ALTERNATIVE ORGANIC FERTILIZERS IN MAIZE (Zea mays L.) CULTIVATION GIBARA VARIETY

ALTERNATIVA DE ABONOS ORGÁNICOS EN EL CULTIVO DEL MAÍZ (Zea mays L.) VARIEDAD GIBARA

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ABSTRACT

The research was carried out from February to July in areas of the Credit and Service Cooperative «José Martí» in the municipality of Gibara. The effect of different fertilization alternatives was evaluated in the cultivation of maize (Zea mays L.), Gibara variety. The study used a randomized block design with five treatments and three replications, which included the use of solid vermicompost, liquid vermicompost, and FitoMás. For statistical processing of the data, a simple analysis of variance and Duncan's multiple range test ($P<0.05$) were applied using the INFOSTAT software. The yields obtained exceeded the historical average in the municipality, which is 1 t/ha. The results demonstrate that biological and organic alternatives favor the growth and development of maize cultivation.

KEYWORDS: agriculture; agricultural product; agroecology; sustainable products

RESUMEN

La investigación se desarrolló en áreas de la Cooperativas de Crédito y Servicio «José Martí» del municipio Gibara. Se evaluó el efecto de diferentes alternativas de fertilización en el cultivo del Maíz (Zea mays L.) variedad Gibara. Para la realización del trabajo se utilizó un experimento con un diseño de bloques al azar con cinco tratamientos y tres réplicas que comprendió el uso de abonos orgánicos humus de lombriz sólido, humus de lombriz líquido y FitoMás. Para el procesamiento estadístico de los datos se aplicó un análisis de varianza simple y una prueba de comparación múltiples de medias Duncan (P<0,05) a través del software estadístico INFOSTAT; los rendimientos alcanzados superaron la media histórica en el municipio que es de 1t/ha^{-1}. Los resultados demuestran que las alternativas biológicas y orgánicas favorecen el crecimiento y desarrollo del cultivo del maíz

PALABRAS CLAVE: agricultura; producto agrícola; agroecología; productos sostenibles

INTRODUCTION

History has demonstrated the importance of agriculture for societal development; it plays an essential role for human beings as it provides basic necessities for life on the planet. Nowadays, organic fertilizers are of great importance, as they have proven effective in increasing yield and improving product quality; furthermore, they supply the biological needs of the soil, possess physicochemical properties that improve and increase crop production, generate resistance to diseases and pests, and are easy to produce (Arango, 2017).

According to De Lisio (2020), organic fertilizers improve soil structure, porosity, aeration, and water retention capacity, conferring to the soil a greater productive capacity, preserving its fertility over time and being sustainable across productive cycles.

Authors such as Corlay & Hernández (2011), cited by Arango (2017), defined the importance of organic fertilizer due to its fertilizing capacity derived from animal, human, vegetable waste, food scraps or other natural organic sources that generate renewal in the soil; likewise, Gómez & Vásquez (2011) determined its advantages in soil recovery, carbon sequestration in the soil and water absorption, among others.

Maize (Zea mays L.) is a basic input for global food security, cultivated mainly using mineral fertilizers and practices that contribute to soil degradation. Organic fertilizers are an alternative that helps limit soil degradation and improve the productivity of these crops (Díaz-Chuquizuta et al., 2022).

Worldwide, maize has become one of the main crops, currently occupying the largest cultivated area among producers in Mexico, Central America and the Caribbean; it serves as an engine for food security, but also for the economy, since its adaptability and versatility have made it an indispensable crop, allowing it to be cultivated on a large scale (Escalante, 2024). Production in Latin America is 56 million tons, which is equivalent to 13.6% of the world total (408-412 million tons worldwide) (Acosta, 2009). The global harvest for the new century is 1,185.9 million tons. In Latin America, just over 190 million tons are produced.

Maize is a very popular plant with a long tradition in Cuba. It is considered one of the grasses that constitute the world's food supply (González et al., 2019). In Cuba, during 2022, maize yield in the state sector was 1.8 $t \cdot ha^{-1}$, while in the non-state sector it was 1.75 $t \cdot ha^{-1}$, for an overall average of 1.77 $t \cdot ha^{-1}$ destined for human and animal consumption (Cuba, 2023).

Maize in Cuba has been a basic food in human nutrition (Valdés et al., 2021); currently, increasing maize yields per unit area is a top priority task for grain producers. This is based on the importance of this grain for human and animal feed, while also allowing for a significant reduction in its importation, which entails enormous foreign currency expenditures in the international market (Díaz, 2003).

Maize yields in Holguín province are generally low due to the marked degradation of agricultural soils and the lack of fertilizers for crop nutrition. Therefore, it is imperative to apply measures that lead to increased yields of this important grain for human and animal feed.

In Holguín municipality, Gibara variety only reaches 1.90 $t \cdot ha^{-1}$ and in the Credit and Service Cooperative (hereinafter CSC) where the work was conducted, yields of 2.2 tons are obtained due to the following problems: poor seed quality, soil deterioration (loss of fertility and erosion) caused by deficient and inadequate fertilization. Given this situation in the «José Martí» CSC, maize production fails to achieve yields consistent with the productive potential of existing varieties; therefore, the present study aims to: evaluate the effect of different organic fertilizer alternatives on maize (Zea mays L.) cultivation, Gibara variety, on a farm belonging to the «José Martí» CSC in Gibara municipality, Holguín.

DEVELOPMENT

The research was conducted in the area corresponding to the «José Martí» CSC, located in Managuaco Popular Council, Gibara municipality, Holguín province. The farm where the study was carried out has an area of 3.95 ha, of which 2 ha are arable, the remainder consisting of fruit trees, a gully and a hill. The soil where the study was conducted is classified as brown clayey-sandy soil, due to the influence of parent materials, marl and transported materials of alluvial origin, according to Gibara Department of Agriculture and the Cuban soil classification system (Hernández et al., 2019).

The experiment consisted of five treatments and three replications, used to compare the productive responses of Gibara variety maize in relation to the organic fertilizer alternatives used, respectively:

T1.- Fertilization with solid vermicompost and application of liquid vermicompost: (solid vermicompost is applied at sowing at a rate of 4 $t \cdot ha^{-1}$, applied in a continuous band in the furrow) and (liquid vermicompost is applied at 20 and 40 days; for this, 1 kg of vermicompost is mixed with 8 liters of water, stirred for 10-20 minutes, left to rest for 24 hours in the shade, then stirred again for 10-15 minutes, strained, and applied in the early morning hours).

T2.- No fertilization was applied and this served as a control.

T3.- Application of fertilization with solid vermicompost. Using the same methodology as treatment T1.

T4.- Application of HLS + FitoMás. Application of fertilization with solid vermicompost. Using the same methodology as treatment T1 and application of FitoMás E to the seed before sowing at a dose of 1.0 $L \cdot ha^{-1}$ and at 20 and 40 days after germination. These applications were carried out with a 16 L Matabi backpack sprayer.

T5.- FitoMás. Application of FitoMás E to the seed before sowing at a dose of 1.0 $L \cdot ha^{-1}$ and at 20 and 40 days after germination. These applications were carried out with a 16 L Matabi backpack sprayer.

Each block consisted of 5 treatments, separated by 1.00 m between them and with a 1.00 m external border. Four rows were sown per plot, using a planting spacing of 0.90 × 0.25 m, a planting density of four plants per linear meter, for a total of 16 plants per treatment. When making observations and measurements, the initial and final 0.5 m and the two outer rows were discarded.

The experiment occupied an area of 216 m^2 per treatment, 14 m^2 per replicate, 72 m^2 with 96 plants per treatment, with a distance of 1 m between three replications, for a total of 480 plants per replication and 1,440 in the area. Thirty percent of the plants were selected for measurement per treatment: 27 in each replicate, 144 in total, and a total of 432 plants to be measured in the experiment.
The following indicators were evaluated:

- ✓ Plant height (m): measured with a graduated ruler, measuring from the ground to the apical tip of the main stem, at 30 and 40 days after germination.
- ✓ Number of leaves: At 30 and 40 days, a count was made of the number of leaves on the plants.

- ✓ Number of rows per ear (unit): a count of the number of rows was made, and the mean was calculated for each treatment.
- ✓ Number of grains per row (unit): a count of the number of grains per row was made, and the mean was calculated for each treatment.
- ✓ Weight of 100 grains (g): 100 seeds from each replicate were weighed, and the mean was calculated for each treatment, using an electronic balance.
- ✓ Yield ($t \cdot ha^{-1}$): The two interior rows of each replicate were harvested, subjected to natural drying and then weighed on an electronic balance.
- ✓ Natural drying was carried out, followed by weighing on an electronic balance.

The methodological design of the research was structured into phases that chronologically and systemically addressed the specific objectives of the study, employing the following research methods:

Observation: The biological and organic fertilization alternatives were assessed for their effect on crop growth and development. Subsequently, the effect of the biological and organic fertilization alternatives on yield and its components in maize cultivation, under the same conditions, was verified.

Variables recorded: Growth indicators were compared using a graduated ruler, measuring from the ground to the apical tip of the main stem. A count of the number of rows was also made and the mean was calculated for each treatment. Additionally, based on production, natural drying was carried out, followed by weighing on an electronic balance.

RESULTS AND DISCUSSION

Analysis of plant height results at 30 and 40 days after sowing for the different treatments evaluated

Table 1 shows that the greatest plant height at 30 and 40 days was achieved by treatment 4 (solid vermicompost with FitoMás), reaching 1.0 and 1.40 m at the two evaluated time points, not differing from treatment 1 but differing from the remaining treatments. These results are lower than those reported by Cubas, Córdova & Jara (2009), who state that maize plants reach 2.0 to 3.0 m. Except for some early cultivars that only reach 0.90 m, Socorro & Martín (1998) report heights of 2.80-2.85 m for dry period and 3.0 m for rainy period for different maize varieties and hybrids. Co-inoculation resulted in the greatest height, which could be attributed to its rapid effect on crop nutrition and nutrient concentration in tissues, according to findings reported by Torres & Francisco (1999).

#	Treatments	Height	
		30 days	40 days
1	Solid vermicompost with liquid vermicompost	0.96 a	1.36 a
2	Control	0.91 c	1.04 c
3	Fertilization with solid vermicompost	0.90 c	1.33 b
4	FitoMás plus solid vermicompost	1.0 a	1.40 a
5	FitoMás	0.93 b	1.34 b
	CV%	3.74	0.86
	ESX±	0.03	0.14

Table 1. Plant height for different treatments evaluated.

Means with uncommon letters in the same column differ according to Duncan's test (P<0.05).

Analysis of leaf number results at 30 and 40 days after sowing for the different treatments evaluated

Table 2 shows the number of leaves per plant at 30 and 40 days. When evaluating the number of leaves per plant, T-4 (Fito Más plus HLS) achieved the highest number at 30 days with 8.11 leaves, not differing from treatments 3 and 5 but differing from the others; at 40 days, it reached 8.8 leaves, differing from the rest, with a difference of 4 leaves compared to the control.

This demonstrates the influence of the combinations on the tendency to increase the total content of phosphorus (P) and potassium (K) per plant, as well as the total content of calcium (Ca), magnesium (Mg) and micronutrients (Mn, Zn, Cu, B, and Fe) in the fraction corresponding to the aboveground part of the plants (Rodelas et al., 1999).

#	Treatments	Number of leaves	
		30 days	40 days
1	Solid vermicompost with liquid vermicompost	5.12 b	7.86 d
2	Control	4.0 c	4.58 e
3	Fertilization with solid vermicompost	8.06 a	8.61 c
4	FitoMás plus solid vermicompost	8.11 a	9.03 a
5	FitoMás	8.08 a	8.70 b
	CV %	26.35	17.54
	ESX ±	1.65	1.40

Table 2. Number of leaves per plant for different treatments evaluated.

Means with uncommon letters in the same column differ according to Duncan's test ($P<0.05$).

Analysis of yield results for the treatments evaluated with the different fertilization alternatives

Table 3 shows the yield indicators. When evaluating the first indicator, number of rows, treatment 3 achieved the highest value with 14.48 rows, a difference of 12.23 rows compared to the control. The number of grains per row, as previously mentioned, is considered one of the most important yield components. Treatment 3, with 48 grains, exceeded the other treatments, with a difference of 32.73 grains compared to the control.

These values exceed the results obtained by Santiesteban (2009), who reported figures of 12 and 14 rows per corncob for all evaluated materials.

#	Treatments	Number of rows	Number of grains per row	Weight of 100 grains (g)	Yield (ha^{-1})
1	Solid vermicompost with liquid vermicompost	14, 40a	37,73b	38,40b	1,6b
2	Control	12,23d	32,73e	31,73e	0,5e
3	Fertilization with solid vermicompost	14,16b	34,23d	34,00d	1,2d
4	FitoMás plus solid vermicompost	14, 48a	48,00a	39, 8a	2, 0a
5	FitoMás	13,80c	36,58c	35,60c	1,4c
	CV %	6,65	7,86	8,52	34,22
	ESX ±	0,90	2,83	3,05	0,47

Table 3. Yield results for treatments evaluated.

Means with uncommon letters in the same column differ according to Duncan's test ($P<0.05$).

Economic analysis

The economic analysis is based on the alternative with its treatments studied under production conditions to obtain a more realistic assessment of the phenomenon and is based on the index proposed by the Food and Agriculture Organization of United Nations (FAO, 1995) for evaluating fertilizer application.

An assessment of T-4 (solid vermicompost + FitoMás), which showed the best results with 2.0 $t \cdot ha^{-1}$, led the author to consider it the most effective, with a production value of 303,908 CUP. When performing the economic assessment in national currency, treatments 1, 4, and 5 showed the highest profit as biological and organic fertilizers. Chemical fertilizers are difficult for the country to acquire due to their high prices.

The value-cost ratio was greater than two, considered a 100% benefit, although it is important to note the direct influence of the affordable prices of organic fertilizers and biostimulants. When evaluating the results of organic fertilization with vermicompost, treatment 1 (HLS + HLL) achieved a value-cost ratio greater than two, obtaining an increase in production of 0.5 $t \cdot ha^{-1}$ compared to the unfertilized control, representing an increase in productive value of 222,931 CUP relative to the control.

For this analysis, the experiment was used as a basis, applying the alternatives in the treatments and combinations to determine maize growth, development and yield, calculated according to the data obtained.

#	Treatments	Yield (t/ha^{-1})	Expenses (cup/ha^{-1})	Production value (cup/ha^{-1})	Net benefit (cup/ha^{-1})	Cost per peso (CUP/ha^{-1})
1	Solid vermicompost with liquid vermicompost	1,6	35500	243126	207626	0,15
2	Control	0,5	35000	75977	40977	0,46
3	Fertilization with solid vermicompost	1,2	35500	182344,8	146844,8	0,19
4	FitoMás plus solid vermicompost	2	40000	303908	263908	0,13
5	FitoMás	1,4	35300	212735,6	177435,6	0,17

Table 4. Economic assessment of the results obtained.

CONCLUSIONS

The results of the conducted experiment demonstrate that evaluation of biological and organic alternatives favors the growth and development of maize cultivation under the conditions of this research. Biological and organic alternatives have a direct effect on the yield and its components in maize cultivation under the same conditions. Treatment 4 (application of solid vermicompost + FitoMás) is the highest yield, with 2.0 $t \cdot ha^{-1}$, and may serve as an alternative in fertilizer scarcity.

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