Colegio de Postgraduados

# Bokashi: An Alternative for Pitahaya Cutting Production

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## ABSTRACT

Bokashi organic fertilizer is a potential alternative substrate for pitahaya cutting production. This study aimed to evaluate root and shoot development in pitahaya cuttings grown with different substrates composed of soil, bokashi, sand, and the inorganic fertilizer ammonium diphosphate (DAP) applied in liquid form. In order to identify the best alternatives for cutting production in the central coastal region of Veracruz, Mexico. River sand and soil were mixed with bokashi in the proportion 1/1 and 1/0.5 (volume/volume) (1Sand/1Bokashi, 1Sand/0.5Bokashi, 1Soil/1Bokashi and 1Soil/0.5Bokashi). Additionally, treatments included only river sand, only soil, and soil with weekly applications of DAP through irrigation water at concentrations of 1% and 5% (Soil+DAP1 and Soil+DAP5). A randomized block experimental design was used; with land slope as the blocking factor. One plant constituted the experimental unit. 54 plants per treatment were considered. Statistical differences were detected in root area ($cm^2$), number of roots, average root length (cm), fresh root weight (g), number of shoots per cutting, length and central diameter of the shoot (g), as well as fresh shoot weight (g). It is concluded that the mixture of silt-loam soil or river sand with bokashi organic fertilizer in the proportion 1:1 (volume/volume) is a viable alternative for obtaining pitahaya cuttings with 13 to 16 roots over a period of 50 days, weighing between 6 and 7 grams of fresh weight and that this is reflected in stems that emit between 2.4 and 3.0 shoots.

## INTRODUCTION

The pitahaya (*Hylocereus undatus*) is a species native to Mexico; however, despite being an indigenous species, it still occupies a relatively small cultivated area. At the national level, a total of 2,538 hectares are reported, distributed across the states of Aguascalientes, Guerrero, Nuevo León, Puebla, Quintana Roo, Sinaloa, Sonora, Tabasco, and Yucatán. Currently, Quintana Roo stands out as the leading producer, accounting for 73% of the total cultivated area (SIAP, 2023). Due to the limited fruit supply in the country and its high demand in the export market, pitahaya reaches attractive prices for producers. At the national level, the average price is $18,242 per ton, with an average yield of 6.35 t/ha (SIAP, 2023). Pitahaya is a crop with significant growth potential due to its characteristics,

such as its acceptance in both local and international markets. It can be consumed as fresh fruit, as a vegetable, and even as forage for animals. As a cactus species, it adapts to various environments, including low-fertility soils, rainfed conditions, and areas with low precipitation (Montesinos Cruz *et al.*, 2015). Currently, one limitation to increasing the cultivated area is the availability of planting material. Due to the limited number of production areas, it is essential to have adequate technology that allows for the rapid production of high-quality cuttings using low-cost and easily accessible inputs.

For mass seedling production, in vitro propagation techniques can be used (Martínez Arroyo, 2023). However, this method requires trained personnel, a higher investment, and a longer period for the plant to reach the productive stage. Traditionally, producers multiply their own cuttings. For proper cutting production, gladioles or stems should be obtained from productive plants to ensure fruit production begins within two years after planting. Cutting production can take place after the fruit harvest, at the time of stem pruning. Traditionally, the substrate used by producers consists of the soil from the production unit. However, it has been shown that some agroecological inputs, such as efficient microorganisms, can promote greater root and shoot production (Carrera Abanto, 2023). Similarly, the use of inorganic fertilizers applied in liquid form can help produce vigorous cuttings (Navarrete Torres, 2023). Another agroecological input that has shown potential for seedling production in other plant species is the organic fertilizer bokashi, mixed with soil in 1:1 or 1:2 (volume/volume) proportions (Gashua *et al.*, 2022). Bokashi has the advantage of being an input that can be prepared by the producer using family labor. The preparation process allows for the use of a variety of regional organic residues, such as manure from intensive livestock farming, local weeds, harvest residues, agro-industrial waste, mine waste, river minerals, etc. (Pérez *et al.*, 2008). The objective of the research was to determine the characteristics of root and shoot production in pitahaya cuttings managed with different substrates consisting of soil, bokashi, sand, and the inorganic fertilizer ammonium diphosphate (DAP) applied in liquid form, with the aim of identifying the best alternatives for cutting production in the central coastal region of Veracruz, Mexico.

## MATERIALS AND METHODS

### Study Area

The research was conducted from January to April 2024 at the Cotaxtla Experimental Field, belonging to the National Institute of Forestry, Agricultural, and Livestock Research (INIFAP), located at km 34.5 on the Veracruz-Córdoba highway, in the municipality of Medellín de Bravo, Veracruz (18° 49’ 59” N; 96° 22’ 59” W). The soil used had a pH of 6.63, with 2.41% organic matter, and a loam texture (23, 17, and 60% clay, sand, and silt). The concentrations of nitrate nitrogen (N), phosphate ($P\text{-}PO_4^-$), sulfate ($S\text{-}SO_4^{-2}$), potassium ($K^+$), calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), iron ($Fe^{2+}$), zinc ($Zn^{2+}$), copper ($Cu^{2+}$), manganese ($Mn^+$), and boron ($B^{3+}$) were 12.8, 96.0, 6.67, 400.0, 1940.0, 320, 72, 8.6, 3.3, 5.5, and 0.2 ppm, respectively. Temperature and precipitation were recorded during the experiment period (Figure 1).

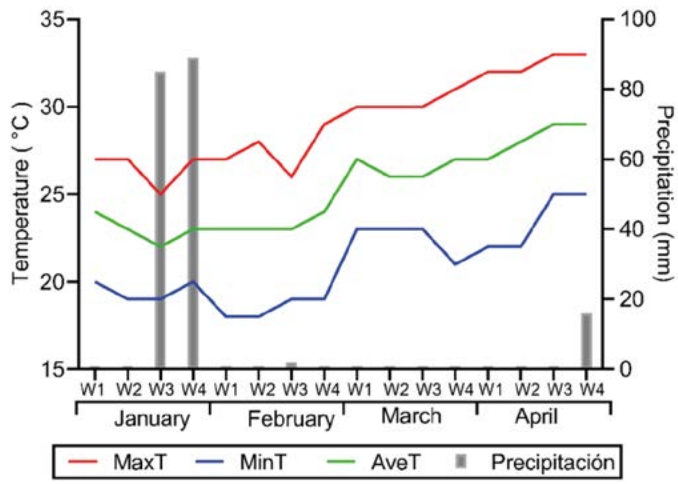


**Figure 1**. Behavior of maximum temperature (MaxT), minimum temperature (MinT), average temperature (AvgT), and precipitation from January to April 2024, in Medellín, Veracruz.

## Pitahaya Cuttings

The cuttings were obtained from productive pitahaya plants (pink skin and white flesh) established at the Cotaxtla Experimental Field. Vigorous and healthy plants were selected. Stems that had reached at least 90% of their final length were cut; these stems were identified by their dark green color, with areoles and fully matured spines (Yadira Vargas Tierras *et al.*, 2024). Stems with a thickness of 5 to 7 cm were selected, and the length of the stems was 25 cm.

## Experimental Design and Treatments

A randomized block experimental design was used, with the slope of the land as the blocking factor. The treatments consisted of different substrates made up of soil, river sand (1 to 3 mm in diameter), bokashi organic fertilizer, and the inorganic fertilizer Ammonium Diphosphate (DAP), which contains 18-46% N-$P_2O_5$. The soil was mixed with bokashi in the ratio 1/1 and 1/0.5 (volume/volume) (1Soil/1Bokashi and 1Soil/0.5Bokashi). Soil was also combined with weekly applications of DAP applied in irrigation water at concentrations of 1 and 5% (Soil+DAP1 and Soil+DAP5), and the exclusive use of soil. Additionally, a mixture of river sand with bokashi in the ratio 1/1 and 1/0.5 (volume/volume) (1Sand/1Bokashi and 1Sand/0.5Bokashi) was used, as well as the exclusive use of sand. One plant constituted the experimental unit. 54 plants per treatment were considered.

The bokashi used was prepared with bovine manure, local grassy weed residues, soil, sand, wheat bran, and ash in a 4:2:1:1:0.7:0.7 (volume/volume ratio. The materials were humidified with a mixture of molasses and water (10% molasses). When the bokashi was used, it had a moisture content of 30%.

The characteristics of the bokashi were as follows: 19.52% and 11.32% organic matter and carbon, respectively; pH of 6.61 and electrical conductivity of 0.43 mS/cm; density of 0.83 g/cm$^3$; C/N ratio of 12.58; 0.9, 1.17, 0.84, 2.67, 0.68, 0.95, 0.03, 0.00, 0.05, and 0.03% total N, $P_2O_5$, $K_2O$, CaO, MgO, $Fe^{2+}$, $Zn^{2+}$, $Cu^{2+}$, $Mn^{2+}$, and $B^{3+}$, respectively.

**Establishment of Cuttings**

To establish the cuttings, excavations were made in the soil. An area of 2×1×0.2 m was dug. The excavated areas were filled with each of the substrates, and then the pitahaya cuttings were planted. Prior to planting, a cut was made at the base of the cuttings to remove the succulent part of the stem, leaving only the woody part. Immediately after, the cut area was submerged for 5 minutes in a solution made of 800 ml of calcium sulfate solution in 20 L of water. In each planting area, the cuttings were arranged in three rows, with 18 plants placed in each row. The space between rows was 30 cm, leaving a 20 cm margin. The distance between cuttings was 10 cm.

To hydrate the cuttings, weekly irrigations were carried out. On each irrigation date, an equivalent of 1.35 L of water was applied per cutting. For the treatments that included DAP, 67.5 or 13.5 g of this fertilizer were applied on each irrigation date. In total, six irrigations were performed, representing a total application of 405 and 81 g for the Soil+DAP5 and Soil+DAP1 treatments, respectively.

**Production of roots and shoots of pitahaya**

The effect of the treatments was evaluated 50 days after planting. In five randomly selected experimental units, the area occupied by the roots ($cm^2$), the number, average length, and fresh weight of roots were recorded. The roots of each shoot were collected, washed, and placed in a forced-air oven at a temperature of 70 °C until constant weight was achieved. Additionally, the number of shoots per stem, as well as the length, central diameter, and fresh weight of the shoots, were recorded.

**Data analysis**

To compare the treatments, an analysis of variance and a Scott-Knott mean comparison test were conducted, both with a 95% probability ($p \leq 0.05$). For each treatment, a Pearson correlation analysis ($p < 0.05$) was performed to determine the degree of association between the root variables and the characteristics of the shoots obtained from the pitahaya cuttings.

## RESULTS AND DISCUSSION

Similar root area was detected with 1Soil/0.5Bokashi, 1Sand/0.5Bokashi, and Sand, all of which outperformed the other treatments (Figure 2a). The highest number of roots was found with 1Soil/1Bokashi, 1Soil/0.5Bokashi, and Soil (Figure 2b). The greatest root length was detected with Sand (Figure 2c). The lowest fresh root weight was found with Soil+DAP1, 1Sand/1Bokashi, and Sand (Figure 2d). No statistical differences were detected in the dry root weight (Figure 2e).

The highest number of shoots was achieved with 1Soil/1Bokashi, 1Soil/0.5Bokashi, Soil+DAP5, and Soil+DAP1 (Figure 3a). The largest shoot diameter was detected with 1Sand/1Bokashi (Figure 3b). The length and fresh weight of shoots obtained with 1Soil/1Bokashi, 1Sand/1Bokashi, and 1Sand/0.5Bokashi were statistically equal, and all three outperformed the other treatments (Figure 3c, d).

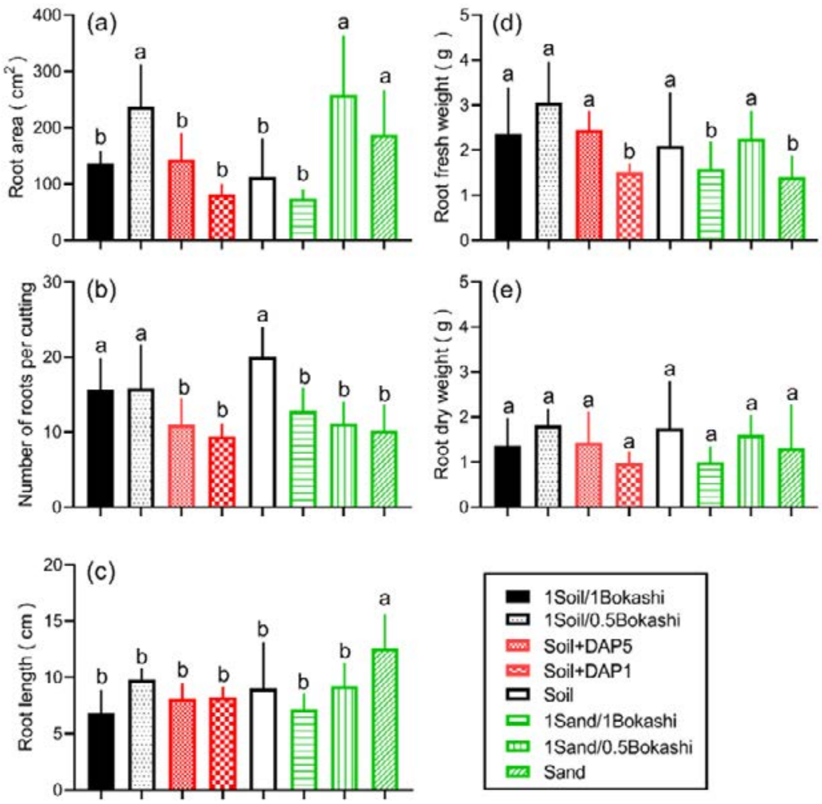


**Figure 2**. Characteristics of pitahaya root cuttings based on different substrates, consisting of the exclusive application of soil or sand, soil or sand mixed with bokashi fertilizer in the ratio 1/1 and 1/0.5 (1Soil/1Bokashi, 1Soil/0.5Bokashi, 1Sand/1Bokashi, and 1Sand/0.5Bokashi), as well as soil with applications of DAP at concentrations of 1% and 5% (Soil+DAP1 and Soil+DAP5), in Medellín, Veracruz.

With the 1Soil/1Bokashi treatment, a high negative correlation was detected between root area and fresh shoot weight, but a positive correlation was found between fresh shoot weight and both fresh and dry root weight, as well as with shoot length and diameter (Table 1). With the 1Soil/0.5Bokashi treatment, a negative correlation was detected between the number of shoots and both root area and dry root weight. Fresh shoot weight was positively correlated with dry root weight and shoot dimensions; however, a negative correlation was observed between the number of shoots and fresh shoot weight (Table 1). With the Soil+DAP5 treatment, only positive correlations were detected. The number of shoots was correlated with root area and length, and fresh shoot weight was correlated with the number, length, and fresh weight of roots, as well as with the shoot dimensions (Table 1). For the Soil+DAP1 treatment, only a correlation between fresh root weight and shoot dimensions was detected (Table 1). In the case of the Soil treatment, a negative correlation was detected between root area and fresh shoot weight. A positive correlation was also found between fresh root weight and both the number and length of roots, as well as with the shoot dimensions (Table 1). For the 1Sand/1Bokashi treatment, a negative correlation was detected between the number of shoots and the number of roots, while a positive correlation was found between fresh shoot weight and the number and length of roots, as well as with the shoot dimensions (Table 1). In the 1Sand/0.5Bokashi treatment, a negative

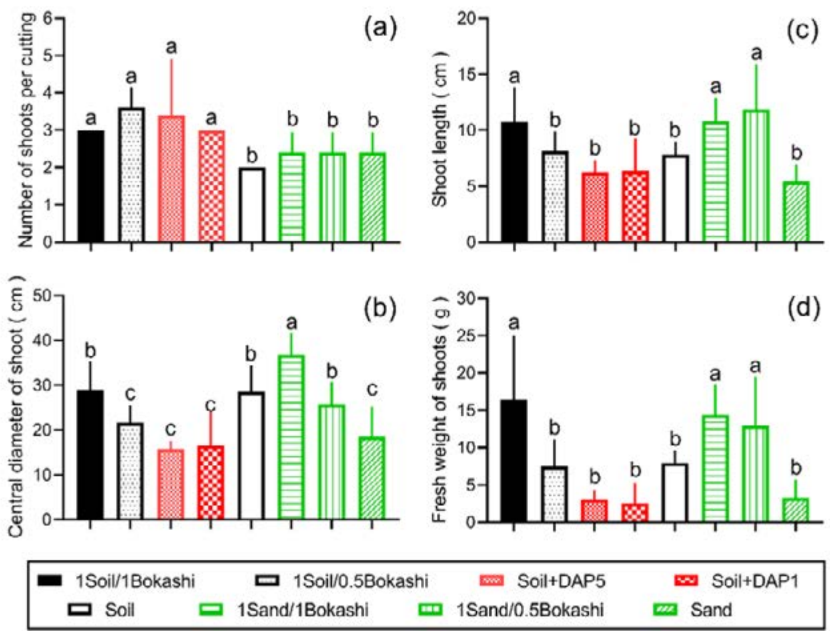


**Figure 3**. Characteristics of pitahaya cuttings' shoots based on different substrates, consisting of exclusive applications of soil or sand, soil or sand mixed with bokashi fertilizer in the ratios of 1/1 and 1/0.5 (1Soil/1Bokashi, 1Soil/0.5Bokashi, 1Sand/1Bokashi, and 1Sand/0.5Bokashi), as well as soil with DAP applications at concentrations of 1% and 5% (Soil+DAP1 and Soil+DAP5), in Medellín, Veracruz.

correlation was detected between the number of shoots and the dry weight of roots, but a positive correlation was found between fresh shoot weight and the number of shoots, dry root weight, and the shoot dimensions (Table 1). In the treatment that only included sand, a positive correlation was detected between the number of shoots and the number and dry weight of roots; however, fresh root weight was negatively correlated with the number and dry weight of roots, as well as with the number of shoots (Table 1). For this study, a silty-loam soil was used, which, according to its chemical characteristics, is classified as a neutral soil of medium fertility (Salgado-García *et al.*, 2006). The exclusive use of soil promoted the maximum number of roots (20 roots per cutting); however, this higher number of roots did not translate into positive effects for shoot production. On the other hand, the exclusive use of river sand favored both the lateral and vertical growth of roots, as it excelled in root area (187 $cm^2$) and was the treatment that achieved the maximum root length (12.6 cm). However, these benefits were not reflected in shoot production and size. Both soil and sand were the treatments with the lowest nutrient availability; therefore, it is speculated that the plant's physiological response was to prioritize root production over shoot production as a survival strategy (Gruber *et al.*, 2013). This would explain the negative correlation detected with these treatments, specifically between the fresh weight of shoots and root area and number. On the other hand, the inorganic fertilizer DAP did not show a difference compared to the exclusive use of soil or sand, as it only promoted positive effects on root fresh weight and the number of shoots produced, specifically when the 5% concentration was applied. Therefore, it is not considered a viable alternative for cutting production.

**Table 1**. Pearson correlation coefficient between shoot characteristics and pitahaya root characteristics based on different substrates, consisting of the exclusive application of soil or sand, soil or sand mixed with bokashi fertilizer in a 1/1 and 1/0.5 ratio (1Soil/1Bokashi, 1Soil/0.5Bokashi, 1Sand/1Bokashi, and 1Sand/0.5Bokashi), as well as soil with DAP applications at concentrations of 1% and 5% (Soil+DAP1 and Soil+DAP5), in Medellín, Veracruz.

| | **Area of the root** | **Number of roots** | **Length of root** | **Fresh weight of root** | **Dry weight of root** | **Number of shoots** | **Length of shoots** | **Central diameter of shoots** |
|---|---|---|---|---|---|---|---|---|
| | 1Soil/1Bokashi | | | | | | | |
| Number of shoots | - | - | - | - | - | 1.00 | - | - |
| Fresh weight of shoots | −0.61 | 0.27 | 0.58 | 0.91 | 0.80 | - | 0.95 | 0.86 |
| | 1Soil/0.5Bokashi | | | | | | | |
| Number of shoots | −0.67 | 0.28 | −0.30 | −0.34 | −0.81 | 1.00 | - | - |
| Fresh weight of shoots | 0.42 | -0.25 | −0.04 | 0.24 | 0.65 | −0.86 | 0.92 | 0.99 |
| | Soil+DAP5 | | | | | | | |
| Number of shoots | 0.64 | 0.42 | 0.71 | −0.32 | −0.31 | 1.00 | - | - |
| Fresh weight of shoots | −0.03 | 0.55 | 0.63 | 0.54 | −0.07 | 0.21 | 0.88 | 0.62 |
| | Soil+DAP1 | | | | | | | |
| Number of shoots | −0.22 | −0.41 | −0.08 | −0.11 | −0.10 | 1.00 | - | - |
| Fresh weight of shoots | 0.20 | 0.14 | −0.15 | 0.27 | 0.08 | −0.38 | 0.91 | 0.80 |
| | Soil | | | | | | | |
| Number of shoots | - | - | - | - | - | 1.00 | - | - |
| Fresh weight of shoots | −0.57 | 0.67 | 0.58 | 0.23 | 0.14 | - | 0.81 | 0.63 |
| | 1Sand/1Bokashi | | | | | | | |
| Number of shoots | 0.08 | −0.53 | 0.20 | 0.40 | 0.39 | 1.00 | - | - |
| Fresh weight of shoots | 0.25 | 0.92 | 0.63 | 0.34 | 0.05 | −0.39 | 1.00 | 0.95 |
| | 1Sand/0.5Bokashi | | | | | | | |
| Number of shoots | −0.34 | −0.22 | 0.26 | −0.45 | −0.50 | 1.00 | - | - |
| Fresh weight of shoots | 0.64 | −0.36 | 0.45 | 0.30 | 0.54 | −0.28 | 0.92 | 0.81 |
| | Sand | | | | | | | |
| Number of shoots | −0.33 | 0.73 | −0.36 | 0.47 | 0.60 | 1.00 | - | - |
| Fresh weight of shoots | −0.12 | −0.85 | −0.13 | −0.40 | −0.54 | −0.78 | 0.80 | 0.48 |

According to the results, bokashi is a good alternative for the production of cuttings. A greater root area achieved by mixing soil or sand with bokashi in a 1:0.5 ratio (volume/volume) indicates that a higher lateral root growth was promoted (237 and 259 $cm^2$ with 1Soil/0.5Bokashi and 1Sand/0.5Bokashi). This characteristic is desirable in commercial plantations since it allows for better utilization of nutrients and water distributed in the soil. The positive correlation between the weight of the shoots and the fresh or dry weight of the roots indicates that the positive effects on root production favored the production and characteristics of the shoots, particularly when soil and sand were used in the 1:1 ratio, as these treatments stood out with the highest number (2.4 to 3.4 shoots/cutting), length (10.7-11.9 cm), central diameter (2.7 to 3.7 cm), and fresh weight of shoots (14.4 to 16.5 g). This better response achieved with bokashi is attributed to the nutrients provided and the increase in organic matter in the substrate. Considering the volume of the planting area (0.4 $m^3$), the density of bokashi (0.8 $g/cm^3$), and an apparent soil density of 1 $g/cm^3$, each plant received 6.7 kg of substrate, of which 3 kg were bokashi. According to the chemical characteristics of bokashi, these 3 kg supplied each plant with 578, 27, 35, 25, 79, and 20 g of organic matter, total N, $P_2O_5$, $K_2O$, CaO, and MgO, respectively. It is speculated that a temperature between 20 and 30 °C, along with weekly irrigation, favored nutrient mineralization; furthermore, the increase in organic matter in the substrate promoted water retention and root aeration (Olle *et al.*, 2020). All these benefits were reflected in cuttings with a better root system and consequently greater shoot production.

## CONCLUSIONS

The mixture of silty-loam soil or river sand with the organic fertilizer bokashi in a 1:1 ratio (volume/volume) is a viable alternative to obtain pitahaya cuttings with 13 to 16 roots, weighing between 6 and 7 grams of fresh weight, over a period of 50 days. This also results in stems emitting between 2.4 and 3.0 shoots, with a fresh weight of 14 to 17 grams. These values are higher than those obtained with the exclusive use of river sand, soil, or soil combined with weekly applications of the inorganic fertilizer DAP.

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