

# Waste management of pseudostem to increase the growth of banana seedlings

## Manejo de residuos de pseudotallo para aumentar el crecimiento de plántulas de banano

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### Abstract

Pseudostem is an abundant residue after harvesting of the banana bunch, serving as a source of water, nutrients and organic substances. The present study aimed to evaluate the effect of pseudostem waste on ‘Nanica’ banana (*Musa* spp. AAA) cultivar in greenhouse under contrasting environmental conditions. For this, an experiment was carried out in the São Paulo State University -UNESP in a randomized block design in a 2 x 2 factorial scheme (presence or absence of waste and two seasons), consisting of four replicates of three experimental plots with two pots per plant. One season was early November/2018 (Summer) and the other half of May/2019 (Winter). A 40 cm portion of the pseudostem collected from of a freshly harvested plant was sectioned into 10 cm portions and placed under the substrate of the seedling-containing pot at both times. Periodically, height, pseudostem diameter and leaf emission were evaluated. After the release of leachate by the residue, plants were taken to the laboratory, and the area of leaves and roots, their respective masses, and the leaf nutrient content were determined. The nutritional composition of the residue was evaluated before being applied for both seasons. In summer, accumulated dry matter in the different organs, leaf area and root area was higher in the presence of the residue, while in winter, only root dry mass was higher ( $P < 0.01$ ). The application of residue had a consistent effect on root growth, which can be exploited in the field.

**Keywords:** Vegetables residues; Nutrient cycling; Growth promoting substances.

### Resumen

El pseudotallo es un residuo abundante resultante después de la cosecha del racimo de banano (*Musa* spp. AAA) que sirve como fuente de agua, nutrientes y sustancias orgánicas. El objetivo del estudio fue evaluar en invernadero el efecto de los residuos de pseudotallo en el cultivo de banano ‘Nanica, bajo condiciones ambientales contrastantes. Para esto, en la Universidad Estadual de São Paulo -UNESP se realizó un experimento en un diseño de bloques al azar en un esquema factorial 2 x 2 (presencia o ausencia de desechos y dos estaciones), con cuatro repeticiones de tres parcelas experimentales con dos macetas por planta. La primera temporada de evaluaciones se realizó a comienzo de noviembre de 2018 (época de verano) y la otra mitad en mayo de 2019 (época de invierno). Para las mediciones, en ambas épocas se tomaron porciones de 40 cm de pseudotallo de una planta recién cosechada, se seccionaron en porciones de 10 cm y se colocaron debajo del sustrato de la maceta que contenía plántulas. Periódicamente, se evaluaron la altura, el diámetro del pseudotallo y la emisión de hojas. Después de la liberación del lixiviado por el residuo, las plantas fueron llevadas al laboratorio y se determinaron, el área de hojas y raíces con las masas respectivas y el contenido de nutrientes en la hoja. La composición nutritiva del residuo se evaluó antes de su aplicación en ambas estaciones del año. En verano, la materia seca acumulada en los diferentes órganos, el área de la hoja y el área de la raíz fue mayor en presencia del residuo; mientras que en invierno, solo la masa seca de la raíz fue más alta ( $P < 0.01$ ). Los resultados mostraron, además, que la incorporación de residuos tuvo un efecto constante sobre el crecimiento de la raíz.

**Palabras clave:** Ciclo de nutrientes; Restos vegetales; Sustancias promotoras del crecimiento.

## Introduction

Banana plant (*Musa* spp.) and plantains belong to the Musaceae family and are widely grown in Brazil and worldwide. They are tropical herbaceous plants with appearance of trees with fibrous trunks that are false stems, referred to as pseudostem (Akpabio et al. 2012), composed of concentric layers of leaf sheaths (Ho et al., 2012). Its fruits are the second most important crop after citrus, accounting for 16% of world fruit production with 120 million tons in an area of over 8 million ha, grown in over 112 countries under tropical and subtropical conditions (FAO, 2019).

Each banana tree produces a single bunch of fruits (Ho et al., 2012). In banana plantations, after harvesting, pseudostem is cut at about 70 cm in height, and thus, several tons of agricultural residues are daily produced (Nkengafac et al., 2019) and according to Ingale et al. (2014) about 220 ton ha<sup>-1</sup> year<sup>-1</sup>. The pseudostem felled is usually abandoned in the soil of plantation and can become organic waste and cause environmental pollution (Li et al., 2010).

Aiming at obtaining greater efficiency in the use of nutrients in banana plantations and preventing negative environmental impacts, in Brazil pseudostem waste is kept on the soil. In banana plantation in Ecuador (Nivelo-Nagua, 2017) and Canary Islands (Hernández and Serrano, 2016) it has been recommended to insert a portion of the decaying pseudostem into the daughter or granddaughter plant covering the full extent of shoots to increase annual growth.

Thus, it is assumed that the targeted distribution of pseudostem waste may contribute to the supply of water, nutrients and organic substances (Ho et al., 2012; Misal et al., 2018). In the case of plants in the child stadium, when there is a deficit in obtaining photoassimilates from the mother plant, for example, when there are adverse weather conditions. Regarding its applicability, it will represent only the best distribution of the crop waste, since it is kept in the production unit on the soil, thus, without great additional cost for its implementation. Additionally, it will be possible to infer about the viability of using banana waste for organic fertilizer production. Thus, the present study aimed to evaluate the effect of pseudostem waste on 'Nanica' banana cultivar in greenhouse under contrasting environmental conditions.

## Material and Methods

The research was conducted in Registro-SP, in a greenhouse belonging to the São Paulo State University -UNESP. The plant material was micropropagated banana (*Musa* spp. AAA, cv.

Nanica) about 10 cm height, transplanted into 20 liter pots containing mixture of ½ soil, ¼ Carolina Soil® and ¼ Vivatto®. Soil used was classified as Cambisol, and its pH was corrected with dolomitic limestone 60 days before the experiment, as indicative of chemical analysis. Were used simple substrate superphosphate and controlled release of 20:0:20 NPK formulation 30 days after transplant (DAT).

A randomized complete block design was used in a 2 x 2 factorial scheme, two seasons and presence or absence of waste, with four replicates of three experimental plots, with two pots per plant. One season was early November/2018 (Summer) and the other half of May/2019 (Winter). To do this, a 40-cm portion of freshly harvested pseudostem was chopped into 10 cm portions and placed under potting substrate containing the seedling at 15 DAT in both seasons. Waste samples used were oven dried at 65 °C to constant weight to determine the dry matter content and analyzed for nutrient content and C/N ratio using methodology proposed by Lanarv (1988).

Plant height, diameter and leaf emission were determined at 60 DAT. Height corresponded to the distance between the insertion of leaf 1, which is the youngest leaf completely unwound, and soil. Pseudostem diameter was determined close to the soil with digital caliper. Leaf emission was determined by counting leaves that emerged after transplantation. Evaluations were performed when waste no longer released leachate when plants were sectioned into shoot and root. At laboratory, roots and leaves were washed and dried with absorbent paper. Then, images were recorded using high resolution digital camera and 100% scale. Digitized files were submitted to the Image J® software to calculate leaf area and root. Subsequently, all plant tissue was submitted to drying in oven with forced air circulation at 65 °C until constant weight for dry matter determination. A portion of the dry leaf material was ground and the nutrient content was determined according to Bataglia et al. (1983).

A Datalogger from Campbell Scientific, Logan, Utah, USA, Model CR 1000, was installed to collect temperature data at 2 cm from the substrate surface every 5 minutes. Other temperature data were obtained from the Meteorological Station (Campbell Scientific, Logan, Utah, USA), connected to the CIIAGRO System - IAC.

Statistical analyses were carried out using the Sisvar 4.2 software. Data were submitted to the Bartlett test and analysis of variance followed by the F-test. Pearson's correlation coefficients (r) were calculated among variables and significance by the t-test.

## Results and discussion

Growing season was an important cause of variation, affecting all variables except for root/shoot ratio (RSR) (Table 1). Climatic conditions indicate that there was reduction of radiation availability (Table 2) and consequently in maximum and minimum temperatures when comparing summer and winter, which is characteristic of the marginal tropical climate of the region (Lima et al., 2019).

In terms of temperature, the ideal conditions for banana cultivation are maximum averages over 21 °C, minimum averages over 15°C, a condition that accelerates leaf emission and consequently plant development. Although in summer, average temperatures were higher, maximum temperatures exceeding 35 °C are observed, as well as in winter, temperatures below 10 °C are also observed (Table 2), conditions that cease the carbon gain by banana plants (Donato et al., 2015).

The difference in the height of plants (H) grown in summer and winter was 17.58 cm ( $P < 0.05$ ), while in the number of leaves was 2.48 ( $P < 0.05$ ), variables influenced only by the effect of season. Regardless of use of pseudostem waste, leaf dry matter (LDM) was also 14.61 g higher in summer than in winter ( $P < 0.05$ ), indicating a clear growth difference between seasons.

The effect of the presence or absence of pseudostem waste on LDM was striking and unrelated to season; plants grown with waste accumulated 22.14 g of leaves (MSF) and without waste 17.30 g ( $P < 0.01$ ). MSR accumulation in

seedlings in the presence of waste was higher in both seasons (Figure 1); however, the extent of difference between presence and absence of waste was greater in summer than in winter.

The effect of waste on pseudostem dry matter (PDM), pseudostem diameter (PD), leaf area (LA) and root area (RA) was significant only in summer. Regardless of season, the root/shoot ratio was higher in plants that received waste (0.59) than in those without waste (0.56) ( $P < 0.05$ ), indicating higher investment in root growth in terms of mass (Table 1). In terms of leaf area (LA) and root area (RA), influence of waste was observed only in summer, as well as in pseudostem diameter (Figure 1).

Banana seedlings with more leaves and higher leaf area (LA) possibly will present larger set and initial growth in the field, due to the higher production of photoassimilates, certainly resulting in faster inflorescence emission. A seedling with a larger root area (RA) can occupy more space in the soil; consequently will have more success in obtaining water and nutrients and less chance of falling in the field.

Although in winter no significant influence of waste on growth and extension of leaf area (LA) and roots was detected (Figure 1), the absence of response was not inconsistent, since linear correlations were found between LDM and LA ( $r = 0.94^{**}$ ), and between RDM and RA ( $0.93^{**}$ ), regardless of season. Root growth promotion in both seasons is a very important result as often plant roots are attacked by nematodes, fungi and banana weevil eggs, as well as dying from stress due to water supersaturation in the soil.

**Table 1.** Analysis of variance for root dry matter (RDM), pseudostem dry matter (PDM), leaf dry matter (LDM), root/shoot ratio (RSR), height (H), leaf emission (LE), pseudostem diameter (PD), leaf area (LA) and root area (RA) of banana seedlings cv. Nanica at 60 DAT.

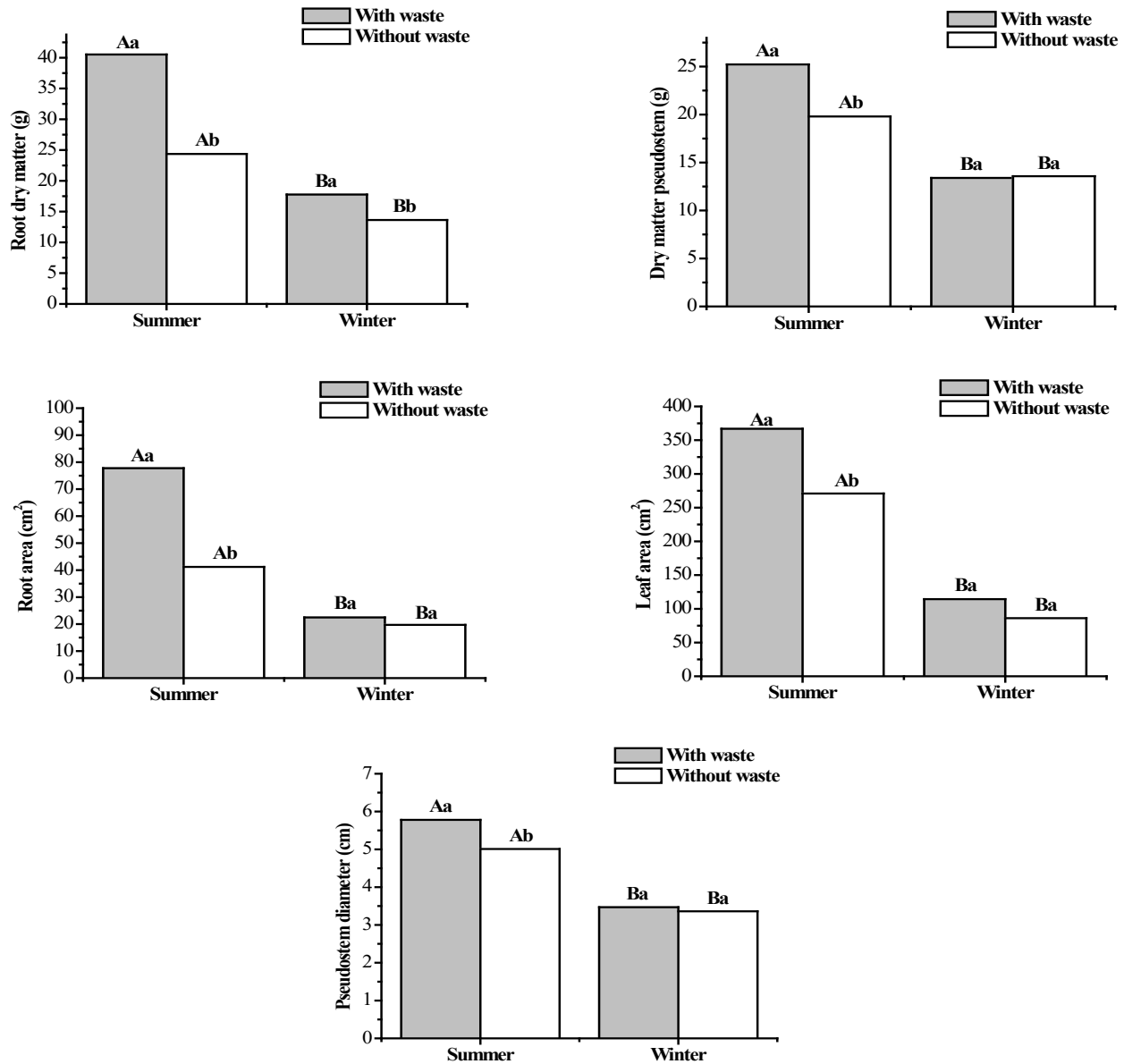
	RDM (g)	PDM (g)	LDM (g)	RSR	H (cm)	LE	PD (cm)	LA (cm <sup>2</sup> )	RA (cm <sup>2</sup> )
Treatment	62.86**	6.73*	21.93**	9.14**	3.73 <sup>NS</sup>	0.17 <sup>NS</sup>	6.77*	32.19**	59.02**
Season	189.62**	82.93*	198.88**	13.40**	303.05**	146.59**	159.16**	438.58**	263.08**
TxS	24.51**	7.01*	2.40 <sup>NS</sup>	2.01 <sup>NS</sup>	3.77 <sup>NS</sup>	0.20 <sup>NS</sup>	4.43*	10.54**	51.08**
Mean	23.31	17.59	19.72	0.62	29.82	7.63	4.31	199.59	38.54
VC (%)	17.22	18.61	17.36	19.24	11.19	9.59	12.05	17.28	20.28

\*,  $P < 0.05$ ; \*\*  $P < 0.01$ ; NS, not significant to F test ( $p < 0.05$ ). VC, variation coefficient.

**Table 2.** Climatic conditions during cultivation period\*.

Season	Conditions	Mean	standard deviation (±)	Minimum value	Maximum value
Summer	Global radiation (MJ m <sup>-2</sup> )	16.53	7.39	3.47	30.57
	Maximum temperature (°C)	28.75	5.09	20.41	39.68
	Minimum temperature (°C)	19.28	2.31	14.10	24.86
Winter	Global radiation (MJ m <sup>-2</sup> )	10.15	4.48	0.06	16.96
	Maximum temperature (°C)	25.37	3.62	16.16	32.15
	Minimum temperature (°C)	15.49	3.53	4.52	21.42

\*Summer of 08/10/18 to 21/12/18 and winter of 08/05/19 to 01/08/19.



**Figure 1.** Pseudostem and root dry matter, leaf area, root area and pseudostem diameter of banana seedlings cv. Nanica at 60 DAT. Means followed by different capital letters for seasons and small letters for treatments differ by the Tukey test ( $P < 0.05$ ).

The average DM content in waste was 5.88%, indicating that the material was a great source of water, which in this study was not limiting due to the two daily irrigations. Regarding nutrient composition, there were no differences in the average levels of waste used in both seasons, which were 5.00, 0.55, 81.00, 7.50, 2.20 and 0.20 g kg<sup>-1</sup> DM, respectively, for N, P, K, Ca, Mg and S; and 10.75, 3.00, 237.50, 171.50 and 7.50 mg g<sup>-1</sup> DM, for B, Cu Fe, Mn and Zn. These results are in agreement with those of Akpabio et al. (2012), Blanco et al. (2013) and Ramu et al. (2017).

The C/N ratio can be of great importance for the degradation rate of hemicellulose, cellulose and lignin, which was high using waste (44.5/1),

indicating slow degradation and use of part of N by microorganisms. This result corroborates the fact that it is mainly composed of cellulosic filaments strongly bonded by hemicelluloses and lignins (Akpabio et al., 2012). There were slight differences in substrate temperature at 2 cm depth in the presence of waste, which in summer ranged from 0.2 to 0.95 °C and in winter from 0.12 to 0.23 °C, indicating little influence on root growth due to temperature change.

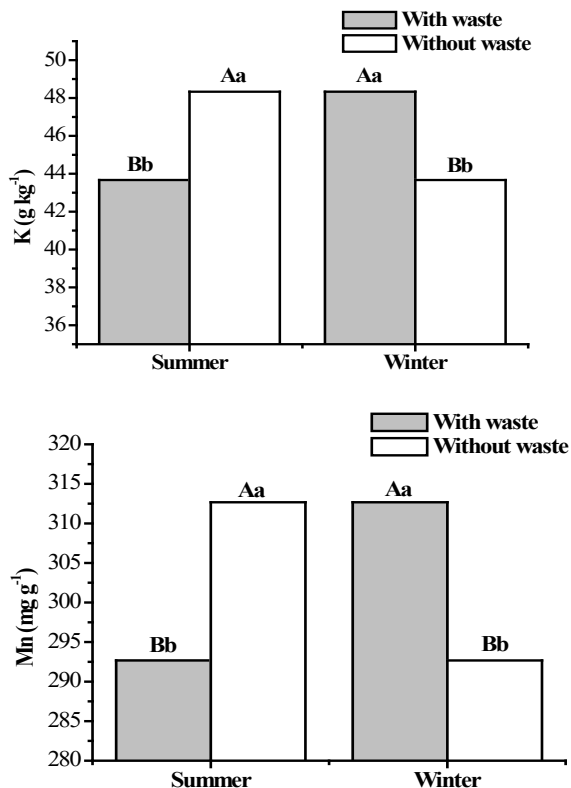
There was no influence of the isolated effects of season and treatment, or the interaction of these factors on seedling nutrient content, except for K and Mn, probably due to the abundance of these nutrients in waste. K was abundant



possibly due to the high supply by fertilization, while Mn was abundant due to the high soil concentration. The mean K contents ranged from 43.67 to 48.33 g kg<sup>-1</sup> DM, while Mn contents ranged from 292.67 to 312.67 mg g<sup>-1</sup> DM. N, P, Ca, Mg and S contents were, respectively, 37.50, 3.30, 6.17, 4.22, 2.20 g kg<sup>-1</sup>, and B, Cu, Fe and Zn of 20.67, 6.83, 170.00 and 20.83 mg g<sup>-1</sup>. The contents of all quantified nutrients were above minimum values established by Borges (2006) for the same cultivar.

K and Mn exhibited identical responses in summer in the presence of waste (Figure 2), plants exhibited low contents in contrast to high LDM and LA, which reflects a dilution effect. In winter, contents were higher for plants cultivated with waste.

Despite the little effect of waste on nutritional status of seedlings, banana sap extracted from pseudostem can be used as liquid fertilizer, improving yields of some crops (Patil and Kolambe, 2011) and saving 20 - 40% fertilizer. The effect on shoot and root growth may be associated with the fact that pseudostem waste contains growth promoting substances like cytokinins and gibberellins (Pail and Kolambe, 2011; Misal et al., 2018), in addition to high content of phenols, flavonoids and tannins



**Figure 2.** K and Mn contents in leaf tissue of banana seedlings cv. Nanica. Means followed by different capital letters for seasons and small letters for treatments differ by the Tukey test ( $p < 0.05$ ).

(Sharma et al., 2017). These organic substances can act as primary antioxidants or free radical scavengers and modulators of plant development by regulating indole acetic acid (IAA) catabolism (Arnaldos et al., 2001).

Severino et al. (2011) showed that the liquid from the banana pseudostem applied to the soil does not improve the growth of 'Prata Anã' banana seedlings, but stimulates the photosynthetic rate, transpiration rate and stomatal conductance. In *Leucaena leucocephala* plantlets; however, responses were manifested mainly in points of foliar and radical growth, reinforcing the hypothesis of presence of auxins in the leachate, which could stimulate rapid cell differentiation and proliferation in the apical meristematic tissue (Duran et al., 2018). Iriany et al. (2018) noted that banana pseudostem along with water hyacinth and rice straw can be used as materials for organic mulch sheets by adding organic matter to the soil, having strength and strength, and helping plants to adapt to climate changes.

## Conclusion

The main perspective of this study is the promotion of root growth with the use of pseudostem waste, consequently helping to reduce environmental impacts caused by its disposal and of use of chemical fertilizers.

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