

Organic Fertilizers and Bioinoculants as Growth Promoters in Common Bean (*Phaseolus vulgaris* L.) Cultivation

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ABSTRACT

Objective: To evaluate the effect of the combined application of organic fertilizers and bioinoculants on the growth and yield of common bean (*Phaseolus vulgaris* L.) as a sustainable alternative to intensive chemical fertilization.

Design/methodology/approach: Four organic fertilizers were prepared, namely amino acids, vermicompost leachate, Bokashi, and Supermagro, and microbial inoculants of *Bacillus* spp. (B6, B14, B17, B18, and B21) and *Trichoderma* spp. (TB, TF, TJ3, TJ7, and TM) were used. Through two greenhouse experiments established under a completely randomized design, the most effective treatments were selected based on morphometric variables, identifying Bokashi, Supermagro, B14 (*Bacillus cereus*), and TF (*Trichoderma virens*) as the most promising. These treatments were subsequently evaluated under field conditions using a factorial randomized complete block design.

Results: In the field experiment, the TF + Bokashi combination (T4) exhibited the highest values for number of seeds per square meter (838.86), aboveground foliar biomass (4.67 t ha⁻¹), and seed yield (3.23 t ha⁻¹), surpassing the other treatments. Significant differences were observed relative to the B14 + Bokashi and B14 + Supermagro combinations, as well as the negative control (without bioinoculant or organic fertilizer) ($p \leq 0.05$).

Limitations on study/implications: None.

Findings/conclusions: The combined application of organic fertilizers and bioinoculants improved the growth and yield of common bean, particularly under the TF + Bokashi combination. These findings demonstrate that this strategy constitutes a viable and sustainable alternative for enhancing crop productivity and reducing reliance on conventional fertilization in Sinaloa.

Keywords: Bokashi, Supermagro, *Bacillus*, *Trichoderma*.

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INTRODUCTION

Contemporary agriculture is largely based on intensive tillage and the extensive use of chemical fertilizers to achieve high yields. However, these practices generate adverse effects

that compromise soil health, microbial biodiversity, and environmental quality. At present, the challenge is to produce sufficient food without undermining the ecological stability of agroecosystems. In the state of Sinaloa, Mexico, where common bean is a crop of considerable economic and social importance, the urgent need to incorporate sustainable techniques that enhance plant nutrition has become increasingly evident, particularly because chemical fertilization remains a frequent practice due to its ease of application and rapid response (Rico-Alderete, 2020).

The agroecological approach promotes the use of natural sources to stimulate crop growth, improve soil health, and control pests, as is the case with organic fertilizers and bioinoculants, which enhance microbial activity and reinforce soil-plant balance (Chávez *et al.*, 2020; Illa *et al.*, 2020). Organic fertilizers produced through the fermentation or decomposition of organic materials have been shown to improve the physical, chemical, and biological properties of soil (INIFAP, 2020). One notable example is the application of amino acids as biostimulants, which help regulate key metabolic processes and increase stress tolerance (Romero *et al.*, 2023). In addition, Bokashi, a fermented organic fertilizer with high microbial activity, improves soil fertility, supplies nutrients, and can partially replace conventional fertilization (López *et al.*, 2023). Likewise, vermicompost leachate provides essential nutrients and beneficial microorganisms (Mesías, 2019), whereas Supermagro supplies nutrients and stimulates soil biological activity, thereby promoting vigorous root development, more uniform flowering, and increased vegetative growth, yield, and harvest quality across different crops (González *et al.*, 2021). On the other hand, bioinoculants regulate the activity of plant pathogens through mechanisms of microbial antagonism while also promoting crop growth (Castillo *et al.*, 2021). Genera such as *Bacillus* and *Trichoderma* clearly exemplify this effect, since several species, particularly native isolates from the state of Sinaloa, have proven to be highly effective (López *et al.*, 2015; López *et al.*, 2019; González, 2021). Accordingly, the effect of combining organic fertilizers (amino acids, Bokashi, vermicompost leachate, and Supermagro) with bioinoculants based on *Bacillus* spp. and *Trichoderma* spp. strains was evaluated for their growth-promoting potential in common bean.

MATERIALS AND METHODS

Origin and preparation of organic fertilizers and bioinoculants

The organic fertilizers amino acids, Bokashi, vermicompost leachate, and Supermagro were prepared in the experimental, demonstration, and production area of the Facultad de Agricultura del Valle del Fuerte (FAVF), whereas the inocula were produced from *Bacillus* spp. strains (B6, B14, B17, B18, and B21) and *Trichoderma* spp. strains (TB, TF, TJ3, TJ7, and TM) provided by the Agricultural Microbiology Laboratory of the FAVF. These native species from northern Sinaloa had previously been isolated, classified, and reported by López-Valenzuela *et al.* (2015), and were subjected to greenhouse assays for preliminary selection. The preparation of the fertilizers is described below:

Bokashi: Wheat straw, soil, cattle manure, charcoal, flours, and bran were arranged layer by layer on a plastic sheet, and molasses was diluted separately. Water was added

uniformly while all ingredients were mixed, using only the amount necessary. The first test was performed until the desired moisture content in the mixture was achieved, after which no additional water was applied. The entire mixture was turned three times until it became uniform. Once mixed, it was spread out to form a bed approximately 50 cm high. The prepared Bokashi was then covered with black plastic. During the first four days, the mixture was turned in the morning and afternoon to prevent the temperature from exceeding 50 °C. As the volume of the mixture decreased, it was turned only once each morning. After 15 days, the fermented fertilizer reached maturity, exhibiting a light color, a sandy powder-like appearance, and a loose consistency, following the technique reported by Restrepo (2007) with some modifications.

Amino acids: This product was obtained according to the technique of Restrepo (2018), as reported by Salaya (2019), with certain modifications introduced in this study. Fully ripe fruits were used, including papaya, banana, melon, mango, and guava (non-acidic fruits), together with whey or unpasteurized milk, molasses, and sufficient water to fill a 200-L plastic drum. The fruits were cut into large pieces and placed in layers inside the container, with abundant undiluted molasses added after each fruit layer. The remaining molasses was poured over the final layer, after which water was added to volume, the ingredients were mixed, and the container was sealed hermetically. The mixture was stirred three times daily (morning, afternoon, and evening) for 10 minutes during the first week, twice daily (morning and late afternoon/evening) during the second week, and once daily in the morning during the third week. The mixture was then left to rest for 30 days before being packaged in dark containers.

Vermicompost leachate: This fertilizer was obtained from vermiculture beds located in the Experimental, Demonstration, and Production Unit of the FAVF, using cow manure processed by California red worms (*Eisenia foetida*).

Supermagro: Fresh cattle manure, water, milk, and molasses were mixed in a 200-L plastic drum, stirred, and left to ferment under hermetically sealed conditions for three days. Every third day, mineral salts dissolved in water (Co, Fe, Mo, Zn, Mg, B, and Cl), together with a complementary ingredient (liver, blood, and fish), molasses, and milk, were added. On the final day of mineral and complementary ingredient addition, water was added to reach a total volume of 180 L. The container was then sealed hermetically and left to ferment for 45 days. After this period, the product was packaged in dark containers, according to the technique described by Restrepo (2007), with some modifications made in this study.

Bacillus spp. inoculum: *Bacillus* spp. strains were reactivated in Luria-Bertani (LB) culture medium [tryptone, yeast extract, and sodium chloride], a standard medium for bacterial growth, and incubated at 28 °C for 24 h. One milliliter of the culture was transferred to 50 mL of LB broth and incubated for 12 h at 28 °C and 250 rpm in an orbital shaker (Lab-Line, model 2345, cat. no. 1542, USA[®]). Finally, 5 mL of the previous culture were transferred to an Erlenmeyer flask containing 250 mL of LB broth and incubated for 12 h at 28 °C and 250 rpm. The concentration of bacterial cultures (CFU mL⁻¹) was evaluated by optical density (OD) and confirmed by serial dilutions until a final concentration of 1×10^6 CFU mL⁻¹ was obtained for application.

***Trichoderma* spp. inoculum:** *Trichoderma* spp. inoculum was prepared in solid medium following the technique of Lewis and Papavizas (1984), with some modifications. The inoculated polyethylene bags were incubated for seven days at $28\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ until full growth and sporulation were achieved. Once *Trichoderma* had completely sporulated within the bags, the inoculum produced on rice grains (*Oryza sativa* L.) (solid inoculum) underwent a series of continuous washes with sterile distilled water to recover the greatest possible number of spores contained in the rice. Subsequently, the inoculum was transferred in liquid form into previously sterilized containers and stored at $4\text{ }^{\circ}\text{C}$ until use. Inoculum concentration was determined by spore counting using a Neubauer chamber, and through dilution it was adjusted to 1×10^7 spores mL^{-1} for application.

Selection of organic fertilizers and *Bacillus* and *Trichoderma* strains in the greenhouse: Two selection assays were established to evaluate organic fertilizers (amino acids, Bokashi, vermicompost leachate, and Supermagro) and microbial inocula based on *Bacillus* (B6, B14, B17, B18, and B21) and *Trichoderma* (TB, TF, TJ3, TJ7, and TM).

First assay: Twelve treatments were evaluated: bean seeds inoculated with five *Bacillus* spp. strains (B6, B14, B17, B18, and B21) and five *Trichoderma* spp. strains (TB, TF, TJ3, TJ7, and TM), one positive control (without strain and with chemical fertilization using urea), and one negative control (without strain and without chemical fertilizer), under a completely randomized design with four replications, resulting in a total of 48 experimental units (EU).

Second assay: Six treatments were evaluated: amino acids, Bokashi, vermicompost leachate, and Supermagro, one positive control (fertilized with urea), and one negative control (without strain and without chemical fertilizer), under a completely randomized design with four replications, for a total of 24 EU. For both experiments, 1-kg pots were used with a substrate composed of peat moss, sand, and soil in a 2:1:1 ratio, respectively. Two bean seeds of the Azufrado Higuera[®] variety were used per treatment (pot) and brought into contact with the *Bacillus* and *Trichoderma* inocula by immersion in a plastic tray for one hour. Finally, the pots were placed inside the greenhouse.

Measured variables: Plant height (cm), root volume (mL), and shoot dry weight (g). Data were collected at 15, 30, and 45 days after sowing (DAS).

Field experiment: evaluation of organic fertilizers in combination with bioinoculants: The trial was conducted in the experimental and demonstration area of the FAVF, on a soil with slightly alkaline pH, low electrical conductivity, and nutrient concentrations of nitrogen (N), phosphorus (P), and potassium (K) ranging from medium to low levels for most crops. The irrigation system implemented was drip irrigation, applied at a frequency adjusted to the crop water requirements during its development. Independently of irrigation, the liquid fertilizer Supermagro was applied only in the corresponding treatments by manual application directed to the base of the plants, ensuring a uniform dose of 1 L m^{-2} in each EU. Solid fertilizers were applied through soil incorporation using a hoe according to each treatment, with doses of 260 g of urea and 2 kg of Bokashi per EU. The experiment consisted of the combined application of strains B14 (*Bacillus cereus*) and TF (*Trichoderma virens*) with the organic fertilizers Bokashi and Supermagro, previously selected in greenhouse assays, resulting in 10 treatments, including one positive

control and one negative control described in Table 1. The experimental design was a factorial randomized complete block design with four replications. Each EU consisted of four rows, each 5 m in length and spaced 0.75 m apart, in which 14 seeds were deposited per linear meter at a depth of 10 cm. The experiment was established with a total of 40 EU, representing a total planted area of 600 m² and a density of 11,200 seeds.

Application of Products and Measured Variables

The products were applied at the time of germination (9 DAS), as well as at 20 and 45 DAS, the latter coinciding with the onset of flowering. Subsequently, measurements and sample collection were carried out to determine morphometric variables, including plant height (cm), root volume (mL), shoot dry weight (g), and leaf area. Likewise, foliar nutrient analysis (%) and crop yield (t ha⁻¹) were evaluated:

Plant height (cm): Plant height was measured with a graduated ruler, considering the distance from the stem base to the terminal bud.

Root volume (mL): The plant root system was immersed in a container with water to soften the surrounding substrate and was then washed with running water. A graduated cylinder was filled with liquid to 100 mL, after which the root was submerged and root volume was determined by liquid displacement.

Shoot dry weight (g): The plant foliage was washed and individually placed in previously labeled brown paper bags. These bags were then introduced into a forced-air drying oven (Ecoshel, model 9065) at 70 °C for 48 h. Thereafter, samples were weighed using a digital balance (Ohaus, ScoutPro 500 g model[®]).

Leaf area: Leaf area was determined based on two sampling events conducted at 60 and 70 DAS by image digitization using a scanner, followed by analysis with the ImageJ. exe software.

Foliar analysis: Nutrient analysis in leaves was performed using 30 young leaves representative of each treatment, which were bagged and labeled at the time of collection. The samples were then dried in an oven at 70 °C for 48 h. Once completely dried, the leaves were ground in a mill until a fine, homogeneous powder was obtained. Digestion

Table 1. Description of treatments in the field experiment.

Treatment	Description
1	<i>Bacillus</i> (B14) + Bokashi
2	<i>Bacillus</i> (B14) + Supermagro
3	<i>Bacillus</i> (B14)
4	<i>Trichoderma</i> (TF) + Bokashi
5	<i>Trichoderma</i> (TF) + Supermagro
6	<i>Trichoderma</i> (TF)
7	Bokashi
8	Supermagro
9	Positive control (T+ = urea)
10	Negative control (T- = no fertilizer and no strain)

and spectrophotometric procedures for the analysis of trace elements present in the samples were conducted at the Plant Nutrition Laboratory of CIIDIR-Sinaloa Unit. Foliar nutrient analysis followed the methodology described in the chemical analysis manual for plant tissue by Alcántar and Sandoval (1999).

Harvest and yield: Once the crop exceeded 100 DAS, manual harvesting was carried out, during which 16 plants were collected per experimental unit. The number of normal pods (NNP), defined as those without physical damage or deformities, was recorded, and seeds were extracted from 20 normal pods per plant (NS20NP). Subsequently, total seed weight (SW) was determined and, finally, aboveground foliar biomass (AFB) was obtained. This procedure was applied uniformly across each of the 10 treatments evaluated. The data obtained for each variable were used to determine average yield and to compare the productive efficiency among treatments.

Statistical analysis: An analysis of variance (ANOVA) was performed using the data obtained from the greenhouse and field experiments. Mean comparisons were conducted using Duncan's multiple range test ($p \leq 0.05$) with the statistical software SAS (version 9.4, 2004).

RESULTS AND DISCUSSION

Selection of Strains and Organic Fertilizers under Greenhouse Conditions

In the greenhouse assay, no significant differences among treatments were detected for plant height (PH) or root volume (RV); however, differences were observed in shoot dry weight (SDW) relative to the negative control (T⁻). In the case of *Bacillus* spp., strain B14 (*Bacillus cereus*) exhibited the highest SDW values, differing significantly from the negative control ($p \leq 0.05$) (Table 2).

Table 2. Mean comparison for the selection of *Bacillus* spp. strains in the greenhouse assay.

Strain	PH (cm)	RV (mL)	SDW (g)
B6	31.75 A	1.35 A	1.16 B
B14*	31.25 A	1.59 A	2.09 A
B17	30.25 A	3.18 A	1.47 AB
B18	29.00 A	2.70 A	1.54 AB
B21	23.75 A	2.30 A	1.13 AB
T (+)	26.88 A	1.76 A	1.77 AB
T (-)	20.25 A	1.12 A	1.03 B
F	1.46	149.56	1.44
P	0.2424	0.0001	0.2458

Means followed by the same letter are not significantly different according to Duncan's test ($p \leq 0.05$).

F-value = F statistic from analysis of variance (ANOVA).

P-value = Probability value associated with the F test.

Selected strain.

PH = Plant height; RV = Root volume; SDW = Shoot dry weight.

T (+) = Positive control.

T (-) = Negative control.

For *Trichoderma* spp., strain TF (*Trichoderma virens*) exhibited significantly greater PH than the negative control, although it did not differ statistically from the remaining treatments. In contrast, no significant differences were observed for RV or SDW (Table 3).

The highest average values for PH and SDW were recorded for strains B14 and TF. Similarly, in the selection of organic fertilizers, significant differences were observed ($p \leq 0.05$) for SDW, with Bokashi and Supermagro standing out over the remaining treatments (Table 4).

Table 3. Mean comparison for the selection of *Trichoderma* spp. strains in the greenhouse assay.

Strain	PH (cm)	RV (mL)	SDW (g)
TB	22.75 AB	2.08 A	1.45 A
TF*	30.88 A	1.76 A	1.78 A
TJ3	25.38 AB	1.65 A	1.58 A
TJ7	23.50 AB	1.84 A	1.68 A
TM	26.75 AB	1.36 A	1.58 A
T (+)	26.88 AB	1.76 A	1.77 A
T (-)	20.20 B	1.21 A	1.03 A
F	1.46	44.85	0.96
P	0.2424	0.0001	0.4758

Means followed by the same letter are not significantly different according to Duncan's test ($p \leq 0.05$).

F-value = F statistic from analysis of variance (ANOVA).

P-value = Probability value associated with the F test.

Selected strain.

PH = Plant height; RV = Root volume; SDW = Shoot dry weight.

T (+) = Positive control.

T (-) = Negative control.

Table 4. Mean comparison for the selection of organic fertilizers in the greenhouse assay.

Organic fertilizer	PH (cm)	RV (mL)	SDW (g)
Amino acids	20.50 A	0.36 A	0.94 B
Bokashi*	23.00 A	1.01 A	2.21 A
Vermicompost leachate	21.00 A	0.42 A	0.86 B
Supermagro*	28.50 A	2.15 A	1.74 AB
T (+)	24.00 A	0.43 A	1.24 AB
T (-)	18.25 A	0.62 A	0.91 B
F	1.09	88.78	2.28
P	0.3977	0.0001	0.0907

Means followed by the same letter are not significantly different according to Duncan's test ($p \leq 0.05$).

F-value = F statistic from analysis of variance (ANOVA).

P-value = Probability value associated with the F test.

Selected organic fertilizer.

PH = Plant height; RV = Root volume; SDW = Shoot dry weight.

T (+) = Positive control.

T (-) = Negative control.

Evaluation of the Combination of Organic Fertilizers and Bioinoculants under Field Conditions

For plant height (PH) and shoot dry weight (SDW), the treatments involving the application of organic fertilizers (Bokashi and Supermagro), either alone or in combination with the bioinoculants B14 and TF, did not show significant differences among themselves or among their respective combinations. Nevertheless, all of these treatments were statistically superior to the negative control (T-), according to Duncan's mean comparison test ($p \leq 0.05$). In particular, for PH, the highest value was recorded in T8 (Supermagro) with 21.07 cm, whereas for SDW, the highest value corresponded to T9 (positive control, T+) with 22.15 g. However, neither of these treatments differed statistically from the remaining treatments under organic management. The negative control (T-) showed the lowest values for both variables, with 16.67 cm for PH and 9.61 g for SDW (Table 5).

Leaf Area and Nutritional Status

The leaf area results were consistent with the growth variables. In both sampling events, a general increase in leaf area was observed across all treatments, associated with the progressive development of the crop (Figure 1). According to Duncan's test ($p \leq 0.05$), the treatments with chemical nitrogen fertilization using urea (T9) and the TF + Bokashi combination (T4) showed higher values than the negative control.

Foliar analysis showed that the TF + Bokashi treatment (T4) stood out by exhibiting higher concentrations of nitrogen (3.223%), phosphorus (0.39%), and potassium (1.077%) in comparison with the untreated control (Table 6). The urea treatment (T9) recorded the

Table 5. Growth promotion in common bean through the application of organic fertilizers and strains of *Bacillus* spp. and *Trichoderma* spp.

Treatment	PH (cm)	RV (mL)	SDW (g)
T1. B14 + Bokashi	19.81 A	1.58 A	15.58 A
T2. B14 + Supermagro	19.77 A	1.63 A	16.41 A
T3. B14 (<i>B. cereus</i>)	19.23 A	1.71 A	14.44 A
T4. TF (<i>T. virens</i>) + Bokashi	19.19 A	2.80 A	19.87 A
T5. TF + Supermagro	19.57 A	1.63 A	16.64 A
T6. TF (<i>T. virens</i>)	19.66 A	1.63 A	16.15 A
T7. Bokashi	19.12 A	1.75 A	20.15 A
T8. Supermagro	21.07 A	1.92 A	20.28 A
T9. T (+)	21.03 A	2.80 A	22.15 A
T10. T (-)	16.67 B	1.58 A	9.61 B
F	10.22	1.31	2.91
P	0.0001	0.2771	0.0153

Means followed by the same letter are not significantly different according to Duncan's test ($p \leq 0.05$).

F-value=F statistic from analysis of variance (ANOVA).

P-value=Probability value associated with the F test.

PH=Plant height; RV=Root volume; SDW=Shoot dry weight.

T (+)=Positive control.

T (-)=Negative control.

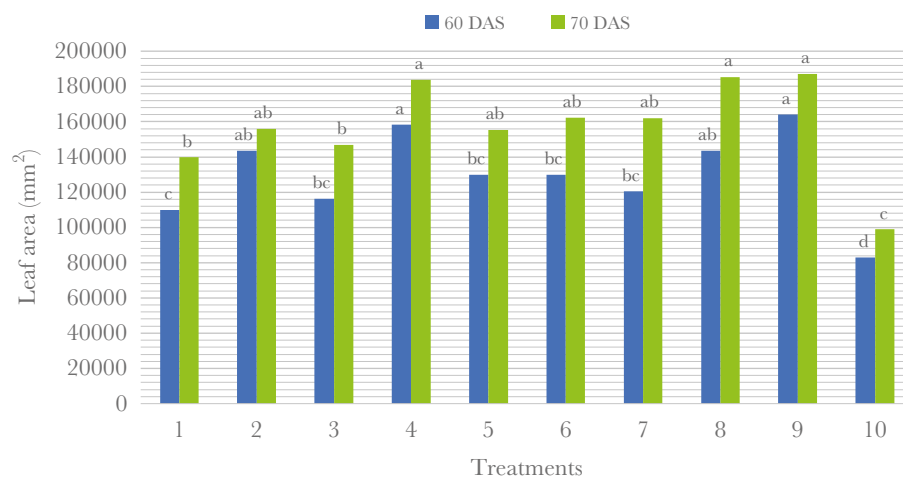


Figure 1. Mean comparison of leaf area by treatment in two sampling events conducted at 60 and 70 DAS. The bars represent the average leaf area value in mm². Means followed by the same letter are not significantly different according to Duncan's test ($p \leq 0.05$).

Table 6. Mean comparison of yield variables in common bean under field conditions.

Treatment	NSM (m ²)	AFB (t ha ⁻¹)	SY (t ha ⁻¹)
T1. B14 + Bokashi	569.86 B	4.28 AB	2.15 B
T2. B14 + Supermagro	602.82 B	4.59 AB	2.46 AB
T3. B14 (<i>B. cereus</i>)	723.09 AB	4.73 AB	2.33 AB
T4. TF + Bokashi	838.86 A	5.67 A	3.23 A
T5. TF + Supermagro	739.71 AB	5.06 AB	2.77 AB
T6. TF (<i>T. virens</i>)	674.09 AB	4.67 AB	2.79 AB
T7. Bokashi	710.11 AB	5.01 AB	2.71 AB
T8. Supermagro	759.42 AB	5.04 AB	2.99 AB
T9. Positive control (+)	632.63 AB	4.73 AB	2.63 AB
T10. Negative control (-)	568.86 B	3.85 B	2.17 B
F	2.06	1.00	1.38
P	0.0713	0.4639	0.2470

Means followed by the same letter are not significantly different according to Duncan's test ($p \leq 0.05$).

F-value=F statistic from analysis of variance (ANOVA).

P-value=Probability value associated with the F test.

NSM=Number of seeds per square meter.

AFB=Aboveground foliar biomass.

SY=Seed yield.

highest nitrogen content (3.6%), as a result of the direct supply of this nutrient. It should be noted that no mean comparison among treatments was performed for this variable, since sufficient material was not available to conduct replicates.

Yield Variables and Nutritional Quality

The ANOVA revealed no statistically significant differences among treatments for aboveground foliar biomass (AFB) and seed yield (SY) ($p \leq 0.05$); however, the number

of seeds per square meter (NSM) showed a trend toward significance. Mean comparison allowed identification of the TF + Bokashi treatment (T4) as the one with the highest yield values in contrast to the negative control (Table 6).

The nutritional analysis of grains harvested under field conditions revealed values for dry matter, ash, protein, neutral detergent fiber (NDF), and acid detergent fiber (ADF). Dry matter values were highly uniform among treatments, ranging from 89.6% to 90.7%, which are considered optimal for forage quality. Ash content ranged from 3.3% to 3.5% of dry weight, and all samples exceeded 3%, thereby ensuring an adequate nutritional contribution. Protein content ranged from 18.3% to 19.1%, with treatments T1 and T2 showing the highest values. The *Trichoderma* + Supermagro treatment (T5) stood out in several respects, as it exhibited a favorable balance of crude protein (17.9%), low NDF content (22.11%), and a low ADF value (6.50%). It should be noted that no mean comparison was performed for this analysis because insufficient material was available to generate replicates. During the selection trials, the bioinoculants B14 (*Bacillus cereus*) and TF (*Trichoderma virens*), together with the fertilizers Bokashi and Supermagro, exhibited the best average values for PH and SDW, which justifies their selection and is consistent with previous results reported in maize (López *et al.*, 2019), lettuce (Lassevich *et al.*, 2020), and garlic (Ávila *et al.*, 2023). The combined application of organic fertilizers and bioinoculants showed favorable effects on growth and yield in common bean cultivation. The use of Bokashi and Supermagro contributed to improving crop performance, in agreement with Ávila *et al.* (2023), who documented significant increases in garlic yield through the application of these bioinputs. Similarly, López *et al.* (2023) reported that Bokashi fertilization significantly increased the growth and yield of saladette tomato (*Solanum lycopersicum* L.), thereby supporting the positive effect of this organic fertilizer on crop productivity. The positive effect of Supermagro observed in the present study may be attributed to its physicochemical and microbiological composition. Burges *et al.* (2023) indicate that this biopreparation contains high microbial diversity and available nutrients, which favor plant tissue quality and crop yield. These findings support the effects observed in treatments that included Supermagro, particularly when combined with *Trichoderma*. Likewise, López *et al.* (2019) reported positive results when using bioinoculants based on *Bacillus* and *Trichoderma*, which contributed to improved development and productivity in maize cultivation. In the present study, seed inoculation with *Bacillus* and *Trichoderma* proved to be an effective method not only for protecting plants but also for promoting their growth and development. The effect of *Bacillus* may be attributed to its capacity to solubilize phosphates, whereas *Trichoderma* enhances phytohormone production, which is consistent with the findings of López-Valenzuela *et al.* (2022). These combinations emerge as a viable alternative for common bean cultivation, as they increased key variables such as aboveground foliar biomass (AFB) and seed yield (SY). Similarly, inoculation with *Trichoderma* and *Bacillus* represents a promising option, given that both microorganisms have proven useful both as biofertilizers and as disease control agents. This is consistent with Poveda and Eugui (2022), who highlight their potential to improve crop productivity and support more sustainable agricultural practices. Regarding the nutritional quality of the grain, the *Trichoderma* + Supermagro treatment (T5) stood out by presenting a favorable

balance of crude protein (17.9%), together with low levels of neutral detergent fiber (NDF) and acid detergent fiber (ADF), which positions it as an advantageous option in terms of nutritional quality and digestibility (Cid *et al.*, 2023). Overall, the analyses show that this integrated approach makes it possible to harness the nutritional and microbiological benefits of both bioinoculants and organic fertilizers, in agreement with Luna *et al.* (2023), who reported improvements in common bean yield under organic fertilization treatments.

CONCLUSIONS

Bioinoculants based on *Bacillus cereus* (B14) and *Trichoderma virens* (TF), when applied in combination with the organic fertilizers Bokashi and Supermagro, showed a better response as growth promoters in common bean cultivation than when applied individually. The TF + Bokashi combination produced positive effects on productive variables in common bean under field conditions; therefore, it may enable a 100% reduction in nitrogen chemical fertilizer application, favorably affecting production costs for farmers while also contributing to the reduction of high levels of contamination and degradation in agricultural soils such as those of Sinaloa.

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