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Article

Production parameters in radishes (*Raphanus sativus L.*) using organic inputs

Parámetros productivos en rábanos (*Raphanus sativus* L.) mediante el uso de insumos orgánicos

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Abstract

The objective was to measure productive parameters in radishes grown using organic inputs. With a randomized block design and three repetitions. The treatments: commercial cultivation (RaT0); biofertilizer, worm leachate and bocashi (RaT1); biofertilizer and Mountain Microorganisms (RaT2). The parameters bulb circumference, bulb length, root length, stem to leaf length, stem circumference, number of leaves and weight. ANOVA and Principal Component Analysis (PCA) were performed. The PCA shows that RaT1 has the greatest positive impact on the diameter and length of the bulb and the weight of radish. Biofertilizers stimulate rooting and provide plant growth-promoting bacteria (GPCV), worm leachates provide humic acids and promote better absorption of minerals, and bocashi favors the availability of minerals due to the fermentation it undergoes during its preparation.

Productive parameters in radishes (*Raphanus sativus* L.) through the use of organic inputs		
Objetivo	Metodología	Contribución
The objective of the study was to perform the measurement of productive parameters in radishes cultivated using organic inputs. A randomized block design with three replications was performed.	The direct seeding system was used, with irrigation at field capacity. The treatments applied were RaT0: commercial cultivation; RaT1: biofertilizer, earthworm and bocashi leachate; RaT2: biofertilizer, and Mountain Microorganisms. Parameters measured were bulb circumference, bulb length, root length, stem-to-leaf length, stem circumference, number of leaves, and weight. For data analysis, an ANOVA and Principal Component Analysis (PCA) were performed.	The data showed that the highest weight, bulb circumference with RaT0 and RaT1 and the highest bulb length with RaT1. On the other hand, the PCA shows that RaT1 has a greater positive impact on the diameter and length of the bulb and the weight of the radish. Biofertilizers stimulate rooting and provide plant growth promoting bacteria (BPCV), earthworm leachates provide humic acids and favor better absorption of minerals, and bocashi favors the availability of minerals due to the fermentation it undergoes during its preparation.

Bocashi, humic acids, *Eisenia foetida*, Mountain microorganisms, Biofertilizer, Auxins

Resumen

El objetivo fue medir parámetros productivos en rábanos cultivados mediante insumos orgánicos. Con un diseño de bloques al azar y tres repeticiones. Los tratamientos: cultivo comercial (RaT0); biofertilizante, lixiviado de lombriz y bocashi (RaT1); biofertilizante y Microorganismos de Montaña (RaT2). Los parámetros circunferencia del bulbo, longitud del bulbo, longitud de la raíz, longitud del tallo a las hojas, circunferencia de los tallos, número de hojas y peso. Se realizó un ANOVA y un Análisis de Componentes Principales (ACP). El ACP muestra que RaT1 tiene mayor impacto positivo sobre el diámetro y longitud del bulbo y el peso de rábano. Los biofertilizantes estimulan el enraizamiento y aportan bacterias promotoras de crecimiento vegetal (BPCV), los lixiviados de lombriz aportan ácidos húmicos y favorecen una mejor absorción de minerales y el bocashi favorece la disponibilidad de los minerales debido a la fermentación que tiene durante su preparación.

Parámetros productivos en rábanos (*Raphanus sativus* L.) mediante el uso de insumos orgánicos		
Objetivo	Metodología	Contribución
El objetivo del estudio fue to measure production parameters in radishes grown using organic inputs.	Se utilizó un diseño de bloques al azar con tres repeticiones. Se empleó el sistema de siembra directa, con riego a capacidad de campo. Los tratamientos aplicados fueron: cultivo comercial (RaT0); biofertilizante, lixiviado de lombriz y bocashi (RaT1); biofertilizante y Microorganismos de Montaña (RaT2). Los parámetros medidos fueron circunferencia del bulbo, longitud del bulbo, longitud de la raíz, longitud del tallo a las hojas, circunferencia de los tallos, número de hojas y peso. Para el análisis de los datos se realizó un ANOVA y un Análisis de Componentes Principales (ACP).	Los datos mostraron que el mayor peso, circunferencia del bulbo con RaT0 y RaT1 y la mayor longitud del bulbo con RaT1. Por otra parte, el ACP muestra que RaT1 tiene mayor impacto positivo sobre el diámetro y longitud del bulbo y el peso de rábano. Los biofertilizantes estimulan el enraizamiento y aportan bacterias promotoras de crecimiento vegetal (BPCV), los lixiviados de lombriz aportan ácidos húmicos y favorecen una mejor absorción de minerales y el bocashi favorece la disponibilidad de los minerales debido a la fermentación que tiene durante su preparación.

Bocashi, ácidos húmicos, *Eisenia foetida*, Microorganismos de montaña, biofertilizante, Auxinas

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Introduction

Radishes (*Raphanus sativus L*) originate from China, although it is found in the wild in some Mediterranean localities (Giaconi and Escaff, 2004), it has rudimentary stems with large leaves and elongated peduncle (Martínez *et al*., 2003).

According to c, radish production takes place in the months of August-October and February-May, however, it can be sown all year round. It develops and grows best in temperate or cool temperate climates. In terms of soil requirements, it favours fertile and deep soils (Ruíz *et al*., 2013).

Medium or light textured soils produce good development of this crop, although it can also develop in heavy textured soils (Ruíz *et al*., 2013). On the other hand, Martínez *et al*. (2003) report that the most suitable soils for this vegetable are loam and clay loam. Organic agriculture uses methods such as crop rotation, compost, worm humus, green manures, rock meal, among others, which contribute to soil nutrition (Consuegra, 2004; WHO, 2007), always seeking the least environmental impact (Consuegra, 2004; WHO, 2007)

In this sense, organic fertilisers improve soil structure and are made from the decomposition of materials of plant origin (plant remains, crop waste) and animal origin (excrements) (FONAG, 2010; Yugsi, 2011) whose aim is to provide the soil with the nutrients necessary for plant growth (FONAG, 2010; Méndez *et al*., 2013), by contributing to improve soil health (Rosales *et al*., 2013) and reducing the use of fertilisers .

Organic fertilisers are classified into solid and liquid fertilisers. Among the liquid fertilisers are biofertilisers, which are used as foliar fertilisers (FONAG, 2010), which are regularly made from animal excrement and leguminous plant residues (Yugsi, 2011) and require an anaerobic fermentation process (Álvarez, 2010).

This type of fertiliser contributes to plant nutrition by providing minerals and phytohormones (Álvarez, 2010), which promotes foliage development, flowering and rooting (MAGAP, 2014), as well as protection against pests and diseases (INIA, 2008; FONAG, 2010).

In particular, earthworm leachate (*Eisenia foetida*), considered a liquid biofertiliser, is obtained by the vermicomposting technique, which consists of extracting liquids from the disintegration of organic matter (Morales, 2011; Pilar, 2013).

This biofertiliser provides minerals necessary for plant growth such as phosphorus (P), potassium (K), magnesium (Mg), sodium (Na) and nitrogen (N) (Rosales *et al*., 2013).

Among the solid organic fertilisers is bocashi, which is made by fermenting plant remains and animal manure aerobically and anaerobically (Yugsi, 2011).

This type of compost favours better plant growth and development because it contributes to the increase of organic matter and microorganisms in the soil, provides natural phytohormones and phyto-regulators, as well as improving soil texture (Herrera et al., 2015; Ross et al., 2000).

On the other hand, beneficial microorganisms such as mountain microorganisms (MM) are a consortium of fungi, bacteria and yeasts that help control pathogenic microorganisms present on plants and in the soil (Suchini, 2012), in addition to promoting germination, flowering and fruiting (MAGAP, 2014). The objective of the present research was to measure the agronomic parameters of bulb and stem circumference; bulb, root and stem length; leaf number and bulb weight of radishes (*Raphanus sativus L*) grown using organic inputs.

Methodology

The present work was carried out in the greenhouse of the facilities of the University of Guanajuato at the Salvatierra campus (20°12'45.51 'N and 100°52'30.09 'W). The direct sowing system of red radish was used in beds 6 m long, 1 m wide, 25 cm high, chosen in completely randomised blocks with three replications.

Irrigation was carried out at field capacity every third day, using a drip irrigation system with a drip tape with perforations every 30 cm. Radishes were harvested one month after sowing to measure the agronomic parameters of bulb circumference, bulb length, root length, stem to leaf length, stem circumference, number of leaves and weight.

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Bulb circumference was represented by the circular space covered by the bulb of the bulb, bulb length by the distance from the bottom of the bulb to the top of the bulb and as for the weight of the radishes, only the bulb was taken into account if the root, leaves and stems.

Preparation of inputs

a) *Biofertiliser.* For the preparation of the biofertiliser, it was carried out according to the recommendations of Restrepo (2007) with some modifications; a 20-litre plastic jug was used in which 300 g of rock flour, 300 g of ash and water without chlorine were added up to half of the container, 1 kg of carrots chopped into small pieces, 3 kg of fresh cow dung and 1 litre of fresh cow milk was added. Separately, 200 ml of molasses was dissolved in 1 litre of water to be added to the other ingredients and 20 litres of water was added to make up the 20 litres. It was left to stand for 40 days under anaerobic conditions as indicated by INIA (2008).

b) *Worm leachate*. The preparation of the earthworm leachate (*Eisenia foetida*) was carried out in accordance with Morales (2011), collecting the leached liquids from the Californian red worm rearing system.

c) *Bocashi.* Bocashi was made according to the methodology proposed by Restrepo (2007) with some modifications in the ingredients, using 2 sacks of sheep manure, 2 sacks of black soil, 2 sacks of ground stubble (sack of 70 cm high x 40 cm wide), 50 kg of bran, 10 kg of ash, 5 kg of charcoal, 250 g of yeast and 2 litres of molasses.

The already mixed materials were moistened to such a degree that when a portion of material is taken and squeezed by hand, no water should drip out, and care was taken that the temperature did not exceed 50 ^{o}C during the 15 days of processing.

d) *Mountain micro-organisms.* For the elaboration of the mountain microorganisms (MM), decomposing leaf litter was collected from the Tetillas hill (20 ° 12‘ 54’‘ North, 100 ° 52’ 41‘’ West), in sites little affected by anthropic factors as mentioned by Ramírez (2012), The mixture was then mixed with 500 ml of molasses, 1 kg of maize flour, 1 kg of ground bran and 1 litre of whey, the previous mixture was enough to be compacted in a 20-litre plastic bucket and sealed anaerobically for a period of 30 days.

To activate the MM in the liquid phase, 200 g of the previous mixture is placed in a cloth sack, to be immersed in a 20-litre plastic bucket of water with 200 ml of dissolved molasses, stirring two to three times a day for four days.

Experimental design

A randomised block experimental design with three replicates was used. Radishes were direct sown in 6 m long by 50 cm wide beds.

a) *Treatments.* The treatments applied consisted of a commercial crop with a 10-20-10 fertiliser and commercial foliar fertilisation (RaT0); a crop with biofertiliser, earthworm leachate and bocashi (RaT1) and a crop with 5% biofertiliser and Mountain Microorganisms (MM) in liquid phase in the soil (RaT2).

For RaT0 the 10-20-10 fertiliser was used 250 g per^{m2} during soil preparation and foliar fertiliser was applied every 8 days. For RaT1 the biofertiliser used was diluted at 5% with non-chlorinated water and foliar applied every 8 days in the morning, the earthworm leachate at 5% with non-chlorinated water applied to the soil once a week during crop development as a field capacity irrigation system and the bocashi 3 kg per^{m2} during soil preparation.

For RaT2 the 3 iofertilizer used was diluted at 5% with non-chlorinated water applied foliarly every 8 days in the morning and the mountain micro-organisms (MM) were activated in liquid phase at 5% with non-chlorinated water and applied to the soil twice during crop development in the early morning.

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b) *Data analysis.* The results obtained for the measured parameters (bulb circumference, bulb length, root length, stem to leaf length, stem circumference, number of leaves and weight) were analysed by analysis of variance (ANOVA), followed by a Tukey test in order to check the existence or not of significant differences between the different treatments. In addition, a Principal Component Analysis (PCA) was performed to determine the variables with the greatest impact and their correlation in OriginPro 2017 software. Data were expressed as the mean ± standard deviation.

Results

The results show that the treatment with the largest bulb circumference was obtained with the control (RaT0) followed by RaT1 (Figure 1), however, no significant statistical differences were observed (P>0.05), indicating that production with organic fertilizers is an alternative to conventional production. In this sense, Romero *et al*. (2012) and Cabrera *et al.* (2012) report that the use of biofertilisers increases vegetable production and yield.

Box 1

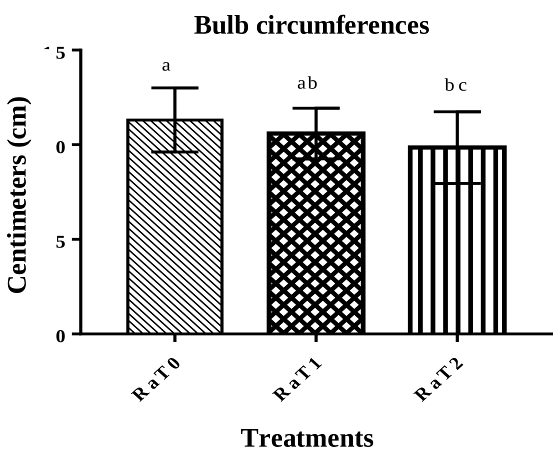

Figure 1
Circumference of radish bulb: commercial control (RaT0), biofertiliser, earthworm (Eisenia foetida) leachate and bocashi (RaT1), biofertiliser and mountain micro-organisms. (RaT2).

Box 2

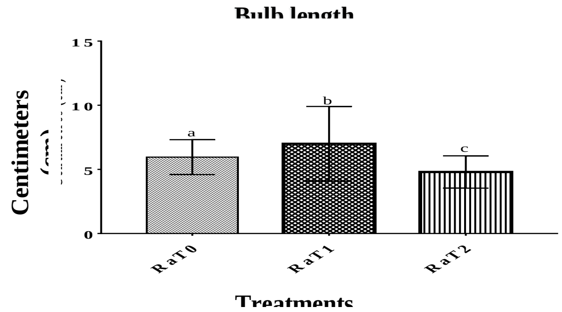

Figure 2
Bulb length of radishes with the treatments: commercial control (RaT0), biofertiliser, earthworm leachate (Eisenia foetida) and bocashi (RaT1), biofertiliser and mountain microorganisms. (RaT2).

Box 3

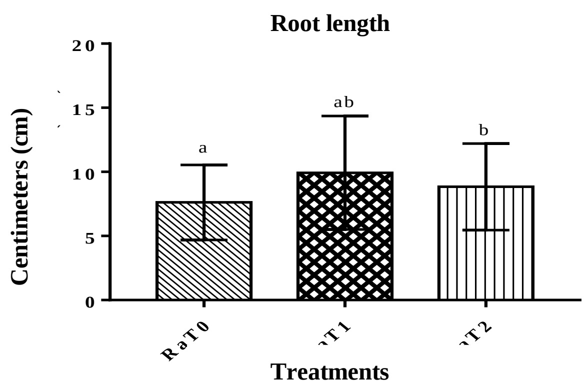

Figure 3
Root length of radishes with the treatments: commercial control (RaT0), biofertiliser, earthworm leachate (Eisenia foetida) and bocashi (RaT1), biofertiliser and mountain microorganisms. (RaT2).

Box 4

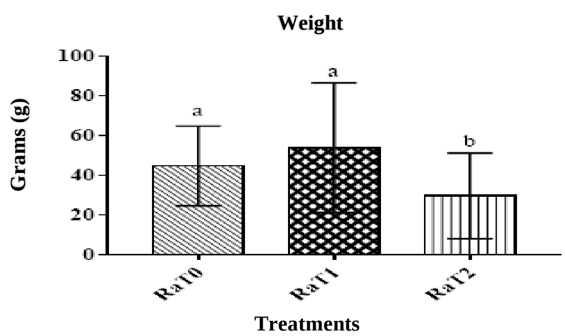

Figure 4
Bulb weight of radishes with the treatments: commercial control (RaT0), biofertiliser, earthworm leachate (Eisenia foetida) and bocashi (RaT1), biofertiliser and mountain microorganisms. (RaT2).

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In Figures 1, 2, 3 and 4 it can be seen that there are statistical differences between the different treatments applied (P<0.05), it is highlighted that the greatest bulb length was obtained with the RaT1 treatment (Figure 2). In agreement with Gómez et al. (2008) and Luna et al. (2015) who obtained similar results in terms of bulb length in radishes and better development of vegetables when using organic fertilizers.

Abou-El-Hassan and Desoky (2013) report that organic fertilisers improve plant growth because they provide macro and micronutrients. In addition, fertilisers such as bocashi contain beneficial microorganisms that stimulate the production of gibberellin in plants, which in turn stimulates fruit development (Camelo et al., 2011).

In relation to root length, it was found that the best treatments were RaT1 and RaT2 (Figure 3). However, no significant statistical differences were observed between RaT2 and RaT0 treatments. On the other hand, significant statistical differences were observed between RaT1 and RaT0 treatment (P<0.05), such that, the best treatment was RaT1, suggesting that root length was favoured by plant growth-promoting bacteria (PGRB) present in the organic inputs through lateral root propagation (Barberi et al, 1988; Barberi et al., 1986; Kolb and Martin; Tien et al., 1979), thus enhancing nutrient and water uptake (Bashan and Honguin, 1998). Another way in which microorganisms can favour plant root growth is through the generation of plant hormones (auxins) that have the capacity to elongate roots, contributing to the uptake of nutrients and water from the soil (Romero, et. al., 2012).

The radishes with the highest weight were those of the RaT0 and RaT1 treatments (Figure 4). The RaT1 treatment did not show significant statistical differences with respect to the RaT0 treatment (P>0.05) but did show significant differences with respect to the RaT2 treatment (P<0.05).

In this sense, the earthworm leachates could have contributed to increase the weight of the radishes due to the action of humic acids that favour a better absorption of minerals (Velasco et al., 2016) and bocashi by providing sufficient nutrients for the growth of the radishes (Velasco et al., 2016) (Restrepo, 2007; MAGAP, 2014).

Box 5

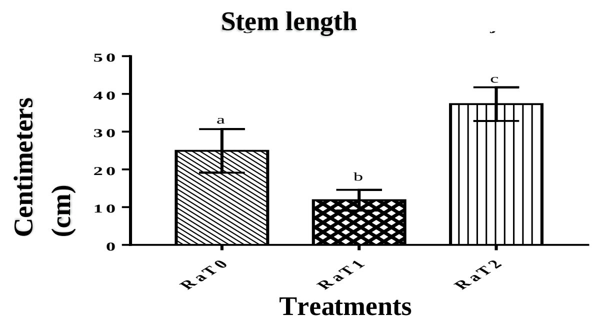

Figure 5

Stem to leaf length in radishes with the treatments: commercial control (RaT0), biofertiliser, earthworm leachate (Eisenia foetida) and bocashi (RaT1), biofertiliser and mountain microorganisms. (RaT2).

Figure 5 shows stem to leaf length, stem circumference and number of leaves in treated radishes. The treatment with the highest stem length was RaT2, being statistically different compared to RaT0 and RaT1 (P<0.05). Cassán *et al*. (2008) report that auxins are phyto-regulators that act on stem cells and promote stem elongation.

In the same way, MM have the ability to produce phytohormones in plants, which could contribute to the development of foliage that is reflected in an increase in stem length and an increase in the number of leaves (Tenecio, 2015). Therefore, the beneficial microorganisms present in the applied organic products induce the production of hormones in radish plants and promote better development and growth, which results in better photosynthetic capacity by the plants, reflecting the physiological state, productivity and health of a plant (Ospina *et al.*, 2018).

Box 6

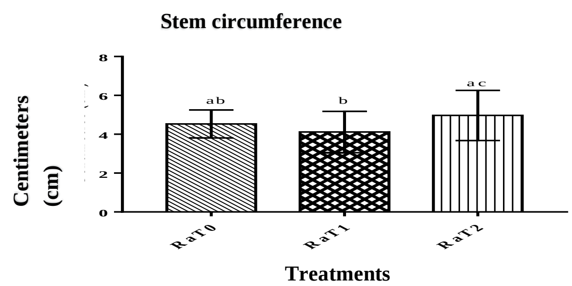

Figure 6

Stem circumference in radishes with the treatments: commercial control (RaT0), biofertiliser, earthworm (Eisenia foetida) leachate and bocashi (RaT1), biofertiliser and mountain microorganisms (RaT2).

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In terms of stem circumference, it was found that the treatments with the largest stem diameter were RaT0 and RaT2 (Figure 6), with no statistical differences between treatments. However, significant statistical differences were observed between treatments RaT0 and RaT2 compared to the control treatment (RaT1) ($P < 0.05$).

These results suggest that organic products such as MM and biofertilisers promote growth due to their phytohormone content (Herrera et al., 2015), which favoured an increase in radish bulb thickness (Tenecio, 2015). In addition, the production of Gibberellin by beneficial bacteria promotes stem growth and bud emergence (Camelo et al., 2011).

Box 7

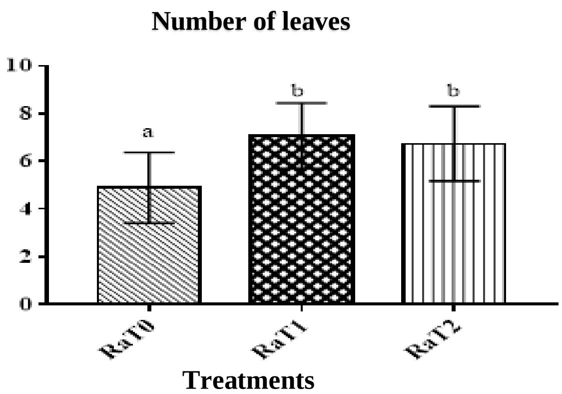

Figure 7

Number of leaves on radishes with the treatments: commercial control (RaT0), biofertiliser, earthworm leachate (Eisenia foetida) and bocashi (RaT1), biofertiliser and mountain microorganisms. (RaT2).

Finally, the number of leaves forming the stems of the radish plants. The radishes with the highest number of leaves were obtained with the organic treatments RaT1 and RaT2 (Figure 7), no statistical differences were observed between treatments.

The results suggest that organic inputs favour leaf production in radishes, probably due to the effect of phytohormones present (Herrera et al., 2015) that help to increase foliage growth.

Box 8

Table 1

Proportion of the overall variance, vectors and eigenvalues of the first four principal components

Variable	Significance	CP1	CP2	CP3	CP4
Bulb circumference	5	0.34289	0.38054	-0.5549	-0.02082
Bulb length	3	0.54176	0.04468	-0.17821	*0.30584*
Length of root	7	0.27244	-0.02949	0.1997	0.75664
Stem length	1	-0.50952	0.4541	0.01033	0.2297
Stem circumference	2	-0.14533	0.70439	0.05043	0.13893
Number of leaves	6	0.24309	0.17839	0.77417	-0.06275
Weight of radishes	4	0.411818	0.34368	0.13586	-0.50747
Eigenvalue	-	1.78484	1.40987	1.10572	1.06259
Explained variance (%)	-	25.5	20.14	15.8	13.18
Cumulative variance (%)	-	25.5	45.64	61.43	76.61

Table 1 shows the 4 principal components that describe the greatest variation in the data, the absolute and cumulative proportion values, describing 76.61 % of the total variation of the information obtained in this study and the importance of each variable, with the variable marked with the number 1 as the one with the greatest impact and number 7 as the one with the least.

For principal component 1 (PC1), the associated variables are bulb length and radish weight, where 25.50 % of the total variability is explained.

For CP2 the variables are stem diameter, stem length and bulb diameter, explaining 20.14% of the total variability.

CP3 is related to the number of leaves and CP4 to root length explaining 15.8 % and 13.18 % of the total variability, respectively.

Figure 8a shows a two-dimensional diagram formed by principal components 1 and 2 (45.64% of the total variability), with the most important variables being stem length and stem diameter, which are also positively associated with each other.

Figura 8. Resultados del análisis de componentes principales. (a) Proyección de variables y (b) comportamiento del Biplot con variables y tratamientos.

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Box 9

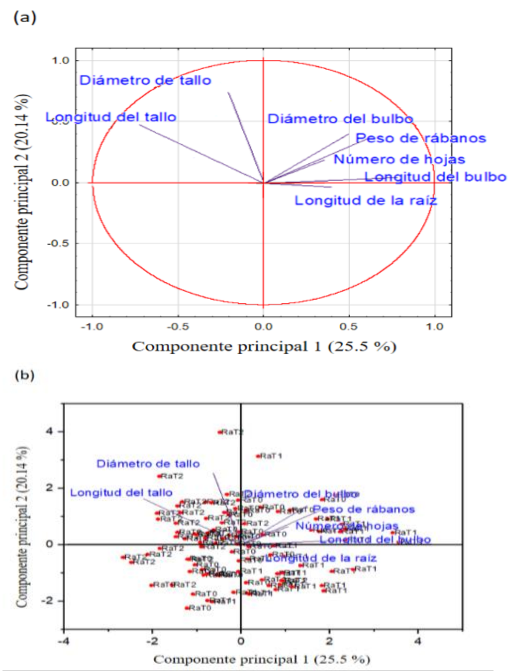

Figure 8

In relation to the parameters bulb diameter, bulb length, root length, number of leaves and radish weight, they were found to be associated with each other, however, they have a negative association with the variables stem diameter and stem length.

That is, by increasing stem diameter and stem length, bulb diameter, bulb length, root length, number of leaves and radish weight will decrease.

In this sense, when looking at Figure 8b, where the variables are found together with the control (RaT0) and the treatments (RaT1 and RaT2). It was observed that RaT1 has a greater positive impact on bulb diameter, bulb length and radish weight.

In contrast, RaT2 has a positive impact on stem diameter and stem length. All this when compared with RaT0 results are in agreement with the above statistical tests (ANOVA and Tukey), showing that RaT1 and RaT2 stimulate plant growth in different parts of the fruit.

Conclusions

The use of organic inputs such as biofertiliser, earthworm leachate (*Eisenia foetida*), bocashi and mountain microorganisms (MM) stimulate fruit development and provide plant growth-promoting bacteria (GGPB) that stimulate root development, as well as containing phytohormones that promote foliage development.

Organic production is an alternative to conventional production in radish cultivation, as it favoured the measured parameters (bulb circumference, bulb length, root length, stem length, stem circumference, number of leaves and weight), because it provides balanced nutrition.

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Authors' contribution

Medina-Saavedra Tarsicio: I contributed to the idea of the project and the development of the research.

Mexicano-Santoyo Lilia: I contributed with the research development, data analysis, revision and editing.

Arroyo-Figueroa Gabriela: I contributed with the revision and editing.

Castro-Jácome Tania Patricia: I contributed to the research method and data analysis.

Availability of data and materials

The data obtained in this research are available.

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