

Response of *Abelmoschus esculentus* L. and *Vigna unguiculata* L. to Vermicompost Leachate Applications



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Respuesta de (*Abelmoschus esculentus* L.) y (*Vigna unguiculata* L.) tratados con Lixiviados de vermicompost

✉ Eneida E. Vilches-León^{1*}, ✉ Alianna Machín-Suárez¹, ✉ Lizandra Guerra-Arzuaga^{II},
✉ Allison Valdés-Castillo^{III}, ✉ Elena Hernández-García^I

¹Universidad Agraria de La Habana “Fructuoso Rodríguez Pérez”, San José de las Lajas, Mayabeque, Cuba.

^{II}Centro Nacional de Sanidad Agropecuaria (CENSA). San José de las Lajas. Mayabeque, Cuba.

^{III}Hostal Guasimas, Cardenas, Matanzas, Cuba.

ABSTRACT: Okra (*Abelmoschus esculentus* L.) and string bean (*Vigna unguiculata* L.) are vegetables that provide important nutrients in the human diet. The use of vermicompost leachates could be nutritional alternatives for these crops, which allow reducing the dependence on chemical fertilizers and the impact on the environment. The objective of the work was to evaluate the response of both vegetables to dilutions 1/10 and 1/20 (v:v) of bovine manure leachate mixed with leucaena or moringa, giving rise to four treatments and one control, replicated three times and distributed according to completely randomized design. The treatments were bovine-leucaena leachate (LBL 1/10 and 1/20), bovine-moringa leachate (LBM 1/10 and 1/20) and the control (without application). The first application of the product was by imbibition of the seeds of both crops for 30' and foliar spraying every 15 days. Some growth and yield indicators were evaluated in both crops. The results indicate that the application of LBL 1/10 showed increases in all the variables evaluated in okra, reaching a yield of 44.7 t ha⁻¹ while in string bean, the LBM 1/20 offers better results for all the variables studied, with a yield of 32.4 t ha⁻¹.

Keywords: okra, string bean, leachates, physiological and productive indicators.

RESUMEN: El quimbombó *Abelmoschus esculentus* L. y la habichuela *Vigna unguiculata* L., son hortalizas que aportan nutrientes importantes en la dieta humana. La utilización de lixiviados de vermicompost pudieran ser alternativas nutricionales para estos cultivos, que permiten disminuir la dependencia de fertilizantes químicos y la afectación al ambiente. El objetivo del trabajo fue evaluar la respuesta de ambas hortalizas a las diluciones 1/10 y 1/20 (v:v) de los lixiviados bovino mezclado con *Leucaena leucocephala* L. o *Moringa oleifera* L., dando origen a cuatro tratamientos y un control, replicados tres veces y distribuidos según diseño completamente aleatorizado. Los tratamientos fueron: lixiviados bovinos leucaena (LBL 1/10 y 1/20), lixiviados bovinos moringa (LBM 1/10 y 1/20) y el control (sin aplicación). La primera aplicación fue por imbibición de las semillas durante 30' en ambos cultivos, el resto por aspersión foliar cada 15 días. Se evaluaron algunos indicadores del crecimiento y el rendimiento en ambos cultivos. Los resultados muestran que la aplicación de LBL 1/10 mostró incrementos en todas las variables evaluadas en el Quimbombó, alcanzando un rendimiento de 44,7 t ha⁻¹ mientras que en la habichuela el LBM 1/20 obtuvo mejores resultados para todas las variables estudiadas, con un rendimiento de 32,4 t ha⁻¹.

Palabras clave: quimbombó, habichuela, lixiviados, indicadores fisiológicos y productivos.

*Author for correspondence: MSc. Eneida E. Vilches León, e-mail: eneida@unah.edu.cu

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INTRODUCTION

The importance of increasing the planting of various crops is what allows satisfying the growing demand of the different territories in Cuba. That is why the production of vegetables has become in recent years a way to improve the diet of inhabitants of urban and rural areas (Abad *et al.*, 2017). Its consumption by man achieves the necessary elements for a balanced nutrition (Moñino *et al.*, 2016).

Okra (*Abelmoschus esculentus* L.) is a long-cycle summer crop, its plants are vigorous, the fruits are not affected at harvest time and it has a high productive potential (Alfonso, 2014). Lately, it is highly demanded by the population. The cultivar Santa Cruz 47, used in this work, has fruits of good quality and palatability (Madariaga *et al.*, 2015).

String bean (*Vigna unguiculata* L.) is a herbaceous legume of high nutritional value, it has a high content of protein, calcium (Ca), vitamin D and a large part of the essential amino acids (Durán-Arrieta, 2017). In Cuba, it is in wide demand. It is mainly produced intensively in urban agriculture orchards (ACTAF-Cuba, 2015).

Studies carried out by Izquierdo *et al.* (2014), argue the improper use of chemical fertilizers and pesticides in order to maintain high yields of these vegetables, with high levels of production, which in turn, over time, have caused the deterioration of soil and food properties. For this reason, it is important to search for sustainable alternatives that, in addition to supplying the nutritional requirements of the plants, improve the yields and quality of the agricultural product (Miranda *et al.*, 2020). An alternative could be the use of vermicompost leachates for partly eliminating the dependence on chemical fertilizers and reducing costs. The objective of this work was to evaluate the response on the growth and productive development of the okra (*Abelmoschus esculentus* L. cv. Santa Cruz 47) and of string bean (*Vigna unguiculata* L) (Canton - 1) to the application of bovine manure leachates combined with leucaena or moringa in dilutions 1/10 and 1/20 (v:v).

These liquid products are rich in humic substances, mineral elements, hormonal compounds and abundant microorganisms. The foliar application of this liquid increases germination, growth, flowering, fruit set and resistance to pathogens of a large number of plant species (Rodríguez-Nodals, 2014).

MATERIALS AND METHODS

The investigation was carried out in a farm belonging to the CCS "Julito Díaz" in the town of Mantilla, Arroyo Naranjo Municipality in Havana-City. The crops studied were established on a fluffy Sialitic Brown soil of carbonate type with a slope of 1% (Hernández-Jiménez *et al.*, 2019). Samples were taken using the British Flag method and analyzed in

the Chemical Analysis Laboratory of the National Institute of Agricultural Sciences (INCA). The determinations were: exchangeable Na⁺, assimilable phosphorus (P₂O₅), exchangeable K⁺, exchangeable Ca²⁺, exchangeable Mg²⁺, organic matter (OM) and pH by the Paneque method (2010), Ca²⁺ and Mg²⁺ (Maslova method modified by Peech), Na²⁺ and K⁺ (Flame Photometry Method), P₂O₅ (Oniani Method), M.O (Walkley Black Method) and pH (Potentiometric Method). Soil preparation was carried out by minimal tillage, harrowing to a depth of 15 cm and furrowing with animal traction. The cultural attentions were carried out according to what is established in the Agricultural Branch Norms for the production of vegetables.

The leachates used were obtained in the Plant Protection Laboratory of the Faculty of Agronomy. Their composition was bovine excreta mixed independently with dry leaves of *Leucaena leucocephala* L. (LBL) or *Moringa oleifera* L. (LBM), consumed during the diet of earthworms of the genus *Eisenia*. Both products were sent to the University's Chemistry Laboratory for further analysis, the rest were diluted by 1/10 and 1/20 (V:V) as they were applied to the leaves.

The seeds of both crops were embedded in the diluted leachates for 30 min, then they were dried and direct and manual sowing was carried out on furrows 60 m long, according to the technical instructions for both crops. The okra cultivar Santa Cruz 47 was planted in alternate rows using a planting framework of 1.20 x 0.30 m with four seeds per nest, occupying an experimental area of 360 m², for 270 plants, of which 45 were sampled per treatment (15 per replica) of the center of the furrows avoiding the edge effect.

For the sowing of the string bean *V. unguiculata* cv: Canton-1, four seeds were deposited per nest with a planting frame of 0.60 x 0.25 m whose experimental area was 144 m² and a total of 540 plants. Each of the three replicates used had five furrows 20 meters long, separated by one meter, in each one four treatments and one control were distributed (Table. 1) using a completely randomized design. In each row, 60 plants from the center were selected for measurements. The leachates were applied foliarly during the vegetative cycle until the beginning of flowering in both crops.

After germination, three weekly irrigations were carried out with sprinklers for 40 minutes, after 15 days it decreased to two weekly irrigations until the end of April, when a rainy season began.

Given the existing climatic conditions and the long cycle of okra, only five moments of its development were taken into account for the application of the treatments.

- Prior to sowing (by imbibition of the seeds for 30min in the respective treatments).
- In the vegetative stage of the crop (at 15, 35 and 50 days after planting).

- Prior to the formation of the first fruit (at 64 days)

Physiological indicators in vegetative growth were evaluated from 15 days after sowing to 73 days, at the beginning of the productive stage.

The evaluated indicators were: plant height and number of leaves.

The productive indicators were evaluated with a frequency of 10 days among which are: number of fruits/plants, average mass of the fruits/plant in (g) and yield in ($t\ ha^{-1}$) from 74, 84 and 94 days, taking these three moments into account for the statistical analysis described.

The morpho-agronomic indicators taken into account in the growth stage of the bean were: height of the plant and number of leaves and in the reproductive phase the following indicators were determined: number of flowers/plant, number of legumes/plant, length of legumes (cm), mass of legumes (g) and yield ($t\ ha^{-1}$)

The data were processed by means of a simple classification variance analysis, comparing the means through the Tukey test with a significance level of 5%. The statistical program used was Statgraphics version PLUS 5.2.

RESULTS AND DISCUSSION

As it can be seen in [Table 2](#), the chemical analysis of the soil for both experiments showed it was poor in nutrients with low fertility, perhaps due to the slope of the land and the rainy season.

[Table 3](#) shows the results of electrical conductivity, total dissolved solids, % salinity and organic carbon of the two leachates.

The results show that the leachate of bovine manure with moringa (BM) presents slightly higher values in

almost all the parameters evaluated compared to that of bovine manure with leucaena (BL). This is due to the fact that cattle during the digestion process absorb a high content of nutrients whose proportion of these is not high in the manure, however, the addition of moringa leaves provides an increase in the content of other mineral elements given the properties of this plant. According to Witt (2020), the dried leaves seem to have a significant amount of magnesium, iron, folate, and vitamins B-6, A, C and E. They are also a moderately good source of calcium, niacin, protein and dietary fiber.

The electrical conductivity results indicate that the application of these leachates does not result in excessive salt content incorporated into the soil or on the plant and the risk of phytotoxicity problems is minimal. These liquid bioproducts are rich in humic substances, stimulating different physiological-biochemical processes of the plant, producing indirect effects on the global system (soil-plant), mineral elements for its nutrition, hormonal compounds and abundant microorganisms in the microbial activity of the soil, its humidity and texture. These results coincide with those reported by [Moreno-Reyes et al. \(2019\)](#). The foliar application of these liquids is capable of increasing germination, growth, flowering, fruit set and resistance to pathogens of a large number of plant species ([Rodríguez-Nodals, 2014](#)).

Physiological Indicators during Vegetative Growth in Okra and String Beans

[Table 4](#). Shows the statistical results of the effect of LBM and LBL at dilutions of 1/10 and 1/20 (v:v) on the vegetative growth indicators of *Abelmoschus esculentus* L. cuv. Santa Cruz 47 and

TABLE 1. Bioproducts used foliarly during the experimental trial on okra and string beans

TREATMENTS	DILUTION	BIOPRODUCTS
(LBM)	1/10	Bovine-Moringa Leachate (V:V)
(LBM)	1/20	Bovine-Moringa Leachate (V:V)
(LBL)	1/10	Bovine-Leucaena leachate (V:V)
(LBL)	1/20	Bovine-Leucaena leachate (V:V)
CONTROL	(just water)	no application

TABLE 2. Chemical analysis of the soil

Cmol kg ⁻¹		Mg 100g ⁻¹		%		
Na ²⁺	K ⁺	Ca ²⁺	Mg ²⁺	P ₂ O ₅	MO	pH
0.35	0.36	11,8	10.5	31,2	3.36	7.5
Very low	Middle	Low	High	High	Middle	Slightly alkaline

TABLE 3. Chemical analysis of the leachates

Leachates	pH	Electrical Conductivity (mS cm ⁻¹)	STD (g L ⁻¹)	Salinity (%)	Organic C (%)
BM	8.8	7.54	4.31	0.40	0.40
BL	8.19	7.02	4.00	0.37	0.37

TABLE 4. Effect of bovine leachates with *L. leucocephala* or *M. oleifera* at dilutions 1/10 and 1/20 (v:v) during the vegetative growth of okra and string beans

Leachate	Okra		Bean	
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves
LBM 1/10	112,89 bc	14,16 ab	25,67 cd	10,9
LBM 1/20	132,70 b	14,26 ab	34,67 a	15,9
LBL 1/10	159,09 a	18,43 a	28,06 bc	13,2
LBL 1/20	116,71 bc	14,33 ab	30,33 b	12,7
CONTROL	96,00 c	11,93 b	23,83 d	10,3
	ESx=6,02	ESx= 0,08	ESx= 0,78	ESx= 0,073
	C.V. 18,08%	C.V. 8,97%	C.V.15,07%	C.V. 11,4%
				NS

Vigna unguiculata L. cuv. Canton-1. It can be seen that in the height of the plants there are significant differences between the treatments in favor of the bovine-leucaena LBL 1/10 surpassing the rest of the treatments, in the number of leaves said treatment only differs from the control

The string bean showed significant differences between BM 1/20 and the rest of the treatments, where the plants reached an average height of 34.67 cm. It is important to highlight that this physiological indicator of growth was favored by the more diluted moringa treatment, in addition to a slight trend in favor of the number of leaves.

The result of both crops regarding the number of leaves could be given because the bioproducts used were capable of causing an adequate endogenous hormonal balance to induce an increase in the cell division process of the buds that originate the leaves (Nápoles *et al.*, 2016).

Researchers such as Morales-Guevara *et al.* (2016), suggest that a greater number of leaves represents a higher leaf surface and therefore, a possible high photosynthetic capacity, which could translate into greater accumulated dry matter and perhaps an increase in yield.

According to authors such as Hernández-del Valle *et al.* (2012), these liquid products contain growth regulators such as auxins, gibberellins and cytokines, low-molecular mass proteins and humic substances that reinforce the biochemical and physiological activity in these plants.

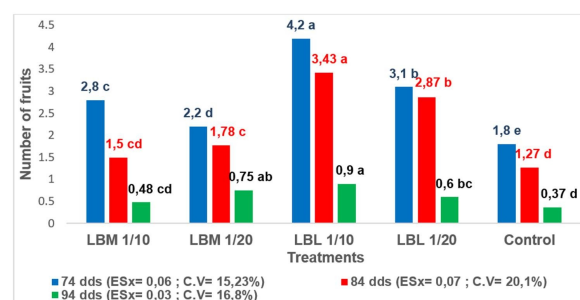
Similar results were reported by Moreno-Reséndez *et al.* (2014) in chili (*Capsicum annuum* L.). Similarly, Ramírez *et al.* (2015) and Moreno-Reyes *et al.* (2019) stated that the use of some concentrations of vermicompost leachates based on bovine manure and vegetable residues induce a greater height of plants in ornamental species. Nevertheless, they differ from those found by Alcivar-Llivicura *et al.* (2021) since in the case of the present experiment, there was a response at 45 days for string bean and at 75 days for okra.

These results in the height of the plants and the number of leaves corroborate what was stated by

Liriano-González *et al.* (2017) related to the use of optimal doses of biostimulants in general, since when applied in the necessary quantity, it promotes the soil-plant exchange of useful substances, thereby increasing the autochthonous, symbiotic and associated microbial population, in the rhizosphere zone and facilitates the natural production of hormones and other essential substances for growth. This shows that the plants in this first stage are in a better physiological state to make efficient use of these treatments.

Productive Indicators of Performance in Okra and String Beans

Figure 1. Effect of bovine leachates with *L. cocephala* or *M. oleifera* at dilutions 1/10 and 1/20 (v:v) on the number of *Abelmoschus esculentus* L. cur fruits. Santa Cruz 47 at (74, 84 and 94 days).



Means with different letters differ significantly according to Tukey (P<0.05).

Figure 1. shows the effect of these leachates on the number of fruits per plant evaluated in okra every 10 days at 74, 84 and 94 days.

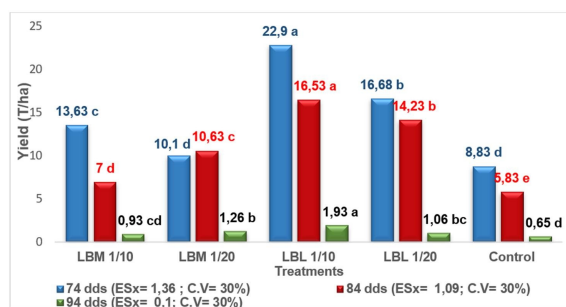
The treatment with the best result was LBL 1/10, which differs from the rest at 74 and 84 days, but not at 94 days where LBL 1/10 does not differ from LBM 1/20, but does from the rest. In this stage, the fruits decreased considerably, perhaps not only because of the phenology of the crop whose production cycle is between 70 and 100 days, but also because the weather conditions during that period were not the best given the continuous rainfall.

By presenting a greater height and number of leaves, the plants under the LBL 1/10 treatment found better physiological conditions so that the leaves could assimilate, process and transform more effectively, solar radiation together with the help of other substances provided by the leachate. That induced a greater number of flowers transformed into fruits. These results agree with what was stated by [Pérez-Velasco \(2015\)](#) in the cultivation of beans and [Moreno-Reséndez et al. \(2014\)](#) in the cultivation of chili. However, they differ from [Montaño-Mata et al. \(2009\)](#) in three varieties of eggplant and [Rodríguez-Dimas et al. \(2009\)](#) in tomato crop, which did not observe significant differences in terms of the number of fruits using compost and worm humus leachates in these crops.

Regarding the mass of the fruits per plant, [Table 5](#) reflects the results of the statistical analysis where significant differences are shown between the treatments for all the moments evaluated. These results correspond to the previous ones where the plants treated with LBL 1/10 achieved better results than the rest of the treatments.

The positive effect of this 1/10 LBL leachate on this yield component is associated with the effect on crop growth, which suggests that the plants that received this treatment could be in a better condition to synthesize, accumulate and translocate larger amounts of photoassimilates from leaves to consumption sites. In line with this approach, it could be that the leachate, at this concentration, acts on the nutrients in the reserve zone, mobilizing them to the zones of greatest metabolic activity, essential for the formation and multiplication of new plant cells, as has been verified in the FitoMas-E ([Montano, 2008](#)). However, these results differ from those found by [Díaz-Franco y Ortegón \(1999\)](#) in the cultivation of *A. esculentus*, stating that its leaves are not adapted to absorb a large amount of nutrients, particularly N, P and K, for which reason the foliar fertilization does not provide increases in okra yield.

[Figure 2](#) shows the effect of leachates on okra yield at the three moments studied, it is observed that with the application of these bioproducts at different



Means with different letters differ significantly according to Tukey (P<0.05).

FIGURE 2. Effect of bovine leachates with *L. leucocephala* or *M. oleifera* at dilutions 1/10 and 1/20 (V:V) on okra yield at 74, 84 and 94 days.

dilutions, higher yields than the control were achieved, highlighting the treatment with leucaena at the highest dilution. LBL 1/10 in the three moments evaluated, which differs significantly from the rest of the treatments.

These results are similar to those found by [Liriano-González et al. \(2017\)](#), since the combination of forms of application such as seed treatment and foliar application of these leachates with a minimum dose increases the yield of the crops under study, however, they differ from those obtained by [Terry-Alfonso et al. \(2017\)](#) who obtained better results with high doses of bioproducts.

[Table 6](#) reflects the effect of the application of leachates on the number of flowers, number of legumes, length and mass of these in the string bean. Bovine-moringa leachate stands out at the lowest BM 1/20 dilution, whose response corresponds to the growth indicators ([Table 4](#)). The use of these organic products in all the indicators exceeded the control, with some significant differences to the rest of the treatments.

These results coincide in some way with those reported by [Baldaquín-Hernández and Labrada-Rodríguez \(2018\)](#), who evaluated the effect of the foliar biostimulants Enerplant and liquid worm humus on string bean, reporting an increase in these indicators.

TABLE 5. Effect of bovine leachates with *L. leucocephala* or *M. oleifera* on the mass of *Abelmoschus esculentus* L. cuv. Santa Cruz 47 at 74, 84 and 94 days

Treatments	Fruit mass (g)		
	74 days	84 days	94 days
LBM 1/10	102,67 c	67 d	36,66 b
LBM 1/20	97 d	81 c	39,66 b
LBL 1/10	134,67 a	111,83 a	45,33 a
LBL 1/20	113,67 b	102 b	40,66 ab
Control	79,67 c	51 e	29,33 c
C.V	17,95 %	27%	14,9 %
Esx	4,89	5,9	1,4

Means with different letters differ significantly according to Tukey (P<0.05)

TABLE 6. Effect of the Leachates with *L. leucocephala* or *M. oleifera* at dilutions 1/10 and 1/20 (v:v) during the productive behavior of the bean *V. unguiculata* L. cur. Canton-1

Treatments	No. of flowers	No. of legumes	Legume Length (cm)	Legume mass (g)	Yield in t/ha-1
LBL 1/20	25,3 ab	24,6 ab	31,08 ab	196,83 ab	23,03 b
LBL 1/10	22,0 abc	21,6 abc	27,76 bc	151,00 b	16,98 c
LBM 1/20	29,16 a	28,83 a	32,42 a	253,50 a	32,4 a
LBM 1/10	19,33 bc	19,0 bc	26,92 c	141,00 b	16,55 c
Control	16,16 c	16,0 c	26,25 c	124,67 b	12,30 c
C.V	14,86%	14,94%	11,20%	37,50%	28%
Esx	0,13	0,12	0,59	11,80	0,9

[Pedroso \(2017\)](#) suggests that a greater number of flowers could represent obtaining a greater number of fruits, which has an impact on obtaining higher yields. In the number of legumes, the effect of the LBM 1/20 leachate stands out from the rest of the treatments, exceeding the control by 40%.

The positive effect of other biological stimulators on the number of fruits per plant has been verified. [Nápoles et al. \(2016\)](#) in this same crop but in Lina variety, using Pectimorf®, also reached higher values in this parameter. These authors observed that the application of the biostimulant in two moments, one at the seed and the other before flowering, induced the plants to increase the number of legumes. According to [Rodríguez-Fernández \(2017\)](#), the biostimulatory actions are of the phytohormonal type, providing physiologically active substances, with an effect not only on this variable, but also on different productive components.

In the variable length of the legumes, again, the plants that were under the most diluted treatments stand out significantly, which shows that the plants treated with BM 1/20 not only presented a greater number of legumes in relation to the rest, but also they reached greater length and mass, surpassing the rest of the treatments except the LBL 1/20. These evaluated results correspond to what was indicated by authors such as [Boudet et al. \(2015\)](#) and [Rodríguez-Fernández \(2017\)](#), who state that the use of biological products, such as worm humus leaching, increases the mass of different yield components due to the production of photosynthates. If the legumes had been hydrated due to the environmental conditions of high humidity, this did not prevent some treatments from being highlighted and the potential of the products used were made known.

Regarding yield, the results ranged between 12 and 33 t ha⁻¹, as it can be seen in [Table 6](#). The highest productions were obtained under the LBM 1/20 treatment with an average yield of 32.4 t ha⁻¹, exceeding by a 62% to the control, also surpassed by 28% those reported by [Mederos \(2015\)](#), in the same crop and variety. That author states that these range between 25 to 30 tha⁻¹ and as a reference value he establishes 23.3 t ha⁻¹.

This result confirms that the use of these organic products at the lowest dilution allows this crop to reach potential yields, and even exceed them. Similar results were reached by [Méndez et al. \(2011\)](#) and [Rivera et al. \(2015\)](#) who observed that foliar spraying at a lower dose of bioproducts such as FitoMas-E, Biobras-16® or QuitoMax® significantly stimulates yield in the bean crop. On the other hand, [Rodríguez-Fernández \(2017b\)](#) found in his experiment that worm humus leachate greatly impacted the growth and productivity of the string bean crop (*Vigna unguiculata* L.)

[Sathiyabama et al. \(2014\)](#) points out that the application of biostimulants enhances the auxins that intervene in the plant reproduction process, producing a synergism between the applied substances and the natural hormones of the plants. That suggests that a similar behavior occurs when this product is applied to the cultivation of okra and string beans, managing to stimulate from growth to yield. Promoting an improving effect on the physiological conditions of both crops that, according to [Hernández-del Valle et al. \(2012\)](#), allows a greater mobilization of reserves to the reproductive organs and that, according to the criteria of [López \(1994\)](#), allow the formation of seeds, flowers and fruits, as well as the increase in their mass.

CONCLUSIONS

The best results in vegetative growth for okra were obtained with the vermicompost leachate product of the combination of bovine excreta with the leaves of *Leucaena leucocephala* L. at the highest dilution (LBL 1/10). The plants reached a greater height (159.09 cm and an average number of leaves of 18), favoring the productive behavior of the crop with higher yields than the rest of the treatments of 44.7 t ha⁻¹, due to the greater number and weight of the fruits.

In string beans, the results were favored by the leachate obtained from the combination of bovine excreta with *Moringa oleifera* L. leaves at the lowest BM 1/20 dilution. It exceeds the height of the plants, number of leaves, length and mass of the legumes compared to the control, which had an impact in favor

of the yield (32.4 t ha⁻¹) superior to the rest of the treatments. This research indicates that the application of these vermicompost leachates is effective as a sustainable alternative, they are low cost, healthy products and acceptable yields are obtained, with minimal impact on the environment.

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Eneida E. Vilches-León, Profesora Universidad Agraria de La Habana “Fructuoso Rodríguez Pérez”, Carretera Tapaste y Autopista Nacional km 23 ½, San José de las Lajas, Mayabeque, Cuba. CP:32700, Apartado Postal: 18-19., e-mail eneida@unah.edu.cu.

Alianna Machín-Suárez, Profesora, Universidad Agraria de La Habana “Fructuoso Rodríguez Pérez”, Carretera Tapaste y Autopista Nacional km 23 ½, San José de las Lajas, Mayabeque, Cuba. CP:32700, Apartado Postal: 18-19., e-mail: alianne_machin@unah.edu.cu.

Lizandra Guerra-Arzuaga, Dirección de Sanidad Vegetal. Centro Nacional de Sanidad Agropecuaria (CENSA). Apartado 10, CP. 32700. San José de las Lajas. Mayabeque, Cuba. e-mail lizguerra@censa.edu.cu.

Allison Valdés-Castillo, Ingeniero Agronomo. Empleado domestico del Hostal situado en la Avenida segunda # 2 A. Guasimas. Cardenas. Matanzas. Cuba. e-mail: allison.valdes95@gmail.com.

Elena Hernández-García, Profesora Universidad Agraria de la Habana “Fructuoso Rodríguez Perez”, Carretera Tapaste y Autopista Nacional km 23 ½, San Jose de las Lajas. Mayabeque, Cuba. CP:32700, Apartado Postal: 18-19., e-mail: elenah@nauta.cu.

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AUTHOR CONTRIBUTIONS: Conceptualization: E. Vilches, **Data curation:** E Viches, A. Machín. **Formal analysis:** E. Vilches, A Machín, L. Guerra, A. Valdés, E. Hernández. **Investigation:** E Vilches, A Machín, L. Guerra, A. Valdés. **Methodology:** E. Vilches, A Machín, E. Hernández. **Supervision:** E Vilches, A. Machín. **Validation:** E Vilches, A. Machín. **Papers/Editorial, original project:** E. Vilches, A Machín. **Writing, revision and edition:** L. Guerra, A. Valdés, E. Hernández.

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