CIÊNCIA E TÉCNICA VITIVINÍCOLA
Ciência Téc. Vitiv. 38(1) 1-9. 2023

Technical Note

BIOSTIMULANTS AND INDOLEBUTYRIC ACID IMPROVE ROOTING OF WOOD CUTTINGS FROM DIFFERENT GRAPEVINE ROOTSTOCKS

BIOESTIMULANTES E ÁCIDO INDOLBUTÍRICO MELHORAM O ENRAIZAMENTO DE ESTACAS LENHOSAS DE DIFERENTES PORTA-ENXERTOS DE VIDEIRA

Alberto Fontanella Brighenti[1,*], Fábio Ribeiro de Freitas[1], Isadora Teixeira Coelho Malohlava[1], Thainá Carolina Graciano Votre[1], José Afonso Voltolini[1], Aparecido Lima da Silva[1], Nelson Pires Feldberg[2], Douglas André Würz[3]

[1]Universidade Federal de Santa Catarina, Centro de Ciências Agrárias, Departamento de Fitotecnia, Rodovia Admar Gonzaga, 1346, Florianópolis, 88034-000, Santa Catarina, Brasil.

[2]Empresa Brasileira de Pesquisa Agropecuária, Estação Experimental Canoinhas, da Embrapa Clima Temperado. Rodovia BR 280, Km 231, Canoinhas, 89460-000, Santa Catarina, Brasil.

[3]Instituto Federal de Santa Catarina, Campus Canoinhas, Avenida Expedicionários, 2150, Canoinhas, 89466-312, Santa Catarina, Brasil.

***** Corresponding author: Tel.: +55(49)9 9951-3256; e-mail: alberto.brighenti@ufsc.br

(Received 24.06.2022. Accepted 04.01.2023)

SUMMARY

The rooting of rootstocks is considered a critical point in the production of high-quality grapevine planting material. To maximize the cutting rhizogenesis process, plant hormones, such as auxins, are used for the development of adventitious roots. In addition, some groups of biostimulant have as their main role the development of root system, ensuring good growth of the plant aerial part. However, research using algae extract-based biostimulants in vegetative propagation of vine rootstocks is scarce. In this sense, the objective of this work was to evaluate the use of the biostimulant based on algae extract and indolebutyric acid (IBA), in the development of the root system and vegetative growth of grapevine rootstocks. The rootstocks evaluated were '3309 C', '101-14 Mgt', 'Paulsen 1103', '99 R', '110 R', 'Kober 5BB', 'SO4', '420A Mgt', 'Solferino', 'Gravesac', 'IAC 572', 'IAC 766', 'IAC 313', 'Harmony', 'Freedom', 'Salt Creek' and 'VR 043-43'. The experimental design was completely randomized with four replications, arranged in a factorial scheme, involving 17 rootstocks associated with four treatments to stimulate rooting (IBA, algae extract, IBA + algae extract and control). The use of indolebutyric acid and algae extract-based biostimulant proved to be efficient in rooting woody cuttings from different vine rootstocks. The use of IBA, algae extract-based biostimulant and IBA combined with algae extract resulted in higher rates of rooting and development than the control. The rootstocks presenting the highest rooting rates and vegetative development were 'IAC 572' and 'Freedom'. 'Gravesac', '101-14 Mgt' and '99 R', showing high rates of rooting and root development, but low vegetative development. The rootstocks exhibiting the lowest rooting rates and vegetative development were 'Salt Creek', 'VR 043-43' and '110 R'.

RESUMO

O enraizamento de porta-enxertos de videira é considerado um ponto crítico na produção de material de propagaçao de alta qualidade. Para maximizar o processo de rizogênese, hormônios vegetais, como as auxinas, são utilizados para o desenvolvimento de raízes adventícias. Além disso, alguns grupos de bioestimulantes têm como principal função o desenvolvimento do sistema radicular das plantas, garantindo o bom crescimento da parte aérea. No entanto, pesquisas utilizando bioestimulantes à base de extrato de algas na propagação vegetativa de porta-enxertos de videira são escassas. O objetivo deste trabalho foi avaliar o uso de bioestimulante à base de extrato de algas e do ácido indolbutírico (AIB), no desenvolvimento do sistema radicular e do crescimento vegetativo de porta-enxertos de videira. Os porta-enxertos avaliados foram '3309 C', '101-14 Mgt', 'Paulsen 1103', '99 R', '110 R', 'Kober 5BB', 'SO4', '420A Mgt', 'Solferino', 'Gravesac', 'IAC 572', 'IAC 766', 'IAC 313', 'Harmony', 'Freedom', 'Salt Creek' e 'VR 043-43'. O delineamento experimental utilizado foi inteiramente casualizado com quatro repetições, em um esquema bifatorial, envolvendo 17 porta-enxertos associados a quatro tratamentos para estimular o enraizamento (AIB, extrato de algas, AIB + extrato de algas e testemunha). O uso de AIB e bioestimulante à base de extrato de algas mostrou-se eficiente no enraizamento de estacas lenhosas de diferentes porta-enxertos de videira. O AIB, o extrato de algas e o uso combinado de AIB e extrato de algas resultou em maiores taxas de enraizamento e desenvolvimento de estacas quando comparados com o controle. Os porta-enxertos que apresentaram as maiores taxas de enraizamento e desenvolvimento vegetativo foram o 'IAC 572' e o 'Freedom'. 'Gravesac', '101-14 Mgt' e '99 R', apresentando altas taxas de enraizamento e desenvolvimento radicular, mas baixo desenvolvimento vegetativo. Os porta-enxertos que exibiram menores taxas de enraizamento e desenvolvimento vegetativo foram 'Salt Creek', 'VR 043-43' e '110 R'.

Keywords: Algae extract, auxin, propagation, grapevine, rootstocks.
Palavras-chave: extrato de algas, auxina, propagação, videira, porta-enxertos.

Article available at https://www.ctv-jve-journal.org or https://doi.org/10.1051/ctv/ctv202338011

INTRODUCTION

It is generally accepted that the phylloxera (*Daktulosphaira vitifoliae*) was unintentionally introduced into Europe at the end of the nineteenth century through infected plant material from North America to fight oidium (powdery mildew), the fungus that threatened European vineyards in the 1850s (Macedo, 2011). Grape phylloxera occurrence almost destroyed European viticulture, and it provoked the most radical switch in viticultural practices of the last two centuries, when grape growing changed from the use of own-rooted '*V. vinifera*' plants to their grafting onto partially resistant American non-*vinifera Vitis* spp. or hybrids used as rootstocks (This *et al*., 2006). Therefore, resistance to phylloxera was the first selection criterion for grapevine rootstocks (Whiting, 2012).

Rootstocks influence water relations, phenology, vigor, production and quality of grapes and wines (Keller, 2020). The choice of rootstock is aimed at adaptation to abiotic stresses such as salinity, drought, acidic, alkaline, low-fertility and shallow soils, as well as to biotic stresses (Smith *et al*., 2017). It is appropriate that the rootstock has characteristics such as vigor, deep root system, resistance to pests (such as nematodes) and diseases(Waite *et al*., 2015). It must root and heal easily on grafting and present satisfactory development in adverse conditions. Rootstock for Brazilian conditions must have characteristics such as tolerance to acidic soils, to aluminum and excessive humidity, traits like resistance to fusariosis (*Fusarium oxysporum* Sch. f.sp. *herbemontis*) and Brazilian ground pearl (*Eurhizococcus brasiliensis*) are also desirable (Fráguas, 1999; Borghezan *et al*., 2003; Leão *et al*., 2020).

Before grafting, the rootstock is propagated by cuttings. Cutting is one of the most important methods of propagating fruit planting material and is based on the principle that it is possible to regenerate a plant from a part of the mother plant, through tissue dedifferentiation (which means to return to an undifferentiated state); the root formation process in cuttings is affected by several factors, which can act alone or together. Among the main ones, the following stand out: genetic variability, physiological condition of mother plant, plant age, cutting type, time of year, environmental conditions and substrate (Pires and Biasi, 2003).

The rooting of rootstocks is considered a critical point in the production of high-quality grapevine planting material, but some substances produced by plants can help this process to occur in the best way. Among the different compounds produced by plants, hormones can be highlighted, which are naturally occurring organic and non-nutrient compounds, which are produced by the plant itself, and which, in low concentrations, promote, inhibit or modifies plant morphological and physiological processes (Vieira, 2010). Therefore, to maximize the cutting rhizogenesis process, plant hormones, such as auxins (indolebutyric acid), are used for the development of adventitious roots and, above all, to increase the percentage of rooting, through accelerating the emission of uniform and quality roots (Baldotto and Baldotto, 2014).

The indolebutyric acid (IBA) works to stimulate the formation of root primordia; its characteristics are low mobility, low photosensitivity, high chemical stability and low toxicity for most plants (Pires and Biasi, 2003). Its action results in a high percentage of rooting of cuttings and shortens the period of cuttings in the nursery (Bastos *et al*., 2009).

In addition to the plant growth regulators, biostimulants can also be used for this purpose. They are defined by many authors as natural or synthetic substances, arising from the mixture of two or more plant bioregulators or with other substances such as amino acids, nutrients and vitamins. Substances and microorganisms capable of altering plant metabolism, favoring its development, can also be included (Calvo, *et al*., 2014; Du Jardin, 2015).

Among the viticultural management processes, the application of biostimulants to grapevines to avoid specific diseases and to improve grape and wine quality is one of the most common practices performed by wine-growers that provides several benefits to the grapevines. These substances can stimulate growth and the synthesis of secondary metabolites, which in turn can provide protection against biotic and abiotic stresses (Gutiérrez-Gamboa *et al*., 2018a).

Some biostimulant groups have as their main role the development of root system, ensuring good growth of plant aerial part and ensuring satisfactory yield; generally, its composition includes natural phytohormones, such as auxins, cytokinins and gibberellins, amino acids, zinc and magnesium sulfates, iron citrate, boric acid, ammonium molybdate, among other macro and micronutrients (Santos *et al*., 2013; Tecchio *et al*., 2015).

Among the natural substances to which biostimulant effects have been ascribed, the use of algae extract in agriculture is being described in several studies (Arioli *et al*., 2015). Seaweed extracts have macro and micronutrients, amino acids and plant hormones in their composition; it may have auxins, cytokinins, gibberellins and abscisic acid, and compounds capable of stimulating the production of these hormones by plants (Sharma *et al*., 2012). The application of products based on algae extract provided positive results, for example, in increasing tomato productivity, production and quality of grapes under alkaline soil conditions, induction of resistance to water deficit in soybean and orange, resistance to pathogen attack in cucumber (Arioli *et al*., 2015); an

Ascophyllum nodosum extract applied to 'Sangiovese', 'Pinot Noir' and 'Cabernet Franc' grapevines improved anthocyanin accumulation in all of these cultivars (Gutiérrez-Gamboa *et al*., 2018a). Also, brown algae, plus boron and zinc applications before the beginning of flowering can allow to improve fruit set, which would affect positively 'Carménère' productivity at harvest (Gutiérrez-Gamboa *et al*., 2018b)

The use of seaweeds in viticulture has allowed to improve grapevine productivity and to enhance grape and wine quality, mostly in terms of their phenolic composition. Their effectiveness seems to be mainly associated to seasonal climatic conditions, to the species of seaweed applied, its structural properties, leaf surface wetting properties of the grapevine variety, the stress and resistance level of the grapevine prior to the application, dosage of the formulation and their implications on relative expression genes in leaves and berries (Gutiérrez-Gamboa and Moreno-Simunovic, 2021).

However, research using algae extract-based biostimulants in vegetative propagation of vine rootstocks is scarce. In this sense, the aim of this study was to evaluate the use of a biostimulant based on algae extract, indolebutyric acid (IBA) and algae extract combined with IBA, in rooting and vegetative growth of 17 vine rootstocks: '3309 C'; '101-14 Mgt'; 'Paulsen 1103'; '99 R'; '110 R'; 'Kober 5BB'; 'SO4'; '420 A Mgt'; 'Solferino'; 'Gravesac'; 'IAC 572'; 'IAC 766'; 'IAC 313'; 'Harmony'; 'Freedom'; 'Salt Creek'; 'VR 043- 43'.

MATERIALS AND METHODS

The work was carried out at Santa Catarina Federal University (UFSC), at the Center for Agricultural Sciences (CCA), located in Florianópolis/SC, Brazil, from August to November 2019 and 2020. The plant material had approximately one year and was collected in the period of dormancy (August) of mother plants kept in the germplasm collection of Embrapa Clima Temperado – Canoinhas Experimental Station.

The evaluated rootstocks and their respective genealogies were: '3309 C' and '101-14 Mgt' ('*V. riparia*' x '*V. rupestris*'); 'Paulsen 1103', '99 R' and '110 R' ('*V. berlandieri*' x '*V. rupestris*'); 'Kober 5BB', 'SO4' and '420 A Mgt' ('*V. berlandieri*' x '*V. riparia*'); 'Solferino' (unknown origin); 'Gravesac' ('161-49 C' x '3309 C'); 'IAC 572' ('101-14 Mgt' x '*V. caribaea*'); 'IAC 766' ('106-8 Mgt' x '*V. caribaea*'); 'IAC 313' ('Golia' x '*V. cinerea*'); 'Harmony' and 'Freedom' ['1613 C' x 'Dogridge' ('*V. champinii*')]; 'Salt Creek' ('*V. champinii*'); 'VR 043-43' ('*V. vinifera*' x '*V. rotundifolia*').

The plant material was segmented into cuttings approximately 30 cm long, selecting those with 8 to 10 mm in diameter. At the base of each cutting, a transverse cut was made, 0.5 cm below the last bud, and at the cutting apex, a cut was made in a bevel, 3 cm above the last bud. Thereafter, the cuttings underwent stratification in a cooling chamber, with an average temperature of 2 ºC ±1 ºC, for 10 days. Afterwards, two lesions were made in the longitudinal direction, approximately 3 cm long, at the base of each cutting (Bettoni *et al.*, 2015).

The cuttings were placed in 8 L pots containing a substrate consisting of a mixture of sand and commercial substrate (Plantmax®). The cuttings were kept in a greenhouse, without temperature control and irrigated two times a week until the experiment was evaluated. In this experiment it was tested four treatments to stimulate rooting (IBA, algae extract, IBA + algae extract and control) and they are described below.

Immersion 2 cm of cutting basal end in a 3000 mg/L solution of indolebutyric acid (IBA) for 20 sec. The IBA was dissolved in 70% alcohol and distilled water was added until the desired concentration was reached. Application of 100 mL of algae extract-based biostimulant SprintAlga TS® (Biolchim) at a concentration of 0.4 mL/L of solution, 25 and 40 days after planting the cuttings. The solution was applied at cuttings base, directly on substrate. The combination of 3000 mg/L of indolebutyric acid (IBA) applied in the form of immersion at cutting base on the day of experiment installation and 0.4 mL/L of SprintAlga TS® (Biolchim) solution, 25 and 40 days after planting the cuttings applied directly on substrate. The control consisted in immersion two centimeters of cutting basal end in distilled water.

The evaluations were carried out approximately 50 days after the last application of biostimulant, and the percentage of survival and rooting of cuttings was determined, through a visual analysis, verifying if the tissues were intact and alive.

Then, the total number of roots emitted from cutting base was counted, as well as the measurement of the largest root length (cm), with the aid of a graduated ruler. The number of leaves emitted, and the shoot length (cm) were also assessed.

The destructive evaluations were carried out in the laboratory, where fresh and dry mass of leaves and roots were determined. The fresh mass was measured on a precision scale (Bel Engineering, Precision balance L, Brazil), and the dry mass was obtained after drying the material in a forced air oven (QUIMIS Q317M, Brazil) at 70 °C for 72 hours.

The experimental design was completely randomized with four replications, arranged in a 17 x 4 factorial scheme, involving 17 rootstocks associated with four treatments to stimulate rooting (IBA, algae extract, IBA + algae extract and control), with three cuttings per plot, totaling 816 cuttings. The data obtained were submitted to the Scott-Knott test ($p<0.05$). Survival and rooting percentage data were .

transformed into arc sine √x/100. The data of root number and shoot number were transformed into log (x + 1) and submitted to statistical analysis.

RESULTS AND DISCUSSION

The rootstocks '101-14 Mgt', 'SO4', 'Solferino', '99 R', 'IAC 572' and 'IAC 766' showed a higher percentage of survival, between 95% and 82.5%, which was statistically superior than the results obtained for the other rootstocks. The lowest percentage of survival, between 30% and 40%, was observed in the rootstocks 'Paulsen 1103', '420 A Mgt' and 'VR 043-43' rootstocks (Table I)

The highest percentage of rooting, between 95% and 67.5%, was obtained in the rootstocks '3309 C', '101-14 Mgt', 'Kober 5BB', 'SO4', 'Solferino', 'Gravesac', '99 R', 'IAC 572', 'IAC 766', 'IAC 313' and 'Harmony'. The lowest percentage of rooting, between 30% and 37.5%, was observed in the 'Paulsen 1103', '420 A Mgt' and 'VR 043-43' rootstocks (Table I).

Table I

Percentage of survival and rooting, average number of roots and shoots, average length of roots and shoots, fresh mass and dry mass of leaves and roots of vine rootstock cuttings subjected to different treatments for rooting

Rootstock	Survival (%)	Rooting (%)	Avg. Root Number	Root Length (cm)	Avg. Leaves Number	Shoot Length (cm)
3309 C	75.0 ± 12.9 B	82.5 ± 17.1 A	14.2 ± 3.1 A	16.4 ± 2.8 B	7.2 ± 2.7 A	14.9 ± 4.9 A
101-14 Mgt	95.0 ± 5.8 A	95.0 ± 5.8 A	15.5 ± 2.0 A	17.9 ± 1.7 B	4.5 ± 0.2 B	13.7 ± 2.7 A
Paulsen 1103	30.0 ± 8.2 D	30.0 ± 8.2 C	3.6 ± 1.8 D	5.9 ± 2.6 D	3.5 ± 1.5 C	4.6 ± 2.4 C
Kober 5BB	72.5 ± 22.2 B	70.0 ± 29.4 A	11.3 ± 5.2 B	14.1 ± 3.8 B	3.8 ± 1.1 C	12.8 ± 3.5 B
SO4	85.0 ± 10.0 A	90.0 ± 8.2 A	10.1 ± 3.0 B	17.1 ± 2.7 B	4.5 ± 0.6 B	7.4 ± 1.6 C
Solferino	82.5 ± 9.6 A	85.0 ± 5.8 A	9.7 ± 2.9 B	14.3 ± 1.7 B	5.0 ± 1.3 B	9.8 ± 2.6 B
Gravesac	75.0 ± 19.2 B	80.0 ± 14.1 A	16.2 ± 4.4 A	16.4 ± 3.2 B	5.2 ± 1.2 B	12.0 ± 4.8 B
420 A Mgt	40.0 ± 18.3 D	37.5 ± 12.6 C	1.8 ± 0.9 D	2.8 ± 2.3 D	1.7 ± 0.4 D	1.2 ± 0.5 C
99 R	85.0 ± 5.8 A	85.0 ± 12.9 A	14.1 ± 3.0 A	11.2 ± 1.7 C	6.7 ± 1.0 A	11.4 ± 1.7 B
110 R	60.0 ± 14.1 C	60.0 ± 14.1 B	2.9 ± 1.2 D	8.0 ± 4.7 C	4.6 ± 1.4 B	5.8 ± 2.0 C
IAC 572	87.5 ± 9.6 A	87.5 ± 9.6 A	9.7 ± 1.1 B	19.5 ± 2.2 A	5.5 ± 1.5 B	18.7 ± 2.5 A
IAC 766	85.0 ± 23.8 A	85.0 ± 23.8 A	7.8 ± 2.8 C	17.2 ± 4.0 B	5.6 ± 1.7 B	12.2 ± 5.5 B
IAC 313	70.0 ± 16.3 B	67.5 ± 12.6 A	4.1 ± 1.6 D	10.7 ± 3.5 C	4.5 ± 1.1 B	11.7 ± 4.4 B
Harmony	75.0 ± 23.8 B	72.5 ± 20.6 A	8.6 ± 4.1 B	13.2 ± 4.5 B	5.6 ± 2.1 B	15.0 ± 6.8 A
Freedom	72.5 ± 12.6 B	72.5 ± 12.6 A	15.1 ± 1.7 A	20.7 ± 2.7 A	6.2 ± 2.1 A	15.2 ± 3.6 A
Salt Creek	55.0 ± 12.9 C	55.0 ± 12.9 B	4.0 ± 0.9 D	8.0 ± 2.3 C	3.3 ± 1.0 C	5.6 ± 1.0 C
VR 043-43	32.5 ± 9.6 D	32.5 ± 9.6 C	2.4 ± 2.4 D	6.0 ± 4.3 D	2.0 ± 1.2 D	4.0 ± 2.6 C

Averages followed by different letters in a column differ from each other by Scott-Knott Test ($p < 0.05$).

In fact, most vine rootstocks do not present great difficulties in rooting when propagated by woody cuttings, but when this is done, this characteristic is inherited from their parents, mainly from the species *Vitis riparia* and *Vitis rupestris*, which root easily (Willians and Antcliff, 1984). This result confirms the good rooting capacity of *Vitis riparia* species and its hybrids, such as 'Kober 5BB' and 'SO4', when propagated by woody cuttings (Monteguti *et al.*, 2008). In previous studies, different responses between cultivars regarding the ability to form adventitious roots in cuttings were observed. One of the main explanations for this behavior is the genetic constitution of the cultivars, which would result in a different rooting potential between them (Dutra *et al.*, 1998).

In the present work, the rootstock 'Paulsen 1103' showed low survival and rooting rates; these results differ from those reported by other researchers. Previous works stated that 'Paulsen 1103' is easy to root, being quite adaptable to various types of soils, and also that the use of IBA is unnecessary, as it does not induced significant differences (Bordin *et al.*, 2005). It is believed that the low rooting and survival rates observed for this rootstock are related to specific conditions of the mother plant from which the cuttings were taken. Factors such as cutting diameter, degree of lignification and concentration of endogenous hormones can markedly interfere the rooting (Hartmann *et al*., 2011).

Hybrid rootstocks, such as 'Richter 99' and 'VR043-43', have potential for cultivation, as they present a genotype that is tolerant or resistant to the etiological agents of vine decline and dieback. The 'Richter 99' ('*V. berlandieri*' x '*V. rupestris*') is recommended for regions with fusariosis occurrence (Garrido *et al*., 2004). In southern Brazil, the rootstock 'VR 043-43' is widespread due to its tolerance to fusariosis and Brazilian ground pearl (*Eurhizococcus brasiliensis*) (Broetto *et al*., 2011; Souza *et al*., 2015). The hybrid between *vinifera* x *rotundifolia* 'VR043-43' is especially difficult to root dormant cuttings. Because '*Vitis rotundifolia*' different number of chromosomes from others vitis species, presenting a lower development rate when traditional propagation techniques are used. The causes of low rooting are possibly related to the presence of inhibitors or the absence of promoters(Pires and Biasi, 2003). However, it is possible to find higher rooting rates of the VR043-43 rootstock when herbaceous cuttings are used and growth regulators are applied (Lone *et al*., 2010).

Woody cuttings from rootstocks '3309 C', '101-14 Mgt', '99 R' and 'Freedom' produced the highest number of roots, between 14 and 16, while cuttings from rootstocks 'Paulsen 1103', '420 A Mgt', 'IAC 313', 'Salt Creek' and 'VR 043-43' produced less roots, between 1.8 and 4.1 (Table I). In a study that evaluated the same rootstocks, the highest number of roots was produced by rootstocks '101-14 Mgt', '3309 C', 'Gravesac' and 'Harmony', and the lowest number of roots was observed in '110R', '420 A Mgt' and 'VR 043-43' (Würz *et al*., 2022), thus complementing the results of the present work. The longest root length, between 19.5 and 20.7 cm, was obtained in 'IAC 572' and 'Freedom' rootstocks, while the shortest root lengths were presented by the 'Paulsen 1103', '420 A Mgt' and 'VR 043-43' rootstocks, between 2.8 and 6.0 cm (Table I). According to Regina *et al*. (2012), these results indicate that '420 A Mgt' was not recommended to produce rooted vine cuttings by the table grafting technique. In addition, the authors also indicated low rooting potential of this rootstock. Similar results were also obtained by Würz *et al*. (2022) when evaluating the rooting potential of different vine rootstocks.

The cuttings of rootstocks '3309 C', '99 R' and 'Freedom' produced the highest number of leaves (between 6.2 and 7.2), while the cuttings of rootstocks '420 A Mgt' and 'VR 043-43' produced the lowest one (between 1.7 and 2.0). The cuttings of the rootstock '3309 C', '101-14 Mgt', 'IAC 572', 'Harmony' and 'Freedom' had the longest shoot length, with values between 13.7 and 18.7 cm. On the contrary, the cuttings of rootstocks 'Paulsen 1103', 'SO4', '420 A Mgt', '110R', 'Salt Creek' and 'VR 043-43' had the shortest average shoot length, with values between 1.2 and 7.4 cm (Table I). For destructive analyses, no statistically significant differences were found for the fresh mass of leaves and dry mass of leaves of different rootstocks. However, 'Paulsen 1103', 'Kober 5BB', 'Gravesac', 'IAC 572' and 'VR 043-43' rootstocks had the highest root fresh masses, while rootstocks '3309 C', 'Paulsen 1103', 'Kober 5BB', 'SO4', 'IAC 572' and 'Freedom' had the highest root dry mass (Table II). In a similar work, the rootstock 'VR 043-43' demonstrated superiority over the other rootstocks analyzed when observing the fresh mass of roots. This differentiated response between genotypes regarding rooting capacity can be explained, among other ways, by different genetic characteristics (Bettoni *et al*., 2014).

Regarding the effect of treatments, results of Table III show that cuttings submitted to the control treatment presented significantly lower results than the other treatments, which in turn did not differ from each other. These outcomes reveal a positive effect of phytohormones and biostimulants used in the vegetative propagation of vine rootstocks.

Auxins play an important role in controlling the growth and development of the plants; besides, they also influence the production of primary, secondary, and adventitious roots (Šebánek, 2008). Some of the processes regulated by IBA include formation of embryo in development, induction of cell division, stem and coleoptile elongation, apical dominance, induction of rooting, vascular tissue differentiation, fruit development, and tropic movements such as bending toward light (Kumar *et al*., 2019). The historical use of IBA phytohormone has been widely used in vegetative propagation, both for rootstocks and for grapevines. Wide bases of studies corroborate what was observed in the present work, in which the use of this hormone proved to be efficient in the rooting and vegetative development of woody and semi-woody grapevine rootstock cuttings (Doğan *et al*., 2019; Uddin *et al*., 2020).

In some studies, the use of the synthetic hormone IBA did not show a significant effect in increasing the rooting index of 'IAC 766' rootstock (Driusso and Trevisan, 2020). However, the use of this technique showed a positive influence on the development of shoots and roots produced from rootstock cuttings (Bettoni *et al*., 2014; Uzunoğlu and Gökbayrak, 2018). It is also worth mentioning that the 3000 mg/L concentration used in this study is considered efficient for a range of materials; the use of less diluted solutions tends to reduce the rooting efficiency of woody rootstock cuttings (Salibe *et al*., 2010).

Regarding the effect of algae extracts in vegetative propagation protocols, studies have shown that such products promote the development of quality planting material in rose and dragon fruit (Parađiković *et al*., 2019; Freitas *et al*., 2021). Significant results using biostimulants in the production of planting material have also been observed in cuttings multiplication of species that are difficult to propagate. The use of these products showed an encouraging performance compared to the use of rooting inducers already consolidated (Trofimuk *et al*., 2020). In a previous work, the use of algae extract-based biostimulant promoted a significant increase in shoot length, root density, root area, root length, root dry matter and shoot dry matter of cv. 'Crimson Seedless' (Ribeiro *et al*., 2017). The combination of IBA and biostimulants also proved to be efficient in rooting other fruit species (Freitas *et al*., 2021).

Table II

Fresh mass and dry mass of leaves and roots of vine rootstock cuttings subjected to different treatments for rooting

Rootstock	Leaves Fresh Mass (g)	Leaves Dry Mass (g)	Roots Fresh Mass (g)	Roots Dry Mass (g)
3309 C	3.20 ± 1.21 ns	0.79 ± 0.34 ns	1.02 ± 0.54 B	0.48 ± 0.20 A
101-14 Mgt	2.54 ± 1.20	0.70 ± 0.27	0.76 ± 0.56 B	0.34 ± 0.15 B
Paulsen 1103	4.61 ± 2.48	1.16 ± 0.60	1.31 ± 0.88 A	0.47 ± 0.28 A
Kober 5BB	3.51 ± 1.87	0.90 ± 0.46	1.78 ± 0.30 A	0.66 ± 0.11 A
SO4	3.48 ± 0.55	0.76 ± 0.18	1.01 ± 0.31 B	0.49 ± 0.05 A
Solferino	3.32 ± 0.56	0.77 ± 0.13	0.43 ± 0.15 B	0.26 ± 0.04 B
Gravesac	3.22 ± 1.17	0.81 ± 0.12	1.53 ± 0.72 A	0.36 ± 0.14 B
420 A Mgt	1.48 ± 0.36	0.30 ± 0.09	0.97 ± 1.06 B	0.26 ± 0.37 B
99 R	2.31 ± 0.51	0.54 ± 0.18	0.35 ± 0.08 B	0.24 ± 0.06 B
110 R	2.38 ± 0.70	0.62 ± 0.21	0.32 ± 0.26 B	0.16 ± 0.07 B
IAC 572	4.91 ± 1.59	0.93 ± 0.21	2.23 ± 0.44 A	0.70 ± 0.03 A
IAC 766	3.91 ± 1.18	0.80 ± 0.22	1.15 ± 0.46 B	0.33 ± 0.13 B
IAC 313	3.97 ± 1.30	0.87 ± 0.26	0.95 ± 0.48 B	0.27 ± 0.16 B
Harmony	3.43 ± 1.16	0.83 ± 0.29	0.90 ± 0.29 B	0.37 ± 0.08 B
Freedom	3.16 ± 0.91	0.76 ± 0.24	0.83 ± 0.22 B	0.49 ± 0.11 A
Salt Creek	2.59 ± 0.93	0.64 ± 0.16	0.56 ± 0.33 B	0.19 ± 0.15 B
VR 043-43	3.18 ± 2.57	0.63 ± 0.35	1.51 ± 0.76 A	0.28 ± 0.14 B

Averages followed by different letters in a column differ from each other by Scott-Knott Test ($p < 0.05$); ns - non-significant.

Table III

Percentage of survival and rooting, average number of roots and shoots, average length of roots and shoots, fresh mass and dry mass of leaves and roots of vine rootstock cuttings subjected to different treatments for rooting

Variable	IBA	Bioestimulant	IBA + Bioest.	Control
Survival (%)	70.0 ± 26.2 A	79.4 ± 20.1 A	72.4 ± 17.9 A	55.3 ± 22.1 B
Rooting (%)	72.4 ± 25.9 A	77.1 ± 21.7 A	72.9 ± 20.5 A	57.1 ± 23.7 B
Root Number	8.9 ± 5.7 A	9.9 ± 5.7 A	10.3 ± 5.4 A	6.4 ± 4.7 B
Root Length (cm)	12.6 ± 6.1 A	14.3 ± 6.3 A	14.7 ± 5.1 A	10.0 ± 5.1 B
Leaves Number	4.9 ± 1.9 A	5.6 ± 2.2 A	5.0 ± 1.6 A	3.2 ± 1.1 B
Shoot Length (cm)	11.2 ± 5.7 A	12.1 ± 6.7 A	10.9 ± 4.8 A	7.2 ± 4.1 B
Leaves Fresh Mass (g)	3.83 ± 2.19 A	3.45 ± 1.98 A	3.66 ± 1.44 A	2.05 ± 1.32 B
Leaves Dry Mass (g)	0.86 ± 0.52 A	0.81 ± 0.49 A	0.84 ± 0.38 A	0.50 ± 0.37 B
Roots Fresh Mass (g)	1.05 ± 0.84 A	1.14 ± 0.94 A	1.20 ± 0.91 A	0.74 ± 0.81 B
Roots Dry Mass (g)	0.39 ± 0.27 ns	0.39 ± 0.31	0.38 ± 0.23	0.32 ± 0.31

Treatments: 3000 mg/L IBA; 0,4 mL SprintAlga TS®; 3000 mg/L IBA + 0,4 mL SprintAlga TS®; Control. Averages followed by different letters in a row differ from each other by Scott-Knott Test ($p < 0.05$). ns - non-significant.

According to the results of the analysis of variance (*p* value < 0.05), it can be stated that there was a statistical difference for the variables analyzed as a function of the different rootstocks. Thus, it is possible to state that this parameter influences all analyzed variables. For the treatment parameter, there was a statistical difference in all analyzed variables, except root dry mass. Concerning the rootstock x treatment interaction, no significant effect was observed for the analyzed variables (Table IV).

Table IV

Analysis of variance and coefficient of variation for the factors rootstock, treatment and for rootstock*treatment interaction

Variable/Factor	Rootstock	Treatment	Rootstock * Treatment	CV (%)
Survival (%)	< 0.001	< 0.001	0.924	16.5
Rooting (%)	< 0.001	< 0.001	0.697	17.8
Root Number	< 0.001	< 0.001	0.202	24.8
Root Length (cm)	< 0.001	< 0.001	0.996	18.3
Leaves Number	< 0.001	< 0.001	0.896	22.3
Shoot Length (cm)	< 0.001	< 0.001	0.128	27.6
Leaves Fresh Mass (g)	0.012	< 0.001	0.122	33.8
Leaves Dry Mass (g)	0.009	< 0.001	0.721	30.9
Roots Fresh Mass (g)	< 0.001	0.005	0.123	48.8
Roots Dry Mass (g)	< 0.001	0.360	0.105	42.9

CONCLUSIONS

The use of indolebutyric acid (IBA) and algae extract-based biostimulant proved to be efficient in rooting woody cuttings from different vine rootstocks.

The use of growth regulator, biostimulant and IBA combined with algae extract-based biostimulant resulted in higher rates of rooting and vegetative development than the control.

The rootstocks showing the highest rooting rates and the highest vegetative development were 'IAC 572' and 'Freedom'. 'Gravesac', '101-14 Mgt' and '99 R' exhibited higher rates of rooting and root development, but less shoot development.

The rootstocks presenting the lowest rooting rates and the lowest vegetative development were 'Salt Creek', 'VR 043-43' and '110 R'.

CONFLICTS OF INTEREST: The authors declare no conflict of interest.

REFERENCES

Arioli T., Mattner S.W., Winberg P.C., 2015. Applications of seaweed extracts in Australian agriculture: past, present and future. *J. Appl. Phycol.*, **27**, 2007-2015.

Baldotto L.E.B., Baldotto M.A., 2014. Adventitious rooting on the Brazilian redcloak and sanchezia after application of indole-butyric and humic acids. *Hort. Bras.*, **32**, 434-439.

Bastos D.C., Scarpare Filho J.L., Libardi M.N., Pio R., 2009. Estiolamento, incisão na base da estaca e uso do ácido indolbutírico na propagação da caramboleira por estacas lenhosas. *Cienc. Agrotec.*, **33**, 313-318.

Bettoni J.C., Gardin J.P.P., Feldberg N.P., Dalla Costa M., Schumacher R., 2015. Estaquia lenhosa de porta-enxertos de videira promissores para regiões com histórico de morte de plantas. *Rev. Bras. Fruticultura*, **37**, 534- 539.

Bettoni J.C., Gardin J.P.P., Feldberg N.P., Schumacher R., Souza J.A., Furlan C., 2014. O uso de AIB melhora a qualidade de raízes em estacas herbáceas de porta-enxertos de videira. *Evidência*, **14**, 47-56.

Bordin I., Hidalgo P.C., Bürkle R., Roberto S.R., 2005. Efeito da presença da folha no enraizamento de estacas semilenhosas de porta-enxertos de videira. *Cienc. Rural*, **35**, 215-218.

Borghezan M., Moraes L.K.A., Moreira F.M., Silva A.L., 2003. Propagação in vitro e avaliação de parâmetros morfofisiológicos de porta-enxertos de videira. *Pesqui. Agropecu. Bras.*, **38**, 783-789.

Broetto D., Baumann Junior O., Sato A.J., Botelho R.V., 2011. Desenvolvimento e ocorrência de pérola-da-terra em videiras rústicas e finas enxertadas sobre os porta-enxertos ‘VR043-43’ e ‘Paulsen 1103’. *Rev. Bras. Fruticultura*, **v. esp.**, 404-410.

Calvo P., Nelson L., Kloepper J.W., 2014. Agricultural uses of plant biostimulants. *Plant Soil,* **383**, 3-41.

Doğan A., Uyak C., Kazankaya A., 2019. Effects of Indole-Butyric Acid Doses, Different Rooting Media and Cutting Thicknesses on Rooting Ratios and Root Qualities of 41B, 5 BB and 420A American Grapevine Rootstocks. *J. Appl. Biol. Sci*., **10**, 08-15.

Driusso O., Trevisan F., 2020. Enraizamento e desenvolvimento de porta enxertos de videira IAC-766, com uso de diferentes substratos e doses de ácido indolbutírico. *Scientia Vitae,* **10**, 38-46.

Du Jardin P., 2015. Plant biostimulants: Definition, concept, main categories and regulation. *Sci. Hortic*., **196**, 3-14.

Dutra L.F., Tonietto A., Kersten E., 1998. Efeito da aplicação de ethefon em ameixeira (*Prunus salicina* Lindl) e do IBA no enraizamento de suas estacas. *Sci. Agric*., **55**, 296-304.

Fráguas J.C., 1999. Tolerância de porta-enxertos de videira ao alumínio do solo. *Pesqui. Agropecu. Bras.*, **34**, 1193-1200.

Freitas F.R., Brighenti A.F., Coutinho M.D.C., Voltolini J.A., Malohlava I.T.C., Tomazetti T.C., Lone A.B., 2021. Efeito de extrato de algas no enraizamento de estaca de pitaia. *Agropecu. Catarinense*, **34**, 34-36.

Garrido L.R., Sonego O.R., Urben A.F., 2004. *Cylindrocarpon destructans*, causador do “pé-preto” da videira no Rio Grande do Sul. *Fitopatol. Bras*., **29**, 548-550.

Gutiérrez-Gamboa G., Moreno-Simunovic Y., 2021. Seaweeds in viticulture: a review focused on grape quality. Ciência Téc. Vitiv., **36**, 9-21.

Gutiérrez-Gamboa G., Romanazzi G., Garde-Cerdán T., Pérez-Álvarez E.P., 2018a. A review of the use of biostimulants in the vineyard for improved grape and wine quality: effects on prevention of grapevine diseases. *J. Sci. Food Agric*., **99**, 1001–1009.

Gutiérrez-Gamboa G., Garde-Cerdán T., Souza-Da Costa B., Moreno-Simunovic Y., 2018b. Strategies for the improvement of fruit set in *Vitis vinifera* L. cv. ‘Carménère’ through different foliar biostimulants in two different locations. *Ciência Téc. Vitiv*., **33**, 177-183.

Hartmann H.T., Kester D.E., Davies Junior F.T., Geneve R.L., 2011. Plant propagation: principles and practices. 915 p. Prentice-Hall, Boston.

Keller M., 2020. The science of grapevines: anatomy and physiology. 400 p. Academic Press, Elsevier.

Kumar S., Malik A., Yadav R., Yadav G., 2019. Role of different rooting media and auxins for rooting in floricultural crops: A review. *Int. J. Chem. Stud.*, **7**, 1778-1783.

Leão P.C.S., Chaves A.R.M., Silva D.J., 2020. Porta-enxertos e sua influência na produtividade e desempenho agronômico de videiras ‘Syrah’ e ‘Chenin Blanc’ no Vale do São Francisco. 12 p. Embrapa, Petrolina.

Lone A.B., López E.L., Rovaris S.R.S., Klesener D.F., Higashibara L., Ataíde L.T., Roberto S.R., 2010. Efeito do AIB no enraizamento de estacas herbáceas do porta-enxerto de videira VR 43-43 em diferentes substratos. *Semin. Cienc. Agrar*., **31**, 599-604.

Macedo M., 2011. Port wine landscape: railroads, phylloxera, and agricultural science. *Agric. Hist.*, **85**, 157–173.

Monteguti D., Biasi L.A., Peresuti R.A., Sachi A.T., Oliveira O.R., Skalitz R., 2008. Enraizamento de estacas lenhosas de porta-enxertos de videira com uso de fertilizante orgânico. *Sci. Agrar*., **9**, 99-103.

Parađiković N, Teklić T, Zeljković S, Lisjak M, Špoljarević M., 2019. Biostimulants research in some horticultural plant species - A review. *Food Energy Secur*., **8**, e00162.

Pires E.J.P., Biasi L.A., 2003. Propagação da videira. In: Uva: Tecnologia da produção, pós-colheita e mercado. 295-350. Pommer C.V. (ed.), Cinco Continentes, Porto Alegre.

Regina M.A., Souza C.R., Novelli Dias F.A., 2012. Propagação de Vitis spp. pela enxertia de mesa utilizando diferentes porta-enxertos. *Rev. Bras. Fruticultura*, **34**, 897-904.

Ribeiro R.F., Lobo J.T., Cavalcante I.H.L., Tenreiro I.G.P., Lima D.D., 2017. Bioestimulante na Produção de Mudas de Videira cv. Crimson Seedless. *Sci. Agrar*., **18**, 36-42.

Santos V.M., Melo A.V., Cardoso D.F., Gonçalves A.H., Varanda M.A.F., Taubinger M., 2013. Uso de bioestimulantes no crescimento de plantas de *Zea mays* L. *Rev. Bras. Milho Sorgo*, **12**, 307-318.

Salibe A.B., Braga G.C., Pio R., Yuji C., Da Silva F.R.É.Z., Da Silva T.P., 2010. Enraizamento de estacas do porta-enxerto de videira 'VR 043-43' submetidas a estratificação, ácido indolbutírico e ácido bórico. *Bragantia*, **69**, 617-622.

Šebánek J., 2008. Vegetative physiology tree propagation. 60 p. Mendel University of Agriculture and Forestry in Brno.

Sharma S.H.S., Lyons G., McRoberts C., McCall D., Carmichael E., Andrews F., Swan R., McCormack R., Mellon R., 2012. Biostimulant activity of brown seaweed species from Strangford Lough: compositional analyses of polysaccharides and bioassay of extracts using mung bean (*Vigno mungo*

L.) and pak choi (*Brassica rapa chinensis* L.). *J. Appl. Phycol*., **24**, 1081-1091.

Smith B.P., Morales N.B., Thomas M.R., Smith H.M., Clingeleffer P.R., 2017. Grapevine rootstocks resistant to the root-knot nematode *Meloidogyne javanica*. *Aust. J. Grape Wine Res*., **23**, 125-131.

Souza E.L., Dalbó M.A., Rosier J.P., Dambrós R.N., Andrade E.R., Arioli C.J., Parizotto C., Brighenti E., Bruna E.D., 2015. Avaliação de cultivares de uva 2013-2014. 50 p. Epagri, Florianópolis.

Tecchio M.A, Leonel L, Reis L.L, Simonetti L.M., Silva, M.J.R., 2015. Stimulate no desenvolvimento de mudas de kunquat 'Nagami'. *Irriga Ed. Esp.*, **1**, 97-106.

This P., Lacombe T., Thomas M. R., 2006. Historical origins and genetic diversity of wine grapes. *Trends Genet*., **22**, 511–519.

Trofimuk L.P., Kirillov P.S., Egorov A.A., 2020. Application of biostimulants for vegetative propagation of endangered *Abies gracilis*. *J. For. Res*., **31**, 1195-1199.

Uddin A.F.M.J., Rakibuzzaman M., Raisa I., Maliha M., Husna M.A., 2020. Impact of natural substances and synthetic hormone on grapevine cutting. *J. Biosci. Agric. Res*., **25**, 2069-2074.

Uzunoğlu Ö., Gökbayrak Z., 2018. Influence of IAA, 28-homobrassinolide and 24-epibrassinolide on Adventitious Rooting in Grapevine. *COMU J. Agric. Fac.*, **6**, 23-30.

Vieira E.L., Santos G., dos Santos A.R., Silva J.S., 2010. Manual de Fisiologia Vegetal. 230 p. EDUFMA, São Luis.

Waite H., Whitelaw-Weckert M., Torley, P., 2015. Grapevine propagation: principles and methods for the production of high-quality grapevine planting material. *N. Z. J. Crop Hortic. Sci*., **43**, 144-161.

Whiting J., 2012. Rootstock breeding and associated R&D in the viticulture and wine industry. 54 p. Grape and Wine Research and Development Corporation, Adelaide.

Willians P.L., Antcliff A.J., 1984. Successful propagation of *Vitis berlandieri* and *Vitis cinerea* from hardwood cuttings. *Am. J. Enol. Vitic.*, **35**, 75-76.

Würz D.A., Brighenti A.F., Feldberg N.P., 2022. Rooting potential of grapevine rootstocks cuttings. *Rev. Ceres*, **69**, 001-009.