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Root pruning and Osmocote® provides better Jatoba seedlings

Poda radicular e Osmocote® proporciona melhor muda de Jatobá

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Abstract

The species *Hymenaea courbaril* L. (Jatoba) is widely used in the timber industry. However, its population was reduced due to high exploitation rate, being at risk of extinction. Therefore, production of seedlings of this species should be improved to meet the demand of reforestation programs. Given the above, this study evaluates the effect of Osmocote® rates and root pruning on the growth of Jatoba seedlings transplanted into plastic bags. A randomized complete block design was used in a 5 x 3 factorial scheme, corresponding to five rates of Osmocote® fertilizer (0.0; 2.0; 4.0; 6.0; and 8.0 g L^{-1}) and three root pruning intensities (0%; 25%; and 50%). At 105 days after transplantation, the following were evaluated: plant height, stem diameter, number of leaves, shoot dry weight, root dry weight, total dry weight, height/stem diameter ratio, and Dickson quality index. Rates below 4.0 g L^{-1} or above 6.0 g L^{-1} decreased seedling quality. The most prominent variables in this study were plant height, total dry weight, and number of leaves of *H. courbaril* seedlings. Osmocote® rates between 4.4 and 6.6 g L^{-1} combined with 25% root pruning provided the best results for the growth of transplanted Jatoba seedlings.

Additional keywords: controlled-release fertilizer; medicinal plant; native species.

Resumo

A espécie *Hymenaea courbaril* L. (Jatobá) é muito usada na indústria madeireira. Todavia, sua população foi reduzida pela alta taxa de exploração, havendo risco de extinção. Portanto a produção de mudas dessa espécie deve ser aprimorada com o objetivo de atender a demanda dos programas de reflorestamento. Assim, objetivou-se avaliar o efeito de doses de Osmocote® e do nível de poda radicular sobre o crescimento das mudas de Jatobá transplantadas para sacos plásticos. O delineamento adotado foi o em blocos casualizados, em esquema fatorial 5 x 3, referentes a cinco doses do adubo Osmocote® (0,0; 2,0; 4,0; 6,0 e 8,0 g L^{-1}) e três níveis de poda radicular (0%, 25% e 50%). Aos 105 dias após o transplante, foi realizada a avaliação da altura, diâmetro do caule, número de folhas, massa seca da parte aérea, massa seca da raiz, massa seca total, além da razão altura/diâmetro do caule e do índice de qualidade de Dickson. O uso de doses abaixo de 4,0 g L^{-1} ou acima de 6,0 g L^{-1} diminuíram a qualidade das mudas. As variáveis que mais se destacaram neste estudo foram a altura, a massa seca total e o número de folhas das mudas de *H. courbaril*. A poda de 25% do sistema radicular combinada às doses de Osmocote® entre 4,4 e 6,6 g L^{-1} promoveram os melhores resultados para o crescimento das mudas de Jatobá transplantadas.

Palavras-chave adicionais: espécies nativas; fertilizante de liberação controlada; planta medicinal.

Introduction

Jatoba (*Hymenaea courbaril* L., family Fabaceae) is a tropical tree species that occurs naturally in several Brazilian biomes (Silva et al., 2016). Jatoba is mainly used in the timber sector, but other minor uses are also attributed to the species (Gonzaga et al., 2016).

Because of Jatoba's high exploitation rate, its reserves are decreasing, which may lead to its extinction (Silva et al., 2016). It is therefore important to propagate this species on a large scale to ensure a sustainable supply of raw materials in the future. Notwithstanding, acquisition of seedlings of native regional species, both in quantity and quality, is one of the obstacles of reforestation programs (e.g., restoration of degraded areas, economic reforestation, and urban afforestation).

In this context, seedling production is a basic step for the initial success of any forestry project, be it for conservation or commercial purposes (Dutra et al., 2016). However, several factors have limited this production, among which stand out fertilization practices, little known for native species (Rossa et al., 2013).

Fertilization techniques are a relevant factor to increase seedling growth and quality in forest essences (Rossa et al., 2013). Among the fertilization techniques used in forest nurseries, controlled-release fertilizers (CLF) have been highlighted as one of the most viable and rational alternatives. An example of this type of fertilizer is Osmocote®, which is found in many formulations and brands (Plus, Scotts, and Forth Cote) (Navroski et al., 2016).

Recent studies have shown that Osmocote® provided better development and growth of *Peltophorum dubium*, *Toona ciliata* M. Roem, and *Mimosa scabrella* Benth seedlings (Dutra et al., 2016; Somavilla et al., 2014; Stüpp et al., 2015). Due to these positive results, evaluating this technique in the production of Jatoba seedlings is important for improving the seedling production system of this species.

In addition to using fertilizer, the nursery farmer can use root pruning to increase seedling nursery period. Seedlings grown in tubes for a longer than ideal rotation period (transplant to the field or to a larger container) tend have their roots entangled, which is imposed by the restriction of exploitable substrate range (Bamberg et al., 2013). In this sense, root pruning can be useful to optimize the production of seedlings with better morphological and physiological characteristics (Azevedo et al., 2010).

Root pruning is a technique generally used to regulate vegetative growth (Gao et al., 2018). In addition, other benefits for seedling development have been demonstrated in several studies. For example, root pruning in seedlings grown in tubes stimulates the emission of thin roots important for water and nutrient uptake (Freitas et al., 2009). It also facilitates the acquisition of nutrients with low mobility in the soil, such as phosphorus, an essential element for seedling growth (Azevedo et al., 2010). Finally, root pruning increases the total soluble solids content at harvest (Carra et al., 2017).

However, no records were found in the literature regarding the use of these two combined techniques for the production of Jatoba seedlings. Thus, the hypothesis is that the combined use of root pruning and Osmocote® rate optimization improves the quality of Jatoba seedlings.

In this sense, the present study evaluates the effect of Osmocote® rates and root pruning on the growth of Jatoba seedlings transplanted into plastic bags.

Materials and methods

Study site

The study was conducted in a greenhouse at the Federal University of Pará, Altamira Campus, located in Altamira city, Pará State. This city is situated at an altitude of 109 m at coordinates 03º12'10” S and 52º12'21” W. According to the Köppen classification, the climate is equatorial Am and Aw, with average temperatures of 26 °C and average monthly rainfall of 1,700 mm (Alvarez et al., 2013).

Treatments and experimental design

Fifteen treatments were evaluated, consisting of five Osmocote® rates (0.0; 2.0; 4.0; 6.0; and 8.0 g L^{1}) and three root pruning intensities (0%; 25%; and 50%). The treatments were arranged in a 5 x 3 factorial scheme in a randomized block design with six replications. Each experimental unit consisted of one plant.

Experiment installation and conduction

For seedling production, fruits were collected from mother plants in the forest area of the Electric Power Plants of Northern Brazil S/A (ELETRONORTE), located in Vitória do Xingu city, Pará State.

In the laboratory, fruits were properly cleaned, pulped, and the extracted seeds were packed in plastic bags and kept at room temperature until sowing. The seeds were superficially disinfected using 70% (v/v) ethanol solution and 2.5% (v/v) sodium hypochlorite, being then washed in sterile distilled water. To overcome dormancy, the seeds were sanded on the opposite end to the hilum. Subsequently, they were sown in 11.5 dm^3 polyethylene trays containing sterilized sand autoclaved at 120 ºC for 120 minutes.

The germinated seeds were pricked out into 0.280 dm^3 tubes containing coconut fiber substrate (AMAFIBRA®), indicated for forest use. At 90 days after emergence, after root removal from the tubes, the seedlings were considered suitable for treatment application. Then, the treatments (pruning intensities) were performed using pruning shears on seedling roots. Pruning was performed with the aid of a millimeter ruler. Cuttings were performed considering the distance from the neck region to the end of the main root of seedlings. Following this step, seedlings were transplanted into 25 x 11 cm polyethylene bags containing a mix of coconut fiber substrate and Osmocote® (Osmocote® Plus NPK 15-9-12 with a release time of 3 to 4 months), according to the rates established in the treatments.

The transplanted seedlings were sprinkled daily in two 30-minute applications (one in the morning and one in the afternoon). The seedlings remained in a greenhouse for 105 days after transplanting (DAT), under a 50% shade screen (Sombrite®).

At 105 DAT, the seedlings were evaluated for height (H, cm), stem diameter (SD, mm), and number of leaves (NL). Seedling height was measured with the aid of a millimeter ruler positioned at ground level to their apical meristem. Stem diameter was measured in the neck region using a digital caliper. Soon after, seedlings were removed and separated into shoots and roots. The roots were washed under running water and placed on paper towels to remove excess water. Subsequently, they were placed in paper bags and taken to an oven with forced air circulation at 65 ºC until constant weight. Shoot dry mass (SDM, g), root dry mass (RDM, g), and total dry mass (TDM, g) were then obtained. Two relationships between the previous variables were also determined, height/stem diameter ratio (HSDR) and Dickson Quality Index (DQI), calculated by the equation:

$$DQI = \frac{TDM}{\frac{H}{SD} + \frac{SDM}{RDM}} \quad (1)$$

Statistical analysis

Initially, it was verified whether the data of the analyzed variables met the basic assumptions of normality and homoscedasticity. Once these parameters were met, the data were subjected to analysis of variance at 5% probability. When the F value was significant, the treatments were subjected to polynomial regression analysis. In the case of significant effect of quadratic equations, the rate of maximum technical efficiency (MTE) was determined. The maximum technical efficiency (MTE) was determined from the equation $y = a + bx + cx^2$. To determine the "x" value in MTE, the following function was derived: $\frac{dy}{dx} = b + 2cx$. The statistical package SISVAR 5.3 (Ferreira, 2011) was used for data analysis.

Results and discussion

All variables analyzed were significantly influenced ($p<0.05$) by the factor Osmocote® rate (R) (Table 1). Root pruning (P) alone had a significant effect at 5% probability only for the variables SDM and HSDR. Analysis of variance showed interaction ($p<0.05$) between the factors (P*R) for the characteristics H, NL, RDM, TDM, and DQI (Table 1). The averages of all variables followed a quadratic model in response to controlled-release fertilizer rates.

Table 1 - Summary of variance analysis for growth and quality characteristics of *Hymenaea courbaril* L. seedlings as function of root pruning intensities (P) and Osmocote® rates (R).

Sources of variation	Mean square values							
	H	SD	HSDR	NL	SDM	RDM	TDM	DQI
Block	12.0^{ns}	0.24^{ns}	0.24^{ns}	4.31^{ns}	0.13^{ns}	0.25^{ns}	0.277^{ns}	0.84^{ns}
Pruning intensities(P)	117.0^{*}	0.01^{ns}	1.06^{*}	0.34^{ns}	0.11^{*}	0.64^{ns}	1.684^{*}	0.44^{ns}
Osmocote Rates (R)	1490.0^{*}	0.20^{*}	8.4^{*}	268.09^{*}	163.0^{*}	1.55*	3.684^{*}	0.89^{*}
P*R	7.0^{*}	0.06^{ns}	0.7^{ns}	34.01^{*}	1.5^{ns}	0.87*	0.54^{*}	0.82^{*}
Average	45.08	6.53	6.90	10.62	7.96	3.06	11.28	1.20
CV(%)	2.21	8.47	8.02	16.25	10.35	31.84	17.39	16.53

H: height; SD: stem diameter (mm); HSDR: height/stem diameter ratio; NL: number of leaves; SDM: shoot dry mass; RDM: root dry mass; TDM: total dry mass; DQI: Dickson Quality Index; CV: coefficient of variation. ^{ns}: not significant to the F test ($p>0.05$); * significant to the F test ($p<0.05$).

The height of *H. Courbaril* seedlings varied as a function of Osmocote® rates and root pruning intensities, following a quadratic model (Figure 1A). For 25% root pruning, the rate of (MTE) was estimated at 6.6 g L^{-1}. In this treatment, plant height was 61.72 cm, corresponding to an increase of 75.2% over the control treatment without addition of Osmocote®. For 50% root pruning, the rate of (MTE) was estimated at 6.8 g L^{-1}, corresponding to a height of 40.73 cm and a cumulative increase of 37% compared to the treatment without Osmocote®. Regarding the absence of root pruning, the rate of (MTE) led to a 25.5% increase in height compared to the treatment without fertilizer. Considering the maximum points between the two types of pruning, 25% root pruning corresponded to an increase of 21.0 cm or 51.5%. Moreover, from the rate of MTE, there was a decrease in average seedling height. This behavior can be attributed to excess Osmocote®, since height values decreased even in the treatment without root pruning. This reduction in seedling after a certain fertilizer rate may be related to chemical changes in the substrate, excess nutrients, and increased salinity (Freitas et al., 2011; Silva, 2014). Similar behavior was observed in the height growth of *Eucalyptus dunnii* Maiden and *Peltophorum dubium* seedlings as a function of fertilizer rate (Navroski et al., 2016; Dutra et al., 2016).

Height is an excellent feature for assessing the quality of forest seedlings. In addition, height measurement consists of an easy to perform, nondestructive method (Duarte et al., 2015). Despite the good performance for the variable height, it can provide an erroneous quality information when used alone (Nicoletti et al., 2015). Thus, the selection of quality seedlings requires the measurement of other variables.

The highest seedling SD (6.68 mm) was estimated with the rate of MTE of 4.6 g L^{-1} (Figure 1B). Based on the growth increment at the estimated rate, the difference between fertilized and unfertilized seedlings was 2.5%. This result indicates that SD was little influenced by the fertilizer rates used. However, this result corroborates several studies that have reported the significant effect of Osmocote® on SD (Neto & Botrel, 2009; Somavilla et al., 2014; Silva et al., 2019). In contrast, root pruning had no effect on SD, which is a result is very similar to that obtained by other researchers (Freitas et al., 2009; Azevedo et al., 2010). Notwithstanding, although SD was not influenced by both factors, this parameter remains one of the most relevant for the evaluation of seedling survival and growth potential after field transplantation (Pias et al., 2015).

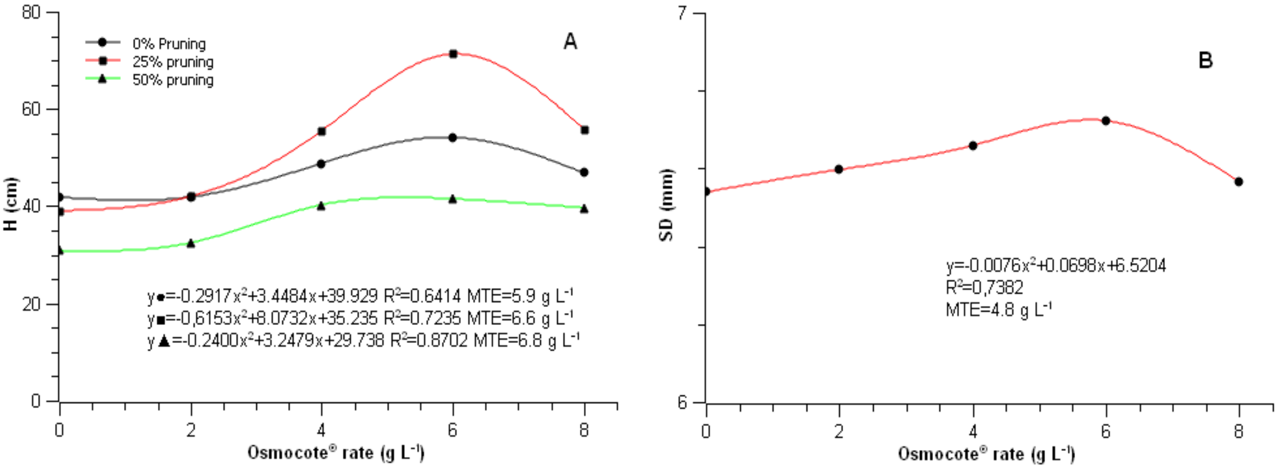

Figure 1 - A) Height (H, cm) and B) stem diameter (SD, mm) of *H. courbaril* seedlings as function of root pruning intensities (P) and Osmocote® rates (R).

The rate of MTE was estimated at 5.7 g L^{-1}, corresponding to a HSDR of 9.68 (Figure 2A). It is known that the height/stem diameter ratio expresses the balance of seedling growth in the nursery, relating these two important morphological parameters in only one index. The HSDR index should be considered for seedling classification due to its ease of measurement (Ataíde et al., 2010). According to Carneiro (1995), values between 5.8 and 8.1 are indicated for this ratio. Therefore, the value obtained in this study for the HSDR index is above the ideal. On the other hand, for forest species seedlings, José et al. (2009) state that the HSDR should be less than 10. Thus, it can be inferred from the HSDR value that Jatoba seedlings are of high quality.

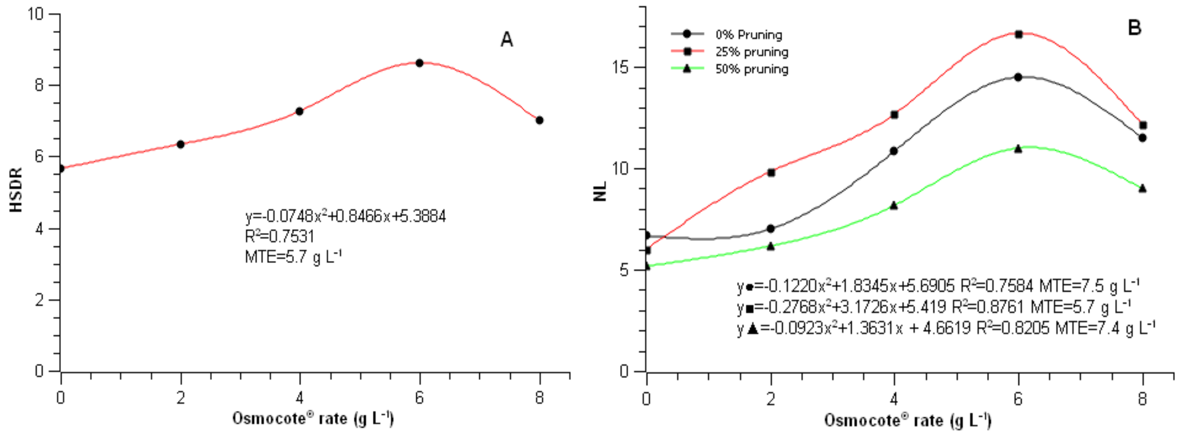

Figure 2 - A) Height/Stem diameter ratio (HSDR) and B) Number of leaves (NL) of H. courbaril seedlings as function of root pruning intensities (P) and Osmocote® rates (R).

The best value for NL (14.5 leaves), obtained with 25% root pruning, was estimated at the rate of MTE of 5.7 g L^{-1} (Figure 2B). The cumulative increase in NL was 167.6% compared to the treatment without fertilizer. For 50% root pruning, the rate of MTE was estimated at 7.4 g L^{-1}, corresponding to 9.70 leaves and a cumulative increase of 106.4% compared to the treatment without Osmocote®.

Based on the results, it was found that all treatments had a positive effect on the development of Jatoba seedlings. However, the best result of this study suggests that Osmocote® associated with less root pruning provides higher leaf emission rate. Similar results were obtained by Brito et al. (2018) when analyzing Osmocote® rates in the production of *Schinopsis brasiliensis* seedlings. According to these authors, the higher emission of leaves in response to Osmocote® fertilization was determinant for the increased photosynthetic capacity of plants.

The highest value (7.98 g) for shoot dry mass (SDM) was estimated at the rate of MTE of 5.4 g L^{-1} (Figure 3A). Based on the growth increment at the estimated rate, the difference between fertilized and unfertilized seedlings was 39.7%. However, from the MTE rate, there was a decrease in SDM. This quadratic behavior was also verified by Brondani et al. (2008) when using Osmocote® fertilizer. Neto & Botrel (2009) observed a quadratic response for SDM in pine seedlings when using Osmocote®. On the other hand, Serrano et al. (2006) noted an increasing linear response for SDM as a function of Osmocote® fertilization in *Citrus limonia*. Therefore, these divergences regarding the dry mass of Osmocote®-fertilized seedlings may be largely related to the species under study (Somavilla et al., 2014).

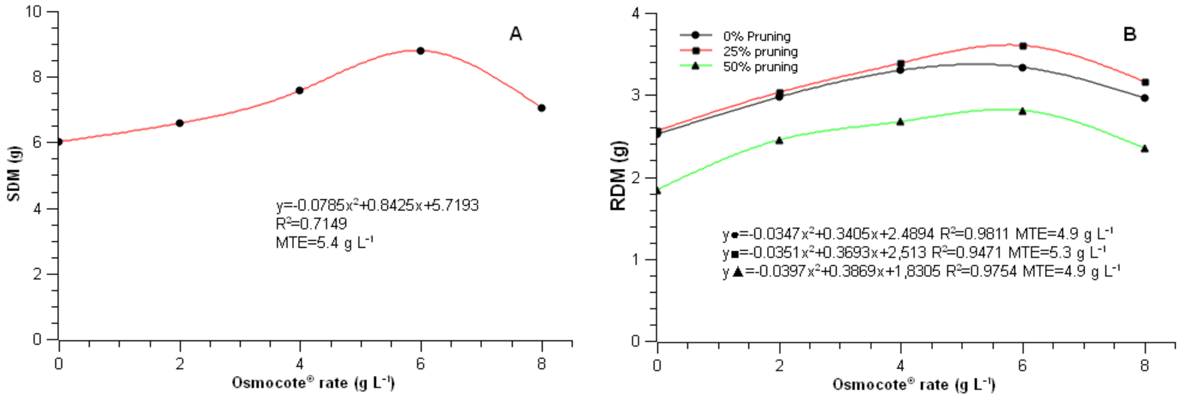

Figure 3 - A) Shoot dry mass (SDM) and B) root dry mass (RDM) of *H. courbaril* seedlings as function of root pruning intensities (P) and Osmocote® rates (R).

The lowest value (2.77 g) of root dry mass (RDM) was observed with 50% root pruning, at the rate of MTE of 4.9 g L^{-1} (Figure 3B). For 25% root pruning, the rate of MTE was estimated at 5.26 g L^{-1}, corresponding to a root dry mass of 3.48 g, with an increase of 38.5% compared to the treatment without Osmocote®. Considering the maximum points between the two types of pruning, 25% root pruning accounted for an increase of 0.71 g or 25.6%. This result corroborates other studies in which RDM has been shown to follow a quadratic model under high rates of controlled--release fertilizer (Rós et al., 2011; Rossa et at., 2015; Dutra et al., 2016; Brito et al., 2018; Silva et al., 2019). Similarly, reports in the literature indicate increased RDM under less root pruning (Alvarenga et al., 1994). Therefore, it can be inferred that the combinations of these two factors provided seedlings with good root development. According to Carneiro (1995), RDM is the best and most used parameter for determining root growth, and a good indicator of seedling quality and development after planting in the field.

Total dry mass (TDM) followed a quadratic model for both pruning intensities (Figure 4A). For 25% root pruning, the rate of MTE was estimated at 5.0 g L^{-1}, corresponding to a TDM of 15.4 g, with an increase of 62.9% compared to the treatment without fertilizer. For 50% root pruning, the rate of MTE was estimated at 4.5 g L^{-1}, corresponding to a TDM of 10.5 g and an increase of 19.2% compared to the treatment without fertilizer. Considering the maximum points between the two types of pruning, 25% root pruning accounted for an increase of 4.9 g or 46.7%. Similar to the other variables mentioned above, there was a reduction in TDM at higher Osmocote® rates. According to Larcher (2006), once the plant demand is met, higher fertilizer rates will not result in growth responses and may also cause toxicity. This information corroborates the results obtained in this study.

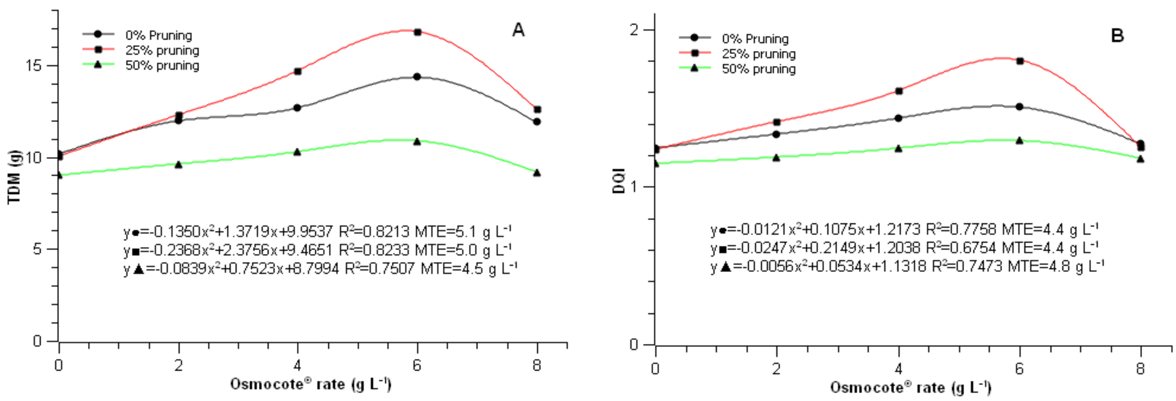

Figure 4 - A) Total dry mass (TDM) and B) Dickson Quality Index (DQI) of *H. courbaril* seedlings as function of root pruning intensities (P) and Osmocote® rates (R).

For DQI (Figure 4B), the rate of MTE was 4.4 g L^{-1}, with the highest estimated DQI value (1.67) at 25% root pruning. For this treatment, the cumulative increase in DQI was 39% compared to the treatment without fertilizer. For 50% root pruning, the DQI for Jatoba was 1.26 at the rate of MTE, corresponding to an 11% increase compared to the treatment without fertilizer. Regarding the absence of root pruning, there was an increase of 20% in the DQI of Jatoba compared to the treatment without fertilizer. According to Hunt (1990), DQI for forest species seedlings must be greater than 0.2 to indicate good quality and high survival after field planting. Therefore, the results obtained for DQI in this study were superior to those suggested by Hunt (1990). However, it is necessary to establish DQI tests for each forest species of interest (Rossa et al., 2015). Binotto et al. (2010) also reported that SD is highly related to DQI. Rates that allow higher SD will favor better seedling quality and, therefore, a higher DQI value. In the present study, the highest DQI value was obtained with an Osmocote® rate close to that which provided the best SD result, therefore indicating good quality.

It is thus evident that among the factors that influenced the growth and quality of Jatoba seedlings, Osmocote® had a great effect on morphological parameters due to the physical and chemical characteristics of its formulation. In addition, 25% root pruning combined with fertilizer use was superior to the other treatments used in the research.

Jatoba seedlings had their maximum growth from different Osmocote® rates for each variable. Thus, the choice of the Osmocote® rate to be applied will depend on the variable to be chosen as the most representative of seedling development. The results of this study demonstrated that the rates of MTE for the variables that determine the quality of *H. courbaril* seedlings were between 4.4 and 6.6 g L^{-1}.

Conclusion

Osmocote® can be recommended for use in Jatoba seedlings transplanted into plastic bags, with the rates of MTE between 4.4 and 6.6 g L^{-1} providing the best results for their growth. In addition, 25% root pruning provided the best conditions for the growth of transplanted Jatoba plants.

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