Journal of Experimental Agriculture International

43(1): 84-90, 2021; Article no.JEAI.66510
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Propagation by Stem Cuttings of *Tropaeolum pentaphyllum* Lam. (Crem): An Alternative for Production of Seed Tubers

Júlio Tagliari Balestrin[1], Tiago Lodi de Souza[2], Alan Serafini Betto[1], Daniela da Silva[3] and Juliana Marcia Rogalski[1*]

[1]Núcleo de Ciências Biológicas e Ambientais, Instituto Federal do Rio Grande do Sul – Campus Sertão, Sertão, RS, Brazil.
[2]École nationale supérieure des sciences agronomiques de Bordeaux, France.
[3]Departamento de Fitossanidade, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil.

Authors' contributions

This work was carried out in collaboration among all authors. Authors JTB, TLS, ASB, DS and JMR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JTB, TLS and ASB managed the analyses of the study. Authors JTB and DS managed the literature searches. Author JMR supervised the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2021/v43i130634
Editor(s):
(1) Professor. Rusu Teodor, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.
Reviewers:
(1) Aparecida Leonir da Silva, Universidade de São Paulo, Brazil.
(2) Ana Cruz Morillo Coronado, Universidad Pedagógica y Tecnológica de Colombia, Colombia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/66510

Original Research Article

Received 12 January 2021
Accepted 16 March 2021
Published 25 March 2021

ABSTRACT

The herbaceous vine *Tropaeolum pentaphyllum* Lam. (Tropaeolaceae), popularly known as crem, has great potential for use, especially its tubers. However, there is still a lack of studies regarding this species. The objective of this study was to test the viability of propagation by stem cuttings for the production of *T. pentaphyllum* seed tubers. Two experiments were carried out in a greenhouse under controlled conditions. In both experiments, experimental design was completely randomized. In the first one, five treatments were evaluated (stem cuttings with 10, 15, 20, 25, and 30 cm) with three replicates, each one with 10 stem cuttings. In the second experiment, three treatments were evaluated (stem cuttings positions: apical, middle and basal), with four replications, each one with

**Corresponding author: E-mail: juliana.rogalski@sertao.ifrs.edu.br;*

10 stem cuttings. Data were submitted to analysis of variance (ANOVA) and the means were compared by Tukey's test ($p < 0.05$). Stem cuttings with 15 cm length had the highest rate of tuber formation (20.0%) and produced tubers with highest mass (3.2 g). Cuttings from the middle portion of the stem had the highest rooting (52.5%) and tuber formation (45.0%) rates. Thus, cuttings with 15 cm length from the middle portion of the stem are indicated for propagation by cuttings of *T. pentaphyllum*. Considering the potential for the use of this species in the future, the results found in this study are very important, since the propagation by cuttings would enable the production of a large amount of seed tubers in a short period of time.

Keywords: Tropaeolum pentaphyllum; alternative crop; unconventional food plant; horticulture; tuber; vegetative propagation.

1. INTRODUCTION

The species *Tropaeolum pentaphyllum* Lam. (Tropaeolaceae), popularly known as crem, is considered an unconventional food plant [1]. The main use of this species concerns the production of preserves from the tubers, which are consumed as a condiment [2]. Consumption of fresh tubers does not occur due to the very high pungency [3]. In Brazil, consumption of preserve crem tubers is very widespread among people of European descent [3].

Tubers of *T. pentaphyllum* have antimicrobial, antiscorbutic and depurative action [3,4]. The levels of vitamin C and linoleic acid in the composition of fatty acids, and those of sulfur, calcium and phosphorus present in the tubers are remarkable [5]. There are also significant amounts of fiber (16.79%) and inulin (70.92 mg g-1) [6,7].

A variety of nutritional and medicinal attributes and rusticity (tolerance to frost and pests), combined with the high commercial value of tubers, can make the crop attractive. In Rio Grande do Sul State, the kilogram of fresh crem tubers is sold around R$40,00. Therefore, this species should be among the main vegetable crops in Brazil, showing great potential for exploration in the future [3]. However, habitat loss, promoted by the advancement of agricultural activities and combined with the extraction of tubers *in situ*, has prevented crem preservation.

In Brazil, the herbaceous vine *T. pentaphyllum* occurs in the South and Southeast regions [8]. The aerial stem of crem is annual while its tubers are perennials. The sprouting of the crem tubers starts in March and senescence of the aerial stem occurs from September to November. The tubers are dormant during the summer, starting to sprout again in the fall, when the temperature and day length decrease [9]. Thus, the species has a short annual cycle.

Propagation of *T. pentaphyllum* is primarily carried out by planting tubers. Although seed propagation is not widespread, it is also possible [2]. Yet, the irregular sprouting of tubers and difficulties in seed germination are some obstacles for crem cultivation. Kinupp et al. [3] described propagation by stem cuttings of *T. pentaphyllum* as a possibly unfeasible technique. However, there are no studies that prove the non-viability of propagation by stem cuttings of crem.

The objective of this study was to test the viability of propagation by stem cuttings as an alternative for the production of *T. pentaphyllum* seed tubers, aiming for conservation and expansion of cultivation of this species.

2. MATERIALS AND METHODS

Two experiments were carried out in a greenhouse with controlled environmental conditions (temperature of 25ºC and daily irrigation by fogging) at Instituto Federal do Rio Grande do Sul − *Campus* Sertão (28°02'42"S, 52°16'17"W and altitude of 737 m a.s.l.) located in Sertão Municipality, Rio Grande do Sul State (RS), Brazil. The first experiment was performed in May 2017 and the second one in May 2018. In both experiments, the stem cuttings were monitored from their implantation to senescence of the aerial stem.

The cuttings used were taken from stems of 20 plants of *T. pentaphyllum*, grown in a greenhouse. The tubers of *T. pentaphyllum* that originated the plants used in the experiment were obtained from farmers in the northern region of Rio Grande do Sul, Brazil. The tubers started to sprout in March and after two months, in May, the cuttings were taken – when the plants were in vegetative stage with well-developed stems. The cuttings were placed individually in 120 cm^3 tree pots containing peat as substrate.

In 2017, in the first experiment, stem cuttings of different lengths from the apical position of the stem were evaluated. Five treatments were conducted (stem cuttings with 10, 15, 20, 25 and 30 cm) with three replicates, each one with 10 stem cuttings, a total of 150 cuttings.

In 2018, in the second experiment, cuttings from different stem positions were evaluated, all of them with 15 cm length. Three treatments were evaluated (stem cuttings positions: apical, middle and basal) with four replications, each one with 10 stem cuttings, a total of 120 cuttings.

The experimental design used was completely randomized in both experiments. In the first experiment, after senescence of the aerial stem, the variables analyzed were: rooting (%) and tuber formation (%). In the second experiment, the variables analyzed were: cuttings survival (%) and number of shoots, at 30, 60 and 90 days. Furthermore, after senescence of the aerial stem, rooting (%) and tuber formation (%) were evaluated. Data were subjected to a normality test to check for possible transformation needs, which were not detected. Then they were subjected to analysis of variance (ANOVA), and the means were compared by Tukey's test ($p < 0.05$), using the software Sisvar 5.6.

In both experiments, the tuber biometry (length, width, thickness and mass) was evaluated. Tuber biometry was analyzed using descriptive statistics (mean ± confidence interval ($\alpha = 0.05$).

3. RESULTS

3.1 Experiment 1

The stem cuttings with the largest length (20, 25, and 30 cm) had the greatest rooting when compared to the stem cuttings of the shortest length (10 and 15 cm) (Table 1). However, stem cuttings with 15 cm length had the highest tuber formation, showing statistical difference from other lengths. The duration of the plants, from implantation of the experiment to senescence of the aerial stem, ranged from 84 to 112 days, with an average of 105 ± 11 days.

Stem cuttings with 20 cm length produced tubers that presented the greatest length (Table 2). Stem cuttings with 15 cm length produced tubers with the greatest width, thickness and mass.

Table 1. Rates of rooting (%) and tuber formation (%) on stem cuttings from different lengths of *Tropaeolum pentaphyllum* (crem) after the senescence of aerial stem

Stem cutting length (cm)	Rooting (%)	Tuber formation (%)
10	56.7b	10.0b
15	66.7b	20.0a
20	96.7a	10.0b
25	100.0a	6.7b
30	100.0a	10.0b
CV(%)	5.3	22.8

**Means followed by the same small letter do not differ by the Tukey's test (p < 0.05). CV-Coefficient of variation (%)*

Table 2. Tuber biometrics (length, width, thickness and mass) obtained on stem cuttings from different lengths of *Tropaeolum pentaphyllum* (crem)

Stem cutting length (cm)	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)
	$\bar{x}$ ± CI	$\bar{x}$ ± CI	$\bar{x}$ ± CI	$\bar{x}$ ± CI
10	1.20 ± 0.45	1.60 ± 0.45	1.60 ± 0.34	1.70 ± 0.91
15	1.30 ± 0.24	2.00 ± 0.08	1.80 ± 0.08	3.20 ± 0.56
20	2.10 ± 0.34	1.70 ± 0.34	1.20 ± 0.45	2.60 ± 1.81
25	1.50 ± 0.69	1.70 ± 0.42	1.50 ± 0.28	2.10 ± 0.06
30	1.40 ± 0.23	1.80 ± 0.57	1.60 ± 0.34	2.50 ± 1.58

** $\bar{x}$ = mean. CI = confidence interval ($\alpha = 0.05$)*

3.2 Experiment 2

Sprouting and number of shoots increased during the period evaluated in all treatments (Table 3). At 30 and 60 days after the implementation of the experiment, middle and basal stem cuttings had higher sprouting and number of shoots, showing statistical difference from apical cuttings. However, 90 days after implementation of the experiment there were no statistical differences between treatments for these variables.

Cuttings survival decreased during the period evaluated in all treatments (Table 3). However, 90 days after implementation of the experiment, middle and basal stem cuttings had highest cuttings survival, showing statistical difference from apical cuttings. Duration of the plants, from implementation of the experiment to senescence, ranged from 119 to 175 days, with an average of 158 ± 18 days.

Middle stem cuttings had highest rooting and tuber formation, showing statistical difference from the other treatments (apical and basal stem cuttings) (Table 4).

The tubers produced from cuttings of different stem positions did not differ in size (length, width and thickness) and mass (Table 5).

4. DISCUSSION

Stem cuttings with longer length had the highest rooting, possibly due to the higher content of carbohydrate reserves present in relation to cuttings of shorter length [10]. In other species, such as *Prunus mume* Sieb. et Zucc. [11], *Jatropha curcas* L. [12], *Myrciaria dubia* (Kunth) McVaugh [13] and *Hylocereus undatus* (Haw.) Britton and Rose [14] was also observed higher rooting in larger cuttings.

Middle and basal stem cuttings had higher sprouting and number of sprouts compared to apical stem cuttings, possibly due to the absence of apical dominance, which promotes the sprouting of axillary buds [15]. In *Ipomoea batatas* L. (sweet potato), the cuttings stem positions also affect the sprouting; cuttings without the apex of the stem had the highest emission of shoots [16].

The higher sprouting in middle and basal stem cuttings results in a greater number of apical shoots, which is closely related to the production of auxin [16,17]. Therefore, sprouting increases the proportion of auxin in relation to cytokinin, promoting induction of adventitious roots [18,19]. There are incontestable evidences that auxin promotes rooting, causing starch hydrolysis and mobilization of sugars and nutrients at the base of cuttings, during adventitious root generation [20,21].

Table 3. Rates of sprouting (%), cutting survival (%), and number of shoots, on cuttings from different stem positions of *Tropaeolum pentaphyllum* (crem)

Stem cutting position	Days after experiment implantation								
	30	60	90	30	60	90	30	60	90
	Sprouting (%)			Number of shoots			Cutting survival (%)		
Apical	0.0b	29.5b	85.5a	0.0b	1.2b	1.3a	92.5a	85.0b	37.5b
Middle	66.5a	90.0a	100.0a	1.4a	1.7a	2.0a	97.5a	97.5a	62.5a
Basal	85.0a	97.3a	100.0a	1.5a	1.8a	1.9a	97.5a	92.5ab	67.5a
CV (%)	37.6	11.8	10.4	21.1	15.6	21.9	5.2	5.7	8.9

**Means followed by the same small letter do not differ by the Tukey's test ($p < 0.05$). CV-Coefficient of variation (%)*

Table 4. Rates of rooting (%), and tuber formation (%) on cuttings from different stem positions of *Tropaeolum pentaphyllum* (crem) after the senescence of aerial stem

Stem cutting position	Rooting (%)	Tuber formation (%)
Apical	30.0c	22.5b
Middle	52.5a	45.0a
Basal	40.0b	25.0b
CV (%)	7.0	17.9

**Means followed by the same small letter do not differ by the Tukey's test ($p < 0.05$). CV-Coefficient of variation (%)*

Table 5. Tuber biometrics (length, width, thickness and mass) obtained on cuttings from different stem positions of *Tropaeolum pentaphyllum* (crem)

Stem cutting position	Length (mm)	Width (mm)	Thickness (mm)	Mass (g)
	$\bar{x}$ ± CI	$\bar{x}$ ± CI	$\bar{x}$ ± CI	$\bar{x}$ ± CI
Apical	10.34 ± 1.53	9.28 ± 1.60	7.59 ± 1.53	0.54 ± 0.29
Middle	10.70 ± 1.22	9.23 ± 1.19	7.28 ± 1.07	0.58 ± 0.18
Basal	11.31 ± 1.43	9.91 ± 1.55	7.35 ± 1.46	0.66 ± 0.25

** $\bar{x}$ = mean. CI = confidence interval (α = 0.05)*

The greatest rooting in middle stem cuttings in relation to apical and basal stem cuttings occurred, possibly, due to the greater sensitivity to dehydration of apical stem cuttings and to the greatest lignification of basal stem cuttings [22]. The greatest sensitivity to dehydration prevents the survival of cuttings, while lignification prevents the emission of adventitious roots. In *Malpighia emarginata* DC. [22], *Syzygium cumini* (L.) Skeels [23], *Hyptis suaveolens* (L.) Poit [24] and *Hyptis pectinata* (L.) Poit [25] also occurred greater rooting in middle stem cuttings.

Crem has a short annual cycle and its aerial stem dies annually while its tubers are perennial. Thus, propagation by stem cuttings of *T. pentaphyllum* only can considered viable if there is production of tubers, which allows starting a new cycle. Therefore, stem cuttings of the middle position with 15 cm length, due to the greater formation of tubers, are indicated for production of *T. pentaphyllum* seed tubers.

The average duration of the plants obtained by propagation by stem cuttings verified in the two experiments did not present statistical differences when compared to the planting of seed tubers (123 ± 33 days). However, tubers obtained from propagation by stem cuttings are small, without sufficient size for consumption and/or commercialization.

On the other hand, regardless of the size of the tubers, the presence of buds in the tubers allows using them as propagules in a new growing cycle, next year. So, the tubers produced by propagation by stem cuttings can be called seed tubers, as in potato cultivation (*Solanum tuberosum* L.) [26].

Considering the agronomic potential presented by *T. pentaphyllum*, propagation by stem cuttings may be an ally of nurseries in the future, since it enables to obtain a large amount of seed tubers in a short period of time.

5. CONCLUSION

Stem cuttings with 15 cm long had the highest tuber formation and tubers with the greatest mass. Middle stem cuttings had the highest tuber formation. Thus, middle stem cuttings with 15 cm length are indicated for the propagation by stem cuttings of *T. pentaphyllum*, being indicated for production of seed tubers.

Considering the fact that *T. pentaphyllum* is understudied, the results found in this study are very important since this species has great potential for use in the future.

ACKNOWLEDGEMENTS

JTB received a scholarship from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq/ATP-B); TLS received a scholarship from Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul (FAPERGS); ASB received a scholarship from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq/PIBITI); DS received a scholarship from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq/PIBITI); and JMR received a scholarship from PET Conexões – Licenciatura em Ciências Agrícolas (MEC/PET).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Kinupp VF. Unconventional food plants from metropolitan region of Porto Alegre, RS. Thesis (Doctor in Phytotechnics) – UFRGS; 2007.
2. Kinupp VF, Lorenzi H. Plantas alimentícias não convencionais (PANC) no Brasil: Guia de identificação, aspectos nutricionais e receitas ilustradas. São Paulo: Instituto Plantarum; 2014.

3. Kinupp VF, Lisbôa GN, Barros IBI. Plantas para o Futuro – Região Sul. In: Coradin L, Siminski A, Reis C, editors. Espécies Nativas da Flora Brasileira de Valor Econômico Atual ou Potencial. Brasília: MMA; 2011.
4. Mors WB, Rizzini CT, Pereira NA, Defilipps RA. Medicinal plants of Brazil. Michigan: Reference Publications; 2000.
5. Braga VB, Vieira MM, Barros IBI. Nutritional potential of leaves and tubers of crem (*Tropaeolum pentaphyllum* Lam.). Revista de Nutrição. 2018;31:423-432. DOI:https://doi.org/10.1590/1678-98652018000400007
6. Binda CS. Verification and quantification of inuline on the aerial parts of crem plants (*Tropaeolum pentaphyllum*). Dissertation (Master in Food Engineering) – URI; 2013.
7. Simões GD. Crem (*Tropaeolum pentaphyllum* Lam): Chemical characterization, antioxidant and its application as a condiment in a vegetable paste. Dissertation (Master in Food Science and Technology) – UFSM; 2015.
8. Sparre B. Tropeoláceas. In: Reitz R, editor. Flora ilustrada Catarinense. Itajaí: Herbário Barbosa Rodrigues; 1972.
9. Fabbri LT, Valla JJ. Some aspects of the reproductive biology of *Tropaeolum pentaphyllum (Tropaeolaceae)*. Darwiniana. 1998;36:51-58.
10. Hartmann HT, Kester DE, Davies Jr FT, Geneve RL. Hartmann and Kerster's plant propagation: Principles and practices. 8. ed. New Jersey: Prentice Hall; 2011.
11. Mayer NA, Pereira FM, Nachtigal JC. Effect of the length of herbaceous cuttings of two clones of japanese apricot (*Prunus mume* sieb & zucc.) in adventicious rooting. Revista Brasileira de Fruticultura. 2002;24:500-504. DOI: https://doi.org/10.1590/S0100-29452002000200044
12. Lima RLS, Severino LS, Pereira WE, Lucena AMA, Ghey HR, Arriel NHC. Length of cuttings and the part of the branch section for production of *Jatropha* seedlings. Revista Brasileira de Engenharia Agrícola e Ambiental. 2010;14:1234-1239.
13. Delgado JPM, Yuyama K. Cutting lenght of camu-camu with indolebutyric acid for clonal production. Revista Brasileira de Fruticultura. 2010;32:522-526. DOI: http://dx.doi.org/10.1590/S0100-29452010005000066
14. Pontes Filho FST, Almeida EIB, Barroso MMA, Cajazeira JP, Corrêa MCM. Length of cuttings and concentrations of indolebutyric acid (IBA) in the vegetative propagation of pitaya. Revista Ciência Agronômica. 2014;45: 788-793. DOI: http://dx.doi.org/10.1590/S1806-66902014000400017
15. Taiz L, Zeiger E, Moller I, Murphy A. Fisiologia e desenvolvimento vegetal. 6. ed. Porto Alegre: Artmed; 2017.
16. Netsai N, Moses M, Tuarira M. Effect of cutting position and vine pruning level on yield of Sweet Potato (*Ipomoea batatas* L.). Journal of Aridland Agriculture. 2019;5:01-05. DOI: https://doi.org/10.25081/jaa.2019.v5.5255
17. Oboho EG, Iyadi, JN. Rooting potential of mature stem cuttings of some forest tree species for vegetative propagation. Journal of Applied and Natural Science. 2013;5:442–446. DOI: https://doi.org/10.31018/jans.v5i2.350
18. Ibáñez-Torres A. Rooting experiments with *Euphorbia lagascae* cuttings. Anales de Biología. 2004;26:101-104.
19. Steffens B, Rasmussen A. The physiology of adventitious roots. Plant Physiology. 2016;170:603–617. DOI: https://doi.org/10.1104/pp.15.01360
20. Khare CP. Indian medicinal plants: An illustrated dictionary. Berlin: Springer-Verlag; 2007.
21. Siddiqui MI, Hussain SA. Effect of indole butyric acid and types of cuttings on root initiation of *Ficus hawaii*. Sarhad Journal of Agriculture. 2007;23:919-925.
22. Lima RLS, Siqueira DL, Weber OB, Cazetta JO. Size and part of the branch to be used as barbados cherry cuttings. Revista Brasileira de Fruticultura. 2006;28:83-86. DOI: https://doi.org/10.1590/S0100-29452006000100024
23. Lima YOU, Ritter M, Alcântara GB, Lima OM, Fogaça LA, Quoirin M, Cuquel FL, Biasi LA. Cuttings types and substrates for Jambolão adventitious rooting. Scientia Agraria. 2007;8:449-453. DOI: http://dx.doi.org/10.5380/rsa.v8i4.9896
24. Maia SSS, Pinto JEBP, Silva FN, Oliveira C. Rooting of *Hyptis suaveolens* (L.) Poit (*Lamiaceae*) in relation to the position of the cuttings in plant branches. Revista

Brasileira de Ciências Agrárias. 2008;3:317-320. DOI:http://dx.doi.org/10.5039/agraria.v3i4a330

25. Carvalho JSB, Nunes MFPN, Campos GPA, Goes MCC. Influence of different types of cuttings and substrates on vegetative propagation of *Hyptis pectinata*. Revista de Ciências Agroveterinárias. 2015;14:89-91.

26. Queiroz LRM, Kawakami J, Muller MML, Umburanas RC, Eschemback V. Tuber, seed size and spacing on potato yield under field conditions. Comunicata Scientiae. 2013;4:308-315. DOI: https://doi.org/10.14295/cs.v4i3.344.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/66510