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Productive and economic potential of the application of biofertilizer in hybrid corn DAS 3383

Potencial productivo y económico de la aplicación de biofertilizante en maíz híbrido DAS 3383

Potencial produtivo e econômico da aplicação de biofertilizanteemmilho híbrido DAS 3383

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Abstract

The excessive and inappropriate use of synthetic fertilizers has the potential to cause significant environmental and economic issues. The utilization of biofertilizers represents a sustainable and environmentally friendly alternative for the enhancement of crop productivity. Accordingly, the present study evaluated the productive and economic behavior of applying biofertilizers on hybrid corn DAS 3383 under a completely random block design, with five treatments and three repetitions. The following treatments were employed: a control treatment devoid of any fertilization (CONTROL), a conventional treatment comprising NPK fertilization (NPK), a treatment incorporating 5 % biofertilizer (5BIO), a treatment incorporating 15 % biofertilizer (15BIO), and a treatment incorporating 25 % biofertilizer (25BIO). At the 90-day mark, the NPK treatment exhibited the greatest plant height (272.81 cm), while at the 108-day interval, the cob insertion height (170.40 cm) was also the highest. However, the 25BIO treatment yielded the most optimal results in terms of cob length (14.29 cm), diameter (6.07 cm), 1,000-grain weight (31.70 g), and yield (9 $t.ha^{-1}$). This treatment also demonstrated the highest net benefit ($2,019.10) and favorable profitability (72 %) compared to the other treatments. The results of the orthogonal contrast analysis indicate that there are significant linear effects for the majority of variables, with no discernible quadratic effects. This evidence substantiates the potential of biofertilizers in enhancing maize crop productivity. By repurposing organic waste from the agricultural sector and employing it as an alternative to chemical fertilizers, these findings contribute to the advancement of more sustainable and profitable agricultural practices.

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Resumen

El uso excesivo e inapropiado de fertilizantes sintéticos puede ocasionar graves problemas ambientales y económicos. El uso de biofertilizantes representa una alternativa sostenible y respetuosa con el medio ambiente para mejorar la productividad de los cultivos. Por tanto, en el presente estudio se evaluó el comportamiento productivo y económico de la aplicación de biofertilizantes en maíz híbrido DAS 3383 bajo un diseño de bloques completamente al azar, con cinco tratamientos y tres repeticiones. Los tratamientos utilizados fueron: testigo sin fertilización (CONTROL), fertilización convencional con NPK (NPK), 5 % de biofertilizante (5BIO), 15 % de biofertilizante (15BIO) y 25 % de biofertilizante (25BIO). A los 90 días, el tratamiento NPK obtuvo una mayor altura de planta (272,81 cm), así como a los 108 días, la altura de inserción de la mazorca (170,40 cm). Sin embargo, los mejores resultados en longitud (14,29 cm) y diámetro (6,07 cm) de mazorca, peso de 1.000 granos (31,70 g) y rendimiento (9 $t.ha^{-1}$) se obtuvieron con el tratamiento 25BIO, con un beneficio neto de 2.019,10 $ y una rentabilidad favorable del 72 %. El análisis de contraste ortogonal muestra que existen efectos lineales significativos para la mayoría de las variables, sin presentar efectos cuadráticos. Se demuestra el potencial de los biofertilizantes aplicados al cultivo de maíz, aprovechando así los residuos orgánicos del sector agrícola y su uso como alternativa para reducir el uso de los fertilizantes químicos, contribuyendo al desarrollo de prácticas agrícolas más sostenibles y rentables.

Palabras clave: fertilizante orgánico, genotipo, semilla, residuos orgánicos, rentabilidad.

Resumo

O uso excessivo e inadequado de fertilizantes sintéticos pode causar graves problemas ambientais e econômicos. O uso de biofertilizantes representa uma alternativa sustentável e amiga do ambiente para melhorar a produtividade das culturas. Portanto, neste estudo avaliou-se o comportamento produtivo e econômico da aplicação de biofertilizantes em milho híbrido DAS 3383 sob um desenho de blocos completamente aleatório, com cinco tratamentos e três repetições. Os tratamentos utilizados foram: controle sem fertilização (CONTROL), fertilização convencional com NPK (NPK), 5 % de biofertilizante (5BIO), 15 % de biofertilizante (15BIO) e25 % de biofertilizante (25BIO). Aos 90 dias, o tratamento NPK obteve uma maior altura de planta (272,81 cm), assim como aos 108 dias, a altura de inserção do espinho (170,40 cm). No entanto, os melhores resultados em comprimento (14,29 cm) e diâmetro (6,07 cm) de espiga, peso de 1000 grãos (31,70 g) e rendimento (9 $t.ha^{-1}$) foram obtidos com o tratamento 25BIO, com um lucro líquido de 2.019, 10 $ e uma rentabilidade favorável de 72 %. A análise de contraste ortogonal mostra que existem efeitos lineares significativos para a maioria das variáveis, sem apresentar efeitos quadráticos. Assim, demonstra-se o potencial dos biofertilizantes aplicados ao cultivo de milho, aproveitando os resíduos orgânicos do setor agrícola e seu uso como alternativa para reduzir os fertilizantes químicos, Contribuindo para o desenvolvimento de práticas agrícolas mais sustentáveis e rentáveis.

Palavras-chave: fertilizante orgânico, genótipo, semente, residuos orgânicos, rentabilidade.

Introduction

The sowing of corn (*Zea mays* L.) is considered a production primary by its degree and importance in the food chain (Díaz-Chuquizuta *et al*., 2022); can be used for food human and animal (Guamán *et al*., 2020). In addition, it is used in the production of biofuels or as a raw material to produce zein nanoparticles for pest control in crops agricultural (Lira *et al*., 2018). The quality and genotype of the seed planted are significant factors influencing the yield of the corn crop. Additionally, the type of soil, climate, and crop behavior from sowing to harvest must be considered (Remache *et al*., 2017).

At the moment exists wide acceptance of corn genotypes improved by part of the producers corn growers, and what they present properties outstanding in grain portion and quality, plant vigor, stress tolerance abiotic, pests, pathologies and high performance, which adapt to different conditions geographical and agrosystems (Fajardo *et al*., 2024); however, due to its impact negative in the environment (Golik *et al*., 2023). It is necessary implement new practices that remedy production needs and promote he balance in the ecosystems through practices ecologically healthy with fertilizer use organic (Obid *et al*., 2016).

In this sense, the corn yellow hard Ecuadorian is one of the agricultural products more important in the economy national (Analuisa *et al*., 2023). It is the main raw material for the production of food concentrates for animals (Pomboza-Tamaquiza *et al*., 2018). This cereal is sown in coastal areas under different environmental conditions such as humidity, temperature, light, rain and soil (Llanos *et al*., 2020). The largest production is located in the provinces of Los Ríos, Manabí, Guayas and the rest in the province of Loja (López *et al*., 2021). It should be noted that about 90 % of corn is planting during the rainy season. Due to the diversity of conditions in which they grown the corn and the need for seeds adapted to climates of 22 and 23 °C (Verdezoto-Mendoza *et al*., 2021), it is necessary to study the genetic material of the corn hybrid yellow hard DAS 3383 and its cost effectiveness in mountainous areas.

In crop plantations, they need macro and micronutrients to meet their growth and production needs. In this sense, the soils have high deficiencies of some nutritional elements, so producers use chemical fertilizers as a remedy (Hirzel *et al*., 2016). However, their use provokes impacts negative effects on the environment, which include: i) soil degradation, ii) air pollution and iii) biological imbalances, especially in monocultures if they are not managed appropriately (Lagunes *et al*., 2018).

Moreover, plants only absorb between 30 and 50 % of these fertilizers, while the rest is deposited in the soil, causing pollution, including water resources, soil acidification and human health effects (De Luna-Vega *et al*., 2016). They are currently being studied fertilization alternatives that significantly improve the returns productive of the crops and perhaps avoid soil degradation (Vera Rodríguez *et al*., 2024; Beltarn & Bernal, 2022); strengthening fertilizer implementation organics that provide nutrients to crops and improve soil fertility (Diaz Almea & Contreras-Miranda, 2022).

Biol is a liquid biofertilizer produced in a biodigester, such as the result of anaerobic fermentation of organic waste (Medina *et al*., 2018). It is also an excellent soil and foliar fertilizer. Its foliar application varies from 10 to 100 % with an average of 3-6 applications, especially in the stages critical of the crop and its application edaphic generally during the irrigation in variable concentrations up to 100 %, achieving increase in yields (Chávez, 2017). However, it acts more efficient when applied directly on the roots, favoring its nutrition and increasing its productivity level. The biol components depend mainly on the type of matter organic and the type of animal manure used, the which has a composition chemistry of matter organic, nitrogen, phosphorus, potassium and micronutrients (Medina & Toro, 2019); which are elements very necessary for the growth, flowering and maturation in plantations (Tadeo *et al*., 2017).

A job reports the literature with the application of three doses of biofertilizer from fish waste (1, 1.25, and 1.5 %) to increase the growth parameters vegetative and performance of the corn crops, where the better treatment observed was he biofertilizer with 1.25 %, reducing the fertilizer dose conventional by up to (50 %) (Maquen-Perleche *et al*., 2023).

As evidenced in the review bibliographic, the utilization of biofertilizers has been observed to result in a notable enhancement in crop performance. This phenomenon has also been documented in the cultivation of corn. Additionally, the incorporation of biofuels derived from locally sourced organic materials has been shown to mitigate environmental impact, enhance organic waste recycling, reduce production costs, and promote sustainable agricultural practices. In this context, the study had as objective to assess he behavior productive and economic use of biofertilizer liquid (biol) in corn hybrid DAS 3383 at different concentrations, in order to identify a dose promising biofertilizer for corn crop.

Materials and methods

Studio location

The research was carried out in the winter, between the months of December 2022 - April 2023 in the Nuevo Porvenir Campus, in the Canton of Chillanes, Bolívar Province - Ecuador (1°55’60″ S 79°4′0″ W, 800 m a.s.l.). The study area has a temperate humid climate, with a temperature that varies between 18.04 and 23.01 °C (Verdezoto *et al*., 2021). The soil conditions of the “Nuevo Porvenir” farm are presented in table 1.

Obtaining the biofertilizer

The preparation of liquid biofertilizers was carried out from cattle manure, considering the methodology used in a work reported in the literature, with some modifications, such as the use of local raw materials (Pomboza *et al*., 2016).The materials and quantities used are presented in table 2.

The biofertilizer used was obtained from a storage tank made of PVC plastic material of the Rochem brand with a capacity of 60 L, which was properly sealed. The anaerobic fermentation process was carried out for 60 days and stored at room temperature. For biogas output, a hose adapter (1 cm in diameter) was made in the upper part of the biodigester, which was connected to another smaller volume container with water. Once the anaerobic fermentation was completed, the biodigester was opened and the liquid sample was filtered to retain the suspended solids and thus purify the sample.

Table 2. Materials and quantities used in the preparation of the biofertilizer.

Supplies	Quantities (kg)
Water	40
Cattle manure	30
Molasses	2.4
Ash	2
Legume (*Euphorbia cotinifolia*, *Colocasia esculenta*)	2
Legume shells (beans, broad beans, peanuts)	2
Milk	1
Sugar	0.23
Grain salt	0.23
Saccharomyces cerevisiae	0.05

The chemical characterization of the biofertilizer obtained was carried out in the Fertilizer Laboratory of the Phyto and Zoosanitary Regulation and Control Agency AGROCALIDAD, from a sample of 150 mL, which was stored in an amber bottle to prevent its degradation in contact with solar radiation prior to analysis.

Table 3 shows the results of the physical-chemical analysis of the elaborated biofertilizer.

Table 3. Chemical characterization of the prepared biofertilizer.

Parameter	Result	Unit of measurement	Parameter	Result	Unit of measurement
pH	6.87	-	CaO	0.11	%
CE	20.1	$mS.cm^{-1}$	MgO	0.14	%
MO	5.51	%	Na	0.16	%
NT	0.46	%	Fe	< 0.5	ppm
P_2O_5	0.01	%	Zn	< 0.2	ppm
K_2O	0.32	%			

CE: Electrical Conductivity, MO: Organic Matter, P_2O_5: Phosphorus Oxide, K_2O: Potassium Oxide, CaO: Calcium Oxide, MgO: Magnesium Oxide, Na: Sodium, Fe: Iron, Zn: Zinc. Source: Laboratory of soils, plant tissues and waters of the South Experimental Station of the National Agricultural Research Institute, Ecuador

The slurry improves soil nutrition with a pH of 6.87 and an electrical conductivity of 20.1 $mS.cm^{-1}$. Its organic matter of 5.51 improves soil structure and retains moisture. It contains 0.46 of total nitrogen, which is essential for corn growth. In agreement with Pérez & Álvarez (2021), the use of biofertilizers is an economically and environmentally viable alternative to incorporate nutrients, organic carbon and improve the physicochemical properties of soils and their importance in terms of their microbial activity

The P_2O_5 content is 0.01, an essential nutrient for the growth and development of corn, important for photosynthesis, root formation

Table 1. Chemical analysis of the soil of the “Nuevo Porvenir” farm.

pH	%	cmol.kg^{-1}					Mg.kg^{-1}			
	MO	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
6.87	5.51	0.28	<3.5	0.11	4.65	0.88	185.5	12.12	8.85	<1.60
Slightly acidic	High	Half	Low	Low	High	High	High	Half	High	Low

MO: Organic Matter, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Fe: Iron, Mn: Manganese, Cu: Copper, Zn: Zinc. Source: Laboratory of soils, plant tissues and waters of the Southern Experimental Station of INIAP-Ecuador.

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and tassel and cob production. The K_2O content was 0.32, it is another essential nutrient for the corn growth as it helps in water absorption, regulation of stomata opening and closing, and synthesis of proteins and carbohydrates. Calcium oxide (0.11), an essential nutrient for the plant growth and development, contributes to the formation of cell walls, strengthens plant structure, and aids in the absorption of other nutrients. Magnesium oxide (0.14) is a key component of chlorophyll, the pigment responsible for photosynthesis in plants.

Sodium content is 0.16, which is essential for plants, but in excessive amounts it can interfere with the absorption of other nutrients and cause salinity problems, with negative effects on growth and development. Iron and zinc levels are less than 0.5 and 0.2 respectively. Both iron and zinc are essential micronutrients for plants and play important roles in various metabolic and enzymatic processes. Adequate nutrient supply can optimize corn crop yield. The comparison of works reported in the literature (Hassanpour *et al*., 2021), showed that the best fertilization treatment is the combined use of biofertilizer and enriched organic fertilizer, which generated a net profit of 71.5 million rials and a yield of 12.5 $t.ha^{-1}$compared to other treatments.

In order to increase the income of the farmer, it is important to focus on the net benefits and yields obtained from the fertilizing effect. However, its potential is likely to increase, taking into account various factors such as: i) increasing the concentrations of this biofertilizer obtained, ii) combining its formulation with other types of manure (pig, goat, poultry), and iii) combining different types of organic manure waste (greater amount of nitrogen) to increase its productivity and efficiency at the time of application (Pérez & Álvarez, 2021).

Soil biofertilization

The preparation of the land was carried out under conventional tillage, using machinery to plow the soil, forming plots of 4.8 x 2.4 m, the seeds were sown at a distance of 20 cm between plants and 80 cm between rows, introducing a seed per hole, achieving a population of 72 plants per experimental unit and a population of 1,080 plants throughout the experimentation. Before sowing, the DAS 3383 hard hybrid corn seeds were treated with Triodicard at a dose of 20 $mL.kg^{-1}$ seeds according to the instructions of Vera *et al*. (2020).

The mode of application of all treatments was through the edaphic route directly to each plant. The Biol in its different concentrations of 5, 15 and 25 % was diluted with water (v.v.) at application frequencies of 8, 23 and 38 days after sowing (das), while the conventional NPK chemical fertilization was applied in three applications at 8 das (8-20-20 % NPK, AGRIPAC®), 23 das (15-10-30 % NPK, FERPACIFIC®) and 38 das (21-0-0-24 % NPK, AGRIPAC®).

Economic analysis

The economic analysis was carried out using the partial budgeting method proposed by Rodríguez *et al*. (2020). First, the income is determined and adjusted to the field yield, which is reduced by 10 % due to the loss of production. The adjusted yield is multiplied by the official price for the month of June 2023 in Ecuador per quintal of corn ($16.89) with 13 % humidity and 1 % impurities (Ministerio de Agricultura y Ganadería [MAGAP], 2022), and the gross field profit is obtained. In the costs, those that vary due to the effect of the treatments were determined. To obtain the net benefit per treatment, the total of the costs that vary must be subtracted from the gross field benefit. Then the marginal rate of return is calculated, the same one that is decoded (percentage increase in net benefit as a result of a 1 % increase in varying costs). Finally, a sensitivity study is performed on the marginal rate of return, observing the relationship of costs, expenses and profits with respect to sales.

Design and statistical analysis

The research was carried out under a completely randomized block experimental design (DBCA) chosen to block the possible variation in soil conditions and avoid variability in the results, using 5 treatments: CONTROL (control without fertilization), NPK (conventional NPK fertilization), 5BIO (5 % biofertilizer), 15BIO (15 % biofertilizer) and, 25BIO (biofertilizer 25 %) with 3 repetitions, with a total of 15 experimental units.

To evaluate the productive behavior of DASS 3383 hybrid corn, several crop variables were analyzed, including: plant height at 90 days, ear insertion height at 108 days, ear cob length and diameter of the at harvest, and 1,000 grains weight. The orthogonal contrast technique was also used to compare the different treatments on the analyzed variables to observe their quadratic or linear effects. The result obtained in the orthogonal contrast of the treatments result analyzes how the result varies with depending on proportional changes in the treatments. This technique is useful for comparing two or more treatments and measuring their significant linear effects.

An ANOVA analysis was carried out to determine if there were significant differences between treatments and to separate the means, using the Tukey test ($p<0.05$) for the comparison and separation of means in the present study, which was carried out using the program InfoStaf statistic version 2020.

Results and discusssion

Productive behavior

Biol treatments with higher concentrations (15BIO, 25BIO) showed significant improvements in all variables compared to the control group. These improvements included increases in plant height, ear length and diameter, grain weight, and yield ($p<0.05$). Therefore, the results obtained show the potential of the biofertilizer produced in corn crops, because the higher the biol concentration are statistically significant in all the variables evaluated in comparison with the CONTROL treatment (control, without fertilization), which establishes that the quality in the production of the corn crop studied depend on the different concentrations of biofertilizer. Other works found in the literature report similar results when a fertile Minco compost was applied (Escalona *et al*., 2021), and conventional fertilization at the height of the plant after 30 days (Vera *et al*., 2020). Likewise, when evaluating the insertion height of the cob, significant differences were obtained with respect to CONTROL, reporting the best results with chemical fertilization (170.40 cm), which is probably due to the genetic constitution of the genetic material affected by the degree of fertilization and fertilization (Cabrera-Ponce *et al*., 2019). Which are also influenced by other factors, such as genetic factors of the plant, its variety, climatic conditions and fertility from the soil (Vera *et al*., 2021).

It is believe that by increasing the dose of biol (25 %), the contribution and availability of nutrients in the soil and in the plant will be greater, being solubilized which with the help of beneficial soil microorganisms, making them more accessible to the roots, providing a greater supply of essential nutrients for the growth and development of plants compared to low doses of biol (5 and 15 %) and in relation to the control treatment (0 % fertilization). On this basis, it is important to emphasize that biol provides several macro and micro elements necessary for the metabolism and vital functions of plants in contrast to conventional fertilizers with limited elements such as NPK. In addition, the use of conventional chemical fertilizers in the short and medium term leaves a residual impact on the environment, as in the case of ammoniacal nitrogen, which limits the ability of future corn crops to reach their optimal performance because it blocks the simple absorption of nutrients contained in the soil (Garcia *et al*., 2021; Collahuazo & Araujo, 2019). Therefore, the use of biofertilizers has a favorable response that has been widely accepted internationally, being an alternative for the production of various crops, including corn, thus allowing the use of nutrients in partnership with plants and plant growth, in such a way so that yields are maintained or increased (Canseco *et al*., 2020).

Orthogonal contrasts

Table 4 shows the results of the orthogonal contrast, which observes the effect of the different treatments on the different variables in the study.

The orthogonal contrast results show significant linear effects for plant height for the contrasts (CONTROL & NPK & 5BIO & 15BIO & 25BIO), (NPK & 5BIO) (NPK & 15BIO), (NPK & 25BIO). Likewise, it is observed that there are significant linear effects in the insertion height of the cob for some contrasts (CONTROL & NPK & 5BIO & 15BIO & 25BIO), (NPK & 5BIO), and between (NPK & 25BIO). It is also observable that there are significant linear effects on the length of the ears for the contrasts between the treatments (CONTROL & NPK & 5BIO & 15BIO & 25BIO) in the same way, the contrast (NPK & 5BIO), (5BIO & 15BIO) and (5BIO & 25BIO).

For the variable ear diameter, there is a significant linear effect for the contrast between the treatments (CONTROL & NPK & 5BIO & 15BIO & 25BIO), (5BIO & 25BIO) and (15BIO & 25BIO).There is a significant linear effect in the weight of the 1000 grains for the contrasts (CONTROL & NPK & 5BIO & 15BIO & 25BIO), (NPK & 5BIO), (NPK & 25BIO), (5BIO & 25BIO) and (15BIO & 25BIO).

Finally, a significant linear effect in crop yield is observed for the contrasts (CONTROL & NPK & 5BIO & 15BIO & 25BIO), (NPK & 5BIO), (NPK & 25BIO), (5BIO & 25BIO) and (15BIO & 25BIO).

The results of the contrast demonstrate statistically significant linear effects on multiple corn variables, including plant height, ear length, and yield. No quadratic effects were observed, which implies that, as the BIOL dose increases, the variables respond consistently.

This finding facilitates the prediction of results and decision-making in agricultural management. In alignment with the findings of Delgado & Prada (2022), the linear effects evaluated through orthogonal contrasts enable the representation of the behavior of the productive parameters based on the inclusion levels of the treatments. Consequently, it is feasible to construct linear combinations of the effects of the treatments and ascertain whether there are statistically significant differences between them.

Economic analysis

The economic analysis was carried out for each of the treatments in the study of hybrid corn DAS 3383, under the effect of 5 forms of fertilization as shown in Table 5, where the partial budget of the research can be seen.

As expected, the control treatment without carrying out fertilization presents the lowest net benefit of $ 1,316.10, but when carrying out conventional fertilization based on NPK (NPK) it increases to $ 1,582.10, increasing the profitability of the crop by 25 %, while when comparing it with the best biofertilization formulation (25BIO) according to the results obtained, a greater net benefit ($ 2,019.10) was obtained, obtaining a greater profitability of 72 % per hectare with respect to the treatment that did not receive fertilization.

Figure 1 show the profitability analysis in response to the treatments performed.

In this sense, the biofertilizer obtained from the anaerobic fermentation of cattle manure and agroindustrial waste could be a great alternative for fertilization in corn crops, reporting the best results when using 25 % biol/water (v.v.) with a greater net benefit ($ 2,019.10) and a greater profitability of 72 % per hectare compared to the control treatment without fertilization.

Conclusions

Based on the economic analysis, it is concluded that the CONTROL treatment has the lowest net benefit of $ 1,316.10 and lower profitability. By adding conventional fertilization based on NPK (NPK), the net benefit increases to $ 1,582.10, increasing the profitability by 25 %, while by using a prepared biofertilizer (25BIO), a higher net benefit of $ 2,019.10 was obtained, obtaining a profitability of 72 % per hectare.

Table 4. Orthogonal contrasts for treatments.

	Contrasts for treatments F / p-valor						
	CONTROL & NPK & 5BIO & 15BIO & 25BIO	NPK & 5BIO	NPK & 15BIO	NPK & 25BIO	5BIO & 15BIO	5BIO & 25BIO	15BIO & 25BIO
Plant height	34.23 / 0.0004***	13.55 / 0.0062***	12.40 / 0.0078***	7.99 / 0.0223**	0.03 / 0.8773	0.73 / 0.4179	0.48 / 0.5070
Cob insertion height	43.24 / 0.0002***	14.76 / 0.0049***	3.09 / 0.1167	8.47 / 0.0196**	4.34 / 0.0707	0.87 / 0.3787	1.33 / 0.2826
Cob length	46.58 / 0.0001***	16.44 / 0.0037***	1.83 / 0.2135	0.65 / 0.4422	7.37 / 0.0270**	23.65 / 0.0013***	4.67 / 0.0628
Cob diameter	120.26 / <0.0001***	0.43 / 0.5286	0.05 / 0.8211	5.07 / 0.0544	0.18 / 0.6820	8.47 / 0.0196**	6.18 / 0.0377**
1,000 grain weight	373.51 / <0.0001***	12.21 / 0.0082***	5.30 / 0.0503	34.42 / 0.0004***	1.42 / 0.2677	87.61 / <0.0001***	66.72 / <0.0001***
Yield	121.00 / <0.001***	22.50 / 0.0015***	10.00 / 0.133	22.50 / 0.0015***	2.50 / 0.1525	90.00 / <0.0001***	62.50 / <0.0001***

CONTROL Witness; NPK Conventional NPK fertilizer; 5BIO: 5 % biofertilizer; 15BIO: 15 % biofertilizer; 25BIO: 25 % biofertilizer. *** highly significant; ** significant, p<0.05.

Table 5. Partial budget of the experiment on the effect of different forms of fertilization in corn variety DAS 3383.

Parameters	Treatments				
	CONTROL	**NPK**	**5BIO**	**15BIO**	**25BIO**
Average yield kg.ha^{-1}	6.000.00	8.000.00	7.000.00	7.330.00	9.000.00
Adjusted yield kg.ha^{-1}	5.400.00	7.200.00	6.300.00	6.597.00	8.100.00
Gross profit \$.kg^{-1}.ha^{-1}	1.998.00	2.664.00	2.331.00	2.440.89	2.997.00
Soil preparation \$.ha^{-1}	150.00	150.00	150.00	150.00	150.00
Sowing \$.ha^{-1}	326.90	326.90	326.90	326.90	326.90
Fertilization \$.ha^{-1}	0.00	400.00	60.00	179.00	296.00
Application \$.ha^{-1}	25.00	25.00	25.00	25.00	25.00
Harvest \$.ha^{-1}	180.00	180.00	180.00	180.00	180.00
Total, Costs that vary \$.ha^{-1}	681.90	1.081.90	741.90	860.90	977.90
Net Profit \$	1.316.10	1.582.10	1.589.10	1.579.99	2.019.10

CONTROL: Witness; NPK: Conventional NPK fertilizer; 5BIO: 5 % biofertilizer; 15BIO: 15 % biofertilizer; 25BIO: Biofertilizer at 25 %.

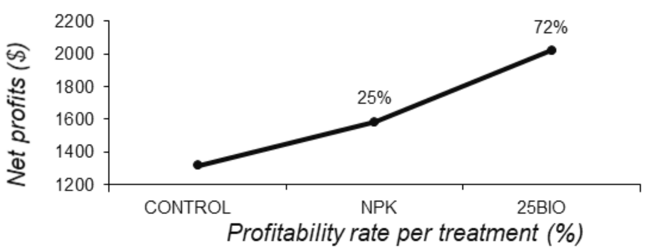

Figure 1. Comparison of net benefits and profitability rate by treatments (CONTROL without fertilization; NPK conventional NPK fertilization; 25BIO (25 % biofertilizer with best response) in DAS 3383 hybrid corn.

The results of the orthogonal contrast show that there are significant linear effects in the variables (plant height, cob insertion height, cob length, cob diameter, 1,000 grain weight, yield) for the contrasts (CONTROL & NPK & 5BIO & 15BIO & 25BIO) and (NPK & 5BIO) in the latter, except for cob diameter. The contrasts (NPK & 15BIO) for plant height, (NPK & 25BIO) for plant height, cob insertion height, 1000 grain weight, and Yield, (5BIO & 15BIO) for cob length, (5BIO & 25BIO) also showed significant linear effects, for the variables cob length, cob diameter, 1000 grain weight, yield and (15BIO & 25BIO) for cob diameter, 1000 grain weight, yield. No significant quadratic effects were observed for the variables; this could be because the linear relationship predominant, i.e. as the dose of BIOL increases, the response also increases constantly.

In this sense, the use of biofertilizers obtained on corn crops is a favorable option for the environment, improving the quality of soils and increasing their productivity; furthermore, with the results obtained, its productive and economic potential is demonstrated as a great fertilization alternative.

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