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Vegetative propagation of hops (*Humulus lupulus*), effect of biostimulants, size and position of cuttings

Propagação vegetativa de lúpulo (Humulus lupulus), efeito de bioestimulantes, tamanho e posição das estacas

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ABSTRACT

The aim of this work was to evaluate the effect of different cutting lengths, the use of biostimulants and diameter of cuttings on hops vegetative propagation. The work was conducted in a greenhouse at the Center for Agricultural Sciences (CCA) at the Federal University of Santa Catarina (UFSC), in Florianópolis/SC, Brazil, between October 2019 and January 2021. In experiment 1, cuttings with one, two and three buds were tested, with and without application of biostimulant SprintAlga TS® (Biolchim) in Brewer's Gold and Cascade cultivars. In experiment 2, cuttings with diameter of 1.5 cm, 2.5 cm and 3.5 cm were tested for Northern Brewer cultivar. In both experiments, survival, rooting, root length, root quality, number of shoots and shoot length were evaluated. In experiment 1, Cascade had lower survival, rooting and development compared to Brewer's Gold. The use of biostimulant increased survival and rooting rates of both cultivars. For Brewer's Gold the use of biostimulant improved root quality and increased shoot number, root and shoot length. For Brewer's Gold, 3-bud cuttings improved root quality and increased number of shoots. For Cascade, 1-bud cuttings showed the highest survival, rooting and development rates. In experiment 2, the highest rates of survival, rooting and the longest root length were obtained with 1.5 cm diameter cuttings. Larger diameter cuttings (2.5 and 3.5 cm) produced fewer shoots, but longer shoots.

KEYWORDS: rooting; root quality; Northern Brewer; Cascade; Brewer's Gold.

RESUMO

Objetiva-se com este trabalho avaliar o efeito de diferentes comprimentos e diâmetros de estacas e da utilização de bioestimulantes na propagação vegetativa de lúpulo. O trabalho foi conduzido em uma estufa no Centro de Ciências Agrárias (CCA) da Universidade Federal de Santa Catarina (UFSC), em Florianópolis/SC, Brasil, entre outubro de 2019 e janeiro de 2021. No experimento 1 foram testadas estacas com uma, duas e três gemas, com e sem aplicação do bioestimulante SprintAlga TS® (Biolchim) nas cultivares Brewer´s Gold e Cascade. No experimento 2 foram testadas estacas de 1,5 cm, 2,5 cm e 3,5 cm de diâmetro para a cultivar Northern Brewer. Foram avaliados o percentual de sobrevivência, enraizamento, comprimento de raízes, qualidade da raiz, número e comprimento de brotações. No experimento 1 Cascade apresentou menores percentuais de sobrevivência, enraizamento e desenvolvimento. O uso do bioestimulante aumentou a sobrevivência e o enraizamento de ambas as cultivares. Para Brewer's Gold o bioestimulante aumentou a qualidade das raízes, número de brotações, comprimento de raiz e de brotação. Estacas de Brewer's Gold com 3 gemas favoreceram a qualidade das raízes e número de brotações. Estacas de Cascade com 1 gema apresentaram maior percentual de sobrevivência, enraizamento e desenvolvimento. No experimento 2 as estacas de 1,5 cm de diâmetro apresentaram maior sobrevivência, enraizamento e comprimento de raiz. Estacas com 2,5 e 3,5 cm produziram menor número de brotações, mas de maior comprimento.

PALAVRAS-CHAVE: enraizamento; qualidade de raiz; Northern Brewer; Cascade; Brewer's Gold.

INTRODUCTION

The hop (*Humulus lupulus*) is a plant originating from the northern hemisphere, belongs to Cannabaceae family, it is a vine growing plant, dioecious, perennial in the underground part and annual in the aerial part (SMALL 2016). Only female plants are used for beer production due to their greater amount of lupulin-secreting glands, which is responsible for flavor and aroma of the drink, acts as a natural preservative and helps in the formation of foams (KNEEN 2003).

Brazil imports practically 100% of hops used in the beer industry (MAPA 2021) and it has stood out in the brewery sector, producing around 14 billion liters per year and generating more than 2 million jobs (CERVBRASIL 2021). According to the Brazilian Association of Hops Producers (2021), the country currently has a little more than 50 hectares planted, and an estimated production of 20 tons per year. Therefore, in order to see Brazil as a vector for the development of hop culture, it is first necessary to adapt it to the country and make it economically viable for growers (MACHADO et al. 2018).

The implantation of a given crop begins with the planning to obtain or produce quality and healthy nursery plants. Hops have three main methods of propagation, the first method is propagation by rhizome, using plants older than three years, this is the main way to preserve the desired characteristics (SARNIGHAUSEN et al. 2017), but this method makes it difficult to expand the cultivation area for growers, since a plant gives rise to a main rhizome and few secondary shoots (SANTOS et al. 2014), this method results in a smaller production of plants. The second method is seed propagation, which is used when the objective is to obtain plants for selection and genetic breeding (FACHINELLO et al. 2005). The third method is by cutting, in which younger plants are used, which is a more accessible method at the time of annual pruning (SOUSA et al. 2018), producing a greater volume of propagation material for rooting.

Furthermore, the use of biostimulants in plant production has been shown to be efficient in the quantity and quality of plants (HAWRYLAK-NOWAK et al. 2019) due to the presence of promoting substances that improve plant growth, including ethylene, abscisic acid, cytokinins, auxins, gibberellins, betaines and polyamines in algae extracts (PRASAD et al. 2010).

Brazil still has an incipient hop production and there are few researches concerning propagation via cuttings, but the area dedicated to cultivating this plant is expected to double in the next two years, and its productivity increased by 160% from 2020 to 2021 (APROLÚPULO 2021). Therefore, faster propagation methods such as cuttings become necessary to meet the growing demand for seedlings. With that in mind, this study aims to provide an initial elucidation on the best way to prepare hop cuttings.

Therefore, the aim of this work was to evaluate the effect of different cutting lengths and the use of biostimulants on vegetative propagation of 'Cascade' and 'Brewer's Gold' hop cultivars, and also to evaluate the effect of cutting position and diameter on vegetative propagation of ‘Northern Brewer’ hop cultivar.

MATERIAL AND METHODS

The work was conducted in a greenhouse at the Center for Agricultural Sciences (CCA) at the Federal University of Santa Catarina (UFSC), in Florianópolis/SC, Brazil, between October 2019 and January 2021. The vegetative material was collected from mother plants in a certified nursery in the city of Gramado/RS and transported to the experiment site.

The herbaceous cuttings were conducted in plastic trays with 30 cells 8 cm long, a pair of leaves with the area sectioned in half. For both experiments, the substrate used was a mixture of 40% carbonized rice husk and 60% peat, following the recommendation of FAGHERAZZI et al. (2018). The irrigation system worked through intermittent nebulization, which consisted of emitting a mist of microdrops, during 8 seconds of nebulization every 15 minutes.

Experiment 1 - Do the number of buds and the application of biostimulant interfere with the rooting of hop cuttings?

In this experiment, different lengths of cuttings were tested, with one bud, two buds and three buds; with and without application of the biostimulant SprintAlga TS® (Biolchim). The evaluated hop cultivars were ‘Brewer's Gold’ and ‘Cascade’. The length of the cuttings was standardized between 3 and 7 cm. The biostimulant application was carried out in two stages; the first, 12 days after the experiment installation, and the second, 24 days after the experiment installation, at a concentration of 0.4 mL L^{-1}. The biostimulant was applied on the leaves and on the substrate.

The experimental design was completely randomized block design with treatments distributed in a 3x2 bi-factorial scheme, the factors were three cutting lengths (1 bud, 2 buds and 3 buds) and application of

SprintAlga TS® (Biolchim), (with and without biostimulant) with repetitions of twenty cuttings, the plot was composed by ten useful plants, 100 cuttings for each cultivar, with a total of 200 cuttings.

Experiment 2 - Do the diameters and positions of cuttings influence the rooting of hop cuttings?

In experiment 2, three different diameters/positions of cuttings were evaluated, 1.5 cm (cutting of apical position), 2.5 cm (cutting of middle position) and 3.5 cm (cutting of basal position). The length of the cuttings was standardized between 5 and 7 cm. The cultivar evaluated was Northern Brewer. The experimental design was completely randomized block design with 5 blocks, 20 cuttings per plot, totaling 300 cuttings.

In both experiments, after 60 days, survival percentage, number of shoots and shoot length (mm), rooting percentage (%), root length (cm) and root quality were evaluated. The shoot length and root length variables were measured with a millimeter ruler. Root quality was determined from scores given by the same evaluator on a scale of 1 to 3. A score of 1 was given for cuttings with few roots, 2 for cuttings with an average number of roots and 3 for cuttings with many roots (Figure 1).

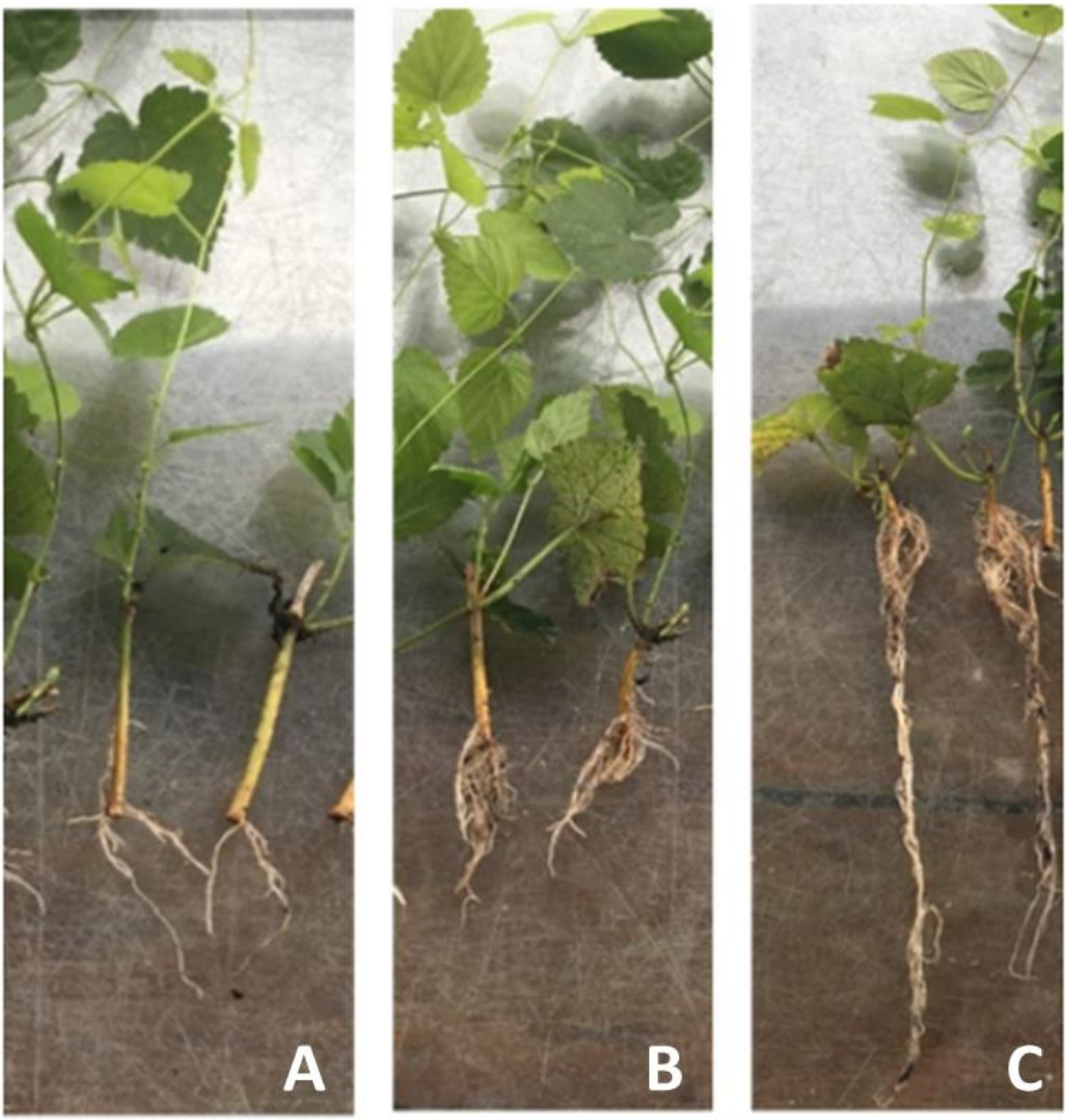

Figure 1. Root quality scale. Score of 1 was given for cuttings with few roots (A), 2 for cuttings with an average number of roots (B) and 3 for cuttings with many roots (C).

The data obtained were subjected to analysis of variance (ANOVA) and Tukey test ($p \leq 0.05$), using the R v. 3.5.1 software (R CORE TEAM 2013). Data of survival and rooting percentage were transformed into arc sine √x/100. Data of root number and shoot number were transformed into log (x + 1) and submitted to statistical analysis.

RESULTS

Experiment 1 - The application of a biostimulant enhanced all rooting parameters in Brewer's Gold cultivar, whereas cutting size demonstrated diverse effects on these parameters in both cultivars.

For the cultivar Brewer's Gold, there was no effect of cut size on the survival percentage and on average, the values found for this variable ranged from 70 to 85%. The cuttings treated with biostimulant had a survival percentage of 96.7% and were statistically superior to the control, which had a survival percentage of 63.3%. The lowest survival percentage of Brewer's Gold cultivar was found in 2-shoot cuttings without biostimulant application (Table 1).

For cultivar Cascade, a higher survival percentage was found in cuttings with 1 bud (95%) compared to the others. Cuttings treated with biostimulant had a survival percentage of 66.7% and were statistically superior to the control, which presented a survival percentage of 43.3%. For Cascade, the highest percentage of survival was found in cuttings of 1 bud with or without the use of biostimulant (Table 1).

For cultivar Brewer's Gold, there was no effect of cutting size on rooting percentage, on average the values found ranged from 70 to 85% of rooting. The cuttings treated with biostimulant had a rooting percentage of 96.7% and were statistically superior to the control, which presented a rooting percentage of 63.3%. The lowest rooting percentage of Brewer's Gold cultivar was found in 2-bud cuttings without the application of biostimulant (Table 1).

For cultivar Cascade, a higher percentage of rooting was found in cuttings of 1 bud (95%) compared to the others. The cuttings treated with biostimulant presented a rooting percentage of 66.7% and were statistically superior to the control, which presented a rooting percentage of 40%. For Cascade, the highest percentage of rooting was found in 1-bud cuttings with or without the use of biostimulant (Table 1).

Table 1. Survival and rooting percentage of different size cuttings, with and without application of biostimulants of cultivars ‘Brewer's Gold’ and ‘Cascade’.

Cutting Size	Survival (%)			Rooting (%)		
	Biostimulant	Control	Average	Biostimulant	Control	Average
			Brewer’s Gold			
1 Bud	100 aA	70 aAB	85 A	100 aA	70 aAB	85 A
2 Buds	100 aA	40 bB	70 A	100 aA	40 bB	70 A
3 Buds	90 aA	80 aA	85 A	90 aA	80 aA	85 A
Average	96.7 a	63.3 b		96.7 a	63.3 b	
C.V. (%)	35.5			42.1		
			Cascade			
1 Bud	100 aA	90 aA	95 A	100 aA	90 aA	95 A
2 Buds	50 aB	20 aB	35 B	50 aB	10 bB	30 B
3 Buds	50 aB	20 aB	35 B	50 aB	20 aB	35 B
Average	66.7 a	43.3 b		66.7 a	40 b	
C.V. (%)	38.9			39.1		

* Means followed by different lowercase letters on the line differ statistically by Tukey Test ($p \leq 0.05$) for the fator biostimulant. * Means followed by different capital letters in the column differ statistically by Tukey Test ($p \leq 0.05$) for cutting factor.

Regarding the variable of root quality for Brewer's Gold, there was a significant effect of cutting size. The highest value found for root quality was in cuttings with 3 buds with an average of 2.2, and the lowest value was in cuttings with 2 buds with an average of 1.4 with or without the use of biostimulant. The cuttings treated with biostimulant presented better root quality with 2.2 and were statistically superior to the control, which presented a root quality value of 1.3 (Table 2).

For the cultivar Cascade, the highest value of root quality was found in cuttings with 1 bud (2.0) compared to the others. The use of the biostimulant had no effect on root quality, on average the values found were 1.2 and 0.9 (Table 2).

For cultivar Brewer's Gold, there was no effect of cutting size in relation to root length, on average the values found ranged from 10.4 cm to 12.9 cm. The cuttings treated with biostimulant had a root length of 14.4 cm and were statistically superior to the control, which had a root length of 8.8 cm. The smallest root length of Brewer's Gold was found in 2-bud cuttings, without the application of biostimulant (Table 2).

For the Cascade cultivar, the highest root length was found in cuttings with 1 bud (8.7cm) compared to the others. The use of biostimulant had no significant effect on root length. The longest root length of Cascade was found in cuttings with 1 bud, regardless of the application or not of biostimulants (Table 2).

Table 2. Qualidade e comprimento radicular (cm) de estacas de diferentes tamanhos, com e sem aplicação de bioestimulantes nas cultivares ‘Brewer's Gold’ e ‘Cascade’.

Cutting Size	Root Quality			Root length (cm)		
	Biostimulant	Control	Average	Biostimulant	Control	Average
			Brewer’s Gold			
1 Bud	2.4 aA	1.1 bB	1.8 AB	13.1 aA	9.8 aA	11.5 A
2 Buds	2.0 aA	0.8 bB	1.4 B	13.5 aA	7.2 bA	10.4 A
3 Buds	2.3 aA	2.0 aA	2.2 A	16.6 aA	9.3 bA	12.9 A
Average	2.2 a	1.3 b		14.4 a	8.8 b	
C.V. (%)		31.7			28.6	
			Cascade			
1 Bud	2.1 aA	1.8 aA	2.0 A	9.3 aA	8.2 aA	8.7 A
2 Buds	0.7 aB	0.4 aB	0.6 B	2.8 aB	1.5 aB	2.1 B
3 Buds	0.8 aB	0.6 aB	0.7 B	3.1 aB	3.0 aAB	3.0 B
Average	1.2 a	0.9 a		5.0 a	4.3 a	
C.V. (%)		30.8			35.9	

* Means followed by different lowercase letters on the line differ statistically by Tukey Test (p ≤ 0.05) for the fator biostimulant. * Means followed by different capital letters in the column differ statistically by Tukey Test (p ≤ 0.05) for cutting factor.

Regarding the number of shoots, for cultivar Brewer's Gold there was an effect of cutting size. The highest number of shoots was obtained in cuttings with 3 buds (1.9), and the lowest number of shoots was found in cuttings with 2 buds (1.3). The cuttings that received the treatment with biostimulants had a higher number of shoots (1.9) and were statistically higher than the control, which presented an average number of shoots of 1.2 (Table 3).

For Cascade there was no effect of cutting size on the number of shoots. The highest number of shoots was found in cuttings with 1 bud (1.6) and the lowest number of shoots was found in cuttings with 2 buds (0.5). For cuttings with and without application of biostimulants, there was no effect on the number of shoots, on average the values found varied between 1.3 and 0.8 (Table 3). The lowest number of shoots of Cascade was found in 2-bud cuttings with and without the application of biostimulants (Table 3).

For cultivar Brewer's Gold, there was no effect of cutting size on shoot length, on average the values found ranged from 15.9 to 23.3 cm. The cuttings treated with biostimulants had a shoot length of 23 cm and were statistically superior to the control, which was 15.4 cm long. The shorter shoot length of the Brewer's Gold cultivar was found in 3-bud cuttings without biostimulant application (Table 3).

For Cascade, the greatest shoot length was found in cuttings with 1 bud (20.1 cm), for cuttings with 2 and 3 buds there was no statistically significant difference. The cuttings treated with biostimulants had a shoot length of 11 cm and the control 8.1 cm, however there was no statistically significant difference. The largest shoot length of Cascade was found in 1-bud cuttings with and without biostimulant application (Table 3).

Table 3. Number of shoots and shoot length (cm) of different size cuttings, with and without application of biostimulants of cultivars ‘Brewer's Gold’ and ‘Cascade’.

Cutting Size	Number of Shoots			Shoot length (cm)		
	Biostimulant	Control	Average	Biostimulant	Control	Average
			Brewer’s Gold			
1 Bud	1.8 aA	1.1 bB	1.5 B	29.0 aA	17.6 bA	23.3 A
2 Buds	2.0 aA	0.6 bB	1.3 B	24.9 aAB	11.7 bA	18.3 A
3 Buds	2.0 aA	1.8 aA	1.9 A	15.1 aB	16.8 aA	15.9 A
Average	1.9 a	1.2 b		23.0 a	15.4 b	
C.V. (%)		29.6			32.3	
			Cascade			
1 Bud	1.9 aA	1.4 aA	1.6 A	18.8 aA	22.4 aA	20.1 A
2 Buds	0.8 aB	0.2 aB	0.5 B	6.6 aB	1.6 aB	4.1 B
3 Buds	1.1 aAB	0.7 aAB	0.9 AB	7.5 aAB	0.5 aB	4.0 B

Average	1.3 a	0.8 a		11.0 a	8.1 a
C.V. (%)		32.6			36.9

* Means followed by different lowercase letters on the line differ statistically by Tukey Test ($p \leq 0.05$) for the fator biostimulant. * Means followed by different capital letters in the column differ statistically by Tukey Test ($p \leq 0.05$) for cutting factor.

Experiment 2 - Cutting diameter had significantly affected the survival rate, rooting rate, root length, and number of shoots, while root quality remained unaffected

Cutting diameter interfered in survival rate, 1.5 cm cuttings had 62.5% survival and was statistically superior to 3.5 cm cuttings (30.6%), but it did not differ from cuttings with diameter of 2.5 cm (47.1%) (Table 4).

The cutting diameter/position affected the rooting rate. The 1.5 cm/apical cuttings presented 62.5% of rooting and was statistically superior to 2.5 cm/middle (41.4%) and 3.5 cm/basal (29.2%) cuttings, in which they did not. showed statistical differences between them (Table 4).

The cutting diameter/position influenced the root length, cuttings of 1.5 cm in diameter/apical had a root length of 8.3 cm and was statistically superior to cuttings of 2.5 cm, which had a root length of 5.4 cm, but did not differ from the 3.5 cm diameter cuttings (Table 4).

The cutting diameter/position also affected the number of shoots, with 1.5 cm diameter/apical cuttings showing an average of 1.09 shoots and was statistically superior to 3.5 cm diameter/basal cuttings, which showed an average of 0.55 shoots and did not differ from 2.5 cm diameter/middle cuttings (Table 4).

The result obtained for the average shoot length was the opposite of that obtained for shoot number. Larger diameter cuttings (2.5 and 3.5 cm) produced a smaller number of shoots, but with a longer length, between 20.8 and 24.7 cm, statistically superior to smaller diameter cuttings (Table 4).

The cutting diameter/position did not interfere in root quality, it was found an average of 2.07 for cuttings with 1.5 cm diameter, 1.97 for 2.5 cm and 1.67 for 3.5 cm diameter (Table 4).

Table 4. Survival and rooting percentage, root quality, root length (cm), number of shoots and shoot length (cm) of different diameter/position cuttings of cultivar ‘Northern Brewer’.

Diameter - Position	Survival (%)	Rooting (%)	Root Quality	Root Length (cm)	Number of Shoots	Shoot Length (cm)
1.5 cm - Apical	62.5 a	62.5 a	2.07 a	8.3 a	1.1 a	7.1 b
2.5 cm - Middle	41.7 ab	41.4 b	1.97 a	5.4 b	0.8 ab	24.7 a
3.5 cm - Basal	30.6 b	29.2 b	1.67 a	7.4 ab	0.6 b	20.8 a
C.V. (%)	25.4	28.6	37.9	29.8	35.8	32.4

* Means followed by different lowercase letters in the column differ statistically by Tukey Test ($p \leq 0.05$).

DISCUSSION

Experiment 1

1. *Survival & rooting*

In the present work, higher rooting rates were obtained in cuttings of shorter length, with 1 bud, this result diverges from several authors. In a study using branch cuttings of *Physalis peruviana*, length of cuttings assigned to the 5 cm treatment were shown significantly the highest mortality rate, lowest rooting rate and root weight (CAVUSOGLU & KASIM 2022). In a study about rooting of cutting of *Greyia radlkoferi* (Melianthaceae), when 5, 10, 15 and 20 cm cuttings of used, 5 cm cuttings gave the least survival rate, rooting rate and root length (MALELE et al. 2021).

The percentage of survival was higher with the use of SprintAlga TS® algae extract. Plant-derived protein biostimulants exhibit hormone-like activities promoting plant growth and yield (KIM et al. 2019). In a previous work, an improvement in survival rate and rooting rate of pitaya (*Selenicereus undatus*) cuttings when submitted to the application of algae extract SprintAlga TS® was also verified (FREITAS et al. 2021).

Both the cutting length and diameter significantly affected the rooting ability, as well as the effect of an interaction between the cutting length and diameter.

Another explanation is that cutting length affects water velocity and nutrient transfer. An equilibrium between photosynthesis and transpiration and the rate of water and nutrient transport are important factors influencing rooting, and cuttings with a modest size (OUYANG et al. 2015). The development of adventitious root primordia is controlled by multiple endogenous and environmental factors. Among these factors, auxin, light, temperature, and nutrient elements are the most important (WEI et al. 2019).

2. *Root quality and root length*

In this work, it was observed that the use of the biostimulant SprintAlga TS® contributed to increase root length of cultivar Brewer's Gold. Similar results were obtained by TAVARES et al. (2020), who found an increase in the development of marigold roots when subjected to treatment with algae extract. It is believed that these results are related to the presence of auxins and cytokinins in the composition of algae extracts (MACKINNON et al. 2010, MICHALAK et al. 2016). These hormones are related to root formation, as well as accelerating root development (NEUMANN et al. 2017, TAIZ & ZEIGER 2017).

3. *Number of shoots and shoot length*

It is believed that the greater number of shoots observed in cuttings treated with the biostimulant SprintAlga TS®, especially for Brewer's Gold, may be related to the presence of hormones that have an effect on plant growth such as cytokinins (CALVO et al. 2014, MICHALAK et al. 2016). It was observed in other studies that cuttings treated with cytokinins such as Benzyladenine present a greater number of shoots (ELOBEIDY 2006, DHRUVE et al. 2018, SIDDIQUA et al. 2018).

Experiment 2

1. *Survival & rooting*

The size or diameter of the cutting directly influences its nutritional status, where the amount of reserve, the number of buds, carbohydrate and endogenous auxin content are related according to the length and diameter (HOSSEL et al. 2017). The concentration of nutrients may be expected to be lower in harder, more lignified cuttings (GONZÁLEZ et al. 2019).

High rates of survival and rooting may be associated with the youthfulness of the propagation material used (HARTMANN et al. 2011, WENDLING et al. 2014). With regard to the most appropriate time to obtain cuttings, there are differences between species, with some rooting better in early spring until early autumn (FACHINELLO et al. 1995). Hop cuttings were collected during late spring and summer when new shoots sprouted, similar to what was done by FAGHERAZZI et al. (2018).

According to DAO et al. (2020), in a study of *Garcinia kola*, the successful rooting of hardwood cutting can be due to their large diameter. Similar results were noticed by RANA & SOOD (2011) on vegetative propagation of *Ficus roxburghii* Wall. These authors noticed that cuttings with large diameter presented higher sprouting and rooting ability due to their more food reserves in these cuttings. The results obtained in this study are not in agreement with the aforementioned author, attributing the difference in results to the intrinsic characteristics of the species.

It is believed that the lower survival and rooting rates observed in larger diameter cuttings may be related to their higher degree of lignification, since the larger diameter cuttings were located in the basal position, while the smaller diameter ones were located in the apical position of the branch. The apical cuttings superiority in relation to the medium and basal ones, can be attributed to the fact that the apical propagules have an herbaceous consistency, the presence of leaves and by the higher rates of endogenous auxins in stem apices (GOMES et al. 2018).

2. *Root quality & root length*

The success of rooting percentage in apical cuttings can be highly associated with presence of leaves which produce significant level of endogenous auxins and provide more stimuli on the base of cutting to promote rooting, while hardwood cuttings depends on their high-level carbohydrates or food reserves (DAO et al. 2020).

3. *Number of shoots & shoot length*

Shoot emission is an important characteristic for the formation of quality plants, since, after depletion of the cutting reserves, the presence of new leaves is essential for plant nutrition (GOMES & KRINSKI 2016).

The higher number of shoots on the apical cuttings indicates the importance of photosynthesis carried out by the leaves. Similar results were also recorded for *Sterculia foetida* (AZAD et al. 2018) and *Cannabis sativa* (CAPLAN et al. 2018).

Other authors found different results, for example, TOFANELLI et al. (2003) found a greater number of shoots in cuttings with a larger diameter of peach tree cv. Okinawa. According to FACHINELLO et al. (1995) this happens due to the greater availability of reserves in cuttings with larger diameter, favoring shoot emission.

The factors determining the rooting and sprouting of leafy softwood cuttings are very different, depending on photosynthates produced in the propagation bed, while hardwood cuttings depend on the hydrolysis and availability of carbohydrates stored within the stem tissues (LEAKEY 2014).

CONCLUSION

In experiment 1, cultivar Cascade had lower survival, rooting and development rates compared to cultivar Brewer's Gold, regardless of cutting length and use of biostimulants.

The use of the biostimulant SprintAlga TS® (Biolchim) increased survival and rooting rates of both cultivars. For cv. Brewer's Gold the use of biostimulant improved root quality and increased shoot number, root length and shoot length.

For cv. Brewer's Gold, 3-bud cuttings improved root quality and increased number of shoots. For cv. Cascade, 1-bud cuttings showed the highest survival, rooting and development rates.

In experiment 2, the highest rates of survival, rooting and the longest root length of cv. Northern Brewer were obtained with 1.5 cm diameter/apical cuttings. Larger diameter cuttings (2.5 and 3.5 cm) produced fewer shoots, but longer shoots. The diameter/position of the cuttings did not influence the root quality.

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