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Rooting of ‘Pedro Sato’ guava cuttings as a function of diameter, types of cuts and treatment with bioestimulant

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Abstract: For the propagation of guava seedlings to occur, it is necessary to address numerous factors, therefore, the objective was to verify the influence of the diameter and type of cut on the base of ‘Pedro Sato’ guava tree cuttings. Experiment I: implemented in a 3 × 5 factorial scheme, consisting of three types of cut at the base of the cutting and five biostimulant concentrations (0, 5, 10, 15 and 20 g L^{-1}). Experiment II: implemented in a 2 × 5 factorial scheme, composed of two stem diameters (D1: 3 - 3,99 mm; D2: 4 - 4,99 mm) combined with five biostimulant concentrations (0, 5, 10, 15 and 20 g L^{-1}), and both experiments were conducted in a completely randomized design, with 4 replicates of 10 cuttings per plot. Considering the above, it could be concluded that the use of biostimulant increases the rooting rate. Cut with the removal of lateral portions at the base of the cutting promotes greater mortality, while evidencing less increase in root length. In experiment II, it was found that cuttings with diameter between 4 and 4.99 mm show greater survival rate at concentrations of 0 and 5 g L^{-1}, while cuttings with diameter between 3 and 3.99 mm have higher rooting rate at concentrations 0 and 5 g L^{-1} but with high mortality rate at concentration of 5 g L^{-1}.

Index terms: stem diameter, mixed mineral fertilizer, *Psidium*, cut type.

Enraizamento de estacas de goiabeira ‘Pedro Sato’ em função do diâmetro, tipos de cortes e tratamento com bioestimulante

Resumo: Para que a propagação de mudas de goiabeira ocorra, é necessária a abordagem de inúmeros fatores; portanto, objetivou-se verificar a influência do diâmetro e do tipo de corte na base de estacas de goiabeira ‘Pedro Sato’, tratadas com bioestimulante, no processo rizogênico. Experimento I: implantado em esquema

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fatorial 3 × 5, composto por três tipos de corte na base das estacas, combinados com cinco concentrações do bioestimulante (0; 5; 10; 15; 20 g L^{-1}). O experimento II: implantado em esquema fatorial 2 × 5, composto por duas classes de diâmetros de caule (D1: 3 a 3,99 mm; D2: 4 a 4,99 mm), combinados com cinco concentrações do bioestimulante (0; 5; 10; 15; 20 g L^{-1}), ambos em delineamento experimental inteiramente casualizado, com 4 repetições de 10 estacas por parcela. Diante das avaliações realizadas, pode-se concluir que a utilização do bioestimulante aumenta o percentual de Enraizamento; o corte com retirada de porções laterais na base da estaca promove maior mortalidade e menor incremento no comprimento de raiz; no experimento II, verificou-se que as estacas com diâmetro entre 4 e 4,99 mm propiciam maior sobrevivência nas concentrações de 0 e 5 g L^{-1}, enquanto as estacas com diâmetro entre 3 e 3,99 mm têm maior percentual de enraizamento nas concentrações de 0 e 5 g L^{-1}, mas com um elevado percentual de mortalidade na concentração de 5 g L^{-1}.

Termos para indexação: diâmetro de caule, fertilizante mineral misto, *Psidium*, tipo de lesão.

Introduction

Guava (*Psidium guajava* L.) is a fruit from the Myrtaceae family of great importance, being among the 50 best-known edible tropical fruits worldwide and with commercial importance in more than 50 countries, according to economic data. Guava consumption has grown in several countries, in Brazil in 2022, the harvested area was 22.630 hectares, with production of 564.764 tons, a value higher than that obtained in 2021, with harvested area of 22.077 hectares and production of 551.400 tons, showing production increment of 2.42%. In the national context, in 2022, the Northeastern region of Brazil had increase in production (281.524 tons), followed by the Southeastern (231.849 tons), Southern (31.522 tons), Mid-Western (12.727 tons) and Northern regions (7.142 tons) (IBGE, 2022).

The increase in guava production and consumption, observed in economic data, is due to the expansion of cultivation in different regions, due to its pleasant taste, affordable prices and availability for a long period of time during the year, in addition to its consumption diversification (COSTA et al., 2019a). But, currently, with the increasing demands of the consumer market for fruits of high commercial standard, the producer should use quality nursery plants, which are essential to obtain satisfactory production.

In this sense, increase in demand and production of quality nursery plants has been observed (CESARIN et al., 2020), providing standardization and homogenization of orchards, which does not occur in orchards formed by seeds, because a seminiferous propagation is not a practice commercially used, due to the high heterogeneity of plants, as it favors non-uniformity in several characteristics of propagated plants (COSTA et al., 2019a), except when it is desired to obtain rootstocks for the grafting process. On the other hand, cuttings are a propagative method whose principle is the regeneration of tissues, which, under appropriate conditions, stimulate the adventitious rhizogenic process in detached segments of the mother plant, originating a new plant. This method is widely used in fruit growing, as it maintains the genetic characteristics of the mother plant, generating greater uniformity of orchards, increasing productivity, improving fruit quality, and requiring short period for the formation of nursery plants suitable for the field, also presenting ease of execution, not requiring very specialized labor, and reduced costs when compared to other techniques (KAREEM et al., 2016; COSTA et al., 2019a).

However, for the propagation of guava cuttings, it is necessary to align numerous factors in addition to the propagation method. Among these, we can highlight the composition of substrates, types of cuttings (COSTA et al., 2019a), immersion times of the base of cuttings in biostimulants or plant growth regulators and their types and concentrations (COSTA et al., 2019b), the diameter of cuttings, type of cut made at the base of cuttings and the concentration of elements that assist in the maintenance and development of the newly cloned plant.

Regarding the cut at the base of cuttings, it is possible to verify the importance of breaking the physical barrier exerted by sclerenchyma rings, increasing the respiratory rate and the levels of auxin, carbohydrates and ethylene in the injured area, favoring the emission of adventitious roots (BASTOS et al., 2009; BETTONI et al., 2014) in addition to facilitating the contact of nutrients with the vascular tissue (DAMIANI, 2009). The diameter of cuttings is a factor that can affect the survival and the rooting potential, and the ideal diameter varies according to the species and the nature of cuttings (FERREIRA et al., 2010). Cuttings with larger diameter have increased reserve storage capacity, thereby enhancing their ability to support and expedite the rooting process. In contrast, cuttings with larger diameter may have greater amount of lignified tissue, which can negatively impact the rhizogenic capacity (CAMPOS et al., 2017).

Recently, the use of biostimulants that favor the rhizogenic process has increased among researchers, as it is a way of using natural products to stimulate natural processes, such as nutrient absorption and tolerance to abiotic stresses, unlike plant regulators that may contain synthetic elements in their composition, which do not always have the same field of action. Biostimulants act to increase the absorption of water and nutrients, and hormonal balance, which is part of the essential factors in the formation of nursery plants (OLIVEIRA et al., 2017). Radimaxi 20® is among the biostimulants available on the market, which has in its formulation Ca (25.6%), S (1.8%), Zn (2.5%) and Co (1.5%), some of these being important as cofactors in the rhizogenic process, such as zinc (OLIVEIRA et al., 2010).

Given the importance of clonal propagation by cuttings in the formation of guava orchards and the influence of diameter, basal cut and biostimulants in obtaining new plants, the objective of this study was to verify the influence of these factors, as well as their interaction for the rhizogenic process and formation of ‘Pedro Sato’ guava seedlings.

Material and Methods

Location and experimental design

Two experiments were conducted (experiment I and II) between the months of February and May 2018, in greenhouse located at the Department of Agronomy, Federal University of Viçosa (UFV), located in the municipality of Viçosa, state of Minas Gerais (latitude 20º 45 ‘14 “S, longitude 42º 52’ 55” W, with altitude of approximately 650m a.s.l.).

Both experiments were conducted in a completely randomized design, with 4 replicates of 10 cuttings per plot. Experiment I was implemented in a 3 × 5 factorial scheme, consisting of three types of cuts at the base of cuttings [Bevel cut (CB), bevel cut with 1 lateral wound (CL1) and bevel cut with 2 lateral wounds (CL2)] and five Radimaxi 20® biostimulant concentrations (0, 5, 10, 15 and 20 g L^{-1}). Experiment II was implemented in a 2 × 5 factorial scheme, being composed of two stem diameters (D1: 3 - 3.99 mm; D2: 4 - 4.99 mm) combined with five biostimulant concentrations (0, 5, 10, 15, and 20 g L^{-1}) only, with beveled cut at the base. Radimaxi 20® biostimulant was used in the form of mixed mineral fertilizer, presenting Ca (25.6%), S (1.8%), Zn (2.5%) and Co (1.5%) in its composition.

Collection, preparation and treatment of cuttings

'Pedro Sato' guava cuttings were collected from 15-year-old mother plants, deriving of asexual propagation, belonging to the experimental orchard. At the time of collection, mother plants were in condition of vegetative growth flow and with the last pruning carried out ± 80 days prior of the harvesting of shoots.

For experiments, semihardwood cuttings were collected from the middle part of lateral branches, with eight pairs of leaves, wrapped in moistened paper and packed in plastic bags, forming a humid chamber, and then transported to the greenhouse.

In experiment I, cuts were made at the base of cuttings (bevel cut, bevel cut with 1 lateral wound and bevel cut with 2 lateral wounds), with diameter varying from 3 to 4.99 mm. However, the lateral cut had on average 2 - 3 centimeters in length. In experiment II, cuttings were separated by diameter class according to the respective treatments (3 to 3.99 mm / 4 to 4.99 mm) and a straight cut was made at the apex and bevel at the base. In both cases, cuttings remained with 3 knots, with approximately 12 cm in length, with a pair of leaves at the apex kept with limbs reduced to half the total leaf length to maximize the physical space and reduce the transpiration rate (Figure 1).

Figure 1. Scheme of the conduction of experiments, from the collection of cuttings from mother plants, verification of diameters, cuts at the base until rooting.

After selecting the diameters and making cuts at the base of cuttings, plants were treated with polyvinylpyrrolidone solution (PVP) at concentration of 1 g L^{-1}, for 10 minutes. After immersion, cuttings were removed and allowed to drain for 1 min. Subsequently, 2 cm of the base of cuttings were immersed in Radimaxi 20® solution for 10 seconds, according to the defined treatments, and then two thirds of the length of cuttings were then staked in polyethylene bags containing washed sand and commercial substrate (MecPlant®), at proportion 1:1 (v/v). Biostimulant solutions were prepared by diluting Radimaxi 20® doses (5, 10, 15 and 20 g L^{-1}) in 100 ml of alcohol P.A separately, being the volume of each solution subsequently completed with 1L of distilled water. After dilution, the preparation was kept in volumetric flask for 24 hours, with solutions being stirred every 2 hours.

Cuttings were maintained throughout the experimental period under intermittent misting system, with activation for 10 seconds at 10-minute intervals. For the control of fungal diseases, cuttings were treated with biweekly fungicide sprays, whose active ingredient is tebuconazole (0.2g / L of water).

Data collection and statistical analysis

At 90 days after the installation of the experiment, the following traits were measured: survival rate (%), rooted cuttings (%), unrooted live cuttings (%), cuttings with callus (%), cuts with leaf retention (%), cut mortality (%), number of roots per cut (No.), root length (cm), shoot fresh mass (g), shoot dry mass (g), root fresh mass (g) and root dry mass (g).

Traits rooted cuttings (%), unrooted live cuttings (%), cuttings with callus (%), cuts with leaf retention (%) and shoot dry mass (g) were correlated only with the percentage of cuttings that remained alive until the end of the experiment. Traits mean number of roots per cut (No.), mean length of roots per cut (cm) and root dry mass (g) were correlated only with the percentage of cuttings that rooted and ended with the percentage of dead cuttings, considering all as dead cuttings at the end of the experiment.

Regarding statistical analyses, the Lilliefors test was performed using the Genes software (CRUZ, 2013), and traits that did not meet the assumption of normality were submitted to transformation. In experiment I, all traits analyzed were transformed, while in experiment II, only traits survival rate, rooted cuttings, unrooted live cuttings, cut mortality, cuttings with callus and cuts with leaf retention were transformed. For traits given in percentage, the transformation by the function $\sqrt{(x + 0.5)}$ was used and for counting data, the function (log + 1) was used. After transformation, analysis of variance and F test ($P \leq 0.10$) were performed, and the means were compared using the Tukey test and the Sisvar software (FERREIRA, 2019).

Results and Discussion

Experiment I

The factors under study showed significant interaction for traits survival rate and mortality (Table 1). The interaction between Radimaxi 20® biostimulant concentrations and types of cuts at the base of cuttings influenced the survival rate. The highest survival rate was obtained in the absence of biostimulant using the bevel cut (CB), and at concentration 15 g L^{-1}, the highest values were obtained using lateral cuts CL1 and CL2, whereas the other concentrations did not show significant differences in relation to types of cuts. Regarding the type of cut, only CB and CL2 showed significant differences in relation to the survival rate, with the highest values observed at concentration of 0 g L^{-1} for CB and concentrations of 5, 10 and 20 g L^{-1} for CL2. Proportionally contrary to the survival rate, mortality also showed significant interaction at concentration of 0 g L^{-1}, where CB presented the lowest cut mortality percentage, among the types of cuts.

Regarding the rooting percentage, it was found that the biostimulant concentration of 5 g L^{-1} was responsible for the highest average number of cuttings that responded to the treatment, expressing rhizogenesis at the base of cuttings, not differing from concentrations of 0, 10 g L^{-1}, and 20 g L^{-1}, in contrast, concentration of 15 g L^{-1} registered the lowest average number of unrooted live cuttings. For variable root length, concentrations of 10 and 20 g L^{-1} showed the largest root lengths and the CB type stood out from the other types of cuts (Tables 1 and 2), but no differing from treatments 1 and 2. However, as observed in experiment I, there were no significant differences in cuts with leaf retention, mean number of roots per cut, root fresh and dry mass in relation to types of cuts and concentrations used.

Table 1. Survival rate of semihardwood cuttings (SURVIVAL), cut mortality (MORTALITY), cuts with leaf retention (LEAF RETENTION) and rooted cuttings (RC), of ‘Pedro Sato’ guava using biostimulant and different cuts at the base of cuttings, Viçosa, MG

Types of cuts at the base of cuttings		CB	CL1	CL2	CB	CL1	CL2	CB	CL1	CL2	Average	CB	CL1	CL2	Average
Survival rate and mortality		SURVIVAL RATE %			MORTALITY %			LEAF RETENTION %				RC %			
Radimaxi 20® concentration (g.L^{-1})	0	92.50Aa	65.00Ba	67.50Aba	7.50Bb	35.00Aa	32.50Aa	74.16	90.83	95.83	86.94	23.05	20.86	41.66	28.52ab
	5	75.00Aab	65.00Aa	72.50Aa	25.00Aab	37.50Aa	27.50Aa	79.41	69.91	86.50	78.61	38.39	34.67	29.76	34.27a
	10	67.50Aab	67.50Aa	80.00Aa	32.50Aab	30.00Aa	20.00Aa	87.50	83.92	71.57	81.00	34.72	22.76	9.02	22.16ab
	15	60.00Bb	82.50Aa	72.50Aba	40.00Aa	17.50Aa	27.50Aa	82.85	69.09	90.35	80.76	24.28	6.25	16.87	15.80b
	20	65.00Aab	75.00Aa	85.00Aa	35.00Aa	25.00Aa	15.00Aa	80.35	77.23	88.19	81.92	26.78	16.51	27.98	23.75ab
Average		**72.00**	**71.00**	**75.50**	**28.00**	**29.00**	**24.50**	**80.85**	**78.20**	**86.49**		**29.44**	**20.21**	**25.06**	
CV (%)			**11.52**			**31.35**			**15.03**				**46.25**		
Factors	**DF**							**F**							
Concentration (Cc)	4		0.328 ^{ns}			0.469 ^{ns}			0.522 ^{ns}				2.067♦		
Types of cuts (Tc)	2		0.483 ^{ns}			0.740 ^{ns}			1.370 ^{ns}				1.250 ^{ns}		
Interaction (Cc x Tc)	8		2.228 *			2.367*			0.857 ^{ns}				0.999 ^{ns}		
Residual	45		-			-			-				-		

Averages followed by the same lowercase letter in the column and uppercase in the row do not differ by the Tukey’s test. GL: Degrees of freedom. ns. **. * and ♦: not significant and significant at 1%. 5% and 10% by the F test. respectively. (CB) bevel cut. (CL1) bevel cut with 1 lateral wound. (CL2) bevel cut with 2 lateral wounds.

Table 2. Mean number of roots per cut (semihardwood) (NR). mean length of roots per cut (LR). and root fresh and dry mass (FMR and MSR. respectively). of ‘Pedro Sato’ guava using biostimulant and different cuts at the base of cuttings. Viçosa. MG

Types of cuts the base of the cuttings		CB	CL1	CL2	Average	CB	CL1	CL2	Average	CB	CL1	CL2	Average	CB	CL1	CL2
Related to rooted cuttings			NR				LR (cm)				FMR (g)				MSR (g)	
Radimaxi 20® concentration (g.L^{-1})	0	1.02	1.50	2.16	1.56	2.28	5.19	4.78	4.08ab	0.49	0.95	1.00	0.81	0.13	0.19	0.24
	5	1.54	0.91	1.41	1.29	5.99	2.70	3.72	4.13ab	1.07	0.42	0.56	0.68	0.23	0.08	0.14
	10	1.91	1.87	0.87	1.55	5.79	5.04	3.55	4.79a	1.10	1.00	0.48	0.86	0.19	0.22	0.08
	15	1.12	0.25	0.58	0.65	5.15	0.52	3.27	2.98b	0.64	0.15	0.31	0.37	0.15	0.04	0.08
	20	1.75	1.00	0.97	1.24	6.06	6.18	3.12	5.12a	2.47	0.78	0.45	1.23	0.20	0.17	0.12
Average		**1.47**	**1.11**	**1.20**		**5.05A**	**3.92B**	**3.68B**		**1.15**	**0.66**	**0.56**		**0.18**	**0.14**	**0.13**
CV (%)			**346.41**				**53.78**				**774.60**				**0.00**	
Factors	**DF**								**F**							
Concentration (Cc)	4		0.500 ^{ns}				2.786*				1.000 ^{ns}				1.0E+000$^{9\ ns}$	
Types of cuts (Tc)	2		0.800 ^{ns}				2.679♦				1.000 ^{ns}				1.0E+000$^{9\ ns}$	
Interaction (Cc x Tc)	8		0.800 ^{ns}				1.741 ^{ns}				1.000 ^{ns}				1.0E+000$^{9\ ns}$	
Residual	45		-				-				-				-	

Averages followed by the same lowercase letter in the column and uppercase in the row do not differ by the Tukey’s test. GL: Degrees of freedom. ns. **. * and ♦: not significant and significant at 1%. 5% and 10% by the F test. respectively. (CB) bevel cut. (CL1) bevel cut with 1 lateral wound. (CL2) bevel cut with 2 lateral wounds.

Experiment II

Experiment II evaluated the effects of biostimulant concentrations and the diameter of guava cuttings on traits survival rate. unrooted live cuttings, rooted cuttings. shoot fresh mass, cut mortality and root fresh mass and both exhibited significant interaction among factors under study. In addition, traits cuts with leaf retention and shoot dry mass were significant considering factor cutting diameter (Tables 3 and 4).

Regarding survival rate, it was found that significant differences occurred at concentrations of 10 and 20 g L^{-1}, where diameter class 2 (4 to 4.99mm) presented the highest survival rate of 'Pedro Sato' guava cuttings (85% and 77.50%. respectively). In rooted cuttings, only concentrations 0 and 10 g L^{-1} differed, but corroborating with the survival rate. Diameter class 2 also responded better to treatment with Radimaxi 20® biostimulant. Consistently, both cuts with leaf retention and shoot dry mass, as well as the root fresh mass, diameter class 2 (4 to 4.99 mm) obtained superior results, compared to diameter class 1 (3 to 3.99 mm).

The survival rate of cuttings is intrinsically linked to the concentration of reserves, which must be sufficient to preserve their activity, until there is regeneration of fundamental tissues and the full capacity for self-support is reestablished, thus being able to form a new plant (Tables 1 and 3). In other words, the nutritional status of mother plants and consequently the propagule is an extremely important factor for the success of vegetative propagation, as it will determine the balance of carbohydrates, nitrogenous substances, amino acids, auxins, among other metabolic compounds, essential to plant maintenance (GUIRRA et al., 2021). Moreover, the nutritional status of plants can synergistically interact with various factors, affecting survival rate, rhizogenesis, growth, and post-propagation vigor (PIRES, 2015).

In cases where the concentration of reserves is inadequate, the survival of cuttings and rooting is compromised and this effect can be observed in experiment II, where the increase in diameter directly affected these traits, in which larger diameter may have higher concentration of reserves and consequently the cut can respond better to certain stimuli. In this case, it is also essential to maintain the leaf activity, aiming to complement, not only the maintenance of reserves, but also their remobilization, and also to promote the synthesis of new compounds useful to the cutting setting (COSTA et al., 2019a).

Although rooting and mineral nutrition are closely related, little is known about the isolated action of nutrients present in the mother plant that can contribute to rhizogenesis due to the difficulty of isolating and characterizing the factors that control them, due to their complex interaction (LOPES, 2016). However, according to Carvalho and Silva (2012), the nutrients involved in the various metabolic processes associated with the differentiation and formation of the root meristem are essential for the initiation of the root formation process, where the mobilization of nutrients, such as Ca, at the base of cuttings is closely related to totipotency and indicates the importance of mineral nutrients in the process. This occurs due to the action of calcium in the cell division process, formation of the middle lamella, root elongation and cell wall, so that its deficiency will directly act on the structuring of the root formation (CUNHA et al., 2009).

Cunha et al., (2009) reported that in the differentiation and de-differentiation of tissues, other elements are essential. which are found in the biostimulant under study, such as zinc, which participates in the synthesis of tryptophan, which is a precursor of auxin and acts as a rooting cofactor. Another element is sulfur, which acts in carbohydrate metabolism, therefore being fundamental in the root induction phase. In addition to these elements,

Table 3. Survival rate of semihardwood cuttings (SURVIVAL). cut with leaf retention (LR). unrooted live cuttings (ULC). cuttings with callus (CALLUS). rooted cuttings (RC) and shoot fresh and dry mass of cuttings (FMAP and DSAP. respectively). of 'Pedro Sato' guava using biostimulant and different cutting diameters. Viçosa. MG

Cutting diameter		D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
Live cuttings		SURVIVAL RATE %		LR %		ULC %		CALLUS %		RC%		FMAP (g)		DSAP (g)	
Radimaxi 20® concentration (g.L^{-1})	0	75.00Aab	75.00Aa	70.71	90.17	49.52Bb	80.80Aa	79.52	89.93	46.30Aa	19.19Ba	2.21Bab	3.88Aa	0.80	1.39
	5	87.50Aa	72.50Aa	74.79	86.60	70.69Aab	64.28Aa	81.25	93.30	29.30Aa	35.71Aa	2.69Bab	3.81Aa	0.96	1.42
	10	60.00Bab	85.00Aa	82.70	85.00	62.29Aab	81.87Aa	85.83	84.37	37.70Aa	18.12Ba	2.82Aa	3.48Aa	0.99	1.24
	15	67.50Aab	65.00Aa	72.08	90.27	80.20Aa	69.44Aa	76.87	70.83	19.79Aa	30.55Aa	2.79Bab	3.88Aa	0.84	1.37
	20	57.50Bb	77.50Aa	73.69	78.21	68.92Aab	72.50Aa	77.85	76.07	31.07Aa	27.50Aa	2.24Bb	3.86Aa	0.81	1.32
Average		**69.50**	**75.00**	**74.79B**	**86.05A**	**66.32**	**73.77**	**80.26**	**82.90**	**32.83**	**26.21**	**2.55**	**3.78**	**0.88B**	**1.34A**
CV (%)		**10.66**		**11.88**		**23.18**		**27.53**		**32.52**		**13.79**		**27.49**	
Factors	**DF**							**F**							
Concentration (Cc)	4	1.209^{ns}		0.230^{ns}		0.430^{ns}		0.541^{ns}		0.485^{ns}		1.174^{ns}		1.200^{ns}	
Types of cuts (Tc)	1	1.281^{ns}		4.150$^{\blacklozenge}$		2.045^{ns}		0.144^{ns}		1.140^{ns}		69.000**		4.800*	
Interaction (Cc x Tc)	4	2.418$^{\blacklozenge}$		0.376^{ns}		2.376$^{\blacklozenge}$		0.249^{ns}		2.153$^{\blacklozenge}$		2.478$^{\blacklozenge}$		1.800^{ns}	
Residual	30	-		-		-		-		-		-		-	

Averages followed by the same lowercase letter in the column and uppercase in the row do not differ by the Tukey's test. GL: Degrees of freedom. ns. **. * and ♦: not significant and significant at 1%. 5% and 10% by the F test. respectively. (D1) stem diameters from 3 to 3.99 mm. (D2) stem diameters from 4 to 4.99 mm.

Table 4. Percentage of dead semihardwood cuttings (MORTALITY). mean number of roots per cut (NR). mean length of roots per cut (LR) and root fresh and dry mass of cuttings (FMR and MSR. respectively). of 'Pedro Sato' guava using biostimulant and different cutting diameters. Viçosa. MG

Cutting diameters		D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
		Cutting mortality		Related to rooted cuttings							
		MORTALITY RATE %		NR		LR (cm)		FMR (g)		MSR (g)	
Radimaxi 20® concentration (g.L^{-1})	0	25.00Aab	25.00Aa	1.91	1.50	3.65	8.59	0.38Ba	1.38Aa	0.10	0.30
	5	12.50Bb	27.50Aa	2.06	1.33	4.08	3.42	0.70Aa	0.46Ab	0.18	0.20
	10	40.00Aab	15.00Ba	3.54	1.68	6.32	4.93	1.07Aa	0.93Aab	0.22	0.19
	15	32.50Aab	35.00Aa	1.31	2.00	4.22	3.68	0.64Aa	0.68Aab	0.17	0.14
	20	42.50Aa	22.50Ba	1.33	2.25	4.94	4.30	0.69Aa	0.88Aab	0.14	0.23
Average		**30.50**	**25.00**	**2.03**	**1.75**	**4.64**	**4.98**	**0.69**	**0.86**	**0.16**	**0.21**
CV (%)		**35.15**		**60.54**		**58.82**		**65.46**		**0.00**	
Factors	**DF**					**F**					
Concentration (Cc)	4	0.802^{ns}		0.902^{ns}		0.950^{ns}		1.843^{ns}		1.0E+000$^{9\ ns}$	
Types of cuts (Tc)	1	0.839^{ns}		0.166^{ns}		0.146^{ns}		0.771^{ns}		1.0E+000$^{9\ ns}$	
Interaction (Cc x Tc)	4	2.436$^{\blacklozenge}$		2.006^{ns}		1.487^{ns}		2.271$^{\blacklozenge}$		1.0E+000$^{9\ ns}$	
Residual	30	-		-		-		-		-	

Averages followed by the same lowercase letter in the column and uppercase in the row do not differ by the Tukey's test. GL: Degrees of freedom. ns. **. * and ♦: not significant and significant at 1%. 5% and 10% by the F test. respectively. (D1) stem diameters from 3 to 3.99 mm. (D2) stem diameters from 4 to 4.99 mm.

iron, copper, boron and manganese also participate in the formation of cell walls, lignification and cell elongation, essential for sprouting, rooting or callogenic growth.

The mineral elements, available in biostimulants, must be used not only in the treatment of propagules, but also play a relevant role before the collection of cuttings from mother plants, as they have highly significant effects on plant maintenance indices and subsequent processes (GUIRRA et al., 2021), also presenting essential and specific functions in plant metabolism, which can act as constituents of the organic structure, activators of enzymatic reactions, charge carriers and osmoregulatory (LOPES, 2016).

A technique used in propagation aiming at greater contact of vascular tissues with exogenous elements is the incision at the base of cuttings (DAMIANI, 2009), reducing the number of tissues formed by sclerenchyma, which are responsible for the formation of a barrier that can hinder the cellular signaling process (BETTONI et al., 2014). Thus, when a cut is made at the base of cuttings, tissues are more exposed to nutrients contained in the substrate, helping with physiological responses.

Considering cutting diameter, it appears that larger diameters can promote greater survival rate (Table 3 and 4), mainly due to the greater storage capacity of metabolites, providing greater availability of reserves for a longer period, which can be beneficial to the rhizogenic process and maintenance of the cutting activity, regardless of biostimulant concentration.

On the other hand, the use of higher cutting diameters may present greater rooting difficulties, due to the higher concentration of oxidizing phenolic compounds, especially in the Myrtaceaes species, such as guava, which when injured, presents more intense tissue oxidation, thus compromising the rhizogenic process and, mainly, the greater amount of lignification tissues, which reduces the relationship between tissues and the totipotency capacity, that is, compromising the rooting process (PELIZZA et al., 2011). This is confirmed by the rooting result obtained, in which, regardless of biostimulant concentration, less rooting was observed, when higher cutting diameters were used, specifically D2 (Table 3). Zhang et al., (2010) evaluated the effect of diameter on Feijoa cuttings and found that the diameter of 0.25 - 0.30 cm promotes higher percentage of rooted cuttings, while higher diameters show lower values, because they are tissues with greater totipotency capacity.

Cuttings with smaller diameter have characteristics of younger tissues and with lower degree of lignification, higher proportion of cells capable of de-differentiation, higher cell division rate, high concentration of flavonoids and lower number of phenolic compounds, which can facilitate rooting and the production of new plants in a shorter period of time (COSTA et al., 2017). However, cuttings with smaller diameters accumulate fewer nutrient reserves, showing greater predisposition for tissue dehydration (ARANTES et al., 2021).

In general, there is great variation in the responses of Myrtaceaes to the use of biostimulants and techniques such as lesion at the base and different diameters, which requires further studies on the influence of biostimulants in isolation and in combination with other elements. These results are relevant for a better understanding of factors that act in the formation of seedlings through vegetative propagation.

Conclusion

The use of Radimaxi 20® biostimulant increases the rooting percentage. Cuts with the removal of lateral portions at the base of cuttings promote greater mortality, while evidencing less increase in root length. Cuttings with diameter class 2 (4 to 4.99 mm) show greater survival rate at concentrations of 0 and 5 g L^{-1}.

References

ARANTES. C.R.A.; CORREA. A.R.; SILVA. A.M.P.; SPILLER. C.; CAMILI. E.C.; COELHO. M.F.B. Propagação vegetativa de *Talinum triangulare* em função de diferentes épocas de coleta. tipos de estacas e substrates. **Revista em Agronegócio e Meio Ambiente**. Maringá. v.14. n.3. p.571-85. 2021. *https://doi.org/10.17765/2176-9168.2021v14n3e8213*

BASTOS. D.C.; SCARPARE FILHO. J.A.; LIBARDI. M.N.; PIO. R. Effect of indolebutyric acid. etiolation and basal injury on propagation of star fruit by hardwood cuttings. **Revista de Ciência e Agrotecnologia**. Lavras. v.33. n.1. p.313-8. 2009. *https://doi.org/10.1590/S1413-70542009000100043*

BETTONI. J.C.; GARDIN. J.P.; FELDBERG. N.P.; SCHUMACHER. R.; PETRI. J.L.; SOUZA. J.A. Indução do enraizamento em estacas lenhosas de porta enxerto de videira VR043-43 submetidas a lesões e aplicação de auxinas. **Revista Evidência**. Araxá. v.14 n.2. p.129-38. 2014.

CAMPOS. J.A.; OLIVEIRA. N.J.F.; CHAMBA. J.S.V.; COLEN. F.; COSTA. C.A.; FILHO. A.S.S. Brotação de ora-pro-nóbis em substrato alternativo de casca de arroz carbonizada. **Holos**. Natal. v.07. n.33. p.148-67. 2017. *https://doi.org/10.15628/holos.2017.6424*.

CARVALHO. J.M.F.C.; SILVA. M.M.A. **Plantas matrizes na propagação vegetativa**. Campina Grande: Embrapa Algodão. 2012. 36 p. (Documentos).

CESARIN. V.; MESQUITA. J.A.; OLIVEIRA. S.J.; SANTOS. H.C.A.; RIBEIRO. N.M.; COSTA. Y.K.S.; SANTOS. I.L.; NASCIMENTO. R.S.M.; CARVALHO. L.B. Produção de mudas de açaizeiro. **Revista Agronomia Brasileira**. Jaboticabal. v.4. p.1-7. 2020.

COSTA. J. C. F.; MENDONÇA. R. M. N.; FERNANDES. L. F.; SILVA. G. C.; SILVA. S. M.; PEREIRA. W. E.; CAVALCANTI. L. F.; FIGUEIREDO. L. F. Rooting inducers and organic substrates in the propagation of 'Paluma'; guava by cutting. **African Journal Agricultural Research.** v. 12. n. 5. p. 371-376. 2017. DOI: 10.5897/AJAR2016.11830.

COSTA. J.C.F.; MENDONÇA. R.M.N.; SILVA. G.C.; SILVA. S.M.; PEREIRA. W.E.; SANTOS. C.E.M. Rooting of herbaceous and semihardwood cuttings of guava cv.Século XXI. under varying concentrations of indolebutyric acid. **Journal of Experimental Agriculture International**. Gurgaon. v.33. n.1. p.1-9. 2019a. *https://doi.org/10.9734/JEAI/2019/v33i130135*.

COSTA. J.C.F.; MENDONÇA. R.M.N.; SILVA. G.C.; SILVA. S.M.; PEREIRA. W.E.; SANTOS. C.E.M. Effect of indolebutyric acid immersion period on the rhizogenic process of guava cuttings (*Psidium guajava* L.) cultivar Século XXI. **Journal of Experimental Agriculture International**. Gurgaon. v.32. n.5. p.1-7. 2019b. *https://doi.org/10.9734/JEAI/2019/v32i530120*.

CRUZ. C.D. GENES: a software package for analysis in experimental statistics and quantitative genetics. **Acta Scientiarum**. **Agronomy**. Maringá. v.35. n.3. p.271-6. 2013. *https://doi.org/10.4025/actasciagron.v35i3.21251*.

CUNHA. A.C.M.C.M.; PAIVA. H.N.; BARROS. N.F.; LEITE. H.G.; LEITE. F.P. Relação do estado nutricional de minicepas com o enraizamento de miniestacas de eucalipto. **Revista Brasileira de Ciência do Solo**. Viçosa. MG. v.33. n.3. p.591-9. 2009. *https://doi.org/10.1590/S0100-06832009000300012*.

DAMIANI. C.R.; PELIZZA. T.R.; SCHUCH. M.W.; RUFATO. A.R. Luminosidade e IBA no enraizamento de microestacas de mirtileiro dos grupos *Rabbiteye* e *Southern Highbush*. **Revista Brasileira de Fruticultura**. Jaboticabal. v.31. n.3. p.650-5. 2009. *https://doi.org/10.1590/S0100-29452009000300005*.

FERREIRA. D.F. Sisvar: a computer analyses system to fixed effects split plot type. **Revista Brasileira de Biometria**. Lavras. v.37. n.4. p.529-35. 2019. *https://doi.org/10.28951/rbb.v37i4.450*.

FERREIRA. L.E.; ANDRADE. L.A.; GONÇALVES. G.S.; SOUZA. E.P.; FERREIRA. H.V. Diameter of cuttings and substrates in the vegetative propagation of maniçoba *Manihot glaziovii* Muell.Arg. **Revista Ciência Agronômica**. Fortaleza. v.41. n.3. p.393-402. 2010. *https://doi.org/10.1590/S1806-66902010000300011*.

GUIRRA. B.S.; SILVA. M.F.; SILVA. J.E.S.B.; GUIRRA. K.S. Nutrição da planta matriz determina a qualidade de propágulos. **Caderno de Ciências Agrárias**. Montes Claro. v.13. p.1-6. 2021. *https://doi.org/10.35699/2447-6218.2021.37015*

IBGE - Instituto Brasileiro de Geografia e Estatística. **Produção agrícola municipal**. Rio de Janeiro. 2022. Disponível em: *https://sidra.ibge.gov.br/tabela/1613#resultado*. Acesso em: 11 Jan. 2024.

KAREEM. A.; MANAN. A.; SAEED. S.; REHMAN. S.U.; SHAHZAD. U.; NAFEES. M. Effect of different concentrations of IBA on rooting of Guava *Psidium guajava* L. in low tunnel under shady situation. **Journal of Agriculture and Environment for International Development**. Firenze. v.110. n.2. p.197-203. 2016. *https://doi.org/10.12895/jaeid.20162.432*.

LOPES. A. S. **Enraizamento de miniestacas e nutrição mineral em minicepas de** *Eucalyptus urophylla* S. T Blake. 2016. 94 f. Dissertação (mestrado) - Pós-Graduação em Ciências Florestais e Ambientais. Universidade Federal de Mato Grosso. Cuiabá – MT. 2016.

OLIVEIRA. F.I.C.; GRAGEIRO. L.C.; NEGREIROS. M.Z.; NUNES. G.H.S.; ARAGAO. F.A.S. A cultura do melão. *In*: FIGUEIRÊDO. M.C.B.; GONDIM. R.S.; ARAGÃO. F.A.S. (Ed.). **Produção de melão e mudanças climáticas**: sistemas conservacionistas de cultivo para redução das pegadas de carbono e hídrica. Brasília. DF: Embrapa. 2017. p.17-32.

OLIVEIRA. M.C.; VIEIRA NETO. J.; PIO. R.; OLIVEIRA. A.F.; RAMOS. J.D. Enraizamento de estacas de oliveira submetidas a aplicação de fertilizantes orgânicos e AIB. **Revista Ciência e Agrotecnologia**. Lavras. v.34. n.2. p.337-44. 2010. *https://doi.org/10.1590/S1413-70542010000200010*.

PELIZZA. T.R.; DAMIANI. C.R.; RUFATO. A.R.; SOUZA. A.L.K.; RIBEIRO. M.F.; SCHUCH. M.W. Microestaquia em mirtileiro com diferentes porções do ramo e substratos. **Revista Bragantia**. Campinas. v.70. n.2. p.319-24. 2011. *https://doi.org/10.1590/S0006-87052011000200010*.

PIRES. P.P.; WENDLING. I.; AUER. C.; BRONDANI. G.E. Sazonalidade e soluções nutritivas na miniestaquia de *Araucaria angustifolia* (Bertol.) Kuntze. **Revista Árvore**. Viçosa. MG. v.39. n.2. p.283-93. 2015. *https://doi.org/10.1590/0100-67622015000200008*.

ZHANG. M.; WANG. D.; REN. S.; FAN. L.; LIU. R. Effects of Feijoa cutting diameter on seedling quality. **Agricultural Journal**. Dubai. v.5. n.3. 139-41. 2010. *https://doi.org/10.3923/aj.2010.139.141*.