Scientific Paper

Performance of morpho-physiological traits of *Sorghum bicolor* (L.) Moench cv. UDG-110, after the application of biological fertilization alternatives

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Abstract

Objective: To characterize the agronomic performance of *Sorghum bicolor* (L.) Moench cv. UDG-110 under field conditions with the application of biological fertilization.

Materials and Methods: Six treatments were evaluated: I-control without fertilizer, II-Agromenas G- 1,5 t/ha, III-earthworm humus – 4,0 t/ha, IV-Agromenas-G 1,5 t/ha + FitoMas-E® L/ha, V-earthworm humus 4,0 t/ha + FitoMas-E® L/ha, VI-absolute control with complete formula (140 kg). The productive indicators plant height, stem diameter, total biomass weight, panicle length and width were evaluated. Data were processed through a simple variance analysis for 5 % significance.

Results: There was no statistical inequality for the variable plant height among treatments III, V and VI, but they differed from the others, with values of 1,23, 1,24 and 1,23 m, respectively. The greatest length occurred with treatments III (18,4 cm) and VI (17,6 cm), which did not differ from each other. There were also no differences between VI and V. Similar performance occurred among treatments II, IV and I, the last one being the shortest (13,8 cm). When comparing the total biomass weight, the best result corresponded to VI. However, the treatments to which organic fertilizers were applied (II, III and IV) obtained values of 0,14 kg and exceeded the control without fertilization (0,12 kg).

Conclusions: Biological fertilization is a viable option for the production of *S. bicolor* cv. UDG-110. The most effective biological fertilization alternative was earthworm humus. It was followed by the combination of humus plus FitoMas-E®. In turn, yield indicators were not affected by the use of the biological fertilization alternatives.

Keywords: alternative agriculture, biomass, humus

Introduction

Currently, the world food production scenario poses the challenge of generating technological proposals that imply the promotion of sustainable agricultural models, with a considerable reduction of external inputs to reduce costs and increase economic benefits per unit of product, without deteriorating the environment, according to FAO reports (FAO, 1996). According to this organization, the grain deficit forecast for 2050 will be 450 million tons per year, making it necessary to create strategies to increase production with high yields. For such reason, in the 2030 Agenda, the United Nations System in Cuba proposes as sustainable development goals and targets to put an end to hunger, achieve food security and improve nutrition and promote sustainable agriculture. By the above-mentioned date, it is an unavoidable priority to ensure the sustainability of food production systems and implement resilient agricultural practices that increase productivity and production, contribute to the maintenance of ecosystems, strengthen the capacity to adapt to climate change and extreme weather events (droughts, floods and other disasters) and progressively improve soil and land quality.

Among the actions to protect agricultural ecosystems and prevent their degradation is the application of organic fertilizers. According to Demanet-Filippi and Canales-Cartes (2020), this activity is of significant importance, since organic matter and, particularly, humus, is the basic support for life in this environment; it can also define its productive potential. Biological fertilizers (earthworm humus, filter cake, chicken manure, among others), as well as natural minerals and residues (zeolite, dolomite, Agromena-G), contain useful elements for the improvement of the physical-chemical properties of soils and, consequently, of crops as natural products. These elements increase the availability of nutrients in the soil and generate

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substances that stimulate plant growth. This is translated into a more organic and sustainable agriculture, in addition to having a positive impact on the balance of microbial populations that inhabit the soil (Santamaría-Gómez *et al*., 2018).

There is also a need to sustainably increase cereal production as an alternative to contribute to food security and meet the ever-growing needs of the people. This has led farmers to seek to increase their production levels and obtain higher yields by using different species, varieties and fertilization alternatives. In this regard, *Sorghum bicolor* L. (sorghum) can be cited as the fifth most important cereal crop in the world, after *Triticum aestivum* L. (wheat), *Zea mays* L. (corn), *Oryza sativa* L. (rice) and *Hordeum vulgare* L. (barley), as reported by Santamaría-Gómez *et al*. (2018).

The *S. bicolor* plant adapts to a wide range of environments and produces grain under conditions unfavorable for most other cereals, which is why it has been called "the cereal of the 21st century." Because of its drought resistance, it is considered the most suitable crop for arid regions with erratic rainfall and has low susceptibility to disease. In the early days of its production, it was used primarily for human consumption. However, its consumption by animals has now doubled, as has its use in urban agriculture to prevent the incidence of potential pest insects (Pérez *et al*., 2010). *S. bicolor* produces high volumes of biomass with low levels of inputs, nutrients and water. It also has high nutritional potential under sustainable production conditions. This crop serves a dual purpose, with both grain and straw being ascribed high value. In many areas of the developing world, straw represents up to 50 % of the crop value, especially in drought years (Reyes-Moreno *et al*., 2017).

Although there are several research works on this crop, there are limited studies on biological fertilization alternatives in the integral technology of *S. bicolor* in Cuba. This constitutes a difficulty to achieve stable and sustainable yields. The objective of this work was to characterize the agronomic performance of *S. bicolor* cv. UDG-110 under field conditions, with the use of biological fertilization alternatives.

Materials and Methods

Location of the experimental area. The study was carried out at the Pastures and Forages Research Station Indio Hatuey (EEPFIH), located in the central zone of Matanzas province, in the Perico municipality, at 22º 48' and 7'' North latitude and 79º 32' and 2'' West longitude, at an altitude of 19,01 m.a.s.l. (Hernández-Venereo, 2000).

Soil. The soil is of flat topography, with a slope of 0,5 to 1,0 %, classified as leached Ferralitic Red (Hernández-Jiménez *et al*., 2015).

Treatment and experimental design. A randomized block experimental design was applied, with six treatments and four replicas each, for 24 plots in total. The treatments were: I) control without fertilizers, II) Agromenas-G-1,5 t/ha, III) earthworm humus – 4,0 t/ha, IV) Agromenas-G 1,5 t/ha + FitoMas-E® 1 L/ha, V) earthworm humus 4,0 t/ha + FitoMas-E® 1 L/ha, VI) absolute control with complete formula (9-13-17), 140 kg supplied at two moments (50 % on bottom of the furrow upon sowing and 50 % after 25 days).

Experimental procedure. Plots were marked in the field with stakes and strings, in correspondence with the randomized block scheme. Each plot was identified with signs showing the treatments used. To calculate the amount of fertilizer to be applied in each plot, the following formula was used:

$$Y = a \times b/c \times 100$$

where:

y = amount of fertilizer to be used in the area of the plot in kg.
a = nutrient dose kg/ha
b = plot area m^2
c = nutrient content in percentage (fertilizer carrier).

For the application of Agromenas-G, the same procedure was used. For the earthworm humus, the same formula was used. For foliar application of FitoMas-E®, Jacto backpacks were used, with a capacity of 16 L of water for its dissolution, at a rate of 1 L/ha. Fertilization was organized by treatment and replicated on different days, although the localized method at the bottom of the furrow was used in all of them.

The experiment was planted in strips or plots of ten furrows each, 7,50 m wide and 10 m long, for an area of 75 m² for each treatment, represented in 24 plots for a net experimental area of 0,18 ha and a gross area of 0,307 ha. Measurements were made in 10 subplots or replicas of 0,75 x 1,00 m, randomly distributed.

Evaluation of morpho-physiological traits. The productive indicators were evaluated following the criteria of Villamar-Alvarado (2014). Plant height (m) was measured in the field, from the base of the plant at ground level to its most apical part. Stem thickness (cm) was determined at the fifth node and total biomass in 0,75 m^2. The total number of plants was manually cut (40 sample plants per treatment) and weighed at the time of cutting (forage weight, kg). Similarly, panicle length and width (cm) were measured.

Statistical analysis. The results were subjected to variance analysis, according to a simple linear classification model. Means were compared using Duncan's test for 5 % significance, after verifying that they complied with the normal distribution and homogeneity of variance. The statistical program SPSS® version 22.0 for Microsoft® Windows® was used.

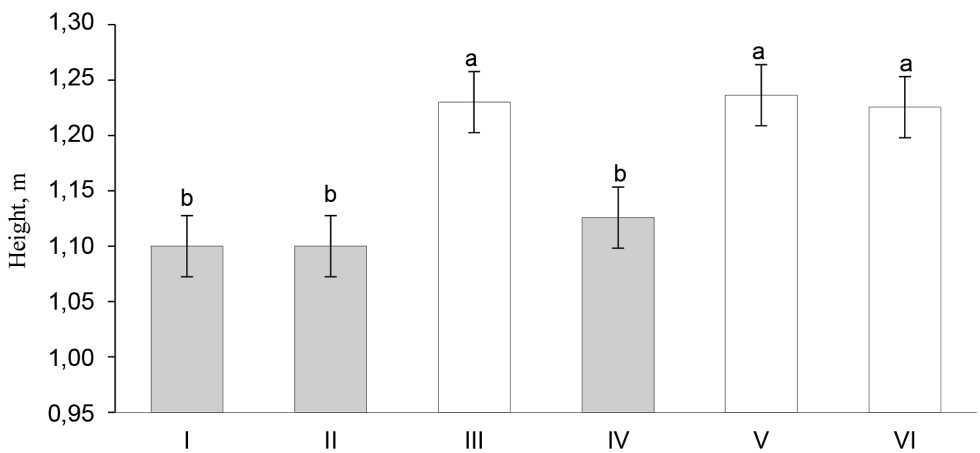
Results and Discussion

Figure 1 shows the performance of height as a function of the biological fertilization alternatives. There were no significant differences among treatments III, V and VI, which differed from the others with values of 1,23, 1,24 and 1,23 m, respectively. There were no significant differences either among treatments I, II and IV (1,10, 1,10 and 1,13 m, respectively).

According to Cardona-Fuentes (2018), height is a physiological characteristic of great importance in plant growth and development. It is determined by the stem elongation, by accumulating inside it the nutrients produced during photosynthesis, which in turn are transferred to the fruit during grain filling. It can be affected by the combined action of four fundamental factors: light, heat, humidity and nutrients. It is also a varietal and environmental characteristic, resulting from the number of nodes and the length of internodes. Height is influenced by the genetic character of the variety, soil type and agronomic management of the crop. Plant height increases when organic fertilizers are applied, which gradually supply assimilable compounds through reactions in which proteins and complex carbohydrates are degraded. This is not the case with fertilizers, which are easily-dissolved soluble substances, favoring rapid assimilation by the plant, but also to rapid washing by drainage water or volatilization (INIA, 2020).

The results with treatment III were similar to those reported by Plaza-Rodríguez (2015) and can be related to the composition of the product, fundamentally humic and fluvic acids. Of the latter, their effects and participation in the different physiological and biochemical processes that take place in plants are known, and they intervene positively in respiration and in the speed of enzymatic reactions of the Krebs cycle. This leads to higher ATP production and influences the selective effects on protein synthesis and increased activity of various enzymes (Madrigales-Reátiga, 2019).

For treatment V, the result is logical, and may correspond to the fact that the union of both products (humus and FitoMas-E®) benefits the performance of this indicator due to the constitution of both. FitoMas-E® is a biostimulant whose chemical composition contains plant growth promoting substances such as amino acids, proteins, peptides,



I-control (without fertilizer), II-Agromenas-G 1,5 t/ha, III- earthworm humus 4,0 t/ha, IV- Agromenas-G 1,5 t/ha + FitoMas-E® 1 L/ha, V- earthworm humus 4,0 t/ha + FitoMas-E® 1 L/ha, VI- absolute control with complete formula (9-13-17) 140 kg.

Figure 1. Height performance as a function of treatments.

carbohydrates and macroelements (NO_3, P_2O_5, K_2O). Plants manufacture the proteins they need and synthesize them from amino acids, which are produced, in turn, through a complex biochemical process that consumes a large amount of biochemical and biological energy (Madrigales-Reátiga, 2019).

Significant differences ($p < 0,05$) were found among treatments (figure 2). The one with the best performance was III, in which thick stems were found, despite the fact that its height under normal production conditions is lower than that of other varieties. It was followed by V and VI, with no differences between them. Reyes-Moreno *et al.* (2017) obtained similar results.

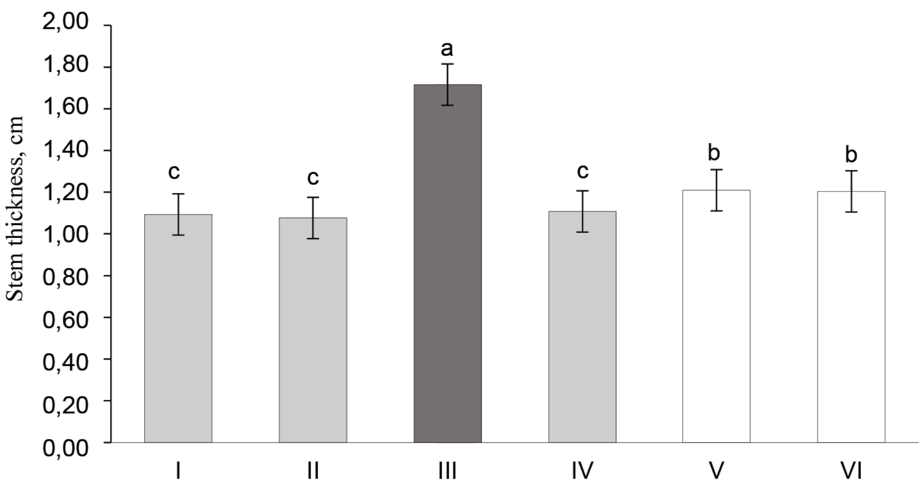
Reports by Chisi and Peterson (2018) refer that stem thickness is an indicator of great importance in *S. bicolor* plantations, as it influences stem bending when affected by strong winds. Similarly, they state that it depends on the variety, environmental and nutritional conditions of the soil. The resistance of the *S. bicolor* plant to bending depends, to a large extent, on the stem diameter, which tends to decrease when planting density increases, due to competition among plants. In this regard, Cardona-Fuentes (2018) points out that nitrogen application is one of the factors that influences plant diameter.

The results of the application of earthworm humus may be due to the high nitrogen content, since this element favors growth and stem diameter. Similarly, the stage of maturity of this fertilizer, in which there is higher availability and assimilation of nutrients by the plant, had an influence. This effect could also be related to the contribution of the humic substances of different metabolites, including potassium and other minerals involved in plant nutrition, which, when absorbed by the roots or leaves, guarantee their adequate development. In appropriate concentrations, these substances favor an increase in stem diameter.

When comparing the total biomass weight of the treatments, there were significant differences (figure 3) among them. The best result corresponded to treatment VI. However, the treatments to which organic fertilizers were applied (II, III and IV) obtained values of 0,14 kg and surpassed the control without fertilization (0,12 kg).

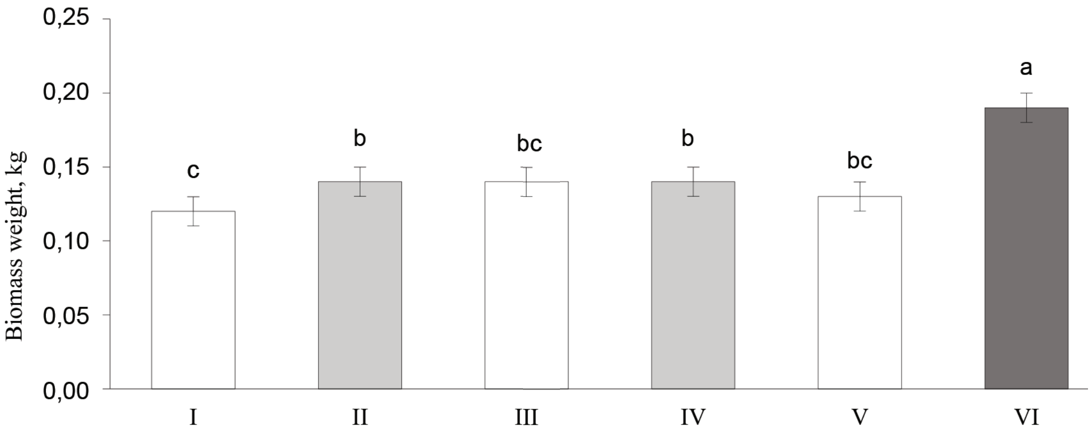
This performance can be categorized as acceptable, according to references by Taiz and Zeiger (2015), especially considering the nature of this cultivar, which is dual-purpose. Probably, the influencing factor was the rapid assimilation of chemical fertilizers by plants, since urea and ammonium fertilizers undergo rapid conversion in most arable soils. When urea or fertilizers containing urea are applied, it is normally hydrolyzed by the enzyme urease to ammonium carbonate. This is broken down to produce NH^3 and NH^{4+}, which are taken up directly by the crop (Taiz and Zeiger, 2015).

Nitrogen is an essential macronutrient for plant organisms and its availability affects plant growth and development. In natural and agricultural environments, this nutrient is found in low amounts. For such reasons, the production of vegetable crops with high yields is associated with the incorporation



I-control (without fertilizer), II-Agromenas-G 1,5 t/ha, III- earthworm humus 4,0 t/ha, I- Agromenas-G 1,5 t/ha + FitoMas-E® 1 L/ha, V- earthworm humus 4,0 t/ha + FitoMas-E® 1 L/ha, VI- absolute control with complete formula (9-13-17) 140 kg.

Figure 2. Stem thickness performance as a function of treatments.



I-control (without fertilizer), II-Agromenas-G 1,5 t/ha, III- earthworm humus 4,0 t/ha, I- Agromenas-G 1,5 t/ha + FitoMas-E® 1 L/ha, V- earthworm humus 4,0 t/ha + FitoMas-E® 1 L/ha, VI- absolute control with complete formula (9-13-17) 140 kg.

Figure 3. Performance of total biomass weight as a function of treatments.

of high concentrations of nitrogen fertilizers to the soil. However, according to references by Cuitiño *et al*. (2021), crops are only able to use 40-50 % of the applied nitrogen, which causes negative effects on the environment. The remaining nitrogen not used by plants is lost by different mechanisms, contaminating soils and water sources.

The physiological relevance of nitrogen for plants is clearly exemplified by its effects on leaf growth, senescence, root system architecture and flowering time, among other aspects. In addition to its effect on plant growth and developmental processes, plant nutritional status is an important factor in the resistance or susceptibility of various crops to certain pathogens. Different studies have proven that the availability of nitrogen in the plant affects the final outcome of the plant-pathogen interaction. However, the physiological mechanisms that explain this interaction are poorly understood and depend on the plant species and the pathogen under study. For these reasons, it is difficult to deduce general rules regarding the role of nitrogen and its effect on plant-pathogen interaction.

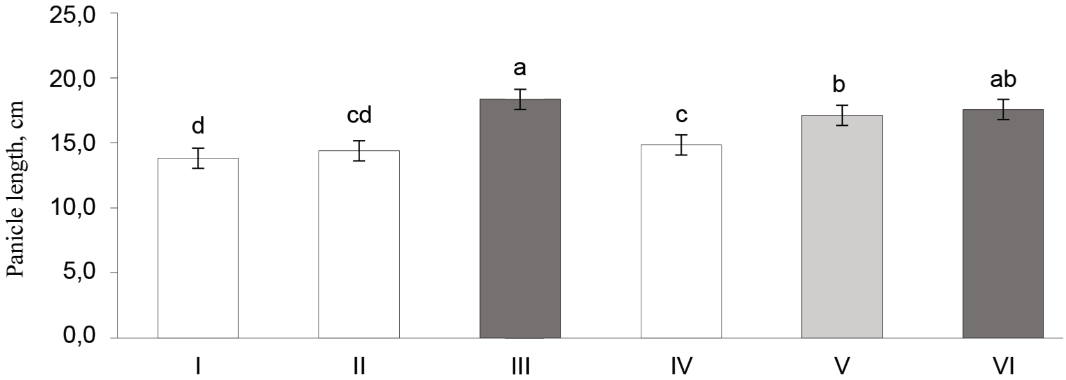
Regarding the performance of organic fertilizer treatments, it should be taken into account that when they are applied they have not had enough time to decompose and provide the necessary nutrients to the crop. It can be considered that the P, K, secondary elements and trace elements contained in these residues are in forms that are directly assimilable for the crop or that will be converted in a reasonably short time (Salas-López *et al*., 2018). In contrast, the N situation is much more complex, as it is linked to the evolution of the organic matter in the residue which, once in the soil, undergoes two parallel processes: mineralization and humification.

Figure 4 shows the performance of panicle length, a descriptor of the phenological phase of flowering, as a function of the treatments. There were significant differences among them. The greatest length occurred with III (18,4 cm) and VI (17,6 cm), which did not differ from each other, and there were no differences either between VI and V. Similar performance occurred among treatments II, IV and I. The last one had the shortest length (13,8 cm).

The highest values of panicle length were obtained in treatments III (18,4 cm) with earthworm humus and VI (17,6 cm), which was the absolute control with fertilizers. However, none of the treatments reached the development according to what was described by Reyes-Moreno *et al*. (2017).

Cardona-Fuentes (2018) reported similar results when evaluating the performance of four sweet *S. bicolor* hybrids for biomass and fermentable sugars production for biofuels. It could be inferred that this was closely related to the edaphoclimatic conditions of the experimental area and the minimum agricultural management that occurred during the crop cycle.

The results in which organic fertilizers showed equality or superiority in the performance of the evaluated variable may be due to the fact that according to Venkateswaran *et al*. (2019) and Lus (2020), they provide a system in which nutrients are recycled and improve the organic matter content and physical properties of the soil, especially porosity, with a corresponding reduction in bulk density and



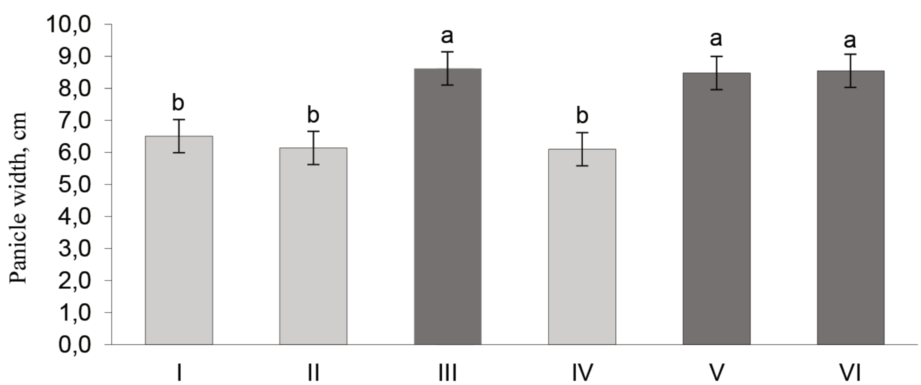
I-control (no fertilizer), II-Agromenas-G 1,5 t/ha, III- earthworm humus 4,0 t/ha, I- Agromenas-G 1,5 t/ha + FitoMas-E® 1 L/ha, V- earthworm humus 4,0 t/ha + FitoMas-E® 1 L/ha, VI-absolute control with complete formula (9-13-17) 140 kg.

Figure 4. Performance of panicle length as a function of treatments.

increase in the amount of available nutrients. They also improve catatonic exchange and, in addition to containing N, P and K, provide other minor elements important for good plant growth.

Likewise, organic fertilizers are considered slow-release fertilizers, whose action is prolonged in time, which contributes to improve the quality of the environment and crop production. These data show that humus has an acceptable availability of nutrients, which are easily assimilated by the plant. It can be used on all crops and at any stage because the release of nutrients is adapted to the needs of plants. In hot weather, plants grow more and also the transformation of organic matter is faster, in addition to delivering nutrients in sufficient quantity to the crop roots. Similar results were obtained by Montossi *et al*. (2020), which supports the obtained response, due to the fact that high temperatures prevailed in the area where the study was conducted. This facilitated the transformation of organic matter. Likewise, it can be said that there is a direct relationship between the amount of added organic fertilizer and the total biomass production of the plants. Thus, an important part of the inorganic nitrogen can be substituted by organic nitrogen from the fertilizer, without affecting the total sugar content of the plants (in fact, increasing it). Another element that could influence the performance of panicle length is the dependence on environmental (mainly temperature) and nutritional factors in which the crop develops, as well as the influence of the photoperiod.

The performance of panicle width showed significant differences (figure 5). The best values were achieved with treatments III, V and IV. The results



I-control (without fertilizer), II-Agromenas-G 1,5 t/ha, III- earthworm humus 4,0 t/ha, I- Agromenas-G 1,5 t/ha + FitoMas-E® 1 L/ha, V- earthworm humus 4,0 t/ha + FitoMas-E® 1 L/ha, VI- absolute control with complete formula (9-13-17) 140 kg.

Figure 5. Performance of panicle width as a function of the treatments

coincide with those reported by Pérez *et al.* (2010), who stated that the optimum range of this indicator for cv. UDG-110 varies between 6 and 10 cm, which is evident in almost all treatments, except in treatment I (control without fertilizers).

It is worth mentioning that the indicator panicle width is inversely proportional to panicle length. Therefore, it is inferred that the expression of this result may be due to the influence of environmental and nutritional factors on this indicator. In this regard, Cuizara-Felipe *et al.* (2021) expressed that soil fertility, temperature, luminosity, plant age and seasons influence the expression of this type of morphological descriptor.

The performance of treatment V may be due to the combined action of earthworm humus plus FitoMas-E®. It is known that the use of plant biostimulants stimulates plant emergence and growth because they are composed of natural substances, such as carbohydrates, low molecular weight peptides and amino acids, which activate the physiological functions of plants, so their application allows a better utilization of nutrients. According to reports by Pérez *et al.* (2010), it represents an option to face problems of abiotic stress, soil salinization, drought and humidity excess. Likewise, it enhances the action of herbicides and other pesticides, thus reducing doses, accelerating the composting process and the degradation of crop residues, and increasing yields.

The performance related to treatment VI is logical, because chemical fertilizers tend to propitiate the best results in crops.

Conclusions

Biological fertilization is a viable option for the production of *S. bicolor* cv. UDG-110. The most effective biological fertilization alternative was earthworm humus, followed by the combination of humus plus FitoMas-E®. Yield indicators were not affected by the use of the biological fertilization alternatives.

Acknowledgments

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Conflict of interest

The authors declare that there is no conflict of interest among them.

Authors' contributions

- Irma Cáceres-Amores. Experiment set-up, data collection and processing, manuscript writing and editing.
- Hilda Beatriz Wencomo-Cárdenas. Research advisory, development of the design and set-up of the experiment, data processing and interpretation.
- Orlando M. Saucedo-Castillo. Genesis of the research idea, collection, interpretation of data and analysis of the results, manuscript preparation and revision.
- Doris Torriente-Díaz. Data collection and processing.
- Yolanda Dora Cáceres-Amores. Data collection, processing and interpretation.

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