academicJournals

Vol. 12(21), pp. 1852-1860, 25 May, 2017
DOI: 10.5897/AJAR2016.11702
Article Number: 459FB6D64450
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

The growth and nutrition of pineapple (*Ananas comosus* L.) plantlets under different water retention regimes and manure

Vander Mendonça[1]*, Luciana Freitas de Medeiros Mendonça[1], Eduardo Castro Pereira[1], Grazianny Andrade Leite[2], José Maria da Costa[1] and Francisco Mickael Câmara de Medeiros[3]

[1]Department of Plant Sciences (DCV), Universidade Federal Rural do Semi-Árido, 59.625-900, Mossoró/RN, Brazil.
[2]Universidade Federal Rural do Pernambuco, 52.171-900, Cabo de Santo Agostinho/PE, Brazil.
[3]Department of Agriculture, Universidade Federal de Lavras, 37.200-000, Lavras/MG, Brazil.

Received 13 September, 2016; Accepted 15 March, 2017

Despite the many advantages of pineapple plants offered by micropropagation, there is difficulty in rooting and slowness in the growth of seedlings, requiring a long period of acclimatization in the greenhouses. The aim of this study was to evaluate organic sources and water retention polymers used for pineapple cultivar seedlings during the acclimatization phase. The experimental design was randomized blocks in a 2 × 2 × 3 factorial design. Bovine and goat manures were the organic sources that provided the greatest increases in growth characteristics for both cultivars. Goat manure was the organic sources that provided the greatest increases in growth characteristics for both cultivars. Provid seedlings with 20 leaves, height of 19.4 cm, diameter of the rosette of 26.03 mm and 23.1 cm of length of the root system at 270 days to "Vitória". For "Imperial" the goat manure promoted seedlings with 20 leaves and height of 27.8 cm in 220 days. Bovine manure provided greater nutritional gains to seedlings. The use of the hydrogel did not favor the growth of shoots. However, it resulted to the increase in root dry mass when incorporated into the manure for both cultivars. The "Imperial" cultivar had a higher macronutrient intake on seedlings' leaves than the "Vitória" cultivar at 270 days of acclimatization.

Key words: Fruit production, *Ananas comosus*, propagation, hydrogel, organic fertilizers.

INTRODUCTION

In 2014, one year after a drought affected the pineapple culture in north of the country, a survey by the Brazilian Institute of Geography and Statistics (IBGE) indicated that the area cultivated with pineapple was 66,544 ha,

*Corresponding author. E-mail: vanderm2000@hotmail.com

with a production of 1,762,938,000 fruits (IBGE, 2016). The states of Paraíba, Bahia and Rio Grande do Norte were major producers in the region.

The state of Rio Grande do Norte ranks sixth among states with the largest production of pineapples. It is concentrated mainly in the municipalities of Ielmo Marinho, Touros and Pureza, and consists of an activity with a great economic and social importance for Rio Grande do Norte.

With a high demand by the market, producers seek to increase the production of several pineapple cultivar seedlings. In this sense, new cultivars have been released both for a better fruit acceptance and an increase of plants resistant to the fusarium wilt disease caused by the fungus *Fusarium subglutinans* f. sp. Ananas, which has been one of the major diseases of this culture leading to major losses in agriculture (Matos et al., 2009; Ventura et al., 2009).

Furthermore, to obtain uniform, high quality, free of diseases and genetically superior seedlings, and especially to produce large-scale plants, micropropagation is an alternative propagation method used for this species (Cid, 2001). Despite many advantages offered by micropropagation for pineapples, there is difficulty in rooting and slowness of seedling growth (Moraes et al., 2010), requiring a long period of acclimatization in greenhouses (Teixeira et al., 2001). The decrease in such period may be an option to lower the cost of the technique and increase the production of seedlings.

In addition, the development of technologies that help plants to tolerate prolonged periods of drought and the use of more tolerant cultivars are essential to minimize the negative impacts of drought. Among the technologies available for water supply to plants, soil conditioners also known as water absorbing polymers or hydrogels have been widely used in agriculture (Ferreira et al., 2014). However, studies with fruits, particularly concerning the formation of seedlings, are still scarce. The use of organic substrates with suitable characteristics for a planted species is also an important technique available for plant propagation as it enables reducing consumption of inputs, such as chemical fertilizers, pesticides and labor (FERMINO and KAMPF, 2003). It also contributes to the reduction of the acclimatization period. Some studies have been conducted incorporating organic matter into substrates for the production of fruit seedlings (Sousa, 1994; Muller et al., 1979; Peixoto, 1986).

In this sense, the aim of this study was to evaluate organic sources and water retention polymers used for pineapple cultivar seedlings during the acclimatization phase.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse located at the Federal Rural University of the Semi-Árido (UFERSA), Campus Leste, in Mossoró, Rio Grande do Norte (RN) state. According to Sobrinho et al. (2011), the climate of Mossoró is BSwh', is a very hot semi-arid region with a rainy season in the summer extending to the autumn. The average temperature is 27.4°C, with a very irregular annual rainfall and an average relative humidity of 68.9%. Pineapple seedlings (*Ananas comosus* L. Merril), cultivars "Vitória" (INCAPER, 2006) and "Imperial" (EMBRAPA, 2003), propagated *in vitro* in plastic pots with a 200 ml capacity were provided by the BioClone Biotechnology Laboratory and maintained in a MS medium described by Murashige and Skoog (1962) without growth regulators and vitamins. Upon arrival at the UFERSA (June 15, 2013), the seedlings were transferred to a pre-acclimatization greenhouse of the Seedling Production Sector of UFERSA, where they remained until the installation of the experiment (July 17, 2013) receiving water every day by an automated micro-sprinkler system.

The experiment was installed when seedlings were at 30 days of pre-acclimatization in the greenhouse. The substrate used for filling the pots (2 L) was composed (v/v) by 70% of soil and 30% of the organic sources tested in the experiment. The organic sources tested were bovine manure (BM), goat manure (GM) and commercial organic compost (OC) Eco Fértil®. They were sieved and mixed until complete homogenization as recommended by Moreira (2001). A sample was taken from each material (soil + organic source) and sent to the soil analysis laboratory of UFERSA for analysis of chemical attributes (Table 1).

The hydrogel was purchased in a commercial form (Biogel Hydro Plus, Biossementes) and the dose was adapted from the dose recommended by the manufacturer for pineapple crops (4 g per pot). The dose was mixed homogeneously to the dry substrate. During the experiment, there were daily irrigations at late morning and late afternoon by a micro-sprinkler system with an average flow of 40 L h^{-1}.

The experimental design was randomized blocks in a 2 × 2 × 3 factorial design. The factors were two pineapple cultivars ("Imperial" and "Vitória"), two hydrogel applications (with and without addition of hydrogel to the substrate), and three tested organic sources (bovine manure, goat manure and organic compost), totaling 12 treatments with 4 replications and 5 plants per plot. Evaluations of growth were performed on the day of transplantation and at 120, 150, 180, 210, 240 and 270 days after seedlings were transplanted to pots. The number of leaves, plant height (cm) and leaf rosette diameter (cm) were quantified.

At the end of the experiment (270 days), the plants were evaluated regarding the number of leaves, plant height (cm), leaf rosette diameter (cm), root length (cm) and weight of root and shoot dry matter (g). The biometric evaluations of plants were performed using rulers. Height measurements were performed from the base of the plants to the highest point of the leaves without changing the structure of the plants. The rosette diameter was measured between the biggest opposing leaves. The length of the "D" leaf was measured after its removal. To analyze fresh and dry matter, precision scales were used. After measuring the fresh weight of shoots, the plant material was packed in paper bags and placed to dry in a forced-air circulation oven at 65°C until constant weight to obtain dry mass.

At the end of the experiment, a nutritional analysis of shoots was conducted. Shoots were separated from roots and washed in running and deionized water, dried with cotton and then sent to the plant nutrition laboratory of UFERSA to perform the foliar chemical analysis of macronutrients and micronutrients. The samples were analyzed as for levels of N, P, K, Ca and Mg according to Battaglia et al. (1983).

Data were submitted to analysis of variance using the software SISVAR (Ferreira, 2011) according to the factorial design adopted and significant means were compared by Scott Knott test at 5% probability.

Table 1. Chemical analysis of the substrates (30% organic sources + 70% soil) used for the acclimatization of pineapple cultivar seedlings. Mossoró-RN, UFERSA, 2014.

Treatment	N	pH	EC	O.M	P	K^+	Na^+	V	m	PST
	g kg^{-1}	water	dS/m	g kg^{-1}		mg dm^{-3}			%	
Soil + BM	0.42	6.03	0.75	21.05	173.64	1120.2	452.86	100	0	19.25
Soil + GM	0.63	5.33	0.9	14.8	183.29	620.25	119.8	100	0	6.74
Soil + OC	0.32	5.3	1.59	36.03	204.51	289.24	1062.3	100	0	47.22

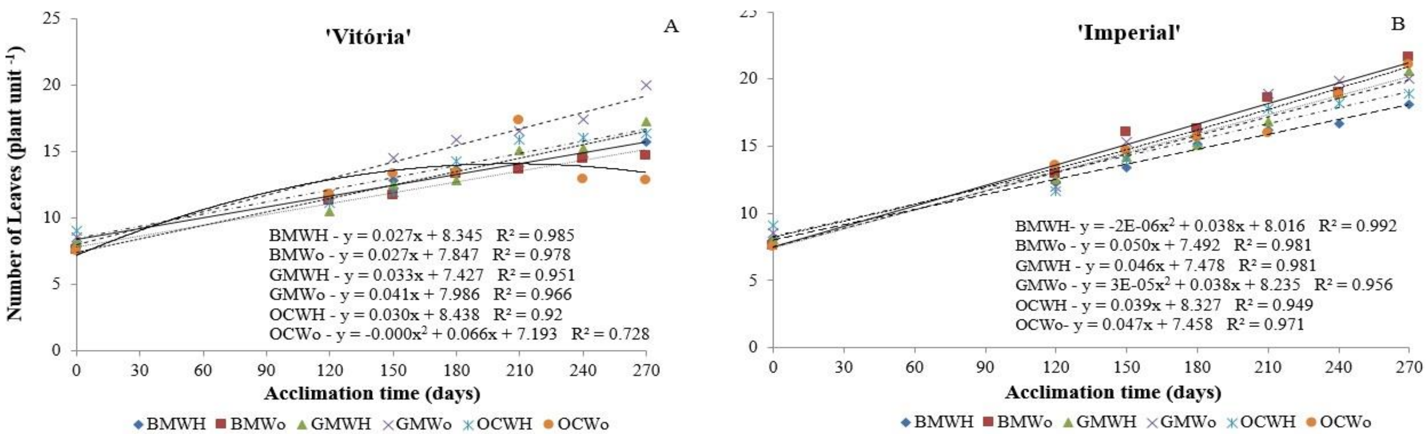

Figure 1. Number of leaves (plant^{-1}) of "Vitória" (A) and "Imperial" (B) pineapple seedlings grown in different organic sources. Bovine manure (BM), goat manure (GM) and organic compost (OC) with (W) and without (Wo) hydrogel (H) at 0, 120, 150, 180, 210, 240 and 270 days of acclimatization.

RESULTS AND DISCUSSION

For the "Vitória" cultivar, only goat manure obtained 17.3 leaves at 210 days potentiated by not using the hydrogel (Figure 1A). The "Imperial" cultivar obtained 17 leaves with all organic carbon sources tested. This happened earlier when the manure was used without the hydrogel (17.1 leaves at 190 days) (Figure 1B).

Berilli et al. (2011) claim 17 visible leaves of acclimated seedlings to be the minimum appropriate amount to transfer them to the field. The goat manure provided in general greater increases in the number of leaves for "Vitória", which may be attributed to the higher N content in its composition (Table 1). This is because this nutrient is responsible for the production of new cells and tissues as it is present in chloroplasts as a constituent of the chlorophyll molecule (photosynthesis). It also participates in the synthesis of vitamins, hormones, coenzyme, alkalis and other compounds.

For the "Imperial" cultivar, as Oliveira and Natale (2013) states, the increase in N rates linearly decreases P, K and S contents and decreases the Mn content quadratically. The increase in K doses linearly decreases leaf contents of N, P, Ca and Mg. This may have happened in this study because the organic sources that provided a greater increase were the sources with less content of N.

Coelho et al. (2007) opine that the absence of effects on height during the first evaluations and the greater growth in the seventh month after transplantation indicate a slow growth of pineapple seedlings during the early stage of development. Also, according to Teixeira et al. (2009), a variable period (between six and eight months) in a greenhouse is necessary for plants to reach 20 to 30 cm, a size suitable for transfer to the field.

On the subject of "Vitória", that number (20 cm) was obtained by using goat manure without hydrogel. It reached 19.6 cm after 270 days (Figure 2A). The "Imperial" cultivar reached 20 cm at day 220 using goat manure and incorporating hydrogel into the substrate (Figure 2B).

Sousa Júnior et al. (2001) state that plant height is a variable that allows visual assessments. It is very important and even decisive to define the time of transplanting seedlings to the field. Coelho et al. (2007) suggest that the absence of effects on height during the first evaluations and the greater growth in the seventh month after transplantation indicate a slow growth of pineapple seedlings during the early stage of development.

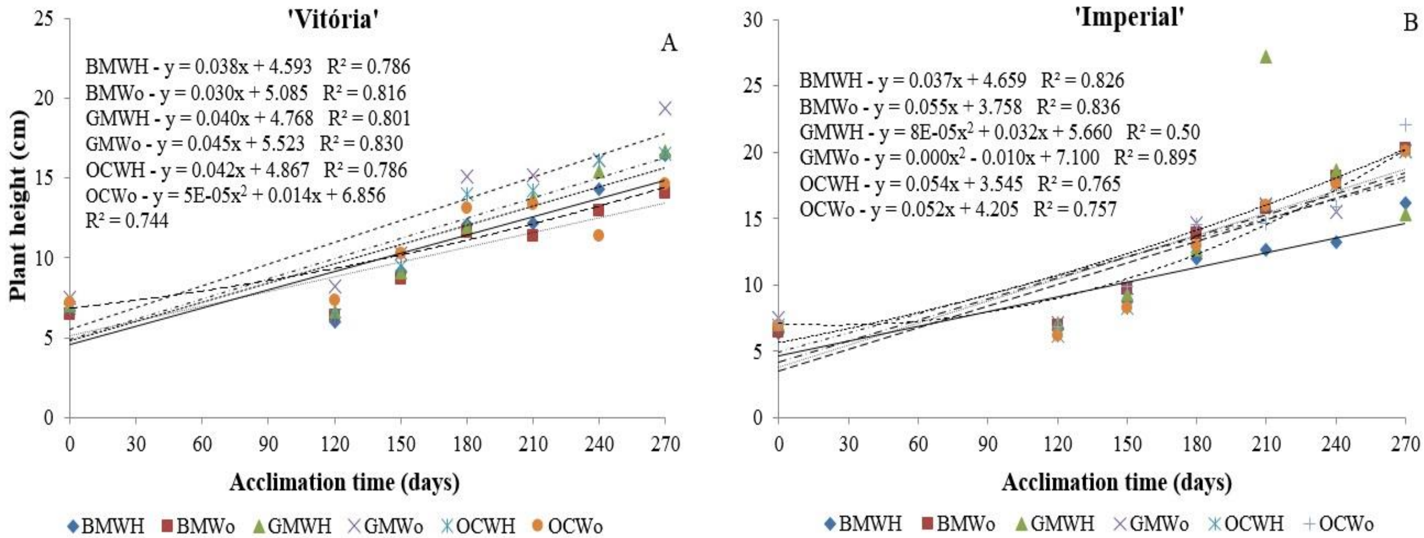

Figure 2. Plant height (cm) of "Vitória" (A) and "Imperial" (B) pineapple seedlings grown in different organic sources: Bovine manure (BM), goat manure (GM) and organic compost (OC) with (W) and without (Wo) hydrogel (H) at 0, 120, 150, 180, 210, 240 and 270 days of acclimatization.

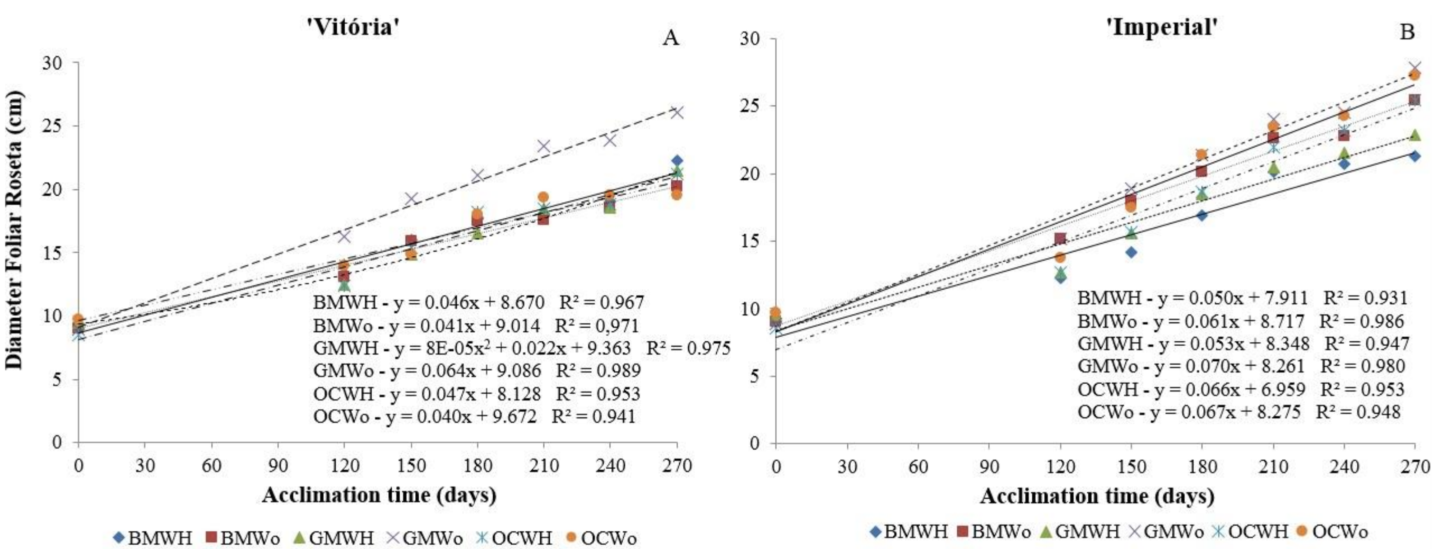

Figure 3. Leaf rosette diameter (cm) of "Vitória" (A) and "Imperial" (B) pineapple seedlings grown in different organic sources: Bovine manure (BM), goat manure (GM) and organic compost (OC) with (W) and without (Wo) hydrogel (H) at 0, 120, 150, 180, 210, 240 and 270 days of acclimatization.

Mews et al. (2015), studying the effects of hydrogel and urea on the production of *Handroanthus ochraceus* seedlings, found that for plant height and stem diameter the doses that had the highest increase values were between 2 and 4 g both for urea and hydrogel. To Lopes et al. (1999), adequate nitrogen nutrition automatically increases the foliar nitrogen and phosphorus, consequently increasing the growth and the production of high-quality seedlings.

During the study period, pineapple seedlings did not reach the minimum value of 30 cm recommended by Berilli et al. (2011) as the ideal value for leaf rosette diameter of seedlings suitable to field conditions. The best approximation was provided by the goat manure without hydrogel, when "Vitória" obtained 28 cm at day 270 of acclimation and "Imperial" obtained 27.4 cm at day 270 (Figure 3).

However, such values were similar to those found by Baldotto et al. (2009), who studied the performance of "Vitória" pineapple cultivar in response to the application

Table 2. Mean values of seedlings growth parameters of “Vitória” and “Imperial” for number of leaves (NL), plant height (PHe), leaf rosette diameter (LRF), length of the root system (LRS), shoot dry matter (SDM), root dry matter (RDM), total dry matter (TDM), ratio between shoot and root dry matter (SDM/RDM) and chlorophyll content (CC).

Cultivars	NL	PHe	LRF	LRS	SDM	RDM	TDM	SDM/RDM	CC
'Vitória'	15.96^{b}	16.3^{b}	21.7^{b}	21.05^{b}	4.8^{b}	0.7^{b}	4.8^{b}	6.7^{a}	5.6^{b}
'Imperial'	20.04^{a}	19.54^{a}	25.01^{a}	26.4^{a}	8.4^{a}	2.5^{a}	11.7^{a}	6.6^{a}	9.7^{a}

Means followed by the same letters do not differ by Scott Knott test (p≤0.05).

Table 3. Means for number of leaves (NL), plant height (PHe), leaf rosette diameter (LRD) and length of the root system (LRS) of seedlings of "Vitória" and "Imperial" pineapple cultivars grown on substrates containing bovine manure (BM), goat manure (GM) and organic compost (OC) with and without hydrogel at 270 days of acclimatization. Mossoró, RN, 2014.

OS ('Vit.')	NL		PHe		LRD		LRS	
	With	Without	With	Without	With	Without	With	Without
BM	15.7^{Aa}	14.6^{Ba}	16.4^{Aa}	14.05^{Aa}	22.3^{Aa}	20.2^{Ba}	21.6^{Aa}	22.6^{Aa}
GM	17.3^{Aa}	20^{Aa}	16.7^{Aa}	19.4^{Aa}	21.5^{Aa}	26.03^{Aa}	21.3^{Aa}	23.1^{Aa}
OC	16.4^{Aa}	12.8^{Bb}	16.5^{Aa}	14.6^{Aa}	21.2^{Aa}	19.1^{Ba}	19.9^{Aa}	17.9^{Ba}
OS ('Imp.')								
BM	18.1^{Ab}	21.6^{Aa}	21^{Aa}	24.5^{Aa}	21.3^{Aa}	25.4^{Aa}	24.2^{Ba}	25^{Aa}
GM	20.6^{Aa}	20.03^{Aa}	24.2^{Aa}	14.6^{Aa}	22.9^{Aa}	27.8^{Aa}	24.3^{Ba}	26.9^{Aa}
OC	18.9^{Aa}	21.1^{Aa}	22.2^{Aa}	20.2^{Aa}	25.4^{Aa}	27.2^{Aa}	29.8^{Aa}	28.6^{Aa}

Means followed by the same capital letters do not differ regarding organic sources. Means followed by the same lowercase letters do not differ regarding the use of hydrogel by Scott Knott test (p≤0.05).

of humic acids during acclimatization. The authors found maximum values of 25.33 and 21.83 cm when 10 and 20 mmol/L of C derived from humic acids of a vermicompost when used respectively.

Considering these values as reference, the goat manure without hydrogel provided 19.3 cm for "Vitória" and 20 cm for "Imperial" at 165 days.

At 270 days, when a destructive analysis of pineapple seedlings was performed, there was a superiority of the "Imperial" cultivar over the "Vitória" cultivar. This superiority was recorded during the evaluation process independent of the applied treatment (Table 2). Probably, this superiority is genetic because the "Imperial" cultivar, according to Matos et al. (2016), has a size similar to the "Pérola" cultivar, with a good development and growth, and a good seedling production.

The comparative performance of the cultivars "Vitória" and "Imperial" with respect to growth, especially during the acclimatization phase of seedlings, are not described in the literature. For "Vitória", the organic sources did not promote an increase in the number of leaves, height of pineapple seedlings, leaf rosette diameter and root growth when hydrogel was incorporated into the substrate used. However, when there was the incorporation of the hydrogel, the goat manure provided higher increases in the number of leaves and leaf rosette diameter. For the length of the root system, goat and bovine manures provided higher gains irrespective of using hydrogel. However, statistical differences for these organic sources were only observed without the incorporation of hydrogel into the substrate (Table 3).

For the "Imperial" cultivar, the hydrogel negatively affected the number of leaves when bovine manure was used as source. However, the organic sources and the hydrogel did not influence plant height and leaf rosette diameter. The length of the root system of the "Imperial" cultivar had higher average values when the hydrogel was not incorporated into the substrate, except for the organic compost, which was in turn potentialized by the incorporation of the hydrogel, statistically differing from the other organic sources (Table 3).

The superiority of bovine and goat manures for shoots of pineapple seedlings, notably "Vitória", can be explained by the higher content of nitrogen (N) and potassium (K) in these sources. These are the elements that pineapple seedlings require the most. Such elements are directly involved in photosynthesis and respiration, which possibly resulted in an increased performance of seedlings when goat and bovine manures were incorporated into the substrate.

Andrade et al. (2015), studying an organic fertilizer for pinecone plants in function of organic substrates, concluded that the substrate containing bovine manure is a great choice for the formation of pinecone seedlings.

Table 4. Means for shoot dry matter (SDM), root dry matter (RDM), chlorophyll index (CI) and ratio between shoot and root dry matter (SDM/RDM) of seedlings of "Vitória" and "Imperial" pineapple cultivars grown on substrates containing bovine manure (BM), goat manure (GM) and organic compost (OC) with and without hydrogel at 270 days of acclimatization. Mossoró, RN, 2014.

OS ('Vit.')	SDM		RDM		CI		SDM/RDM	
	With	Without	With	Without	With	Without	With	Without
BM	4.3^{Aa}	4.8^{Aa}	1.1^{Aa}	0.8^{Aa}	7.5^{Aa}	4^{A}b	6.3^{Aa}	5^{Aa}
GM	3.5^{Aa}	7.7^{Aa}	0.53^{Aa}	0.9^{Aa}	5.1^{Aa}	6^{Aa}	7.3^{Aa}	4.8^{Aa}
OC	5.7^{Aa}	3.1^{Aa}	0.5^{Aa}	0.3^{Aa}	5.2^{Aa}	5.7^{Aa}	9^{Aa}	7.5^{Aa}
OS ('Imp.')								
BM	10.4^{Aa}	7.5^{Aa}	3.02^{Aa}	2.3^{Aa}	9.9^{Aa}	11.3^{Aa}	4.6^{Aa}	64^{Aa}
GM	6.5^{Aa}	8.7^{Aa}	1.6^{A}b	3.2^{Aa}	8^{Aa}	9.9^{Aa}	7.4^{Aa}	7.4^{Aa}
OC	7^{Aa}	10.1^{Aa}	17^{Aa}	3.2^{Aa}	8.5^{Aa}	10.4^{Aa}	5.5^{Aa}	8.5^{Aa}

Means followed by the same capital letters do not differ regarding organic sources. Means followed by the same lowercase letters do not differ regarding use of hydrogel by Scott Knott test (p≤0.05).

Alves and Pinheiro (2008) stated that goat manure is a valuable product and its use provides an important alternative source of income for producers. Some studies have examined the potential use of goat manure and all of them stress its value. Comparing it with bovine manure, however, few data exist in the literature regarding its use, mainly during the acclimatization of pineapple seedlings.

For "Imperial", the increase in N rates linearly decreases P, K and S leaf contents and quadratically decreases the Mn content. The increase in K doses linearly decreases leaf contents of N, P, Ca and Mg (Oliveira and Natale, 2013). This may have happened in this study since the organic sources (organic compost) that provided a greater increase in the length of the root system were the sources with less content of N and K, but with a higher content of organic matter and phosphorus.

According to Lopes (1989), phosphorus promotes early root formation, early root growth, improves the efficiency of water usage and, when at a high level in the soil, helps to keep its absorption by seedlings, even under high soil moisture conditions, which happened in this work due to the action of the hydrogel.

Regarding shoot dry matter, organic sources provided no significant differences for both cultivars regardless of the use of hydrogel (Table 4). However, although there were no significant differences, the goat manure without hydrogel produced greater increases in the shoot dry matter of the "Vitória" cultivar, reflecting the gain that goat manure without hydrogel provided for a number of leaves and length of shoots.

Araújo et al. (2010), studying goat manure in the composition of substrate aiming the formation of papaya seedlings, also found that shoot dry matter responded better to a treatment containing goat manure, which differed significantly from other treatments.

There were no significant differences regarding organic sources and the use of hydrogel for the two cultivars regarding root dry matter, except for the "Imperial" cultivar because the hydrogel negatively affected the goat manure (Table 4). Nevertheless, the highest averages for both "Vitória" and "Imperial" were observed with the use of bovine manure with hydrogel, which indicates that the use of the polymer for this cultivar provided a higher number of roots/rootlets at the expense of their size.

Wofford Jr. (1992) pointed out that the roots of the plants grow inside the beads of the hydrated polymer, with a great development of root hairs providing a larger contact surface of the roots with water sources and nutrients, facilitating absorption.

For the "Imperial" cultivar, there was a considerable performance of the organic compost without hydrogel regarding root dry mass, reflecting the increase in the length of the root system with that treatment.

Flannery and Busscher (1982) point out that despite the contribution to water retention capacity offered by the polymer, it was detrimental to azalea plants not because it was toxic, but because of the lack of aeration in the root system due to presence of the hydrated polymer on the substrate. This was more evident as the polymer dose in the substrate increased. In addition, the organic compost incorporated into the substrate may have contributed to the negative performance of the hydrogel.

Almeida et al. (2011), studying alternative substrates for the production of yellow passion fruit seedlings, found that the highest shoot, root and total dry matter was observed when substrates containing soil + bovine manure, soil + goat manure and Solaris® + bovine manure were used, especially the substrate soil + goat manure, which showed the highest average for these variables.

For the ratio between shoot and root dry matter, no statistical significant effects were observed for both cultivars regarding organic sources and incorporation of hydrogel into the substrate. Regarding chlorophyll content, the incorporation of the hydrogel into the

Table 5. Means for contents of leaf nitrogen (LNC), phosphorus (LPC), potassium (LKC), magnesiun (LMgC) and calcium (LCaC) of seedlings of "Vitória" and "Imperial" pineapple cultivars grown on substrates containing bovine manure (BM), goat manure (GM) and organic compost (OC) with and without hydrogel at 270 days of acclimatization. Mossoró, RN, 2014.

OS ('Vit.')	LNC		LPC		LKC		LCaC		LMgC	
	With	Without	With	Without	With	Without	With	Without	With	Without
BM	13.7^{Aa}	11.7^{Aa}	3.3^{Aa}	2.2^{Ab}	33.6^{Aa}	31.8^{Aa}	1.1^{Aa}	0.9^{Ba}	0.18^{Aa}	0.14^{Aa}
GM	9.6^{Ba}	9.3^{Aa}	2.7^{Aa}	2.6^{Aa}	29.7^{Aa}	20.6^{Bb}	0.8^{Aa}	0.9^{Ba}	0.14^{Aa}	0.13^{Aa}
OC	8.2^{Ba}	9.6^{Aa}	1.7^{Ba}	2.2^{Aa}	21.6^{Ba}	23.3^{Ba}	0.7^{Ab}	1.5^{Aa}	0.16^{Aa}	0.22^{Aa}
OS ('Imp.')										
BM	9.6^{Aa}	11.1^{Aa}	2.1^{Aa}	1.7^{Aa}	28^{Aa}	18.2^{Ab}	1.9^{Aa}	1.9^{Aa}	0.26^{Aa}	0.28^{Aa}
GM	9.6^{Aa}	11.7^{Aa}	2.1^{Aa}	2.1^{Aa}	19.3^{Ba}	19.9^{Aa}	1.9^{Aa}	2.1^{Aa}	0.3^{Aa}	0.26^{Aa}
OC	7.9^{Aa}	10.2^{Aa}	2^{Aa}	2.2^{Aa}	19.3^{Ba}	18.03^{Aa}	2^{Aa}	2.2^{Aa}	0.3^{Aa}	0.28^{AA}

Means followed by the same capital letters do not differ regarding organic sources. Means followed by the same lowercase letters do not differ regarding the use of hydrogel by Scott Knott test ($p \leq 0.05$).

substrate containing bovine manure provided a higher increase in the chlorophyll content for the "Vitória" cultivar when compared to the non-use of hydrogel with this organic source. It was statistically different. For the "Imperial" cultivar, there was no influence by organic sources and hydrogel (Table 4).

The difference in nitrogen content between organic sources was not sufficient to trigger differences in chlorophyll content. Baldotto et al. (2009), studying the performance of the pineapple "Vitória" in response to the application of humic acids during acclimatization, found a higher intensity of the green color when 40 mmol/L of humic acid filter cake were used. This treatment showed nitrogen and magnesium contents of 23.33 and 35.08%, respectively, inferior to the treatment with higher C and Mg contents.

Furthermore, the bovine manure used for the "Vitória" cultivar may have contributed synergistically to the hydrogel for the retention of N, and was reflected in a greater increase in the chlorophyll content in this treatment. Fagundes et al. (2015), studying a water absorbing polymer for the reduction of nutrients leached during the production seedlings of yellow passion fruits, found that N losses by leaching decreased as the dose of the polymer increased: there was a decrease of 47.8% on the leached material of a Bioplant® substrate and a decrease of 33.4% on a Provaso® substrate during the evaluation of nutrients.

The bovine manure was the organic source that contributed the most to the increase in leaf nitrogen content in "Vitória" pineapple seedlings regardless of the hydrogel. However, the bovine manure was statistically higher only with the addition of the hydrogel to the substrate. As for the "Imperial", nitrogen was not influenced by organic sources and hydrogel (Table 5).

Fagundes et al. (2015), studying water absorbing polymers for the reduction of nutrients leached during the seedling production of yellow passion fruits, found that N losses by leaching decreased as the dose of the polymer increased in relation to the leached material without the incorporation of a water absorbing polymer. Furthermore, bovine manure may have influenced the substrate and was structurally reflected in the decrease of the leachate of this nutrient.

Regarding phosphorus, bovine and goat manures performed better with the "Vitória" cultivar when the hydrogel was used, being statistically different. However, only bovine manure was positively influenced by the hydrogel. For the "Imperial", there was no influence of organic sources and hydrogel (Table 5).

Potassium also behaved similarly. Bovine and goat manures increased to a higher degree the leaf content of potassium in "Vitória" when the hydrogel was not incorporated into the substrate. When the hydrogel was used, only bovine manure provided an increase of potassium in leaves of the "Vitória" cultivar. For the "Imperial" cultivar, the bovine manure also provided a higher leaf potassium accumulation when the hydrogel was incorporated into the substrate, differing significantly from the non-use of the hydrogel for this organic source (Table 5).

It is important to note that bovine manure is the source with the highest amount of potassium in its chemical composition among the organic sources evaluated in this study (Table 1). Oliveira and Natale (2013), studying "Imperial" leaf levels of macronutrients and micronutrients in function of nitrogen and potassium doses, stated that the K contents in leaves increased linearly and positively due to the increase in potassium doses that were applied. In addition, the bovine manure may have provided greater bio stabilization to the substrate, with lower losses even without the addition of the polymer. This is possible because its characteristics contributed to increase the water storage capacity and the availability of nutrients to the plants. Combined with it, the availability of water with the addition of the polymer into the substrate promotes the uptake of nutrients by plants (Oliveira et al., 2004), preventing it from being lost by leaching.

According to Table 5, there was a tendency of bovine manure to provide a greater increase in calcium in the "Vitória" cultivar when the hydrogel was used. However, when the hydrogel was not incorporated into the substrate, the organic compost provided higher leaf calcium content, differing statistically by Scott Knott test at 5% probability. For the "Imperial" cultivar, there was no influence of organic sources and the use of the hydrogel. For magnesium, there were no statistical differences regarding organic sources and use of the hydrogel for the two cultivars. In addition, the average values presented in this work for leaf calcium and magnesium contents were lower than those considered suitable by nutritional studies with pineapple seedlings during the acclimatization stage (Teixeira et al., 2009; Baldotto et al., 2009; Leonardo et al., 2013; Ramos et al., 2011; Cruz et al., 2015).

Oliveira and Natale (2013) studied leaf contents of macronutrients and micronutrients in "Imperial" pineapple seedlings and found that, just as Ca, Mg leaf contents decreased with a negative linear effect as the doses of K_2O increased, a behavior similar to that was found by Spironello et al. (2004).

Conclusions

Goat manure was the organic sources that provided the greatest increases in growth characteristics for both cultivars, providing seedlings with 20 leaves, height of 19.4 cm, diameter of the rosette of 26.03 mm and 23.1 cm of length of the root system at 270 days to "Vitória". For "Imperial" the goat manure promoted seedlings with 20 leaves and height of 27.8 cm in 220 days. The bovine manure provided greater nutritional gains to the seedlings. The use of the hydrogel did not favor shoot growth. However, it contributed to the increase in root dry mass when incorporated into the bovine manure for both cultivars. The "Imperial" cultivar had a higher macronutrient transfer to the seedlings' leaves than the "Vitória" cultivar at 270 days of acclimatization.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

To Universidade Federal Rural do Semi-Árido (UFERSA), to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), for granting a Researcher 1D grant (Process Number: 305933 / 2013-2. Call: PQ 2013). First author of this article, which provides several researches, one of which gave rise to this article.

REFERENCES

Almeida JPN, Barros GL, Silva GBP, Procópio IJS, Mendonça V (2011) Substratos alternativos na produção de mudas de maracujazeiro amarelo em bandeja. Rev. Verde 6(1):188-195.

Alves FSF, Pinheiro RR (2008). O esterco cabrino e ovino como fonte de renda. Brasília: Embrapa,. Disponível em: < http://www.agricultura.gov.br/>. Acesso em: 6 mar. 2016.

Andrade AF, Véras MLM, Araújo DL, Melo Filho JS, Andrade R (2015). Aplicação de fertilizante orgânico em plantas de pinha (*Annona squamosa* L.) em função de substratos orgânicos. Rev. Terc. Incl. NUPEAT–IESA–UFG. 5(2):141-154.

Araújo WBM, Alencar RDA, Mendonça V, Medeiros EVM, Andrade RC, Araújo RR (2010). Esterco caprino na composição de substratos para formação de mudas de mamoeiro. Ciênc. Agrotecnol. 34(1):68-73.

Baldotto LEB, Baldotto MA, Giro VB, Canellas LP, Olivares FL, Bressan-Smith R (2009). Desempenho do abacaxizeiro 'Vitória' em resposta à aplicação de ácidos húmicos durante a aclimatação. Rev. Bras. Ciênc. Solo 33(1):979-990.

Bataglia OC, Furlani AMC, Teixeira JPF, Furlani PR, Gallo JR (1983). Métodos de análise química de plantas. Campinas: IAC. 48. (Boletim Técnico, 78).

Berilli SS, Carvalho AJC, Freitas SJ, Berilli APCG, Santos PC (2011). Crescimento de mudas de abacaxizeiro cv. Vitória durante a aclimatação em função do seu tamanho inicial. Revista Brasileira de Fruticultura. Volume Especial E. 632-637.

Cid LPB (2001). A propagação *in vitro* de plantas. O que é isso? Biotecnol. Ciênc. Desenvolv. 3(19):16-21.

Coelho RI, Lopes JC, Carvalho AJC, Amaral JAT, Matta FP (2007). Estado nutricional e características de crescimento do abacaxizeiro 'Jupi' cultivado em latossolo amarelo distrófico em função da adubação com NPK. Ciênc. Agrotecnol. 31(6):1696-1701.

Cruz LIB, Cruz MCM, Castro GDM, Fagundes MCP, Santos JB (2015). Crescimento e nutrição de mudas de abacaxizeiro 'Imperial' associadas com o fungo Piriformospora indica e aplicação de herbicidas. Semina: Ciênc. Agrár. 36(4):2407-2422.

Embrapa (2003). Embrapa Mandioca E Fruticultura. Embrapa lança abacaxi resistente à fusariose na Paraíba. Disponível em: <http://www.cnpmf.embrapa.br/extra_2003/015_Imperial_%20PB_14_05.htm> Acesso em: 23 novembro.

Ibge – Instituto Brasileiro de Geografia e Estatística (2016). Sistema IBGE de Recuperação Automática – SIDRA. Agricultura. Disponível em: http://www.ibge.gov.br/home/disseminacao/eventos/workshop/sidra.shtm

Fagundes MCP, Cruz MCM, Carvalho RP, Oliveira J, Soares BC (2015). Polímero hidroabsorvente na redução de nutrientes lixiviados durante a produção de mudas de maracujazeiro-amarelo. Rev. Caatin. 28(1):121-129.

Fermino MH Kampf AN (2003). Uso do solo bom Jesus com condicionadores orgânicos como alternativa de substrato para plantas. Pesqui. Agropecu. Gaúcha 9(1/2):33-41.

Ferreira DF (2011). Sisvar: A Computer Statistical Analysis System. Ciência e. agrotecnologia. 35(6): 1039-1042.

Ferreira EA, Silva VA, Silva EA, Silveira HRO (2014). Eficiência do hidrogel e respostas fisiológicas de mudas de cultivares apirênicas de citros sob défice hídrico. Pesqui. Agropecu. Trop. 44(2):158-165.

Flannery RL, Busscher WJ (1982). Use of a synthetic polymer in potting soil to improve water holding capacity. Commun. Soil Sci. Plant 13(2):103-111.

Leonardo FAP, Pereira WE, Silva SM, Costa JPC (2013). Teor de clorofila e índice SPAD no abacaxizeiro cv. Vitória em função da adubação nitrogenada. Rev. Bras. Frutic. 35(2):377-383.

Lopes AS (1989). Manual de fertilidade do solo. Piracicaba: Fundação Cargill 177.

Lopes PSS, Melo B, Neto FRC, Ramos JD, Carvalho JD (1999). Adubação nitrogenada e substratos no crescimento de mudas de maracujazeiro amarelo em tubetes. Rev. Univ. Alfenas 5:3-8.

Matos AP, Junghans DT, Spironello A (2016). Variedades de abacaxi resistentes à fusariose. Disponível em <

http://ainfo.cnptia.embrapa.br/digital/bitstream/item/42932/1/Variedades-Abacaxi-Aristoteles.pdf >. Acesso em 15 de Abril de 2016.

Mews CL, Sousa JRL, Azevedo GTOS, Souza AM (2015). Efeito do Hidrogel e Ureia na Produção de Mudas de *Handroanthus ochraceus* (Cham.) Mattos. Flor. Ambient. 22(1):107-116.

Moraes AM, Almeida FAC, Bruno RLA, Filho JC, Nunes ST, Gomes JP (2010). Micropropagação de abacaxizeiro cv. Emepa 1. Rev. Bras. Eng. Agríc. Ambient. 14(9):932-936.

Moreira MA (2001). Produção e aclimatização de mudas micropropagadas de abacaxizeiro: *Ananas comosus* (L) Merrill cv. Pérola. Lavras: 81 f. Tese (Doutorado em Fitotecnia) – UFLA.

Muller CH, Reis GG, Muller AA (1979). Influência do esterco no crescimento e no acúmulo de nutrientes em mudas de mamão Havaí (*Carica papaya)*. Belém: CPATU. Comun. Técn. P 3014.

Murashige T, Skoog F (1962). A revised medium for rapid growth and biossays with tobacco tissue cultures. Physiol. Plant. 15:473-497.

Oliveira RA, Rezende LS, Martinez MA, Miranda GV (2004). Influência de um polímero hidroabsorvente sobre e a retenção de água no solo. Rev. Bras. Eng. Agríc. Ambient. 8(1):160-163.

Oliveira MG, Natale W (2013). Teores foliares de macro e micronutrientes no abacaxizeiro ‘imperial’ em função de doses de nitrogênio e potássio. Xxxiv congresso brasileiro de ciência do solo.

Peixoto JR (1986). Efeito da matéria orgânica, do superfosfato simples e do cloreto de potássio na formação de mudas do maracujazeiro amarelo (*Passiflora edulis* f. Favicarpa Deneger). 101f. Dissertação (Mestrado em Fitotecnia) – UFLA.

Ramos MJM, Monnerat PH Pinho LGR, Silva JA (2011). da. Deficiência de macronutrientes e de boro em abacaxizeiro ‘Imperial’: composição mineral. Rev. Bras. Frutic. 33(1):261-271.

Sobrinho JE, Pereira VC, Oliveira AD, Santos WO, Silva NKC, Maniçoba RM (2011). Climatologia da precipitação no município de Mossoró - RN. Período: 1900-2010. XVII Congresso Brasileiro de Agrometeorologia.

Sousa HU (1994). Efeito da composição e doses de superfosfato simples no crescimento e nutrição de mudas de bananeira (*Musa* sp) cv. Mysore obtidas por cultura de meristemas. Dissertação (Mestrado em Fitotecnia) – UFLA. 75.

Sousa Jr EE, Barboza SBSC, Souza LAC (2001). Efeitos de substratos e recipientes na aclimatação de plântulas de abacaxizeiro [*Ananas comosus* (L.) Merril] cv. Pérola. Pesqui. Agropecu. Trop. 31(2):147-151.

Spironello A, Quaggio JA, Teixeira LAJ, Furlani PR, Sigrist JMM (2004). Pineapple yield and fruit quality effected by NPK fertilization in a tropical soil. Rev. Bras. Frutic. 26(1):155-159.

Teixeira JB, Cruz ARR, Ferreira FR Cabral JR (2001). Biotecnologia aplicada à produção de mudas: Produção de mudas micropropagadas de abacaxi. Biotecnologia Cienc. Desenvolv. 3:42-47.

Teixeira LAJ, Quaggio JA, Zambrosi FCB (2009). Preliminary Dris normas for ’Smooth Cayenne’ pineapple and derivation of critical levels of leaf nutrient concentrations. Proceedings of the VI International Pineapple Symposium ISHS. Acta Hortic. 822:131-138.

Ventura JA, Costa H, Caetano LCS (2009). Abacaxi ‘Vitória’: Uma cultivar resistente à fusariose. Revista Brasileira de Frutic. Jabot. 31(4):931-123.

Wofford Jr DJ (1992). Worldwide research suggestions for cross-linked polyacrilamide in agriculture (*on line*). Disponível em: < http://www.hydrosource.com >.