Use of coproducts from vermiculite extraction in the production of *Piptadenia stipulacea* (Benth.) Ducke seedlings

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Abstract

The extraction of vermiculite generates coproducts that are deposited around mining industries resulting in environmental issues. The aim of this study was to evaluate the use of the equitable combination of fine and ultrafine dust obtained from the extraction of vermiculite, and the necessary amount of cattle manure (CM) added to the substrate to produce *Piptadenia stipulacea* (Benth.) Ducke seedlings. The experiment was conducted between April 2013 and February 2014, in the tree nursery of the UAEF/CSTR/UFCG, Patos, PB, Brazil, using a completely randomized design with six treatments. The treatments consisted of a lowland soil with T0=0% and T1=33% of CM (v/v) and the equitable combination of the coproducts from the vermiculite extraction with T2=0%, T3=5%, T4=10%, and T5=20% of CM. All treatments were performed with five replicates. The significant values obtained for the height, basal diameter, and shoot dry matter were inferior to those obtained from the seedlings developed in lowland soil, with or without the addition of CM. The average value of sprouting decreased when the level of CM addition to the coproducts was 20%, which was demonstrated by the plants from three of five plots of the treatment being unable to produce sprouts after the shoot was cut. If the preference is for using the coproducts, the level of cattle manure must be of approximately 10% since the seedlings present enough vigour to sprout twice and restore its height, basal diameter, and shoot dry matter between 90 and 113 days from the cutting.

Keywords: Mining activity. Degraded areas. Organic matter.

Introduction

Environmental degradation occurs mainly in the arid, semi-arid, and dry sub-humid regions of the planet, resulting from climatic and anthropogenic factors such as livestock, agriculture, and mining activities. These activities are mainly conducted in the semi-arid region of northeastern Brazil, which extends for more than 980 km^2, distributed in all states of the northeastern region (apart from Maranhão) and northern Minas Gerais (ALVES et al., 2009). The environmental imbalance is more critical in Ceará and Paraíba where environmental degradation occurs in more than half of its territories. For Lima et al. (2006), this degradation presents a strong anthropological component since the region inhabits 57.3 million people, in addition to 28.2 million cattle, 7.8 million goats, and 9.3 million sheep, which mostly feed from the native vegetation. Thus, the semi-arid region is

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characterized as the most populated and with the highest degree of anthropic activity in Brazil (LIMA et al., 2006).

However, the improper employment of these activities causes environmental issues. The land recovery process is slow and has uncertain results, demanding actions appropriate for deteriorated ecological conditions, particularly regarding the soil (KITAMURA et al., 2008; PEREIRA et al., 2013). An alternative is the production and planting of native tree species seedlings adapted to degraded areas, which, if cultivated with an alternative substrate instead of the conventional ones, primarily composed of lowland soil and manure, would result in the non-degradation of alluvial areas and the minimization of the environmental impacts caused by coproduct deposition around mining areas (FERREIRA NETO et al., 2007; RODRIGUES et al., 2007).

The substrate used for seedling production must consist of materials that provide the support, moisture, and nutrients necessary for seedling growth (AZEVEDO et al., 2006; PEREIRA et al., 2016). Many materials can be used depending on the region. According to Leite et al. (2015), fine dust contains phosphorus (58 mg dm^3); magnesium (3.8 cmolc dc^{-3}), and calcium (14 cmolc dc^{-3}), levels considered high and superior to those generally observed in soils, with the advantage of being gradually available to the soil solution.

Among the tree species adapted to degraded areas is the *Piptadenia stipulacea* (Benth.) Ducke., a woody Fabaceae of the Mimosoideae subfamily that reaches 4 meters in height and occurs in region from thin shrubby caatinga to dense tree vegetation, from Piauí to Bahia, in deep and well-watered areas, but that also adapts to inhospitable and degraded areas (OLIVEIRA et al., 2009). This species produces wood, firewood, medications, nectar, pollen, and fodder, and can be used in forest restorations and agroforestry systems due to its fast growth and nitrogen fixation in the soil through a symbiosis with nodulating bacteria of the Rhizobium genus (BARBOSA et al., 2013; FARIAS et al., 2013; ALMEIDA et al., 2015).

This study evaluated the use of the equitable combination of fine and ultrafine dust, coproducts of vermiculite extraction, and the necessary amount of cattle manure to be added to the substrate to produce *Piptadenia stipulacea* (Benth.) Ducke. seedlings.

Material and methods

This research was conducted from April 2013 to February 2014 in a screened environment located in the tree nursery of the Forest Engineering Academic Unit/Rural Health and Technology Center/Federal University of Campina Grande (UAEF/CSTR/UFCG), Patos, PB, Brazil.

The substrates tested to cultivate the seedlings were lowland soil or an equitable combination of fine and ultrafine dust, coproducts from vermiculite extraction, enriched with different proportions of cattle manure. The soil was collected from the lowland area at 1 m of depth while the coproducts were obtained from the Mineradora Pedra Lavrada (MPL), located in Santa Luzia, Paraíba, Northeastern Brazil.

The cattle manure, tanned for 30 days, lowland soil, and coproducts were dried, disturbed, homogenized, separately sieved using a 2 mm mesh sieve, and mixed according to the proportions indicated by the experimental treatments. The lowland soil and coproducts were sampled and chemically characterized in the Soils Laboratory of the Patos Campus Agricultural Engineering Academic Unit (TABLE 1), according to the methodology proposed by EMBRAPA (2006).

Table 1. Attributes of the lowland soil and coproducts of vermiculite extraction (fine and ultrafine dust) used to cultivate *Piptadenia stipulacea* (Benth.) Ducke seedlings.

Substrate	pH_{CaCl2}	P	Ca	Mg	K	Na	SB	H+Al	CEC	V
		mg.dm³		----------------------		$cmol_c dm^{-3}$	--------------------			-----%
Lowland soil	6.2	44.1	5.0	2.4	0.18	1.68	7.26	1.1	10.4	89.4
Fine dust	6.4	330	16.5	2.5	0.33	3.70	23.03	0.6	23.6	97.5
Ultrafine dust	6.7	429	26.0	4.0	0.49	6.09	36.58	0.6	37.2	98.4

*SB = sum of bases; CEC = cation exchange capacity; V = saturation by bases.
Source: Prepared by the authors (2014).

Prior to sowing, the *Piptadenia stipulacea* (Benth.) Ducke seeds were placed for 20 seconds in a 100 ml Becker with boiling water after switching off the heat source and cooled in running water at room temperature. Subsequently, 10 seeds were directly sown onto the substrate of each 8,000 cm³ pot. Thinning was conducted thirty days after sowing (DAS), leaving the two most vigorous seedlings in each pot. The pots were kept in a screened environment between April 2013 and February 2014, with daily manual irrigation.

The height and basal diameter data were collected at 37, 41, 44, 58, 65, 72, 86, 100, 193, and 293 DAS. The height (cm) was obtained with a millimetre ruler, placed next to the plant to measure the length between the surface of the substrate and the base of the apical meristem (data collected until 100 DAS) or highest sprout (collected at 190 and 293 DAS). The diameter (mm) was obtained with a digital pachymeter of 0.05 mm precision, corresponding to the diameter of the base of the stem axis of the *Piptadenia stipulacea* (Benth.) Ducke seedlings (data collected until 100 DAS) or to the sum of the basal diameters of the sprouts of both plants from each pot (data collected at 190 and 293 DAS).

The shoot of each seedling was thinned, dehydrated in a forced ventilation oven for 72 h at 60 °C, and weighed at 100 DAS to determine the dry matter (DM) (g) using a digital scale of 0.1 g precision. After thinning the seedlings, the pots were kept in a screened environment under the same environmental and irrigation conditions previously described. When the seedlings recovered, they were thinned anew at 190 and 293 DAS.

The plots were randomized according to a completely randomized design consisting of 6 treatments [lowland soil enriched with T0 = 0% and T1 = 33% of cattle manure (CM), and equitable combination of fine and ultrafine dust, coproducts of the vermiculite extraction, enriched with T2 = 0%, T3 = 5%, T4 = 10%, and T5 = 20% of CM] and 5 replicates, totalizing 30 plots (pots with two plants).

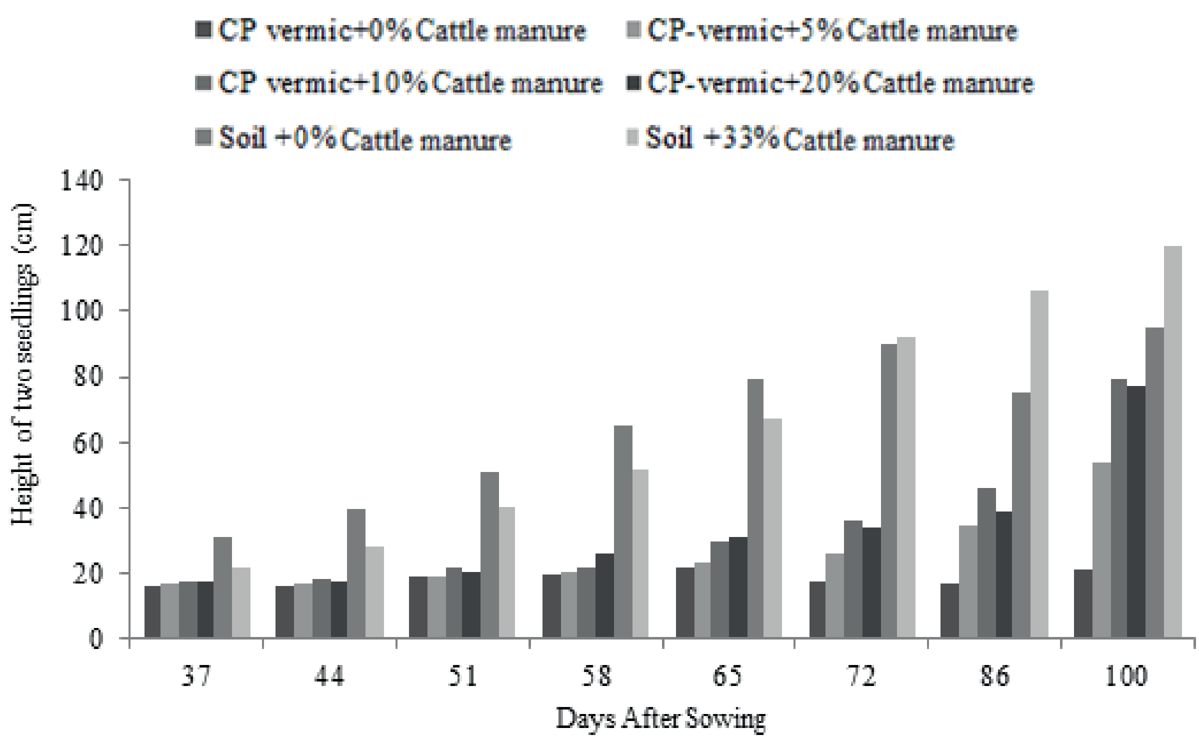
The data of height, basal diameter, and DM analyzed corresponded to the sum of the values observed from both plants of each pot. The effects of treatments were tested applying the ANOVA F test, using the regression models to estimate the effect of the age and levels of cattle manure addition on height, basal diameter, and shoot DM, employing the linear regression analysis techniques for $P < 0.05$.

Results and discussion

Height

Figure 1 shows that, in general, the height of the seedlings significantly increased in the lowland soil added with CM when compared to the other CP-vermiculite treatments. At 100 DAS, concerning the substrate CP-vermiculite with no CM, the seedlings presented low growth, indicating the need for CM in the combination of this type of material. The seedlings presented heights from 21.30 to 120.14 cm/2 seedlings or the equivalent between 10.65 and 60.07 cm seedlings^{-1}. At this age, the CP-vermiculite substrate with 10 % CM provided a mean height of 39.65 cm plant^{-1}, which was already characterized from 72 DAS but remained below the mean values observed in the seedlings in the lowland soil.

Figure 1. Total height of two *Piptadenia stipulacea* (Benth.) Ducke seedlings in function of the age (from 37 to 100 days after sowing) and percentage (volume) of cattle manure added to the coproducts of vermiculite extraction (0, 5, 10, and 20 %, volume) and lowland soil (0 and 33 %).



Source: Prepared by the authors (2014).

It is possible there is an optimal dosage of CM in the lowland soil between the levels of CM considering the existence of only two levels of CM distant from each other (0 % and 33 %) and the apparently negative effect until 65 DAS, which contrasts with the positive effect at 86 and 100 DAS. Thus, when using the conventional substrate, one might be wasting CM at the same time as producing seedlings with quality below expectations. Further studies are necessary to confirm this hypothesis.

The data obtained in this study were similar to those reported by other authors for *Piptadenia stipulacea* (Benth.) Ducke. Farias et al. (2013) found a mean height of 7.1 cm at 14 DAS for seedlings cultivated on a substrate composed of coconut fibre while Barbosa et al. (2013) reported a mean height of 51.25 cm at 120 days after germination, using cambisol in the substrate.

The values of seedling height reported for other tree species of the Caatinga can be of interest and serve to relativize the growth potential of *Piptadenia stipulacea* (Benth.) Ducke. When studying *Myracrodruon urundeuva* Fr. ALL seedlings, Caron et al. (2007) obtained a mean height of 46.4 cm at 112 days, cultivated in a substrate composed of 1/3 coffee straw and 2/3 dystrophic yellow latosol corrected with dolomitic limestone. Bernardino et al. (2006) reported a height between 19.80 and 71.23 cm *Anadenanthera macrocarpa* Benth. seedlings at 100 days after germination, when using the corrected and fertilized subsoil of three soil classes in the substrate. Lima et al. (2010) verified a mean height between 87.67 cm and 105.00 cm for *Enterolobium contortisiliquum* (Vell.) Morong and between 41.67 cm and 54.20 cm for *Hymeneae courbaril* L. var. stilbocarpa (Hayne) Lee et Lang. at 120 days after germination using four levels of shading (0 %, 30 %, 50 %, and 80 %) and Plantmax commercial substrate.

Apart from the CP-vermiculite treatment with 20 % CM, the *Piptadenia stipulacea* (Benth.) Ducke presented a good power of shooting induction, especially in the lowland soil. Note that the sprouting for each treatment is higher at the end of the second (190 and 293 = 113 days) when compared to the first recovery period (between 100 and 190 = 90 days) after the first thinning at 100 DAS (TABLE 2), especially in the lowland soil. This sprouting power is also evident in the CP-vermiculite treatment with no addition of CM. This treatment provided almost zero height growth between 37 and 100 DAS (FIGURE 1). However, somehow the sprouting of the second period reached a mean height superior to that observed in the first 100 DAS. It is possible that the plant reacted to the thinning as well as to the presence of gems, accumulation of reserves in its root system or the gradual release of nutrients by the substrate, enough to result in more vigorous sprouting than that from the previous period.

Table 2. Total height of two *Piptadenia stipulacea* (Benth.) Ducke seedlings (cm/^{2} seedlings) at 100, 190, and 293 days after sowing (DAS) in function of the percentage (%, v) of cattle manure (CM) added to the substrate (equitable combination of vermiculite coproducts = CP-vermic, and lowland soil = Soil)

Treatments	**1st cut 100 DAS**	**2nd cut 190 DAS**	**3rd cut 293 DAS**
CP-vermic+0%CM	21.30	11.60	29.80
CP-vermic+5%CM	53.70	59.74	131.60
CP-vermic+10%CM	79.30	121.2	138.40
CP-vermic+20%CM	77.30	37.80	29.03
Soil+0%CM	94.64	159.0	301.40
Soil+33%CM	120.14	174.7	274.2

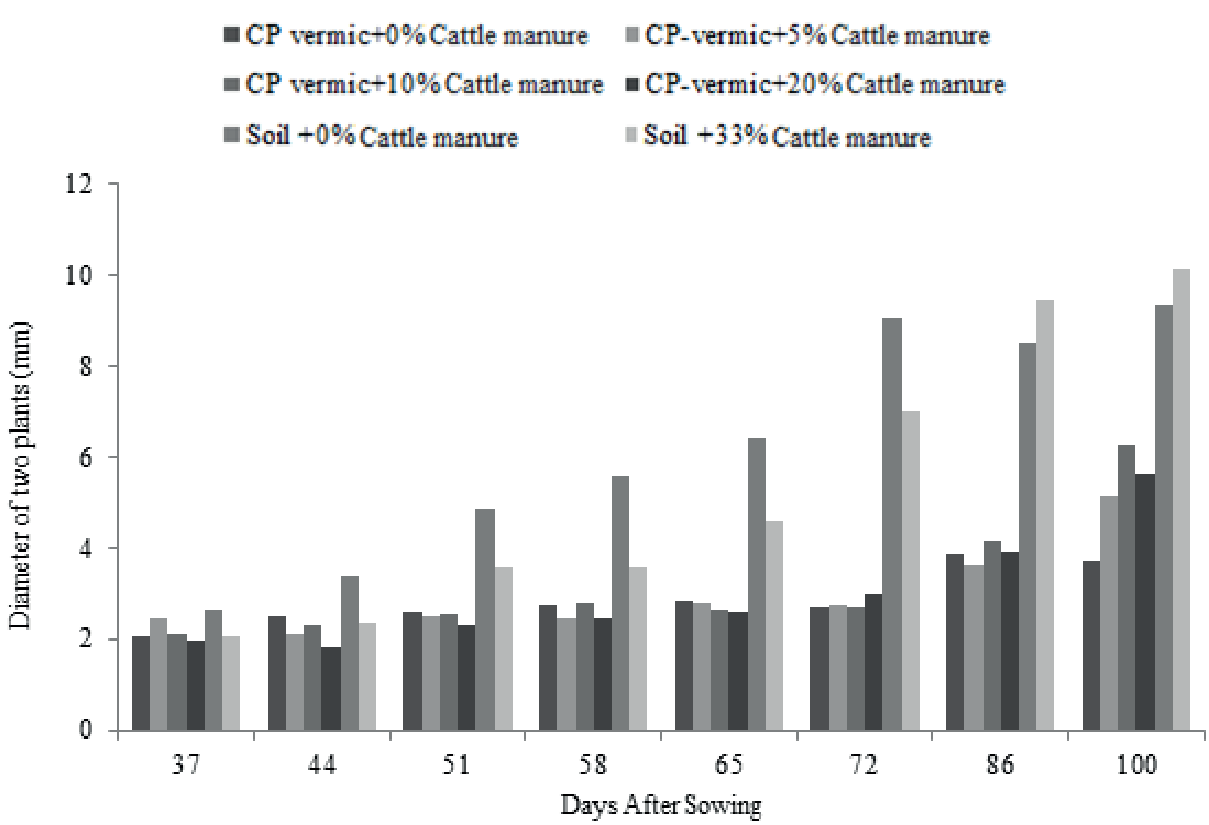
Source: Prepared by the authors (2014).

For some reason this accumulation of reserves or any other factor does not occur in CP-vermiculite enriched with 20 % CM. The plant mortality after the first thinning was high in this treatment (both plants in 3 of the 5 pots presented no sprouting or were dead, and one or two pots from the other treatments with CP-vermiculite presented no sprouting, while all pots with lowland soil showed sprouting). The explanation for this mortality demands additional studies. Thus, it is not advisable to add more than 10 % of CM to CP-vermiculite, unless an additional corrective procedure is performed, such as adding N or K, resulting in a chemically and physically balanced substrate, which should be considered in future studies.

Diameter

In general, the diameter of the seedlings was lower for the CP-vermiculite treatments when compared to those of the lowland soil when measured between 37 and 100 DAS (FIGURE 2). In the treatments with CP-vermiculite, the effect of the CM was only seen with more clarity at 100 DAS, indicating a decrease in the diameter with the addition of 10 % of CM. The effect was reversed for the lowland soil for the same period, at first presenting as negative and reversing at 86 and 100 DAS but at a lower level than expected with the addition between 0 and 33 % of CM. These values suggest the possibility of a maximum point between these levels of CM, similar to what occurred with the CP-vermiculite substrate.

Figure 2. Total basal diameter of two *Piptadenia stipulacea* (Benth.) Ducke plants in function of age (from 37 to 100 days after sowing) and percentage (volume) of cattle manure added to the substrate (coproducts of the extraction of vermiculite = CP-vermic, and lowland soil = Soil).



Source: Prepared by the authors (2014).

At 100 DAS, the mean diameter of the seedlings was between 3.74 and 10.13 mm/2 seedlings (TABLE 3) or the equivalent between 1.87 and 5.06 mm seedling^{-1}. Considering this age and the substrate with CP-vermiculite, the dose of 10 % of CM provided the highest mean (3.14 mm plant^{-1}), suggesting the use of this dosage when using the CP-vermiculite substrate to produce *Piptadenia* *stipulacea* (Benth.) Ducke seedlings. However, when comparing this value with those obtained in the lowland soil and those reported by Barbosa et al. (2013) (6.00 mm) under the conditions already discussed for height, the CP-vermiculite requires other corrections in addition to the addition of 10% CM.

Table 3. Total basal diameter (mm/2 seedlings) of *Piptadenia stipulacea* (Benth.) Ducke. at 100, 190, and 293 days after sowing (DAS)

Treatments	**1st cut 100 DAS**	**2nd cut 190 DAS**	**3rd cut 293 DAS**
CP vermic+0%CM	3.74	1.81	2.53
CP-vermic+5% CM	5.14	5.61	7.77
CP vermic+10% CM	6.28	7.55	9.39
CP-vermic+20% CM	5.60	2.58	3.47
Soil+0% CM	9.35	13.13	11.47
Soil+33% CM	10.13	10.59	17.40

Source: Prepared by the authors (2014).

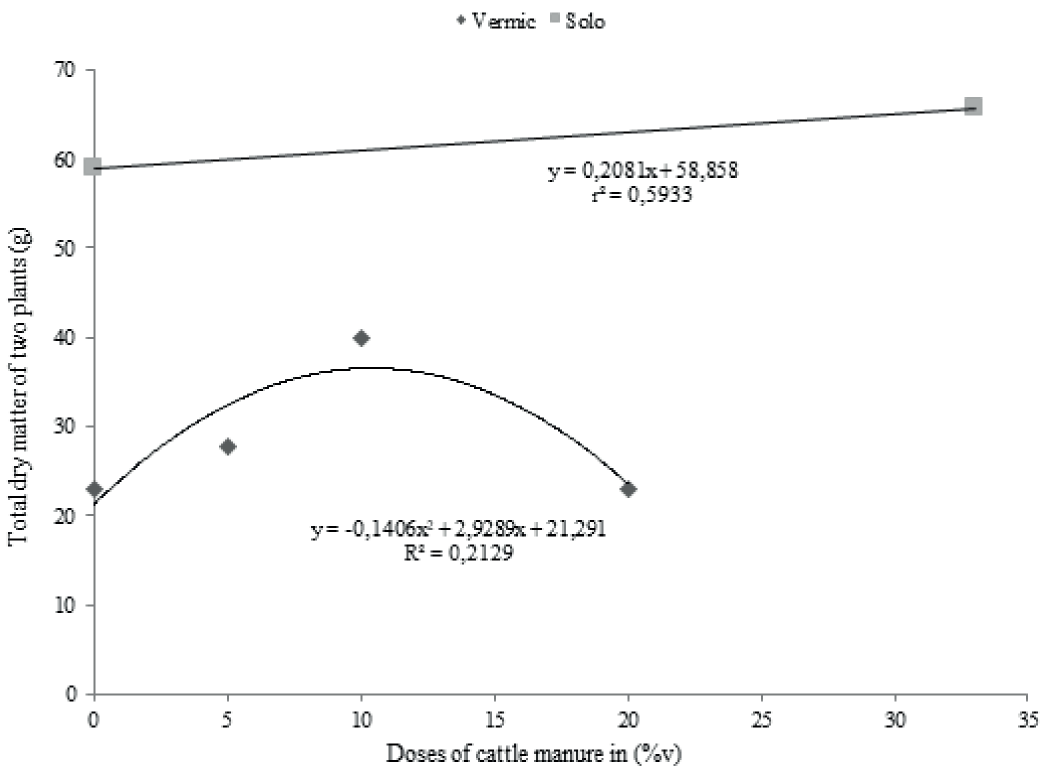
A positive CM effect is observed for the lowland soil when regarding only the means at 100 DAS. However, it is possible that an optimum dose exists for the lowland soil between the two levels of CM distant from each other (0 % and 33 %) considering the apparently adverse effect that occurs until 65 DAS, contrasting with the positive impact at 86 and 100 DAS (FIGURE 2). Thus, when using the conventional substrate, one can be wasting CM and at the same time producing seedlings of a quality inferior to the expected. Further studies are necessary to confirm this hypothesis.

The *Piptadenia stipulacea* (Benth.) Ducke seedlings demonstrated an increasing sprouting power between both measurements (190 and 293 DAS), reaching values superior to those verified for the plants before the first thinning at 100 DAS, apart from the CP-vermiculite treatments with 0 or 20 % of CM, which also resulted in high mortality, as previously reported. In these treatments, the sum of the diameters of all sprouting is higher at the end of the second (between days 190 and 293 = 113 days) than the first (between 100 and 190 = 90 days) recovery period after thinning (TABLE 3), especially in the lowland soil, and exceed the respective values observed at 100 DAS. The reaction power to the thinning of the shoot is striking and, as emphasized, deserves additional studies to elucidate how *Piptadenia stipulacea* (Benth.) Ducke can react to the stress caused by the continuous thinning of its shoot performed in periods from 90 to 113 days and to elucidate the reason this does not occur on the CP-vermiculite substrate with 0 or 20 % of CM.

Dry matter

Figure 3 shows the effects of the type of substrate and the addition of CM on the total production of DM from the three thinnings (plant + sprouting 1 + sprouting 2). In general, the value of total DM produced by the seedlings was higher in the lowland soil. The CM positively affected the production of DM when added in up to 10 % to the CP-vermiculite ($P < 0.05$). The enrichment of the CP-vermiculite with higher levels of CM impaired the production of DM, causing the mortality of a significant percentage of plants.

Figure 3. Shoot dry matter of two *Piptadenia stipulacea* (Benth.) Ducke seedlings resulted from three cuts performed at 100, 190, and 293 days after sowing.



Source: Prepared by the authors (2014).

The total value of DM produced in the three thinnings was of between 23.05 and 65.72 g/2 seedlings (TABLE 4) or the equivalent between 11.53 and 32.86 g seedlings^{-1}. The dose of 10 % of CM resulted in the highest average (20.03 g mol^{-1}) for the CP-vermiculite substrate, which suggests the use of this dose when using this substrate to produce *Piptadenia stipulacea* (Benth.) Ducke seedlings. This tendency was observed in the sprouts collected at 190 and 293 DAS. However, the total value of DM obtained in the treatments with CP-vermiculite reaches a maximum of 68 % when compared to the value of the treatments with lowland soil.

Table 4. Total dry matter (g/2 seedlings) of the shoot of two *Piptadenia stipulacea* (Benth.) Ducke seedlings resulted from the cuts performed at 100, 190, and 293 days after sowing (DAS)

Treatments	Total from three cuts	1st cut 100 DAS	2nd cut 190 DAS	3rd cut 293 DAS
CP vermic+0%CM	23.05	4.54	13.22	5.29
CP-vermic+5% CM	27.72	5.65	9.35	12.72
CP vermic+10% CM	40.05	7.67	14.22	18.16
CP-vermic+20%CM	23.05	8.04	4.68	10.33
Soil+0% CM	58.85	15.22	18.18	25.45
Soil+33% CM	65.72	16.42	14.94	34.36

Source: Prepared by the authors (2014).

The DM values ranged from 4.54 to 16.42 g/2 seedlings, or the equivalent of 2.27 and 8.21 g seedlings^{-1} at 100 DAS. These values were inferior to those reported by Barbosa et al. (2013), Bernardino et. al. (2005), Caron et al. (2007), Gomes et al. (2012), Lima et al. (2010), namely 11.19 g, 14.70 g, 21.52g, and 21.27 g, respectively, under conditions previously reported. This may have occurred because of the adaptation of the species to degraded environments, its fixation of atmospheric nitrogen, and its low nutritional requirement, demanding no addition of cattle manure to the substrate.

Resembling the values observed for the height and basal diameter, the *Piptadenia stipulacea* (Benth.) Ducke presented increasing vigour between both sprouting measurements (190 and 293 DAS), reaching values superior to those verified in the plants at 100 DAS, apart from the CP-vermiculite treatments with 0 or 20 % of CM, for which behaviour was not so clearly expressed and resulted in high mortality. In these treatments, the value of DM for all sprouting was superior at the end of the second (293 DAS) recovery period when compared to the first (190 DAS) (TABLE 3), especially in lowland soil, and overcame the values observed at 100 DAS. Further studies must be conducted to evaluate the striking reaction power to thinning the shoots to elucidate how the *Piptadenia stipulacea* (Benth.) Ducke can react to the stress caused by the successive shoot thinnings performed during 90 to 113 days of recovery, as well as to outline the reason this does not occur in CP-vermiculite substrate with 0 or 20% of CM.

Conclusions

The production of *Piptadenia stipulacea* (Benth.) Ducke using an equitable combination of fine and ultrafine dust, coproducts from the vermiculite extraction, results in smaller seedlings with less shoot dry matter when compared to those produced in lowland soil substrate with or without the addition of cattle manure.

If this coproduct is used to produce *Piptadenia stipulacea* (Benth.) Ducke seedlings, the addition of cattle manure should not exceed 10 %.

Uso de coprodutos da extração de vermiculita na produção de mudas *Piptadenia stipulacea* (Benth.) Ducke

Resumo

A extração de vermiculita gera coprodutos que são depositados no entorno das indústrias mineradoras, causando problemas ambientais. Este estudo objetivou avaliar a utilização da mistura equitativa dos coprodutos poeira fina e ultrafina da extração da vermiculita e a quantidade necessária de esterco bovino a ser adicionada ao substrato de produção de mudas de *Piptadenia stipulacea* (Benth.) Ducke. O experimento foi conduzido entre abril de 2013 e fevereiro de 2014 no Viveiro Florestal da UAEF/CSTR/UFCG, Patos (PB), Brasil, em um delineamento inteiramente casualizado com 6 tratamentos: solo de baixio com T0=0% e T1=33% de EB (v/v), mistura equitativa dos coprodutos da extração de vermiculita com T2=0%, T3=5%, T4=10% e T5=20% de EB e 5 repetições. As médias de altura, diâmetro basal e massa seca da parte aérea das mudas em CP-vermiculita foram menores do que as verificadas nas mudas se desenvolvendo em solo de baixio

sem ou com a adição de EB. Quando o nível de adição de EB aos coprodutos foi de 20% as médias decresceram, bem como o vigor das rebrotas, pois em três das cinco parcelas deste tratamento as plantas não conseguiram emitir brotações após o corte de sua parte aérea. Caso se opte por utilizar os coprodutos, o nível de esterco bovino deve ficar em torno de 10%, uma vez que as mudas apresentam vigor suficiente para rebrotar duas vezes e recompor sua altura, diâmetro basal e matéria seca da parte aérea em 90 a 113 dias do corte de sua parte aérea.
Palavras-chave: Atividade mineradora. Áreas degradadas. Matéria orgânica.

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