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Original article

Effect of FitoMas-E application on the production of *Coffea canephora* Pierre ex Froehner

Efecto de la aplicación de FitoMas-E en la producción de *Coffea canephora* Pierre ex Froehner

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ABSTRACT: During October 2013 to March 2017, in areas of the Agro-Forestry Research Institute at the Tercer Frente Experimental Station, Santiago de Cuba province, the biostimulatory effect of FitoMas-E was studied on the yield of *Coffea canephora* Pierre ex Froehner grown at 3 mx 1.5 m on brown soil under the shade of *Samanea saman* and *Gliricidia sepium*. The treatments were FitoMas-E (FM); FM + $N_{18.85}$ $P_{12.5}$ K_{20} (25 % of the control); FM + $N_{37.5}$ P_{25} K_{40} (control 50 %); FM + $N_{56.3}$ $P_{37.5}$ K_{60} (control 75 %) and N_{75} P_{50} K_{80} - Control. The biostimulant was applied at a dose of 1.0 L ha^{-1} and was fractionated in the phenological phases of flowering, fruit filling and harvest. 60 % of nitrogen and potassium as well as phosphorus 100 % was applied in the months of April-May while in the second application 40 % of the dose of nitrogen and potassium. The production of cherry coffee per plant was evaluated and it was extrapolated to a ton of coffee gold per hectare. FitoMas-E application stimulated the yield of the coffee tree. Significant differences were found between treatments in all the experimental years and in the accumulated harvest. The FitoMas-E application to *Coffea* canephora in the first three years after low pruning in a Brown soil provided high and stable productions of this species with yield accumulated higher than inorganic fertilization and the best benefit/cost ratio, which constitutes an alternative to mineral fertilization with national inputs.

Key words: biostimulant, coffee, yield.

RESUMEN: Durante octubre 2013 a marzo 2017, en áreas del Instituto de Investigaciones Agro-Forestales de la Estación Experimental Tercer Frente, provincia Santiago de Cuba, se estudió el efecto bioestimulador del FitoMas-E en el rendimiento de *Coffea canephora* Pierre ex Froehner, cultivado a 3 m x 1,5 m, en suelo Pardo mullido, bajo sombra de *Samanea saman* y *Gliricidia sepium* .Los tratamientos fueron*:* FitoMas-E (FM); FM+$N_{18.85}$ $P_{12.5}$ K_{20} (25 % del testigo); FM+$N_{37.5}$ P_{25} K_{40} (50 % del testigo); FM+$N_{56.3}$ $P_{37,5}$ K_{60} (75 % del testigo) y N_{75} P_{50} K_{80}-Testigo. El bioestimulante se aplicó en dosis de 1,0 L ha^{-1} y se fraccionó en las fases fenológicas de floración, llenado del fruto y cosecha. El 60 % de nitrógeno y el potasio, así como el 100 % del fosforo se aplicó en los meses de abril-mayo; mientras que en la segunda aplicación, el 40 % de la dosis de nitrógeno y el potasio. Se evaluó la producción de café cereza por planta y se extrapoló a toneladas de café oro por hectárea. La aplicación del FitoMas-E estimuló el rendimiento del cafeto. Se encontraron diferencias significativas entre los tratamientos en todos los años experimentales y en la cosecha acumulada La aplicación de FitoMas-E a *Coffea canephora* en los tres primeros años, después de la poda baja, en suelo Pardo, proporcionó producciones altas y estables de esta especie con rendimiento acumulado superior a la fertilización inorgánica y la mejor relación beneficio/costo, lo que constituye una alternativa con insumos nacionales a la fertilización mineral.

Palabras clave: bioestimulantes, cafeto, rendimiento.

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INTRODUCTION

The use of bioproducts in agriculture is an alternative to achieve ecologically sustainable development; they do not pollute the environment and contribute to the conservation of soil fertility and agroecosystem biodiversity.

Biostimulants were initially used in organic production, but nowadays their use in conventional production has increased due to economic and sustainability imperatives. The market for these products is growing annually and in 2018 reached $2.24 million (1).

Agricultural biostimulants can increase flowering, growth, productivity, and nutrient use efficiency (2) and tolerance to abiotic stresses related perhaps to significant increases in proline and soluble sugars (3). For fruit trees, information is probably limited, since trials with fruit trees have as disadvantages the long period of promotion, the need for a large experimental area, due to the size of the individuals and the separation of trees, and the abiotic and biotic stress conditions experienced over the years by the individuals. It has been shown that soil application or foliar application of humic acid produces a positive effect on growth, yield and fruit quality of peach, apple and apricot (4).

In Cuba, several products have been developed that have demonstrated their efficiency in plant nutrition, growth and agricultural yields, and crop physiology. Among Cuban biostimulants, the most widely used has been FitoMas-E, which is obtained from derivatives of sugar industry wastes. It contains up to 2.5 % saccharides and 1.5 % lipids, in addition to a mineral fraction of 6.5 % total N, 2.7 % P_2O_5 and 5.24 % K_2O.

It has been documented that FitoMas E has the potential to improve the production and quality of crops (5,6), as well as its effect on the germination of star apple seeds (7). It was demonstrated that it is a product that can be applied jointly with other biological products, such as efficient microorganisms in beans (8), Bayfolan in sunflower (9). In bell pepper, efficiency in dry mass production was increased by applying efficient microorganisms, FitoMas-E and Biobras-16 (10).

For coffee plants, research conducted in Brazil showed the positive effect of the biostimulant *Stimulate*, as well as the dependence of this response on the varieties studied (11). Its efficiency in the nursery phase was also demonstrated (12-14). The application of 1 L ha^{-1} FitoMas-E increased the dry biomass and leaf area of the seedlings and the inoculation of mycorrhizae, together with the bioproduct, reduced up to 25 % the mineral fertilizer with results superior to the application of 100 % of the same (15). In red Ferrallitic leached soil, FitoMas increased its efficiency, to the extent that the doses were increased and that with the dose of 6 ml L^{-1} the levels of organic fertilizer in the substrate decreased, without affecting the quality of the coffee seedlings (16).

The available information on the use of biostimulants in the productive phase of coffee plants, worldwide is scarce and contradictory. There are results without response to them and in others with positive response, a situation that is related to the diversity of products, to the properties of each soil, the methods of application of the products and the management adopted by the producers (17). In Cuban coffee growing, it has been demonstrated the positive effect of inorganic fertilization in the increase of *Coffea canephora* yields (18). The high prices of these inputs have caused the search for national alternatives to try to reach and maintain the productive levels of the plantations; however, there is no information available on their use. However, there is no information available on their use in the productive phase. For this reason, the research was carried out with the objective of determining the effect of FitoMas-E on the yield of *Coffea canephora* Pierre ex Froehner and its possible use as a complement to the mineral fertilization of this species.

MATERIALS AND METHODS

The work was carried out in the period October 2013 to March 2017, in areas of the Tercer Frente Agroforestry Experimental Station, located at 150 m a.s.l in Santiago de Cuba province. Precipitation in the experimental period was 1707 mm in 2014, 1240 mm in 2015 and 2119 mm in 2016, while the average temperature in those same years was 27.6 ºC in 2014 and 2015 and 27.1 ºC in 2016.

The coffee plant was grown in a Brown mellow soil (19) with 4.24 % organic matter, pH in water of 4.6; 153 mg P_2O_5 and 101 mg K_2O 100 g soil^{-1}) available and Ca/Mg ratio of 2.3 and K/∑bases of 9.05.

The experiment was set up under carob (*Samanea saman* Merrill) and *Gliricidia sepium* (Jacq) Steud shade, in a plantation of *Coffea canephora* Pierre ex Froehner, established in May 1996 at 3m x 1.5 m subjected to low pruning in 2003, 2007 and 2013.

Treatments evaluated were:

- $N_{75}P_{50}K_{80}$ - Control
- FitoMas-E 1 liter ha^{-1} N0P0K0
- FitoMas-E 1 liter ha^{-1}+ $N_{18.85}P_{12.5}K_{20}$ (control 25 %)
- FitoMas-E 1 liter ha^{-1}+$N_{37.5}P_{25}K_{40}$ (control 50 %)
- FitoMas-E 1 liter ha^{-1}+$N_{56.3}P_{37.5}K_{60}$ (control 75 %)

A randomized block design with four replications was used. Each plot consisted of 18 plants, 16 of which were computational.

FitoMas-E was supplied by the Cuban Institute of Sugarcane Derivatives (ICIDCA) and for its application it was fractioned in three moments, in the phenological phases of flowering (34 % of the total) and fruit filling (33 % of the total) and harvest (33 % of the total), adapting them to the pluviometry of each year (Figures 1 and 2).

Urea, simple superphosphate and potassium chloride were used as carriers. Starting in 2014, the carrier 5-5-24-3 was started to be used and nitrogen doses were balanced with urea.

Mineral fertilization and the application of FitoMas in dependence on treatment were fractioned taking into consideration the pluviometry of the area in each year (Figures 1 and 2). Sixty percent of the nitrogen and potassium doses were applied in the first fertilization of the year and the rest in the second application. All the phosphoric fertilizer was applied in the first fertilization of the year.

The harvest of coffee plants was measured as a response variable. When the cherries matured, the weight in kg per plant of each raisin was taken and was summed at the end of the harvest. This value was extrapolated to one hectare. By multiplying the value obtained by the conversion factor from cherry coffee to gold coffee for each year, the yield in tons of gold coffee per hectare was obtained.

For the processing of the harvest, the normality of the data and the homogeneity of variance were checked. A double classification analysis of variance was performed on the data. Where significant differences were found between treatments, means were checked by Duncan's multiple range test ($p \leq 0.05$).

For the calculation of the economic effect, the value of the accumulated harvest was used, as well as the total fertilizer consumption in the experimental years. The price of 1 L of FitoMas-E was taken as $ 3.00 MN. The price of the $N_{75}P_{50}K_{80}$ fertilizer dose at $ 94.92 MN and that of Robusta coffee at $ 800.00 MN per ton. For the handling, application and capping of fertilizer on one hectare, 8.38 days are needed, but as the fertilizer was divided into two opportunities, 16.77 days were estimated. For the application of FitoMas-E on 1.0 ha, the norm of the

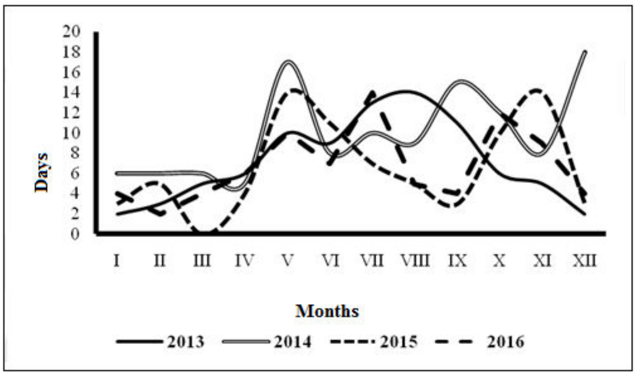

Figure 2. Monthly rainfall days in the experimental period

technology chart is 1.56 days. The wage rate was estimated at $14.48 MN per day.

The following indicators were considered:

- Production value (total production value in pesos ha^{-1}): crop yield multiplied by the selling price of a ton of product.
- Application costs per hectare (total cost in pesos ha^{-1}): sum of the expenses incurred for the application of mineral fertilizers and the biostimulant used in all years.
- Profit ($ ha^{-1}): difference between production value and production costs.
- Economic benefit ($ ha^{-1}): difference between the gain of the treatment analyzed and that of the control treatment.

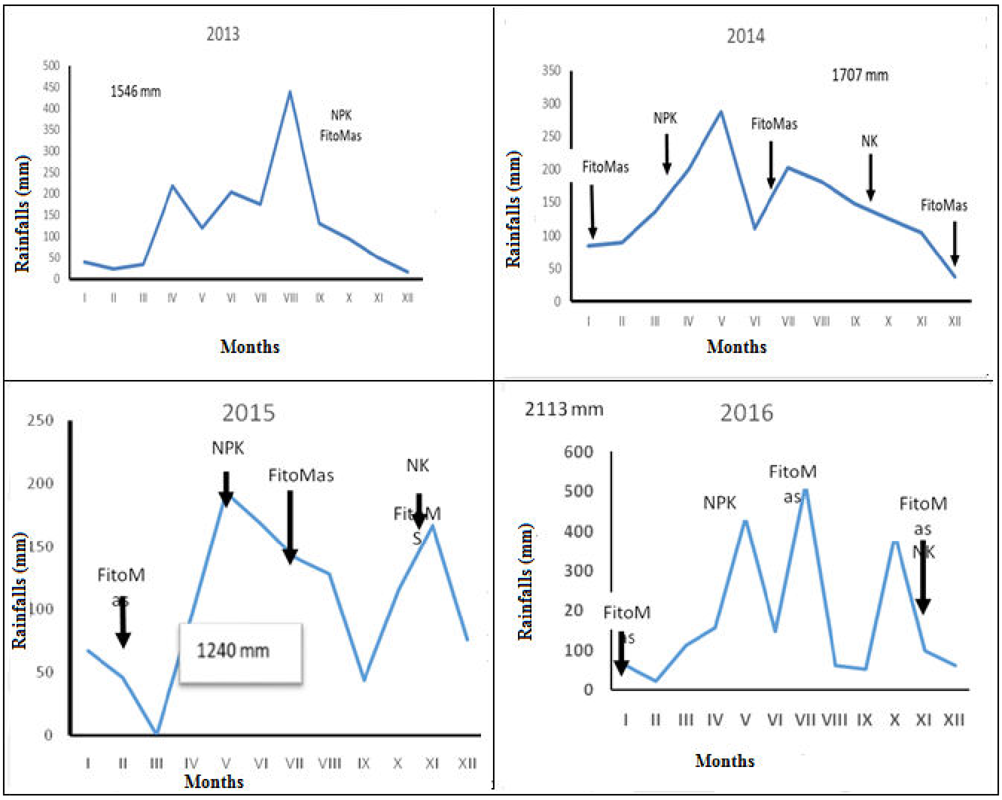

Figure 1. Monthly distribution of rainfall in the experimental period (mm) and application date of fertilizers and biostimulant

- Relative treatment cost ($ ha^{-1}): difference between the costs of the analyzed treatment and those of the control treatment.
- B/C ratio: quotient obtained by dividing the benefit by the cost.

Values of the B/C ratio greater than 1 indicate a gain and a value of 2 indicates a 100 % benefit. Values of 3 or higher correspond to very significant gains.

RESULTS

The application of FitoMas-E had a stimulating effect on coffee yield. Significant differences were found between years, between treatments in all experimental years and in the accumulated harvest (Table 1).

The first year after low pruning (2014) was characterized by the lowest yield level, which may have been caused by the fact that it was the first harvest in the fourth production cycle. This yield represented 75 % of the yield obtained in 2015 (year of highest yield).

Productive levels of the two subsequent years were higher than in 2014, with significant differences between them. This behavior reaffirms the research (20), which concluded that in this locality with rainfall between 1 400 and 1 600 mm no more than 1.30 t ha^{-1} of gold coffee $year^{-1}$ were obtained.

In 2015, the control (mineral fertilization) was significantly superior ($p \leq 0.05$) to the rest of the treatments, with a yield that reflects the productive potential of this area and could be associated with the high rainfall of the previous year (Figure 1) and its better distribution (Figure 2). In this year, the treatment with 25 % of the complete formula + FitoMas-E represented 89 % of the maximum yield achieved and was statistically superior to the treatments that received 50 and 75 % of the complete formula.

In 2016, coffee plants that only received FitoMas-E reached the highest yield levels and were significantly similar to the treatment that received 50 % mineral fertilization. The rest of the treatments, including mineral fertilization, were statistically similar to each other and inferior to the two previously mentioned ($p \leq 0.5$).

The accumulated yield of coffee plants that received 1 L ha^{-1} of FitoMas-E was statistically superior ($p \leq 0.5$) to the rest of the treatments, including mineral fertilization (by 14 %). The treatments that received 25 and 50 % mineral fertilization were similar to each other and superior to the treatment that received 75 % mineral fertilization (Table 1). This result must be related to the effect of the low production of the latter treatment in the initial year as well as to the production alternation process characteristic of this crop. A higher productivity has been found when the coffee plant was cultivated conventionally compared to the organic crop, but this treatment had the highest biennial yield (21).

A similar substitution effect of mineral fertilization by the FitoMas application was found in sugarcane, where variants treated with the bioproduct substituted 50 % of the recommended mineral fertilizer, while in corn, yields achieved with FitoMas-E greatly surpassed those achieved with the variant fertilized with complete formula. In onion, FitoMas-E at 2 L ha^{-1} produced results superior to those achieved with chemical fertilizers (22).

As a conclusion of the experiment, it can be affirmed that the application of FitoMas-E to *Coffea canephora* in the first three years, after low pruning in a Brown soil, with high fertility, constitutes an alternative that provides high and stable productions of this species.

The economic analysis (Table 2) reaffirmed the experimental results from the field, finding that the application of FitoMas-E at a dose of 1 L ha^{-1} provided the highest profit, the greatest benefit and a very notable benefit/cost ratio, due to its higher production level, lower product cost and lower application costs.

This result has a great practical value because it represents a national alternative to the high value of mineral fertilizers in the world market and responds to the country's strategy of substituting imports. On the other hand, the application of the bioproduct would reduce the environmental impact that could result from the application of doses of mineral fertilizers higher than the requirements of the crop.

Table 1. Annual and cumulative yield of *Coffea canephora*, t gold coffee ha^{-1}

	2014	2015	2016	Accumulated
100% CF (control)	0.74 c	1.60 a	0.95 b	3.30 b
FitoMas-E 1 L ha^{-1}	1.35 a	1.08 c	1.34 a	3.76 a
25 % CF	1.01 b	1.43 b	1.01 b	3.44 b
50 % CF	0.89 c	1.13 c	1.28 a	3.30 b
75 % CF	0.82 cd	1.14 c	1.03 b	3.00 c
S.E, x	0.02*	0.05*	0.04*	0.06*
	0.96 C	1.27 A	1.12 B	
S.E, x years		0.02*		

*Means with equal letters do not differ for $p \leq 0.05$ according to Duncan's Test

Means with capital letters to differentiate the effect between years.

CF: complete formula

Table 2. Economic analysis of FitoMas-E application on *Coffea canephora*. Cumulative values for 3 experimental years, for 1 hectare

	Cost of products. $			Cost of application. $			Total costs. $	Yield. t	Ingresos. $	Income. $	Benefict. $	Benefict/ Cost
	FM	FE	Subtotal	FM	FE	Subtotal						
100 % MF. *	284.76		284.76	728.48		728.48	1013.24	3.3	2640.00	1626.76		
FE 1 L ha $^{-1}$	0	9.00	9.00		208.92	208.92	217.92	3.76	3009.46	2791.54	1164.78	5.34
25 % MF + FE 1 L ha $^{-1}$	71.19	9.00	80.19	728.48	208.92	937.4	1017.59	3.44	2750.76	1733.17	106.41	0.10
50 % MF + FE 1 L ha $^{-1}$	142.38	9.00	151.38	728.48	208.92	937.4	1088.78	3.30	2640.21	1551.43	-75.33	-0.07
75 % MF+ FE1 L ha $^{-1}$	213.57	9.00	222.57	728.48	208.92	937.4	1159.97	3.00	2396.87	1236.90	-389.86	-0.34

MF - mineral fertilization. FE FitoMas-E

DISCUSSION

Several factors influence the productive response of *Coffea canephora* to FitoMas-E. One of them may be its use at times of stress in the coffee plant, since the applications were made at the time when water deficit occurs in pre-flowering and flowering in the experimental area, as well as in the fruit formation and development phase (Figure 1). The mineral fertilizer may have contributed to the synchrony of nutrients supply with the crop's requirements. The plant phenological phase is important to be considered for the biostimulant effect and for mango (23), the application of the bioproduct in the initial time of the process of floral stimuli formation, enhances the greater time of product action in branches and, consequently, a greater induction of the production of the floral stimulus.

Biostimulants when applied to plants have physiological effects similar to those of phytonutrients and act in the promotion, modification or inhibition of physiological processes (24). This effect probably depends on the combined action of their components and the synergistic effect between them (25).

The beneficial effect of FitoMas-E can also be related to the presence in its chemical composition of plant growth promoting substances such as amino acids, proteins, peptides, carbohydrates, macroelements (N, P, K, Ca), which could affect both the foliar system and the improvement of soil fertility (26). For mango cultivation, it is founded that the amino acids contained in biostimulants act as precursors and signaling substances, which can be a decisive factor for stress relief during the phase of bud maturation (23). Under adverse growth conditions, such as water stress, plants activate protective mechanisms such as proline biosynthesis, since this amino acid is sensitive to environmental adversities (24).

Another factor may have been the fractionation of both products, which allows a more spaced distribution in time. With the use of FitoMas-E and mineral fertilization, the coffee plants received between four and five applications during the year, double or more than what is usually done with the current technology in the country (27), a fact that undoubtedly increases the efficiency of use of the mineral fertilizer and the biostimulant.

The positive effect of FitoMas-E application could also be directly associated to its nutrient contents, because even though biostimulants are applied at low doses, it has been demonstrated that their use increases the absorption of nutrients from the soil or substrate and their efficiency (1) and increases the growth variables of seedlings (14).

The high efficiency of nitrogen in foliar fertilization is directly correlated with the absorption speed of the nutrient, which, in perennial crops such as coffee and cocoa, varies from one to six hours to absorb 50 % of the applied product (28). Other investigations explain that the increase in nutrient absorption, due to the effect of biostimulants, is attributed to one of the following factors: the increase in the biological and enzymatic activity of soils; the affectation of root structure or the change in the solubility or transport of micronutrients (29).

The diversity of possible factors that can explain the productive response of coffee plants to the application of FitoMas-E implies that further research should be carried out to establish the importance of the factors involved.

CONCLUSIONS

- It was established that the application of FitoMas-E increased the productive levels of *Coffea canephora*.
- FitoMas-E application at a dose of 1 L ha $^{-1}$ in three moments of the vegetative cycle of *Coffea canephora*, allowed obtaining a higher accumulated yield than mineral fertilization and a very notable benefit/cost ratio, which makes it an alternative to mineral fertilization

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