

AGROCHEMICALS AND STEM CUTTING TYPES FOR PLANTLET PRODUCTION OF *Spondias* sp.¹

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ABSTRACT - Umbu-caja (*Spondias* sp.) is a fruit tree native to the Northeast region of Brazil, which is grown because of its highly valuable fruits for fruit processing industries. The objective of this work was to evaluate the effect of agrochemical applications and cutting types on the rooting and development of *Spondias* sp. plantlets. The experiment was conducted at the experimental field of the Embrapa Tropical Agroindustry, in Pacajus, CE, Brazil. A randomized block experimental design was used, with five treatments - control (T1); cuttings with two lesions at the base (CL) + rooting gel (RG) (Sela Gel[®]) (T2); CL + rooting fertilizer (RF) (Radimax[®]) (T3); cuttings with two transversal cross sections at the base (CS) + RG (T4); and CS + RF (T5). The environments (blocks) used were: full sun; 100% shade ceiling; 50% shade walls and ceiling; and 50% shade ceiling. The plots consisted of eight cuttings, totaling 160 cuttings. Propagules were taken from *Spondias* sp. plants to make woody cuttings with length of 25 cm, diameter of 29.7 mm, and mean bud per cutting of 8.7. All cuttings were immediately treated with a 0.05% sodium hypochlorite solution for four minutes before making the lesions and transversal cross sections and applying the treatments. The RG was applied by brushstroke, and the RF was applied by immersion in an aqueous solution of 10 mL L⁻¹ for 10 minutes. The cuttings were planted into 6-liter black plastic pots filled with a pasteurized mixture of vermiculite, coconut husk powder, ground leaf fibers of *Copernicia prunifera*, and carbonized rice husk (2:1:1:1; v v⁻¹). The treatments and blocks significantly affected the rooting and development of cuttings. The treatment with CS and application of the RG (T4) promoted root callus formation, rooting, and vigorous development of plantlets, whereas the RF (T3 and T5) failed to promote root formation.

Keywords: Vegetative propagation. Cutting. *Spondias*.

AGROQUÍMICOS E LESÕES EM ESTACAS DE CAULE NA FORMAÇÃO DE MUDAS DE UMBU-CAJAZEIRA

RESUMO - A umbu-cajazeira (*Spondias* sp.), frutífera nativa do Nordeste brasileiro, produz frutos muito valorizados pelas agroindústrias. O objetivo deste trabalho foi avaliar a aplicação de agroquímicos e lesões no enraizamento e na formação de mudas/estacas, foi conduzido na Embrapa em Pacajus, CE, em blocos ao acaso, com cinco tratamentos: T1 = testemunha, T2 = estacas feridas + Sela Gel[®], T3 = estacas feridas + Radimax[®], T4 = estacas incisadas + Sela Gel[®] e T5 = estacas incisadas + Radimax[®]. Os ambientes (blocos): pleno sol; teto com plena sombra; sombrite 50% nas laterais e no teto; e sombrite 50% no teto. As parcelas tinham oito estacas, totalizando 160 estacas. Dos propágulos retirados de plantas, prepararam-se estacas lenhosas, com 25 cm de comprimento e médias de 29,7 mm de diâmetro e 8,7 gemas/estaca. Em seguida foram tratadas com solução de hipoclorito de sódio a 0,05%/4 minutos; depois fez-se os ferimentos e as incisões e aplicou-se o Sela Gel[®] por pincelamento e o Radimax[®] por imersão em solução de 10 mL/L d'água/10 minutos. O plantio foi em vasos plásticos pretos, com capacidade 6L, cheios com vermiculita + pó de cascas de coco + bagana de carnaúba triturada + cascas de arroz carbonizada (2:1:1:1, v/v), previamente pasteurizados. Entre os tratamentos e os blocos houve diferenças significativas. A incisão e a aplicação do Sela Gel[®] induziram a formação de calo, o enraizamento e a formação de mudas vigorosas, enquanto o Radimax[®] não induziu o enraizamento.

Palavras-chave: Propagação vegetativa. Estaquia. *Spondias*.

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INTRODUCTION

Umbu-caja (*Spondias* sp.) is a fruit tree of the Anacardiaceae family (MITCHELL; DALY, 2015). It is a xerophyte species probably native to the Brazilian Semiarid region. According to Giacometti (1993), it is a hybrid between the umbu tree (*S. tuberosa* Arruda) and the caja tree (*S. mombin* L.); Silva Júnior et al. (2004) called it umbu-caja and indicated that it is a hybrid between these species. Almeida, Carvalho and Guerra (2007) examined the cariology and in situ genomic hybridization and concluded that umbu-caja is not a hybrid; thus, Machado and Carvalho (2015) performed molecular, morphometric, morphological, and temporal divergence investigations and concluded that the plant has a distinct lineage and named it *Spondias bahiensis* sp. nov.

Spondias sp. trees are distributed in backyards in urban and rural areas of the Northeast region of Brazil; There are centenary, productive plants (about 1,500 kg of fruits per harvest season) producing fruits for human and animal consumption. The fruits are drupes, named umbu-caja, caja-umbu, or cajarana. The harvesting is performed by picking the fruits from trees in natural environments or grown without any input or agricultural practice.

Most *Spondias* sp. drupes are sterile, i.e., without seeds. This is the main reason for the propagation of this plant by cutting, which is traditionally done with stem cuttings whose rooting is low and slow, although some growers claim that this plant has easy rooting. Contrastingly, the literature shows low rooting percentages, around 25% to 35% (FAÇANHA, 1997; LOPES, 1997; LIMA et al., 2002; RIBEIRO et al., 2007; BASTOS, 2010), proving that the rooting of cuttings of *Spondias* sp. is difficult.

According to Hartmann et al. (2011), several exogenous and endogenous factors are involved in the cutting rooting capacity, such as season, environmental conditions, propagation system, type of propagule, and the plant nutritional and phytosanitary status, phenological stage, and species. Propagules taken from plants at the end of the vegetative resting stage, defoliated, and with swollen

buds are recommended for *Spondias* spp. (SOUZA; COSTA, 2010).

Adventitious root formation is a complex process dependent on several factors, such as production of endogenous phytohormones and carbohydrates, presence of dormant buds, and emergence of sprouts (SMART et al., 2003). This is due to morphological changes associated with root formation in cuttings, such as callus formation and root development (THOMAS; SCHIEFELBEIN, 2002).

Many plant species respond to auxin application and to cuts at the base of their cuttings, especially woody cuttings. These cuts stimulate cell division, formation of callus and radical primordia, hormone and water absorption, and root emission by disruption of the sclerenchyma rings (HARTMANN et al., 2011).

This context shows the need for studies on rooting and plantlet formation by cuttings of *Spondias* sp. Thus, this work was carried out to evaluate the application of agrochemicals and the use of cuttings with lesions made at the base of cuttings on the rooting and formation of *Spondias* sp. plantlets.

MATERIAL AND METHODS

The experiment was conducted from October 2016 to January 2017 at the Experimental Field of the Embrapa Tropical Agroindustry in Pacajus, CE, Brazil. The experimental period presented average air temperature of 28.15 °C and relative air humidity of 72.79% (Figure 1). A randomized block experimental design was used, with five treatments - control (cuttings without any treatment) (T1); cuttings with two lesions at the base (CL) + rooting gel (RG) (Sela Gel[®]) (T2); CL + rooting fertilizer (RF) (Radimax[®]) (T3); cuttings with two transversal cross sections at the base (CS) + RG (T4); and CS + RF (T5). The environments (blocks) used were: full sun; 100% shade ceiling; 50% shade walls and ceiling; and 50% shade ceiling. The plots consisted of eight cuttings, totaling 160 cuttings.

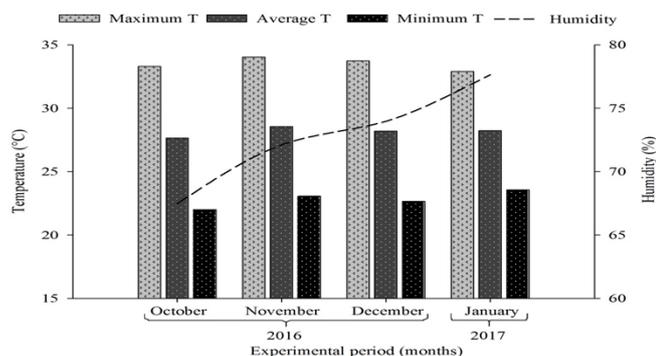


Figure 1. Means for maximum, average, and minimum air temperatures and relative air humidity during the experimental period.

Propagules were taken from wood branches of two 18-year-old *Spondias* sp. plants at the Embrapa Experimental Field in Pacajus, in October 2017. The propagules were left upright under the plant's canopy for seven days. Subsequently, cuttings with length of 25 cm, diameter of 29.7 mm, and mean bud per cutting of 8.7 were prepared. They were then covered with moistened jute bags until the following day, when they were immersed in a 0.05%

sodium hypochlorite solution for 4 minutes. Lesions (two incisions with the tip of a knife) were made for the T2 and T3 treatments, and transversal cross sections (two cuts with a knife, taking approximately 3 cm of the bark on opposite sides of the base of the cuttings) were made for the T4 and T5 treatments (Figure 2). The RG was applied by brushstroke, and the RF was applied by immersing them in an aqueous solution of 10 mL L⁻¹ for 10 minutes.



Figure 2. Preparation of *Spondias* sp. cuttings for the experiment - control (A), and lesions (B) and transversal cross sections (C) at the base of the cuttings.

According to the manufacturer, the rooting gel (RG) (Sela Gel[®]) was formulated to prevent embolism of cuttings after cutting, forming a protective film to prevent air entry, and to promote rooting due to its concentration of indole-3-butyric acid (3.000 mg.L⁻¹) (ECOPLANET, 2012). The rooting fertilizer used (Radimax[®]) was developed as a foliar fertilizer and a rooting improver based on an NPK formulation with specific amino acids and trace elements that promote root development (CODA, 2016).

The cuttings were planted, 10 minutes after the application of the treatments, into 6-liter black plastic pots filled with a pasteurized mixture of vermiculite, coconut husk powder, ground leaf fibers of *Copernicia prunifera*, and carbonized rice husk (2:1:1:1; v v⁻¹), which were previously pasteurized, i.e., submerged in water at 90 °C for 4 minutes.

The 160 cuttings were grown in hoop houses (40×60 cm transparent plastic bags on wire rods attached to the pots, and tied with rubber). The pots were placed inside polypropylene containers on wooden, concrete, and iron supports, in the four environments for rooting (stratified as blocks).

The plants were watered twice a week, by placing water (1.0 L) in the containers under the pots, through capillary absorption, without wetting the cuttings. The plastic bags of the hoop houses were removed at 34 days after the planting of the cuttings because of the contact of the shoots with the inner surface of the hoop houses.

The percentages of cuttings with callus and rooting formations, percentage of plantlets suitable for replanting (vigorous plantlets with more than four developed leaves), and number of leaflets were evaluated 90 days after the cuttings were planted.

Statistical analysis was performed using SAS software (2008); the data were subjected to analysis of variance and transformed into $\sqrt{x+1}$ (STEEL; TORRIE, 1980). The means of all variables in the treatments were compared by the REGWQ and Dunnett tests ($p < 0.05$).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences ($p < 0.01$) by the F test for all variables in all evaluated treatments. The environments presented no significant difference ($p < 0.05$) only for the percentage of cuttings with callus (Table 1). The overall means were 85% cuttings with callus, 42.5% cuttings with rooting, 35.62% plantlets suitable for replanting, and 67.91 leaflets per cut, denoting the

high vigor of the plantlets. The coefficients of variation for percentage of cuttings with callus, rooting, and plantlets suitable for replanting were below 14%, indicating a low dispersion of the data from the means (Table 1). However, the number of leaflets had a coefficient of variation of 82.7%, which is explained by the effects of treatments and propagules. Despite these propagules were homogeneous and originated from the same clone, they had variations in organic compound contents, bud stage, and unknown endogenous factors, which may have affected the shoot, callus, and root formation and the development of leaflets. The cuttings that sprouted and rooted had probably more nutrient reserves and buds, which induced and increased the emission of shoots and development of leaves and leaflets.

Table 1. Analysis of variance for percentage of cuttings with callus, percentage of cuttings with rooting, percentage of plantlets suitable for replanting, and number of leaflets in stem cuttings of *Spondias* sp.

Source of variation	Degrees of freedom	Cuttings with callus (%) ¹		Cuttings with rooting (%)		Plantlets suitable for replanting (%)		Number of leaflets	
		MS	Pr>F ²	MS	Pr>F	MS	Pr>F	MS	Pr>F
Treatment (T)	4	0.1137	0.0001	0.7576	0.0001	0.6128	0.0001	535.1519	0.0001
Environment (E)	3	0.0257	0.2314	0.0715	0.0315	0.0726	0.0305	84.4135	0.0012
T×E	12	0.0400	0.0123	0.0134	0.8647	0.0252	0.3974	33.9983	0.1158
Residue	140	0.0178		0.0236		0.0237		21.9924	
CV (%)		9.86		13.06		13.43		82.70	
Mean		85.00		42.50		35.62		67.91	

MS = Mean square. ¹Data transformed into $\sqrt{X+1}$. ²Significance level of the F test.

The percentages of cuttings that had sprouting were 6.9% at 13 days after planting (DAP), and 55.7% at 20 DAP, varying from 50% in cuttings with two lesions at the base (CL) + rooting gel (RG) (T2) to 59.4% in cuttings with two transversal cross sections at the base (CS) + rooting fertilizer (RF). The last evaluation (90 DAP) showed a higher number of sprouted cuttings and many with differentiated leaflets; 91.87% of the cuttings had at least one sprout, varying between treatments. The cuttings without any treatment (control) had lower sprouting percentage (87.5%), and those with CS + RG showed higher sprouting percentage (96.87%). These results indicate the rooting of cuttings, since the emission of shoots by cuttings occurs due to their nutritional reserves, which are essential for synthesis

of photoassimilates, hormones, and cofactors that induce formation of callus and adventitious roots (HARTMANN et al., 2011). Rooting is essential for differentiation, maintenance, and continuity of the development of leaflets, leaves, and branches, i.e., the formation of a new plant.

The environments used for formation of *Spondias* sp. plantlets showed significant differences for percentage of cuttings with rooting, percentage of plantlets suitable for replanting, and number of leaflets. The cuttings under 100% shade ceiling had the highest percentage of cuttings with rooting (55%), percentage of plantlets suitable for replanting (47.5%), and number of leaflets per plantlets (79.95). The lowest means were found for cuttings under full sun (Figure 3).

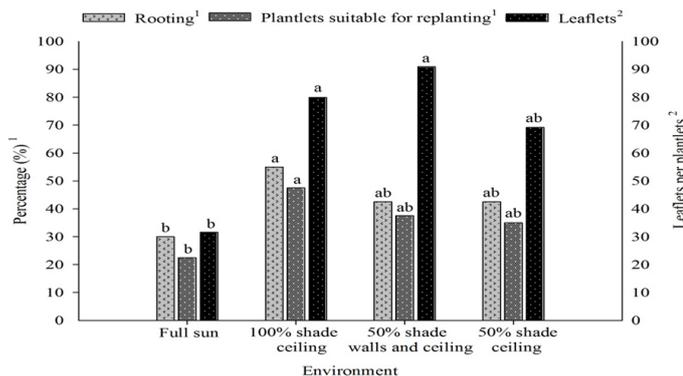


Figure 3. Percentage of cuttings with rooting, percentage of plantlets suitable for replanting, and number of leaflets per plantlets of stem cuttings of *Spondias* sp.

The treatments presented significant differences for all variables by the REGWQ test ($p < 0.05$) (Table 2). The highest percentages of cutting with callus were found for those in the treatment CS + RG (100%), followed by CS + RF

(93.75%) and CL + RG (87.5%); 81.25% of the cuttings in the treatment CL + RF had callus, not differing from the control, which had 62.5% cuttings with callus.

Table 2. Percentage of cuttings with callus, percentage of cuttings with rooting, percentage of plantlets suitable for replanting, and number of leaflets per plantlets in stem cuttings of *Spondias* sp.

Treatments	Cuttings with callus (%) ¹	Cuttings with rooting (%)	Plantlets suitable for replanting (%)	Number of leaflets
Control	62.50 b	12.50 b	9.38 c	18.06 b
CL + RG	87.50 a	68.75 a	56.25 b	112.34 a
CL + RF	81.25 ab	9.38 b	9.38 c	17.56 b
CS + RG	100.00 a	93.75 a	84.38 a	156.00 a
CS + RF	93.75 a	28.13 b	18.75 c	35.56 b

Means followed by the same letter in the column are significantly different by the REGWQ test at $p \leq 0.05$. CL = cuttings with two lesions at the base; CS = cuttings with two transversal cross sections at the base.

The highest percentages of cuttings with rooting were found in the treatments CS + RG (93.75%) and CL + RG (68.75%), differing from the other treatments, which presented less than 28.14% cuttings with rooting (Table 2). Façanha (1997), Vieira (2013), and Bastos et al. (2014) found percentages of cuttings with rooting of 22.5%, 20.74%, and 35%, respectively, confirming that *Spondias* sp. cutting rooting is difficult (SOUZA; COSTA, 2010). However, in the present study, the percentages of cuttings with rooting in the treatments with RG were higher than those found by those studies. This difference was probably due to the concentrations of rooting inhibitor substances present in the cuttings and the concentrations of the rooting improver used in the present study. The RG used (Sela Gel[®]) has an indole-3-butyric acid (IBA)

concentration of 3 g L⁻¹, which may have provided an adequate balance between these substances, leading to a better rooting of the cuttings. According to Pasqual et al. (2001), an adequate endogenous balance between rooting promoters and inhibitors is needed for the rooting initial process.

The lesions and transversal cross sections made in the base of the cuttings influenced positively the callus formation (Figure 4A), confirming that, in some species, lesions or transversal cross sections at the base of cuttings may promote callus formation (HARTMANN et al., 2011). The rooting of the cuttings was influenced by the agrochemical used; the RG used was more efficient for rooting of *Spondias* sp. cuttings (Figure 4B) than the RF probably due to its IBA concentration and promotion of protection against cutting embolism.



Figure 4. Formations of callus and adventitious roots (A) and plantlets (B) from *Spondias* sp. stem cuttings with cross section at the base and treated with rooting gel (Sela Gel[®]).

The highest percentages of plantlets suitable for replanting were found in the treatments with CS + RG (84.38%) and CL + RG (56.25%), differing from the other treatments, which had percentages lower than 18.8% (Table 2). The highest number of leaflets per plantlets (more vigorous plantlets) were found in the treatments CS + RG (156) and CL + RG (122.34), differing from the other treatments, which had means lower than 35.60. Tosta et al. (2012) found mean of 38.4 leaflets per *Spondias* sp. cuttings treated with 4,218 mg L⁻¹ of IBA.

According to the Dunnett's test, the percentages of cuttings with callus, rooting, and plantlets suitable for replanting and the number of leaflets per cutting of plants treated with

agrochemicals had significant differences when compared to the control (Table 3). The treatments CS + RG and CL + RG had 25% and 37.5% more cuttings with callus, respectively. The treatment CS + RG had 31.25% more cuttings with callus than the control. The highest percentage of cuttings with rooting were found in the treatments CS + RG (56.25%) and CL + RG (81.25%). The treatments CS + RG and CL + RG showed better results for plantlets suitable to replanting and number of leaflets per cutting when compared to the control. This denotes the effect of the RG combined with lesions or transversal cross sections on the rooting and vigor of *Spondias* sp. cuttings.

Table 3. Comparison between treatments for percentages of cuttings with callus, rooting, and plantlets suitable for replanting and number of leaflets in *Spondias* sp. stem cuttings.

Treatments	Cuttings with callus (%) ¹ Difference	Cuttings with rooting (%) Difference	Cuttings suitable for replanting (%) Difference	Number of leaflets Difference
CL + RG × Control	25.00 *	56.25 *	46.87 *	94.28 *
CL + RF × Control	18.75	-03.12	00.00	-0.50
CS + RG × Control	37.50 *	81.25 *	75.00 *	137.94 *
CS + RF × Control	31.25 *	15.62	9.37	17.50

*Significantly different by the Dunnett's test at $p < 0.05$.

CONCLUSIONS

Spondias sp. (umbu-caja) cuttings with transversal cross sections and treated with a rooting gel (Sela Gel[®]) had callus formation, rooting, and formed vigorous plantlets.

The use of a rooting fertilizer (Radimax[®]) in *Spondias* sp. cuttings promotes no rooting or plantlet formation.

Environments that provide at least 50% shade can be used to produce *Spondias* sp. cuttings.

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