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Original article

Complementary application of two bioproducts increasing the productivity on common bean

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ABSTRACT

Supplementation with bioproducts (BP) can be an efficient alternative for the crop management, especially in those that are managed with low applications of mineral fertilizers. The objective of this study was to evaluate the complementary application of the bioproducts ME-50 and FitoMas-E (FE) in the increase of the common bean productivity. An experiment was carried out under field conditions with the common bean cultivar Bat-304. Treatments were distributed in a randomized block design, in a factorial scheme (2 × 2). Two levels of mineral fertilization (0 and 50 kg ha^{-1}) and the application of the bioproducts ME-50 (100 mL L^{-1}) and FE (2 L ha^{-1}), with five repetitions were studied. At 40 days after the emergence, the average of trifoliate leaves per plant was determined and in the harvest the number of pods per plant, grains

per plant, grains per pod, mass of 100 grains (g) and yield (kg ha^{-1}) were evaluated. The results showed that application of the ME-50 and FE bioproducts increased the morphophysiological and productive parameters of the bean, with the consequent increase in yield in the presence of mineral fertilization. The results indicated that the ME-50 bioproduct was superior to the FE in both culture conditions. This study suggests that the use of both bioproducts constitutes an important contribution to the productive management of the species which improved the productive component and consequently the yield.

Key words: foliar applications, biostimulants, beneficial microorganisms, *Phaseolus vulgaris* L., yields

INTRODUCTION

The common bean *Phaseolus vulgaris* L., is considered among the food grain plants, it is one of the most important species for human consumption, because in nutritional terms, they constitute a cheap source of protein and minerals [(1)]. Latin America is the region with the highest production of grain, but at the same time, the one that consumes it the most and it is estimated that more than 45 % of world production comes from this region [(2)].

In Cuba, *P. vulgaris* constitutes a food in the daily basic diet of meals. It is cultivated in most of the provinces in a conventional or agro-ecological way, achieving low to medium yields mainly given by the weather conditions, the incidence of pests and the management and application of organic or mineral fertilizers [(3)]; the latter, which affect the environment, both due to its residues in food and the polluting effect on soils and aquifer basins [(4)].

The development of systems that ensure the efficient use of fertilizers without affecting the environment is crucial to maintain crop productivity in the future [(5)]. Low applications of mineral fertilizers complemented by the application of bioproducts certify less contamination, since microorganisms transform all these substances into assimilable nutrients for plants [(6)]. This practice increases the microbial biomass of the soil and the levels of carbon and nitrogen [(7)]. There is also a great deal of interest in improving the nutrient supply to crops with plant growth promoting rhizobacteria (PGPR). Biofertilizers containing PGPR increasingly show economic promise and potential for environmental benefits [(8)].

Currently, among the bioproducts used in Cuban agricultural production, is the FE developed by the Cuban Institute for Research on Derivatives of Sugar Cane (ICIDCA), this bionutrient is the carrier of a set of high-energy biochemical intermediaries that is extremely valuable for crop plants, which is evident in resistance to stress and is reflected in the increase in yields and the improvement of the quality of the crops [(9)]. These beneficial effects with FE supplementation have been demonstrated by several researchers in bean cultivation [(10,11)].

On the other hand, efficient microorganism (ME) technology has also caused impacts on agricultural production in more than 80 countries [12]. Its use has benefited farmers [13], mainly because a group of beneficial microorganisms are introduced that improve soil conditions and thus crop productivity [14]. The use of bioproducts based on this technology has favored the production of several species, such as common beans [15–19], strawberries [20], cucumbers [21] and string beans [22].

However, in the current production of beans, an important strategy is the application of mineral fertilizers at planting time and continue with the supplementation of bioproducts to increase grain productivity. Therefore, if the morpho-physiological and productive indicators are increased, it would better explain the increase in yield.

In view of the foregoing, the following hypotheses arise: the complementary application of the ME-50 and FitoMas-E bioproducts may constitute an efficient alternative to increase the productivity of common beans and it is still possible to determine which bioproduct most favors the yield of this crop. In this sense, the objective of the present investigation was to evaluate the complementary application of the ME-50 and FitoMas-E bioproducts in increasing the productivity of common beans.

MATERIALS AND METHODS

The planting of the common bean cultivar Bat-304 was carried out at the "Mártires de Taguasco" Credit and Services Cooperative (22° 6′17.588″N; 79° 22′33.544″O), Sancti Spíritus, Cuba, from November 2016 to February 2017. The seeds of cv. Bat-304 were obtained at the Sancti Spíritus seed company with 97 % germination, which presents black grains, a potential yield of 2.77 t ha^{-1}, type III growth habit and a cycle between 75 -85 days.

The sowing was done manually at a distance of 0.60 m between rows and 0.05 m between plants. The climatic variables were registered by the Municipal Station of Hydraulic Resources of Cabaiguán, the average daily temperature was 23.57 ± 2.80 ºC, the relative humidity 82.40±6.50 % and the accumulated rainfall during the development of investigation of 233.85 mm. The soil was classified as Carbonated Sialitic Brown [23], called Cambisol [24].

The experimental design was in random blocks, distributed in a 2×2 factorial scheme. Two levels of mineral fertilization (FM) (0 and 50 kg ha^{-1}) and the application of the bioproducts ME-50 (100 mL L^{-1}) and FE (2 L ha^{-1}), with five replicates, were studied. The concentration of ME-50 used for imbibition and foliar applications was selected based on the results obtained previously for this culture [18,25], while the FE dose was chosen through the guidelines and previous results for the bean cultivation [10,17].

The plots were 7.20 m^2 in size, the effective area was 2.75 m^2 and the total area of the experiment was 0.08 ha. The mode of application of the treatments is shown in Table 1, the seeds were soaked for 2 h in the solutions of both bioproducts (Table 1), then they were placed on paper towels to remove excess moisture (~30 min) and they were quickly planted. The foliar applications of the bioproducts were carried out with a 7.6-liter capacity manual sprayer (ECHO MS-21H), applied in the phenological stages V3 and V4 (vegetative) and R5 (reproductive) and mineral fertilization was carried out at the dose of 50 kg ha^{-1} before sowing with the complete formula (N, P, K) [9,13,18] (Table 1).

Table 1. Mode of application, dose and concentrations of the treatments used

Treatments	Application mode				
	Via soil (N, P, K)	Via seeds	Foliar via		
			Stage V3	Stage V4	Stage R5
ME-50		100 mL L^{-1}	100 mL L^{-1}	100 mL L^{-1}	100 mL L^{-1}
ME-50	50 kg ha^{-1}	100 mL L^{-1}	100 mL L^{-1}	100 mL L^{-1}	100 mL L^{-1}
FE	-	2 L ha^{-1}	2 L ha^{-1}	2 L ha^{-1}	2 L ha^{-1}
FE	50 kg ha^{-1}	2 L ha^{-1}	2 L ha^{-1}	2 L ha^{-1}	2 L ha^{-1}

The cultivation tasks were carried out following the recommendations of the technical instructions for cultivation [3] and the cleaning tasks were carried out manually.

ME-50 and FE bioproducts were purchased at the Labiofam Branch in Sancti Spíritus. FitoMas-E is a derivative of the Cuban sugar industry created and developed by ICIDCA. It is a mixture of mineral salts and high energy biochemical substances (amino acids, nitrogenous bases, saccharides and biologically active polysaccharides), 150.0 g L^{-1} of organic extract, 55.0 g L^{-1} of total Nitrogen, 60 g L^{-1} of K_2O and 31.0 g L^{-1} of P_2O_5. The ME-50 bioproduct known as efficient microorganisms, is mainly composed of three species, such as *Bacillus subtilis* B/23-45-10 Nato (5.4 10^4 cfu mL^{-1}), *Lactobacillus bulgaricum* B/103-4-1 (3.6 10^4 ucf mL^{-1}) and *Saccharomyces cereviciae* L-25-7-12 (22.3 10^5 ucf mL^{-1}), with quality certificate issued by ICIDCA, code R-ID-B-Prot-01-01 .

The evaluated variables corresponded to the criteria described for the crop [26]. The samplings were carried out in the effective area of the plots and 40 plants were evaluated per treatment. In the phenological stage R5 the number of leaves per plant (NH) was evaluated and at the end of the cultivation cycle (R9) the number of pods per plant (VP) was evaluated; the number of grains per plant (GP); the number of grains per pod (GV); the average mass of 100 seeds (g) (M100) and the yield (t ha^{-1}).

The obtained data were processed in the AgroEstat® statistical software, to which the normal distribution was determined, using the Shapiro-Wilk test for goodness of fit. When there was normality, a two-way analysis of variance (ANOVA) was performed and the significance of the variance was verified by the Fisher test, when it was significant at 5 % probability of error, the means were compared by the Ranges test. Tukey multiples ($p < 0.05$).

RESULTS AND DISCUSSION

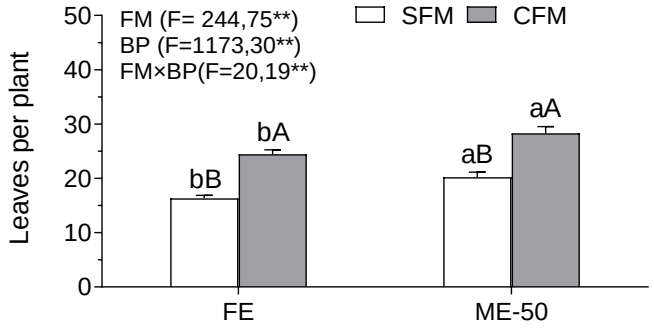
ANOVA revealed a significant interaction ($p < 0.01$) between FM and BP factors in the average of leaves per plant (Figure 1). The application of both bioproducts under FM conditions (50 k ha^{-1}) increased the number of HP in relation to plants without FM ($p < 0.01$), with emphasis on ME-50 treatment because it achieved better performance than FE in both FM conditions. When bean plants were fertilized with (50 k ha^{-1}) the application of ME-50 increased the HP by ~40 % compared to plants without FM and was 23 % higher than the application of FE, but at the same time the application of FE under FM increased the HP by 50 % compared to the plants that did not receive FM. On the other hand, under culture conditions without FM, the application of ME-50 was ~24 % higher compared to FE (Figure 1).

In this study, the beneficial effects of the application of both bioproducts ME-50 and FE on the production of HP from cv. Bat-304. Therefore, it was shown that bean production is impaired under current management conditions, mainly because HP production is not favored. However, the complementary application of both bioproducts favored the HP number (Figure 1). These beneficial effects of both bioproducts in increasing the HP number were possible because microorganisms and substances that stimulate plant growth are introduced [9,27]. The increase in HP is of great physiological importance for the plant, due to the greater photosynthetically active surface of the plant, which favors the production of nutrients and other metabolic processes of the plants [28].

The results showed that the complementary application of ME-50 increased the HP in relation to the absence (Figure 1). These effects could be influenced by the incorporation of microorganisms such as *Bacillus subtilis*, *Lactobacillus bulgaricum* and *Saccharomyces cereviciae*, which help to solubilize and produce substances and nutrients that favor the architecture of plants [14]. These beneficial effects of MEs on increased HP production were previously observed in this species [15–19].

On the other hand, it was observed that the complementary application of the FE favored the production of HP in the cv. Bat-304 in relation to the non-addition of the bioproduct (Figure 1). These results could be modified because this bionutrient incorporated a mixture of mineral salts

and high-energy biochemical substances, which complemented very well with the low mineral FM realized in the increase in HP. These results are consistent with other studies previously described [10,11,15], who reported that FE stimulated morphological indicators in bean plants.



Values represented by the mean of five replicates ± standard deviation (SD) (Means ± SD, n = 5). Lowercase letters indicate differences between the bioproducts at the same level of mineral fertilization and different capital letters indicate differences between the levels of mineral fertilization in the same bioproduct, according to Tukey ($p < 0.05$). ME-50: efficient microorganisms; FE: FitoMas-E. FM: without mineral fertilizer; CFM: with mineral fertilizer; FM × BP mineral fertilization-bioproducts interaction. Values of F, ** significant at 99 % probability of error, according to ANOVA

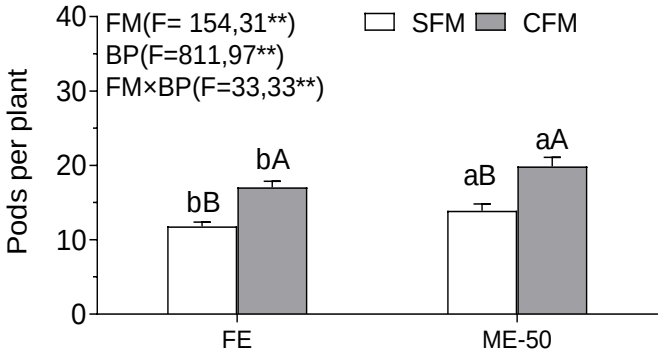
Figure 1. Production of trifoliate leaves per plant obtained in cv. Common bean Bat-304 cultivated under two levels of FM (0 and 50 kg ha^{-1}) combined with the application of the bioproducts ME-50 (100 mL L^{-1}) and FE (2 L ha^{-1})

Pod production per plant showed a significant interaction ($p < 0.01$) between FM and BP factors (Figure 2). The application of the ME-50 and FE bioproducts reached a higher production of the VP under the FM with 50 kg ha^{-1} compared to the plants that were fertilized ($p < 0.01$). Treatment with ME-50 showed a better result in PV compared to FE in both FM conditions and showed significant differences ($p < 0.01$). Under FM conditions, treatment with ME-50 increased the PV by 17 % in relation to FE and it was 43 % higher in relation to plants without FM; however, the bean plants that received the application of FE and fertilized with 50 kg ha^{-1} FC increased the average VP by ~ 45 % compared to those that did not receive FE and FM. On the other hand, when the bean plants did not receive FM, the ME-50 increased the PV by ~ 18 % compared to the application of FE (Figure 2).

The results indicated that the application of the ME-50 achieved a better performance in the production of VP of the cv. Bat-304 compared to FE, regardless of whether or not FM is added. Therefore, these superior effects of treatment with ME-50 in the PV could be influenced by the increase in HP (Figure 1). These findings are consistent with previous studies [25], who demonstrated that, as the morphological architecture of the plant increased, it led to an increase in the formation of inflorescences with the consequent increase in PV. This beneficial effect of

the application of this bioproduct in the increase of VP was previously demonstrated in bean plants [15,16,18].

This study also showed that the application of FE on bean plants grown with 50 kg ha^{-1} of FM significantly increased the production of VP, especially when FM was applied (Figure 2). These results were possible because under these conditions the FE increased the HP (Figure 1). A possible explanation for these results is given by the incorporation of different substances present in the FE that stimulate the morphological and productive parameters of the plants [9]. The results obtained in this study are consistent with the findings reported previously [15,29], who increased the PV in bean plants with the application of FE.



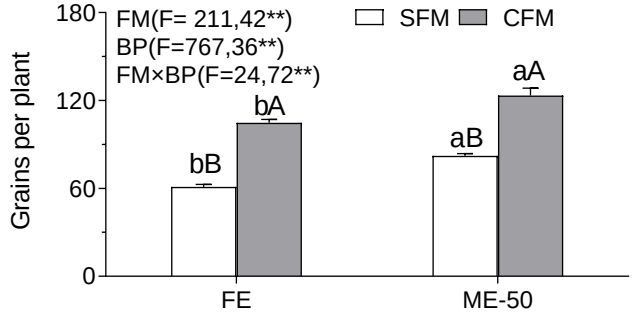
Means ± SD, n = 5. Lowercase letters indicate differences between the bioproducts at the same level of mineral fertilization and different capital letters indicate differences between the levels of mineral fertilization in the same bioproduct, according to Tukey (p <0.05). ME-50: efficient microorganisms; FE: FitoMas-E. SFM: without mineral fertilizer; CFM: with mineral fertilizer; FM × BP mineral fertilization-bioproducts interaction. Values of F, ** significant at 99 % probability of error, according to ANOVA

Figure 2. Pod production per plant obtained in cv. Common bean Bat-304 cultivated under two levels of FM (0 and 50 kg ha^{-1}) combined with the application of the bioproducts ME-50 (100 mL L^{-1}) and FE (2 L ha^{-1})

The average of grains per plant obtained in the cv. Bat-304 presented a significant interaction between FM and BP (p <0.01) (Figure 3). The application of the ME-50 and FE bioproducts significantly increased GP regardless of whether or not FM was added (p <0.01). The application of the ME-50 increased the GP in ~18 % with respect to the FE when the bean plants received 50 kg ha^{-1} of the FM and in ~35 % in the absence of the FM (Figure 3), however, the treatment with ME-50 in the presence of FM increased the GP by ~50 % compared to the absence of FM, while FE in the presence of FM increased the GP by ~72 % compared to the absence of FM (Figure 3).

The results of this study showed strong evidence of the effect of both bioproducts on the increase in GP in bean plants, but the application of ME-50 was significantly superior to FE in the two fertilization conditions evaluated (Figure 3). The response of this variable maintains

the trend of the HP (Figure 1) and that of the VP (Figure 2), which shows the possible effect of both bioproducts in increasing the morphological and productive parameters of the bean. The results obtained in this investigation with the application of the ME-50 are similar to the findings previously found in beans [15] and string beans [22]. On the other hand, the results achieved by the application of the FE in the increase of this component of the yield, were superior in the presence of the FM compared to the absence of this, which could be influenced by the increase in the content of nutrients for growth and development of the plants. These beneficial results of the application of the FE are consistent with the findings previously reported in bean plants [29].



Means ± SD, n = 5. Lowercase letters indicate differences between the bioproducts at the same level of mineral fertilization and different capital letters indicate differences between the levels of mineral fertilization in the same bioproduct, according to Tukey ($p < 0.05$). ME-50: efficient microorganisms; FE: FitoMas-E. SFM: without mineral fertilizer; CFM: with mineral fertilizer; FM × BP mineral fertilization-bioproducts interaction. Values of F, ** significant at 99% probability of error, according to ANOVA

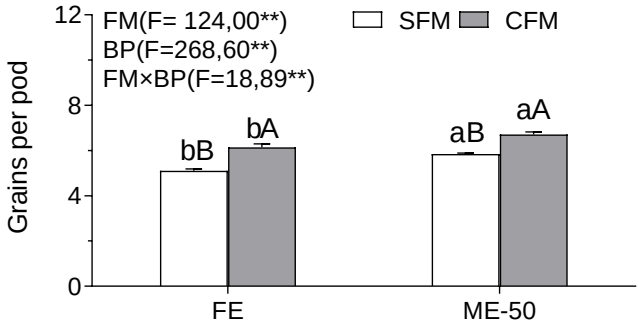
Figure 3. Grain production per plant obtained in cv. Common bean Bat-304 cultivated under two levels of FM (0 and 50 kg ha^{-1}) combined with the application of the bioproducts ME-50 (100 mL L^{-1}) and FE (2 L ha^{-1})

The production of grains by pods in plants of cv. Common bean Bat-304 showed a significant high interaction between FM × BP ($p < 0.01$) (Figure 4). The application of the two bioproducts stimulated GV production, especially in the presence of FM. Treatment with ME-50 increased the GV compared to the application of FE, these increases were ~12 % in the presence of FM and ~12 % in the absence of FM ($p < 0.01$). However, in the presence of FM, the application of ME-50 increased GV by ~15 % compared to the absence of FM ($p < 0.01$). On the other hand, the application of FE in the presence of FM increased the GV by ~20 % in relation to plants grown in the absence of FM (Figure 4).

It was evident that the application of both bioproducts increased the GV average, mainly because this variable also maintained the trend of the previous parameters such as HP, VP and GP (Figures 1-3). The results obtained showed that the treatment with ME-50 benefited the production of GV in the cv. Bean Bat-304 (Figure 4) under the two fertilization conditions

studied. These findings were consistent with previous studies in bean plants [16–18] and string beans [22].

On the other hand, it was also observed that the application of the FE bioproduct benefited the GV average, particularly when FM was added. These results are in line with the results previously reported [10,11,15], who reported that FE modified this productive indicator in bean plants.



Means ± SD, n=5. Lowercase letters indicate differences between the bioproducts at the same level of mineral fertilization and different capital letters indicate differences between the levels of mineral fertilization in the same bioproduct, according to Tukey ($p < 0.05$). ME-50: efficient microorganisms; FE: FitoMas-E. SFM: without mineral fertilizer; CFM: with mineral fertilizer; FM × BP mineral fertilization-bioproducts interaction. Values of F, ** significant at 99 % probability of error, according to ANOVA

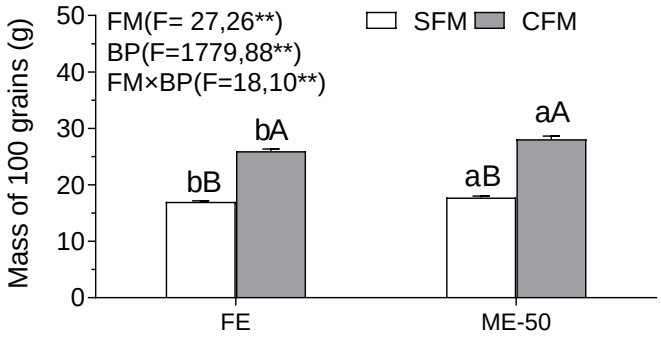
Figure 4. Grain production per pod obtained in cv. Common bean Bat-304 cultivated under two levels of FM (0 and 50 kg ha^{-1}) combined with the application of the bioproducts ME-50 (100 mL L^{-1}) and FE (2 L ha^{-1})

The mass of 100 beans of cv. Bat-304 showed a significant interaction between FM and BP ($p < 0.01$) (Figure 5). The application of both bioproducts increased the M100 in CFM plants compared to SFM plants ($p < 0.01$). While ME-50 treatment was superior to FE in M100 under both evaluated fertilization conditions, the increases were ~10 % in the presence and ~9 % in the absence, respectively ($p < 0.01$) . On the other hand, the application of FE on CFM plants increased the M100 by ~53% compared to the absence of FM (Figure 5).

This study showed that the application of the ME-50 and FE bioproducts stimulated the M100 of cv. Common bean Bat-304, especially when these were grown in the presence of FM, with emphasis on ME-50 treatment (Figure 5). This variable maintained a similar trend to the responses previously observed in parameters such as HP, VP, GP and GV (Figures 1-4), possibly because these were increased. The results of the current study were in agreement with the findings previously observed in bean plants [15,16,18].

On the other hand, the application of the FE bioproduct achieved a better performance in the increase of M100 in the presence of FM compared to the non-application of the bionutrient

(Figure 5), this could be mainly influenced by the increase in the indicators previously observed (Figures 1-4). These results are consistent with the findings previously reported in previous studies in bean plants [10,11,15].



Means ± SD, n=5. Lowercase letters indicate differences between the bioproducts at the same level of mineral fertilization and different capital letters indicate differences between the levels of mineral fertilization in the same bioproduct, according to Tukey ($p < 0.05$). ME-50: efficient microorganisms; FE: FitoMas-E. SFM: without mineral fertilizer; CFM: with mineral fertilizer; FM × BP mineral fertilization-bioproducts interaction. Values of F, ** significant at 99 % probability of error, according to ANOVA

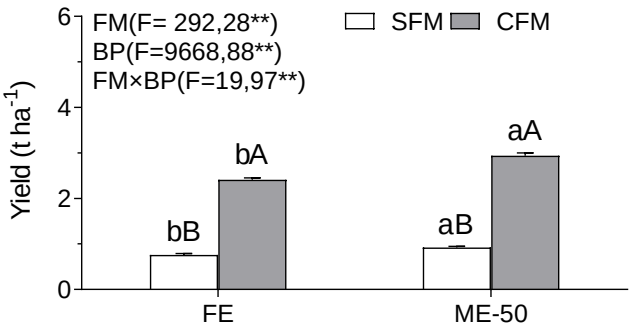
Figure 5. Average mass of 100 grains obtained in cv. Common bean Bat-304 cultivated under two levels of FM (0 and 50 kg ha^{-1}) combined with the application of the bioproducts ME-50 (100 mL L-1) and FE (2 L ha^{-1})

The yield obtained in bean plants showed a significant interaction between FM and BP ($p < 0.01$) (Figure 6). The application of both bioproducts increased grain productivity in the presence of FM compared with plants grown in the absence of FM ($p < 0.01$). In both FM conditions the application of ME-50 showed an increase in yield of ~22 in CFM plants and 21 % in SFM plants compared to FE ($p < 0.01$). However, treatment with FE on CFM plants showed an increase in productivity of 1.65 t ha^{-1} compared to SFM plants ($p < 0.01$) (Figure 6).

In this study it was demonstrated that the complementary application of the ME-50 was efficient in increasing the productivity of the cv. Bat-304, (Figure 6), because it showed an increase in the other parameters evaluated such as HP, VP, GP, GV and M100 (Figure 1-5). These findings occur mainly due to the substances present in the composition of the ME-50 bioproduct that promote plant growth [27], and also due to the incorporation of various genera of microorganisms that promote the decomposition of certain substances (nutrients, hormones, among others), which improve crop development [30,31]. These beneficial effects of applying the ME-50 bioproduct in increasing bean yield were previously described [16,25].

In bean plants, it was evident that supplemental supplementation with FE favored yield because the evaluated indicators such as the number of leaves, pods, grains per plant and per pod, and the mass of 100 grains were increased (Figures 1-5). This could be evidenced by the substances

that make up the bionutrient [9]. These beneficial effects of FE in increasing yield with the application of this bioproduct were reported by several authors in this species [11,15,17].



Means ± SD, n=5. Lowercase letters indicate differences between the bioproducts at the same level of mineral fertilization and different capital letters indicate differences between the levels of mineral fertilization in the same bioproduct, according to Tukey ($p < 0.05$). ME-50: efficient microorganisms; FE: FitoMas-E. SFM: without mineral fertilizer; CFM: with mineral fertilizer; FM × BP mineral fertilization-bioproducts interaction. Values of F, ** significant at 99 % probability of error, according to ANOVA

Figure 6. Average yield obtained in the cv. Common bean Bat-304 cultivated under two levels of FM (0 and 50 kg ha^{-1}) combined with the application of the bioproducts ME-50 (100 mL L^{-1}) and FE (2 L ha^{-1})

Finally, the hypothesis studied was verified, indicating that the application of the ME-50 and FitoMas-E bioproducts applied increased the productivity of common beans, because the morphological and productive parameters evaluated were modified. Additionally, the study findings suggest that it is possible to enhance the productivity of bean plants with the application of these bioproducts and it is still possible to maximize crop yield with the possible joint application of both, the form of application and the availability and amount of mineral fertilizer applied.

CONCLUSIONS

- The results indicated that the complementary application of the ME-50 and FE bioproducts increase the yield of the common bean, especially when the bean plants are fertilized with a dose of 50 kg ha^{-1} of complete formula.
- The findings of this study suggest that the ME-50 bioproduct was superior to the FitoMas-E.
- Therefore, the increase in the productivity of common beans with the complementary application of both ME-50 and FE bioproducts constitutes an important contribution to the productive management of the species and could lead to a sustainable increase in crop yield.

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