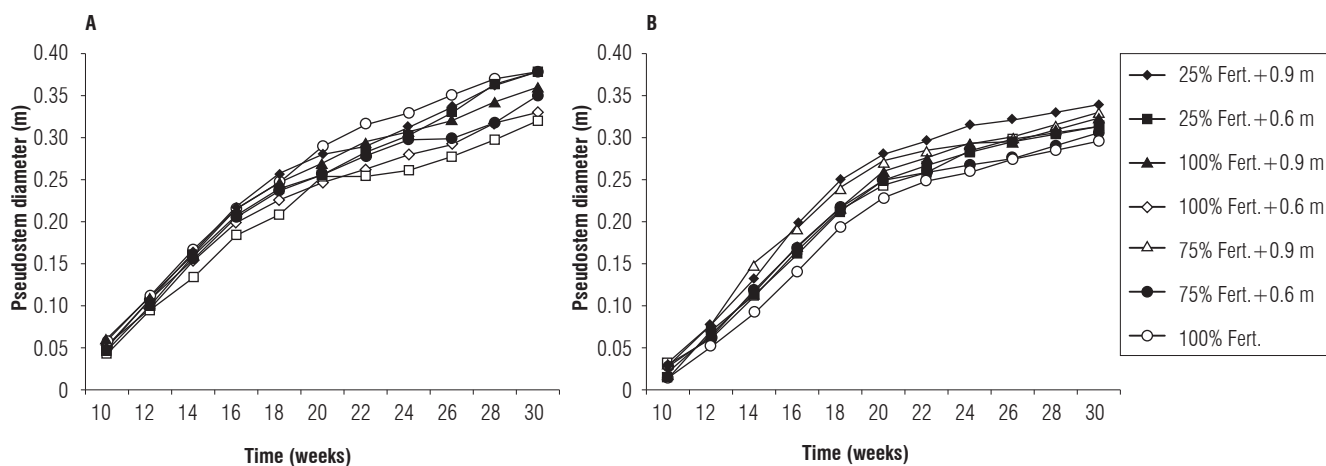

FIGURE 2. Dynamics of pseudostem diameter in banana plants subjected to the different treatments on the Rita María farm (A) and the Retiro farm (B) located in the municipalities of Apartado and Carepa (Colombia), respectively.

The importance of this variable is due to the relationship between the circumference of the pseudostem and the bunch weight as indicative of vigor-weight proportionality (Cuellar and Morales, 2005). The formation of the inflorescence within the pseudostem begins after the floral differentiation process, therefore, thesize of the pseudostem could be related to the bunch size and weight, so that greater perimeter of the pseudostem could resultin increased bunch weight. From our data, it can be seen that the best treatments were those with the insertion height of 0.9 m. With respect to the dose, the best treatment was the highest dose (125%), wherein there may have been a better translocation of fertilizer, which agrees with results reported by Fernández and García (1972), who evaluated the effect of nitrogen nutrition on the pseudostem and found that the correlation was higher for "circumference - number of hands" than for "circumference - bunch weight", which indicates that with a thicker pseudostem, one could expect a greater number of hands. Likewise, these authors mentioned that the reason for this difference seems to be that the weight of the bunches depends on the several aspects of cultural practices, while the number of hands is only dependent on the stages prior to differentiation, and that these are the same stages that control the circumference of the pseudostem.

Leaf area

The plants subjected to different treatments in both farms showed no significant differences in leaf area at any of the evaluated stages (Figs. 3A and 3B). However, towards Stage 2, the higher values were observed in treatments 75% Fert. + 0.9 m (1.93 m^2), 25% Fert. + 0.9 m (1.90 m^2), and 25% Fert. + 0.6 m (1.88 m^2), while the control had a value of 1.80 m^2, with a gain of 0.13 m^2 when comparing 75% Fert. + 0.9 m

with the control for the Rita María farm. The Retiro farm had the best in treatments 75% Fert. + 0.9 m (1.88 m^2), 75% Fert. + 0.6 m (1.87 m^2), and 25% Fert. + 0.9 m (1.79 m^2), while the leaf area for the control was 1.74 m^2, with a gain in leaf area of 0.09 m^2 when comparing 75% Fert. + 0.9 m and the control. The behavior of the curves presented in both graphs fit a second degree polynomial model, where the gain in leaf area tended to decrease as the plant approached the emission of the inflorescence (week 30), which was probably due to a reduced rate of leaf emission (Aristizábal, 2008). According to Robinson and Saúco (2010), the leaf area of the banana in the different clones (Grand Naine and Valery) are similar, with a value of 2.89 m^2, influenced by the number of leaves at flowering. The length and width of leaves were different and, for this reason, if the calculation is performed according to Martínez (1987), it yields values of 1.96 and 2.45 m^2 for Grand Naine and Valery, respectively. This suggests that the leaf areas in the experimental zones presented lower values than those previously reported, presumably due to environmental conditions, but it should be empathized that the lower values of leaf area in Retiro compared to Rita María were due to the morphological characteristics of leaves in the clones.

Since nitrogen is considered as an element involved in growth, development and production of dry matter within the plant (Finol *et al*., 2004), its deficiency causes decreased plant growth, reducing the number of leaves and their size (López and Espinosa, 1995) and short, thin and compact petioles (Robinson and Saúco, 2010); leaf area could be a variable associated with the concentration and availability of nitrogen and, for that reason, various experimental
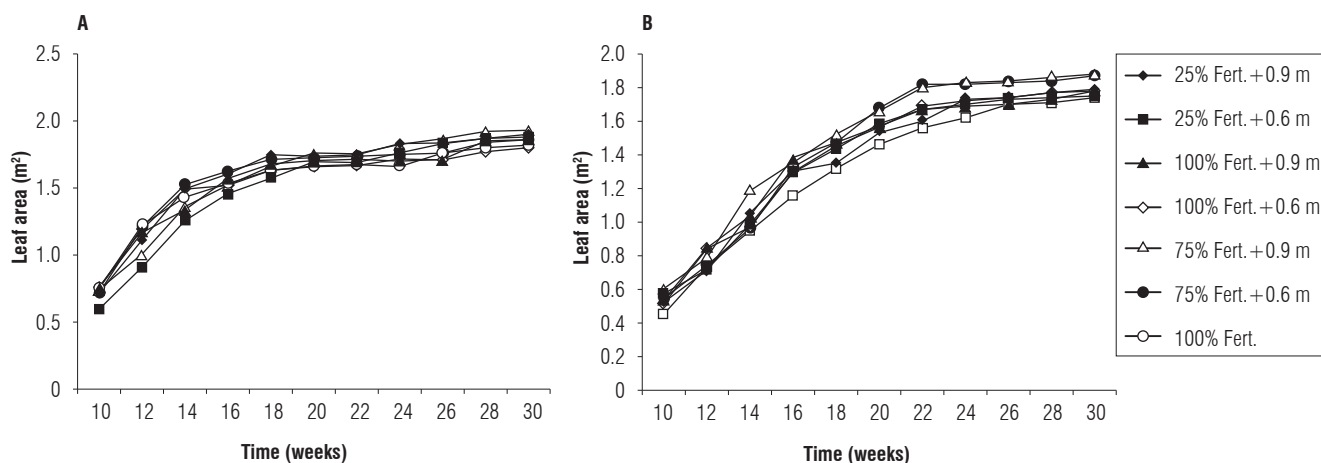

FIGURE 3. Dynamics of leaf area in banana plants subjected to the different treatments on the Rita María farm (A) and on the Retiro farm (B) located in the municipalities of Apartado and Carepa (Colombia), respectively.

results are due to the efficient translocation of this element in each of the treatments.

Number of emitted leaves

The dynamics of the foliar emission during the experiment showed no significant differences at any of the stages evaluated on both farms (Figs. 4A and 4B). However, towards Stage 2, plants had higher values in treatments 25% Fert. + 0.9 m (17), 75% Fert. + 0.9 m (16.5), and 100% Fert + 0.9 m (16.3), while the control had a value of 16.1 for the Rita María farm. On the Retiro farm, the best treatments were 75% Fert. + 0.9 m (16), 25% Fert. + 0.9 m (15.5), and 25% Fert. + 0.6 m (15), while the value of leaf emission for the control was 14.7. Considering the results, it could be concluded that there is little difference in the emergence of leaves in the different treatments compared to the control

treatment, which is consistent with the results reported by Flores and López (1991), who found a difference of 0.11 in leaf emission when comparing fertilizer insertion in the pseudostem and application to the soil in a semicircle. The results also show that, like the other assessed variables, we obtained higher values in treatments involving 0.9 m fertilizer insertion, regardless of the dose used.

The emission of leaves stopped once the emergence of inflorescence occurred, indicating that the growth habit of the plant is determined (Vuylskete *et al.*, 1996), which coincided with results reported by Irizarry *et al.* (1980), who observed that the corm, pseudostem, and leaves stop growing when the inflorescence emerges. From Fig. 2, it could be said that, although there were equal or greater number of leaves in many treatments, this was not reflected in plant height, indicating that petioles and leaves had
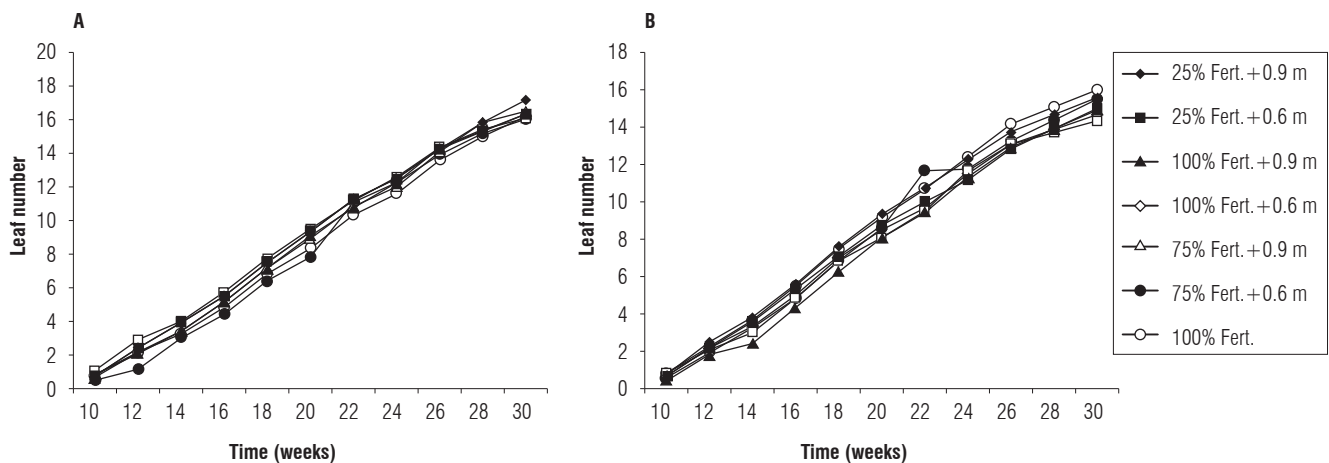

FIGURE 4. Dynamics of leaf emission in banana plants subjected to the different treatments on the Rita María farm (A) and on the Retiro farm (B) located in the municipalities of Apartado and Carepa (Colombia), respectively.
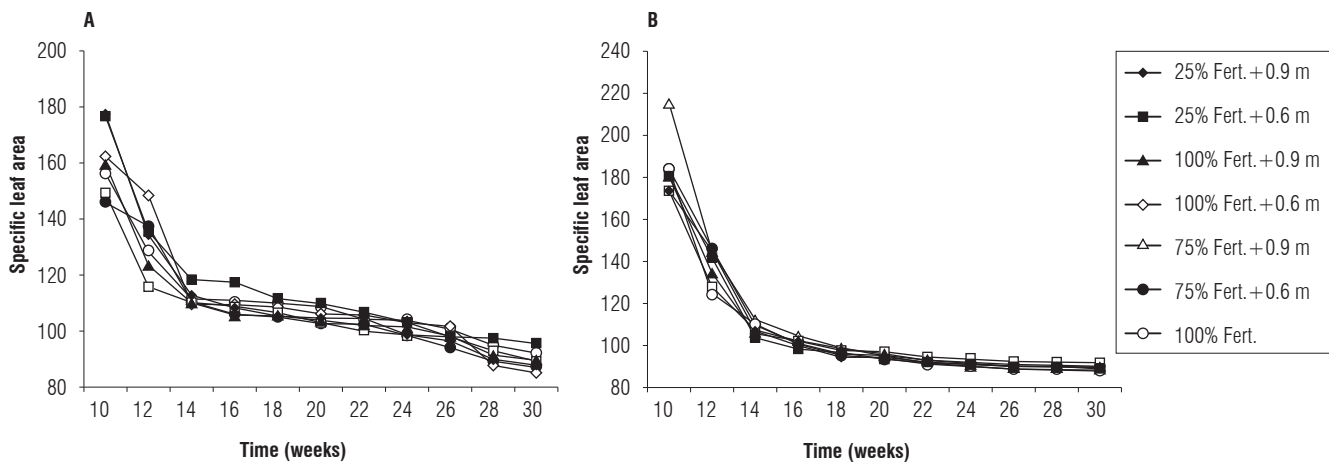

FIGURE 5. Dynamics of specific leaf area in banana plants subjected to the different treatments on the Rita María farm (A) and on the Retiro farm (B) located in the municipalities of Apartado and Carepa (Colombia), respectively.

short, thin and compact internodes, (Robinson and Saúco, 2010), possibly due to a deficiency in nutrient translocation. According to the literature, the deficiencies of various elements delay the leaf emission rate (number and timing of leaf appearance) such as nitrogen, phosphorus, potassium and calcium (López and Espinosa, 1995). For this reason, we can conclude that treatments involving the height of 0.9 m for fertilizer insertion were more efficient in the translocation of these nutrients (especially N, K, and Ca, elements presented in the added fertilizer). Additionally, the pseudostem may store both major and minor elements, which can complement and meet the nutritional requirements of the plants.

Specific leaf area

Figs. 5A and 5B evidenced dynamics of SLA during the experiment, where plants subjected to different treatments had no significant differences in SLA on the two farms. Although no significant differences were found between the treatments, it is valid to note that during Stage 1 (floral differentiation), the decline in SLA was more pronounced, with a reduction from 178 to 110 $m^2 g^{-1}$ on the Rita María farm, approximately, and a reduction from 216 $m^2 g^{-1}$ to 112 $m^2 g^{-1}$ on the Retiro farm. After this stage, decreasing SLA values ranged from 110 to 85 $m^2 g^{-1}$ at the Rita María farm and from 112 to 85 $m^2 g^{-1}$ at the Retiro farm, showing a less pronounced decrease at the end of the experiment for both farms.

The decreasing SLA was due to its inverse relationship with plant height, *i.e.*, the decrease in SLA was due to plant growth as the plant was reaching maturity (Pérez *et al*., 2004). Similarly, this behavior for SLA was also related to nitrogen content in the plant, since Pérez *et al.* (2004)

reported that the nitrogen content in plants diminishes as the plant grows and therefore shows a decline for this variable. A similar, more pronounced trend occurred at the floral differentiation stage in our study, when the content of nitrogen in the plant was higher since at this stage of the life cycle, the plant presented maximum vegetative growth; this serves as an explication of a more pronounced reduction of SLA at the stage of floral differentiation. Finally, the reduction in SLA may be attributed to an alteration in the structure of leaves, increasing concentration of nutrients or non-structural carbohydrates in the leaves (Newton, 1991); this reduction is the result of an inability of the plant to assign these compounds to structural growth (Bazzaz *et al.,* 1987; Baxter *et al.,* 1994).

Specific leaf weight

Figure 6 evidence dynamics of SLW during the experiment, where plants subjected to different treatments showed no significant differences on the two farms. Although no significant differences were found among the treatments, during Stage 1 (floral differentiation) the largest increases of treatments were observed, where there was an increase from 0.006 to 0.008 g m^{-2} on the Rita María farm and an increase from 0.005 to 0.009 g m^{-2} on the Retiro farm. After this period, the increases in SLW ranged from 0.008 to 0.0011 g m^{-2} on the Rita María farm and from 0.009 to 0.0011 g m^{-2} on the Retiro farm, showing a large reduction of SLW at the end of the experiment for both farms.

The behavior of this variable is appropriate in banana plants and related to the SLA, since the variables are reversed, i.e. taking into account the leaf area and the dry weight of leaves, it can be noted that while SLA decreased with time, SLW increased during the same time of the experiment.
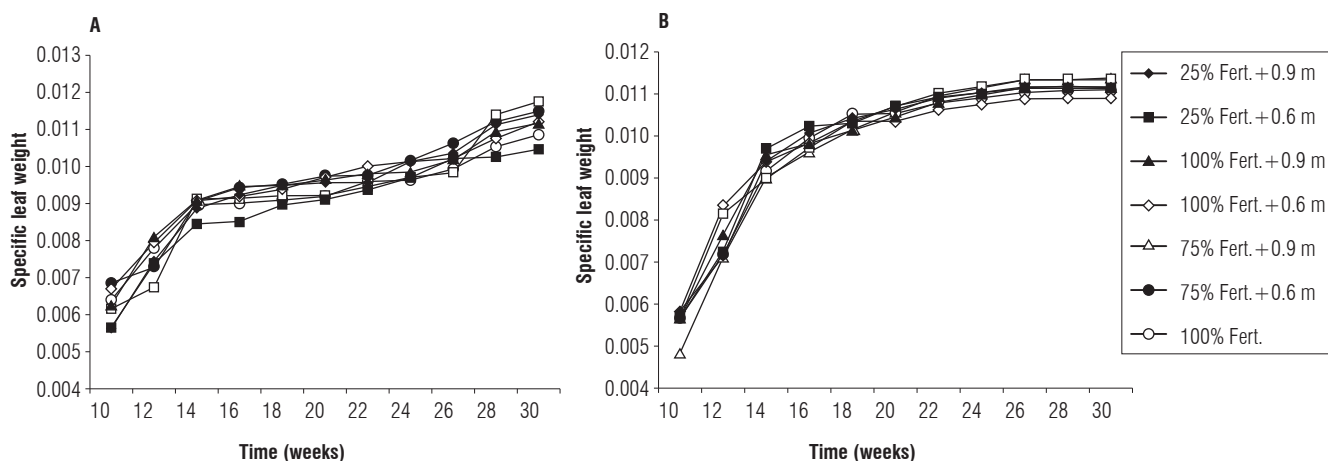

FIGURE 6. Dynamics of specific leaf weight in banana plants subjected to the different treatments on the Rita María farm (A) and on the Retiro farm (B) located in the municipalities of Apartado and Carepa (Colombia), respectively.

SLW can have a very close relationship with the nitrogen content in the plant and over time, SLW is stabilizing as the plant reaches the flowering period, a similar trend is presented by the nitrogen content, while, on the other hand, SLA decreases as the plant is approaching the maturation period in which the nitrogen content is lessening.

Production

Fig. 7A shows the trend in the number of hands in bunches of plants under the experiment, where no significant differences were observed among the treatments, but a slight upward trend in treatments 25% Fert. + 0.9 m (6.8) and 75% Fert. + 0.9 m (6.8) compared to the control (6.6) was recorded, which may indicate that the methodology studied can be equal to or superior to soil fertilization in a semicircle around the sucker. Also, if one compares the pseudostem perimeter, it shows that the treatments of 90-125% (25% Fert. + 0.9 m) and 90-75% (75% Fert. + 0.9 m) were those with the best results. This is consistent with results reported by Fernandez and Garcia (1972), who evaluated the effect of nitrogen nutrition on the circumference of the pseudostem and found that the correlation was higher in the circumference - number of hands relationship than in the circumference - weight of bunches relationship.

In Fig. 7B, it is evidenced that for the number of fingers on the apical and subapical hands, significant differences were not found between the different treatments according to Duncan test, suggesting that the methodology studied (insertion of fertilizer at harvested pseudostem) does not affect the production of fingers compared with the conventional methodology, results similar to those found in the study by Flores and López (1991). The variation of the fingers on different hands is due to the position of the hands on the rachis; the first hands have more fingers than preceding hands, which have a similar number of fingers (Vargas, 1987).

In the graph of bunch weight (Fig. 7C), a similar behavior in treatments involving the insertion height of 0.9 m, regardless of dose, is shown, i.e., treatments that were applied to 0.6 m showed the lowest values in each of the doses (25% Fert. + 0.6 m: 20.5 kg, 100% Fert. + 0.6 m: 20.2 kg, and 75% Fert. + 0.6 m: 18.5 kg) compared with applications that were made at 0.9 m (25% Fert. + 0.9 m: 21.8 kg, 100% Fert. + 0.9 m: 22 kg, and 75% Fert. + 0.9 m: 21.2 kg), possibly due to the translocation efficiency of nutrients when the insertion was made at a greater height. Regarding the control treatment, a value of 21 kg was estimated, indicating that no major differences were found with other treatments, similar to results reported by Flores and López (1991), who found a
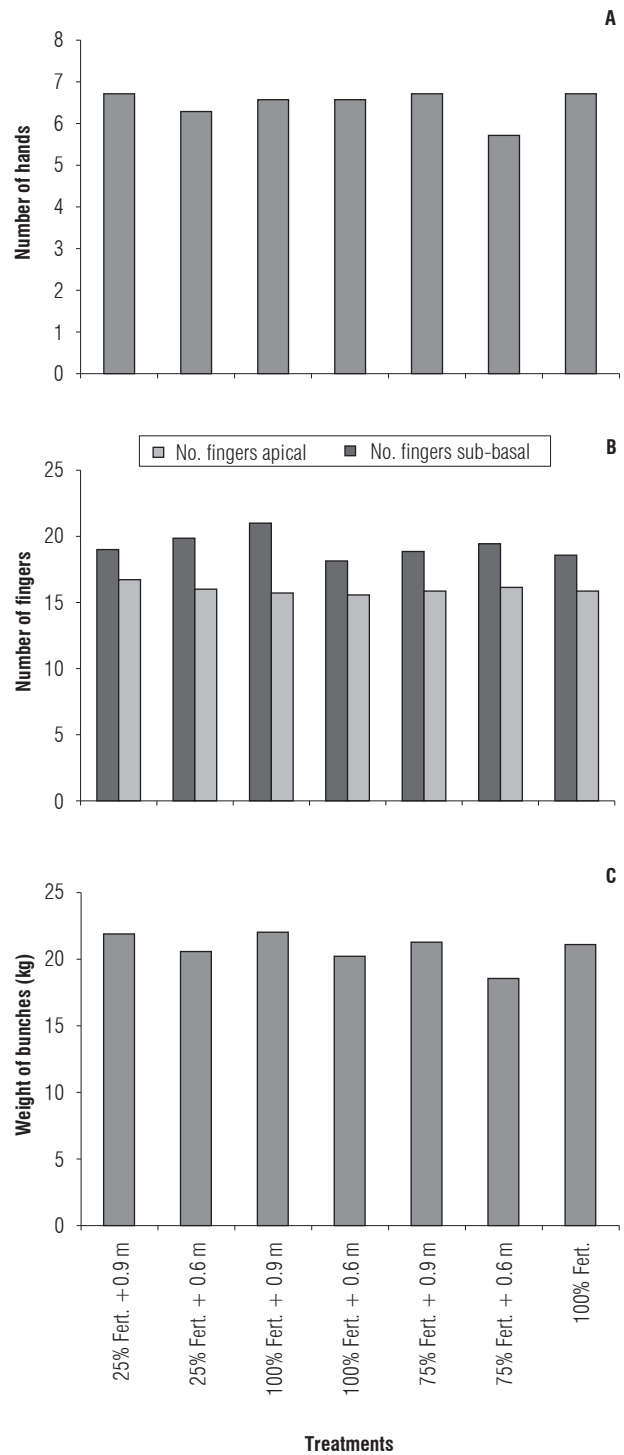

FIGURE 7. A. Average number of hands collected from banana plants subjected to different treatments. B. Number of fingers on basal and apical hands of banana plants subjected to different treatments. C. Estimated bunch weight of plants subjected to different treatments. Means with different letters indicate significant differences according to Duncan's test ($P \le 0.05$).

difference of 0.60 kg, while in our experiment, we found a difference of 0.8 to 1 kg when comparing treatments 25% Fert. + 0.9 m and 100% Fert. + 0.9 m, respectively.

The methodology of fertilizer insertion in the pseudostem of the harvested mother plant is equal to or superior to soil fertilization in a semicircle around the sucker, which could represent economical benefits due to a more efficient application of fertilizers in the culture. Although no significant differences were found between doses of fertilizer, a trend was observed of better plant performance in treatment of 75 and 100% fertilizer dose inserted at 0.9 m.

Literature cited

Ardila, Y.P. 2010. Efecto de micronutrientes (B-Zn), aminoácidos y fosfitos sobre la producción y calidad del banano (*Musa* AAA Simmonds var. Williams) en la zona de Urabá. Undergraduate thesis. Faculty of Agronomy, Universidad Nacional de Colombia, Bogota.

Aristizábal, M. 2008. Evaluación del crecimiento y desarrollo foliar del plátano hondureño enano (*Musa* AAB) en una región cafetera colombiana. Agron. 16, 23-30.

Baxter, R., T.W. Ashenden, T.H. Sparks, and J.F. Farrar. 1994. Effects of elevated carbon dioxide on three montane grass species. I. Growth and dry matter partitioning. J. Exp. Bot. 45, 305-315.

Bazzaz, F.A., N.R. Chiariello, P.D. Coley, and L.F. Pitelka. 1987. Allocating resources to reproduction and defense. New assessments of the costs and benefits of allocation patterns in plants are relating ecological roles to resource use. BioScience 37, 58-67.

Borges, A., A. Gomes, and L. Da Silva. 1997. Solos, Nutrição e adubação a cultura da banana. EMBRAPA; Ministerio da Agricultura e do Abastecimiento, Cruz das Almas, Brazil.

Cavalcante, A., E. Valadares, and U. Tiburcio. 2005. Interdependência na absorção e redistribuição de fósforo entre planta mãe e filha de bananeira. Rev. Bras. Frutic. 27, 255-259.

Cuellar, J. and M. Morales. 2005. Efecto de la densidad y sistema de siembra sobre el rendimiento en banano *Musa* Aaa variedad Williams en la zona bananera departamento del Magdalena. Undegraduate thesis. Universidad del Magdalena, Santa Marta, Colombia.

Díaz, A.C. 2005. Respuestas fisiológicas, productivas y de la mancha de madurez del banano (*Musa* AAA cv. Grand Naine) a la aplicación de calcio en la zona de Urabá. Undegraduate thesis. Faculty of Agronomy, Universidad Nacional de Colombia, Bogota.

Fernández, E. and V. García. 1972. Effect de la nutrition azotée sur le circunference du pseudotronc. Fruits 27, 509-512.

Finol, J., L. Fernández, C. Nava, and D. Esparza. 2004. Efecto de fuentes y dosis de nitrógeno sobre la producción y calidad del fruto del banano (*Musa* grupo AAA subgrupo Cavendish clon Grand Naine) en la planicie aluvial del río Motatán. Rev. Fac. Agron. 21, 220-230.

Flores, C. and C. López. 1991. Formas de colocación de fertilizante en el cultivo de banano. pp. 3-8. In: Book of Abstracts, Reunión Acorbat 91. Acorbat, Villahermosa, Mexico.

Irizarry, H., S. Silva, and J.V. Chandler. 1980. Nutrient uptake by intensively managed plantains as related to stage of growth at two locations. J. Agric. Univ. Puert. Rico 65, 331-345.

Keshava, M. and B. Iyengar. 1994. Effect of time and method of placement on the absorption of phosphorus by Robusta banana. Indian J. Hortic. 51, 130-135.

Labarca, M., L. Sosa, D. Esparza, C. Nava, L. Fernández, and A. Villar. 2005. Evaluación de la colocación del fertilizante en la planta madre una vez cosechada sobre las variables de crecimiento y producción en el cultivo del plátano Harton (*Musa* AAB). Rev. Fac. Agron. 22, 408-420.

López, A. and J. Espinosa. 1995. Manual de nutrición y fertilización del banano. INPOFOS, Quito.

Martínez, G.A. 1987. Determinación del área foliar mínima en plátano en el trópico húmedo. Rev. ICA 19, 183-187.

Newton, P.C.D. 1991. Direct effects of increasing carbon dioxide on pasture plants and communities. New Zeal. J. Agric. Res. 34, 1-24.

Pérez, J., E. Garcia, J. Enríquez, A. Quero, J. Pérez, and A. Hernández. 2004. Análisis de crecimiento, área foliar específica y concentración de nitrógeno en hojas de pasto "mulato" (*Brachiaria híbrido* cv.). Téc. Pecu. Méx. 42, 447-458.

Reyes, M., M. Villegas, M. Colinas, and G. Calderón. 2000. Peso específico, contenido de proteína y de clorofila en hojas de naranjo y tangerino. Agrociencia 34, 49-55.

Rivas, D. 2006. Inyecciones sistémicas en los arboles. Universidad Autónoma de Chapingo, Chapingo, Mexico.

Robinson, J.C. and V.G. Saúco. 2010. Bananas and plantains. 2nd ed. CABI, Wallingford, UK.

Rodríguez, C., G. Cayón, and J. Mira. 2006. Influencia del seudotallo de la planta madre cosechada sobre el crecimiento y producción del hijo de sucesión en banano (*Musa* AAA Simmonds). Agron. Colomb. 24, 274-279.

SAS Institute. 1985. Statistical Analysis System Institute. 5th ed. Cary, NC.

Shand, C. 1975. Investigations on the use of micropore-release packet fertilizer. Investigaciones sobre la utilización del descargador de fertilizantes por microporos. Annual Report 1974. Banana Board, Kingston.

Vargas, G. and M. Soto. 1987. Comparación en calidades y rendimientos del fruto del banano de los clones "Grand Naine" y "Valery". Boletin Técnico. Catie, Turrialba, Costa Rica.

Vargas, A., M. Araya, S. Rojas, and P. Román. 2005. Effect of removing or leaving the suckers at flowering of plantain (*Musa* AAB, cv. 'False Horn' type) on bunch weight and foliar nutrient content of the parent plant. Sci. Hortic. 107, 70-75.

Vuylskete, D., R. Swennen, and E. De Langhe. 1996. Field performance of somaclonal variants of plantain (*Musa* AAB). J. Amer. Soc. Hort. Sci. 121, 42-46.