



Effect of Explant Age and Applied IBA on Growth and Rooting of Apical Stem Cuttings of Potato for Early Generation Seed Potato Production

Zishan Gul ^{a#*}

^a Hazara Agriculture Research Station, Abbottabad, Pakistan.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/AJAAR/2022/v20i1386

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/93579>

Original Research Article

Received: 14/09/2022

Accepted: 17/11/2022

Published: 24/11/2022

ABSTRACT

The aim of this work is to study the effect of explant age and exogenously applied IBA on the growth and rooting potential of potato apical stem cuttings for production of first- generation seed potatoes. The experimental protocol consists in taking apical stem cuttings from potato plantlets at different physiological ages (30 and 60 days old) in interaction with the growth regulator indole-3-butyric acid (IBA) at different concentrations (100, 200, and 300 ppm) to study the production of potato minitubers. The results of the present study showed that mini-cuttings from young potato plants (30 days old) have a higher rooting capacity than mini-cuttings from mature plants. In addition, IBA concentrations, especially at 300 ppm, have a significant effect on most of the characteristics studied, e.g. rooting %, root number, root length, shoot length, and number of leaves. Regarding yield attributes, application of IBA at 300ppm gave the highest average tuber number (6.66) and tuber yield (142.97g) was higher in 30days old explant cuttings. The data presented in this study may encourage potato growers to use potato stem cuttings as a new, cheaper method of growing potatoes instead of expensive imported seed tubers. It is suggested

Senior Research Officer;

*Corresponding author: Email: gul.zishan@gmail.com;

that the use of apical stem cuttings can be a quick and effective method for mass propagation and to increase the yield of minitubers in the seed potato production cycle.

Keywords: Rooting response; shoot tip cuttings; mother plant age; Indole butyric acid; potato minitubers; Rapid Multiplication Technique (RMT).

1. INTRODUCTION

“As a major food crop, potato ranks fourth in terms of production in the world. It is staple food crop in some countries and others used it as a vegetable” [1,2]. Potato tubers provide vitamin C, potassium, and dietary fiber in the diet [3] and potato flesh is a good source of essential nutrients like B1, B2, B6, B9, some antioxidants and several trace elements [4]. It is an important food and cash crop in Pakistan. In Pakistan, potato crops covered 234.4 thousand hectares of area and gave 4,681.0 thousand tons of production [5]. “Although potato production in Pakistan has increased many folds, its per acre yield is far less than in other parts of the world. Among the various factors responsible for low per-acre potato production, the unavailability of certified seed is the most important one” [6].

Usually, three potato crops i.e spring, summer, and autumn are grown in different agro-ecological zones of Pakistan ranging from plains to hilly areas [7]. Potato seed production in Pakistan is informal and usually recycled from previous crop harvests. Currently, the common method for potato propagation is through tubers. Seed selection is basically on size with small ones being preferred due to their less market demand. Seed potato production by using a conventional system has not been effective in eluding or reducing the buildup of diseases which consequently led to reduced seed quality and lower tuber yields [8]. Gildemacher et al. [9]; Nyende et al. (2005) reported that seed recycling and monoculture contributes to the accumulation of seed-borne diseases in potato in subsequent seasons, resulting in losses in both tuber quality and yield over seasons. The use of seed potatoes infected by fungi, bacteria, and/or viruses reduces the potential yield of the crop as a result of the progressive degeneration caused by such pathogens during successive field generations which contributes to disease buildup. This requires the regular renewal of the seed potatoes [10]. A critical constraint in meeting increasing demand is the non-availability of the high-quality seed of most adapted varieties with considerable resistance to pests and diseases.

Certified seed production is an essential factor for higher and disease-free seed potato production. One of the attempts to multiply potato

seeds quickly and in larger quantities is by rapid propagation techniques. Harahagazwe et al. [11] illustrated that for seed potato production, Rapid Multiplication Techniques (RMT) can be carried out with in vitro plantlets and micro-tubers production, or can also be practiced with in vivo production of cuttings and minitubers. Yasmin and Zakaria [12] stated that potato propagation materials like sprout and shoot tip cuttings or nodal segments with at least one bud and true potato seeds can be used.

Rooted apical stem cuttings in the greenhouse are the easiest and cheapest means of propagating potatoes (Struik and Wiersema, 1999) for minitubers production as an initial step in certified seed production. They have faster regeneration potential and are true to type. Their ability to regenerate rapidly gives them great potential for the conservation of potato clones and the production of potato seed. If rooted apical stem cuttings originate from true-to-type and pathogen-free planting material, they serve as an efficient means of producing basic seed. Dahshan, et al. [13] studied the possibility to propagate potatoes through stem cuttings and enhance the growth capabilities of these cutting by using plant growth regulators (PGR) e.g., IBA. Each physiological process in plants is usually regulated by a number of defined hormones, some of them often exerting opposite effects. In potatoes, for example, distinct hormones (IAA, cytokinins, and abscisic acid stimulate some tuberization stages [14].

Ishartati and Rehan [15] reported that potato seeds can be procured through cuttings by treating the cuttings with plant hormones that encourage and accelerate the formation of roots, and new shoots, and enhance the quality and number of shoots and roots.

Plant growth of apical stem cuttings of white potato derived from disease-free G₀ plants for mass production of potato G₁ seed tubers was demonstrated by Nikmatullah et al. [16]. Different cutting lengths, Indole Acetic Acid (IAA) concentrations, and age of mother plants were evaluated for cutting's growth and survival rate. The highest survival rate and cutting growth were obtained from apical cuttings taken from two to three weeks old mother plants treated with 1 ppm IAA.

“Cuttings obtained from tissue-cultured plantlets are seen as an alternative to reduce the number of plantlets that are cultivated *in vitro* and then used in the production of potato mini-tubers. This technique consists of rooting the mini-cuttings taken from newly acclimatized plants. The nutritional status of the plant and the degree of juvenility of propagules may influence the adventitious rooting of potato mini-cuttings” [17]. “The degree of juvenility of propagules can also contribute to rhizogenesis, as a result of the morphological and physiological changes that occur during plant development” [18].

Searching for other means to propagate potatoes is very crucial nowadays because of the very high prices of seed tubers. The present research work has been conducted to assess the effect of the physiological age of the mother plant on the rooting capability of apical mini cuttings of potato clones under Greenhouse conditions and to evaluate the effect of various concentrations of IBA on their rooting performance.

2. MATERIALS AND METHODS

2.1 Experimental Site/Location

This study was conducted in the Green House at Hazara Agriculture Research Station, Abbottabad.

2.2 Experimental Layout

In the experiment, the propagated material consisted of potato plants’ apical mini-cuttings (2-2.5cm). The mini-cuttings of potato variety Roko were taken from mother explants obtained from *in vitro* micro-propagated plantlets and were transplanted in the greenhouse.

The cuttings were planted in sterilized peat moss soil under greenhouse conditions (Fig. 1). For rooting, IBA was used at different concentrations (100 ppm, 200 ppm, and 300 ppm). The experiment was conducted in a 3 × 2 factorial arrangement with factor one was IBA concentrations; and factor two was the physiological age of the explant counted from the

time of transplantation in the greenhouse (30 and 60 days old) having three replications with fifteen mini-cuttings in each replication.

Data on the number of days for root initiation, root number, root length, shoot length, the number of leaves, and the average number of tubers/plant and tuber yield were recorded. The data were subjected to analysis of variance for the F test and the means were compared by the Least significant difference test (LSD) at a 5% probability of error with the aid of computer software Statistix 8 Version 8.1 [19].

3. RESULTS AND DISCUSSION

3.1 Root Initiation

For recording data on root initiation, the apical stem cuttings were uprooted and observed. No roots were recorded in cuttings of both 30 days and 60 days old explant after 10 days of plantation (Table 1). The uprooted cuttings were replanted for the next time observation. All the cuttings were watered regularly to keep the soil moist for rapid root initiation.



Fig. 1. Apical mini cuttings of potato variety Roko planted in peat moss soil in the greenhouse after treatment with different IBA concentrations

Table 1. Percent means root initiation in potato apical cuttings from 30 and 60 Days old mother plants treated with different IBA concentrations

IBA conc.	% Root Initiation					
	After 10 days		After 15 days		After 20 days	
	30 Days old	60 Days old	30 Days old	60Days old	30Days old	60 Days old
100ppm	0	0	53.33bc	33.33c	83.33a	66.67b
200ppm	0	0	86.67a	60b	100a	93.33a
300ppm	0	0	100 a	86.67a	100a	100a

Means followed by different letters are significantly different at $P \leq 0.05$

After 15 days of the plantation, cuttings from 30 days old mother plants showed 100% root initiation at 300ppm IBA concentration (Fig. 2) followed by 86.67% at 200ppm while significantly lower rooting % was recorded in the IBA treatment of 100 ppm (Table 1). Similarly, in the 60 days old explant cuttings the highest mean rooting % after 15 days of the plantation was recorded at 300 ppm IBA i.e 86.67 %. While the lowest 33.33% was found at the lowest IBA concentration (Table 1). The results here are consistent with those of Hossain et al. [20] who observed that root induction in the potato stem cuttings was quicker at a higher IBA concentration than at lower IBA concentrations ($\ll 50 \text{ g L}^{-1}$).



Fig. 2. Root initiation in the apical cuttings

Nizam Uddin *et al.*, [21] also reported similar findings that the maximum (81.66 %; 81.67 %) number of cuttings of MF-I and LT-8 potato lines, respectively induced roots at higher IBA concentrations which were significantly higher than the percentage of roots produced by cuttings treated with 100 ppm IBA.

After 20 days of transplantation, an increase in rooting percentage has been observed in both age groups at all three IBA concentrations (Table 1). However, the rooting % was comparatively higher in cuttings taken from plants at younger growth stages i.e 30 days old. Regarding IBA concentrations at 300ppm 100% rooting was recorded in both 30 days old and 60 days old plant cuttings while at 100ppm 83.33% and 66.67% rooting were found in 30 days old and 60

days old plant cuttings respectively (Table 1). Rasmussen *et al.* [22] stated that apical cuttings of potato plants derived from 2 and 3 week old mother plants had faster root and shoot growth and a higher survival rate. The age of the mother plants determines the maturity of the stem from which the cuttings are taken: maturity increases as the physiological age of the mother plant increases. Juvenile cuttings have been shown to root better than mature cuttings possibly due increase of lignification in older cutting and the production of a rooting inhibitor as the stem age increases [23].

3.2 Root Number

Eight cuttings were randomly selected in each replication of every treatment combination. Regarding root number, after 15 days it was observed that cuttings of younger age mother plants i.e 30 days old had more root numbers as compared to 60 days old mother plant at all three IBA concentrations (Table 2). Further, the different concentrations of IBA also have a significant effect on root number and at 300 ppm concentration, more roots were recorded i.e. 7.53 and 5.50 mean number of roots in 30 days and 60 days old mother plant cuttings, respectively, while at the lowest concentration i.e 100 ppm only 2.50; 2.33 mean root number was recorded in both 30 days and 60 days old age group cuttings (Table 2). A similar trend in the increase in mean root number was observed after 30 days of plantation in cuttings of both age groups at all three IBA concentrations (Table 2). According to Davis and Hassig [24], the production of adventitious roots in plants through cell division, multiplication, and differentiation is also controlled by plant growth substances, especially auxins. This implies that treating stem cuttings with IBA can not only increase the rooting percentage but also root initiation and the number of roots. Various research experiments have confirmed that the application of optimal hormone concentration is very important for the successful rooting of cuttings [25,26]. IBA treatment of stem cuttings may cause cambial activity that resulted in root induction and ultimately an increase in the number of roots per cutting. Nymora and Mnzwa [27] illustrated that IBA increased the elasticity of cambium and thus accelerated cell division and produced more roots in treated cuttings. However, regarding the physiological age of mother plants comparatively, no significant difference in mean root number was seen after 30 days of transplantation (Table 2).

Table 2. Mean number of roots and root length in potato apical cuttings of 30 and 60 Days old mother plants treated with different IBA concentrations after 15 and 30 days of the plantation

IBA conc.	Root number				Root length (cm)			
	After 15 days		After 30 days		After 15 days		After 30 Days	
	30 Days old	60Days old	30 Days old	60 Days old	30 Days old	60 Days old	30Days old	60Days old
100 ppm	2.50d	2.33d	8.46b	8.46b	0.93b	0.21c	4.05a	2.86b
200 ppm	5.05b	3.58c	10.73b	8.80b	0.96b	0.73bc	4.03a	3.76ab
300 ppm	7.53a	5.50b	15.8a	15a	1.93a	1.66a	4,26a	3.60ab

Means followed by different letters are significantly different at P≤0.05

Table 3. Mean numbers of new fresh leaves and shoot length in potato apical cuttings of 30 and 60 Days old mother plants treated with different IBA concentrations

IBA conc.	Shoot length (cm)				Leaf numbers			
	After 30 days		After 50 days		After 30 days		After 50 Days	
	30 Days old	60 Days old	30 Days old	60 Days old	30 Days old	60 Days old	30 Days old	60 Days old
100 ppm	1.17c	1.2c	8.63c	8.1c	2.1b	1.3a	10.6bc	9.3c
200 ppm	1.96ab	0.85c	9.16bc	8.2c	2.6ab	2.4ab	11.5b	9.8bc
300 ppm	2.45a	1.38bc	11.5a	10.6ab	2.9ab	2.4ab	14.3a	11.3b

Means followed by different letters are significantly different at P≤0.05

3.3 Root Length

Data showed that root length recorded in 30 days old explant cuttings after 15 days of plantation is significantly higher than 60 days old explant cuttings (Table 2). After 15 days of plantation regarding IBA concentrations, it is stated that higher IBA concentrations caused an increase in root length in both age groups with the highest 1.93cm and 1.66cm length recorded at 300ppm in 30days old and 60 days old explant cuttings, respectively (Table 2). In apple [28] and Apricot [29] it was reported that root length greatly increased with increasing IBA concentration. The increase in root length may be due to the effect of IBA on metabolic translocation and increased plasticity of the cell wall of cambium cells as reported by Nymora and Mnzwa [27]; Ishtiaq et al., [29]. The results are also supported by the findings of El-Gamal [30] who dipped stem cuttings of potato in potassium of indole butyric acid solution at 6000 ppm for one minute and demonstrated that this treatment succeeded to stimulate adventitious roots and affected the production and growth parameters of potato e.g., fresh and dry weights of roots. After 30 days of transplantation, a considerable increase in average root length has been found in all the IBA treatments for both age group cuttings (Table 2).

3.4 Shoot Length

Vegetative data presented in Table 3 revealed that plantlets developed from cuttings taken from 30 days old explants have greater shoot length as compared to plantlets developed from 60 days old explant cuttings. After 30 days of plantation of cuttings, an increase in shoot length was observed in both age groups and the growth rate was comparatively higher in the cuttings taken from younger age explants i.e 30 days old. This may be due to the fact that the mother plant age determines the maturity of the stem from which the cuttings are taken. The observations reported by Nikmatullah et al. [16] also support our results who found that apical cuttings of potato plants derived from 2 and 3 week old mother plants had faster root and shoot growth and a higher survival rate. The maximum mean shoot length (2.45cm; 1.38cm) was obtained at the highest IBA concentration i.e. at 300ppm in both the age group cuttings i.e. 30 days old and 60 days old, respectively (Table 3). A similar trend in the increase in the growth rate of the cuttings was recorded after 50 days of plantation (Table 3). The results are in agreement with the findings of Dahshan et al. [13] who showed that treated potato cv Lady Rosetta with 6000 ppm IBA

significantly increased the stem cuttings length compared with other treatments. Tsoka et al. [31] also reported higher mean plant height and root length in potato plants derived from apical stem cuttings under the aeroponic system.

3.5 Leaf Number

Data representing mean leaf number showed that at 100ppm IBA concentration the average mean leaf number was lower in both age group cuttings and a considerable increase in mean leaf number has been recorded with the increase in IBA concentration after 30 days and 50 days of plantation (Table 3). Regarding the age of the mother plant, it was found that the mean leaf number was higher in cuttings taken from 30 days old explant as compared to 60 days old explant cuttings (Table 3). The results are consistent with the findings of Bhatia et al., [32] who recorded the superiority of the application of IBA over other plant growth regulators for plant height, the number of branches and the number of leaves in potatoes and gave the highest dry weight of foliage. Similarly Zaman et al., [33] concluded from an *in vitro* study that higher the concentration of auxin (IBA) level will results in production of highest number of leaves per plant.

3.6 Tuber Number and Average Yield

Regarding yield data minitubers were first categorized into three categories based on weight i.e large > 20g; medium 10-20g; small < 10g (Fig. 3). Statistical analysis of the recorded data revealed that the average mean tuber number was higher in cuttings of 30 days old mother plant as compared to 60 days old (Table 4) (Fig. 4) at all the three concentrations of IBA, however, among the three IBA concentrations the average tuber number was higher at 300ppm IBA concentration i.e 6.66 and 4.33 followed by 5.00 and 3.33mean tuber numbers at 200ppm in cuttings of 30 days old and 60 days old age groups, respectively (Table 4). Moreover, it was observed that there was a greater number of small tubers produced at 300ppm concentration (Table 4). The results of our study are supported by the findings of Dahshan et al. [13] who declared that the use of growth regulators especially in high concentration resulted in higher values of the mostly studied potato plant characteristics e.g plant height, plant fresh and dry weights, the number of tubers per plant and total tuber yield per plant as compared to the control.

Table 4. Mean tuber number and average yield per plant in potato apical cuttings taken from 30 and 60 Days old mother plants treated with different IBA concentrations

IBA conc.	Mean Tuber number								Av. Yield per plant (g)	
	30 Days old				60 Days old				30 Days old	60Days old
	large	medium	small	Total	large	medium	small	Total		
100 ppm	1.00a	0.33b	2.66b	4.00bcd	0.33ab	0.33b	2.66b	3.00d	119.67ab	71.54c
200 ppm	0.33ab	1.00ab	3.67ab	5.00b	0.66ab	0.00b	2.66b	3.33cd	101.86bc	78.04c
300 ppm	0.00b	1.66a	5.00a	6.66a	0.00b	0.66ab	3.66ab	4.33bc	142.97a	87.17bc

Means followed by different letters are significantly different at P<0.05



Fig. 3. The three tuber categories based on weight i.e large > 20g; medium 10-20g; small < 10g (left to right)



Fig. 4. Tubers harvested in 60 days old mother plant cuttings (a); tubers from 30 days old age group (b)

The average tuber yield per plant was higher (142.97g) in 30 days old age group at 300ppm IBA concentration. The lowest average tuber yield i.e 71.54g was recorded at 100ppm IBA concentration in 60 days old mother plant age group. Sillu et al. [34] sprayed IBA at concentrations of 100 and 200ppm on potato foliage and found the maximum number of tubers (6.87) per plant, average weight of tuber (69.14 g) and yield of tuber (258.02 g) at higher IBA concentration (200 ppm).

4. CONCLUSION AND RECOMMENDATION

Results of the present study declared that mini-cuttings from young *in vitro* grown potato plants have higher rooting capacity compared to mini-cuttings from mature plants. Moreover, IBA concentrations especially at higher level i.e 300 ppm has a significant effect on most studied characteristics e.g., root number, shoot length and tubers yield.

The findings of this study may encourage potato growers to use potato stem tip cuttings as a new and cheaper method to grow potato instead of expensive imported seed tubers. It is suggested that the use of apical stem cuttings can be a fast and efficient method for mass propagation and to increase the yield of minitubers in the seed potato production cycle.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Mahmood A. A study of planting method and spacing on yield potato using Tps, Asian Journal of Plant Sciences. 2005;4(2) :102-105, 2005.
2. Zamil MF, Rahman MM, Robbani, MG, Khatun T. Combined effect of nitrogen and plant spacing on the growth and yield of potato with economic performance. Bangladesh Res. Publ. J. 2010;3:1062-1070.
3. McGill CR, Kurilich AC, Davignon J. The role of potatoes and potato components in cardiometabolic health: A review. Annals of Medicine. 2013;45: 467–473.
4. Khalid W, Khalid MZ, Aziz A, Tariq A, Ikram A, Rehan M, Younas S, Bashir A, Fatima A. Nutritional Composition and Health Benefits of Potato: A Review. Adv Food & Nutr Sci. 2020;5:7-16. DOI:<http://dx.doi.org/10.21065/25631640.5.7>
5. Pakistan Economic Survey 2020-21. Ministry of Finance, Government of Pakistan. Available:https://www.finance.gov.pk/survey_2021.html
6. Qasim M, Khalid S, Naz A, Khan MZ, Khan SA. Effects of different planting systems on yield of potato crop in Kaghan Valley: A mountainous region of Pakistan. Agricultural Sciences. 2013; 4(4): 175-179. DOI:<https://doi.org/10.4236/as.2013.44025>
7. Khan NP, Akhtar J. Competitiveness and policy analysis of potato production in different agro-ecological zones of Northern Areas: Implications for food security and

- poverty alleviation. Pak. Develop. Rev. 2006;1137-1154.
8. Chindi A, Giorgis GW, Soloman A, Tessama L, Negash K. Rapid multiplication techniques (RMTs): A tool for the production of quality seed potato (*Solanum tuberosum* L.) in Ethiopia. Asian J. Crop Sci.2014;6 (3): 176-185.
 9. Gildemacher PR, Demo P, Barker I, Kaguongo W, Woldegiorgis G, Wagoire WW, Wakahiu M, Leeuwis C, Struik PC. A description of seed potato systems in Kenya, Uganda and Ethiopia. American Journal of Potato Research. 2009; 86: 373-82.
DOI: <https://doi.org/10.1007/s12230-009-9092-0>
 10. Bisognin DA, Bandinelli MG, Kielse P, Fischer H. Rooting Potential of Mini-Cuttings for the Production of Potato Plantlets. American Journal of Plant Sciences. 2015; 06(02):366-371. DOI: <https://doi.org/10.4236/ajps.2015.62042>.
 11. Harahagazwe D, Andrade-piedra J, Schulte-geldermann E. Current Situation of Rapid Multiplication Techniques for Early Generation Seed Potato Production in Sub-Saharan Africa. CGIAR Research Program on Roots, Tubers and Bananas (RTB). (RTB Working Paper. No. 2018-1.). 2018.
DOI:<https://doi.org/10.4160/23096586RTBWP20181>
 12. Yasmin MFM, Zakaria. Effect of Planting Time and Density of Top Shoot Cuttings in Potato Production. International Journal of Natural and Social Sciences. 2019; 6(1): 60–68.
DOI:<https://doi.org/doi.org/10.1016/j.anres.2014.08.001>
 13. Dahshan AMA, Zaki HEM, Moustafa, YMM, Abdel-Mageed YT, Hassan MAM. Using stem tip cuttings in potato production. Minia J. of Agric. Res. & Develop.2018; 38 (2): 363-389.
Available:<https://www.researchgate.net/publication/329371871>
 14. Kolachevskaya OO, Sergeeva LI, Getman IA, Lomin SN, Savelieva EM, Romanov G A. Core features of the hormonal status in *in vitro* grown potato plants. Plant Signal Behav. 2018;13(5): e1467697pp1-4.
DOI: <https://doi.org/10.1080/15592324.2018.1467697>
 15. Ishartati E, Rehan PR. 2019. Application of leaf fertilizer and plant hormones to accelerate shoot cuttings growth on the potato varieties of Granola Lembang (*Solanum tuberosum* L.). Journal of Tropical Crop Science and Technology 1(2): 52-63.
Available:<https://doi.org/10.22219/jtcst.v1i2.10277>
 16. Nikmatullah A, Ramadhan I, Sarjan M. Growth and yield of apical stem cuttings of white potato (*Solanum tuberosum* L.) derived from disease-free G0 plants. Journal of Applied Horticulture. 2018; 20(2): 139-145.
 17. Silva EC, Pinto CA, Souza-Dias JAC, Araújo TH. Uso de Reguladores de Crescimento em Brotos Destacados de Batata-Semente. Horticultura Brasileira. 2011; 29: 504-509.
DOI: <http://dx.doi.org/10.1590/S0102-05362011000400010>
 18. Hackett WP. Donor Plant Maturation and Adventitious Root Formation. In: Davies, T.D., Haissig, B.E. and Sankhla, N., Eds., Adventitious Root Formation in Cuttings, Dioscorides Press, Portland. 1987.
 19. Analytical software. Statistix 8.1. User's Manual. Analytical Software, Tallahassee, Florida; 2005.
 20. Hossain MJ, Khan MA, Hoque MA. Effect of IBA and NAA on rooting of potato stem cuttings. J. Indian Potato Assoc. 1998; 25(1 &2): 53-56.
 21. Nizam Uddin, Mirza B, Qamar M, Khabir A. Root formation in true potato seed parental lines by IBA application. Pak. J. Agri. Sci. 2005; 42(3-4): 29-35.
 22. Rasmussen A, Hosseini SA, Hajirezaei MR, Druége U, Geelen D. Adventitious rooting declines with the vegetative to reproductive switch and involves a changed auxin homeostasis. J. Exp. Bot 2015; 66. (5):1437-1452.
DOI: <http://dx.doi.org/10.1093/jxb/eru499>
 23. Milborrow BV. Inhibitors. In: Advanced Plant Physiology. M.B. Wilkins (ed.). Pitman Publishing, London.1994.
 24. Davis DT, Hassig BE. Chemical control of adventitious root formation in cuttings. Bull. Plant Growth Regul. Soc. Am. 1990; 18:1-17.
 25. Leakey RRB, Chapman VR, Longman KA. Physiological studies for tree improvement and conservation. Some factors affecting root initiation of *Triplochiton scleroxylon* K. Schum. For Ecol. Manage. 1982; 4: 53- 66.
 26. Ezzat A S. Effect of Some Treatments on Improving Seed Multiplication Ratio in Potato by Stem Cutting. J. Plant Production. 2016; 7(7): 683–693.

- DOI: <https://doi.org/10.21608/JPP.2016.46138>
27. Nymora MS, Mnzwa. Rooting response to Juvenile and adult cuttings of apple (*Malus sylvestris* L.) and peach (*Prunus persica* L.) to IBA in Tanzania, Beitrage Zuetropischen Landwirtschaft and veterinarmeddizin. 1983;20(2):135-140 (Hort. Absts. 53(8):552).
 28. Badshah N, Rahman N, Zubair M. Effect of indolebutyric acid (IBA) on the cuttings of M-26 and M-27 apple rootstocks. Sarhad J. Agri. 1995;11(4): 449-453.
 29. Ishtiaq HM, Wazir, KD, Haq AI. Initiation of roots in Trevatt and Nencape apricot cuttings as affected by indolebutyric acid (IBA). Sarhad J. Agric. 1988; 4(6): 793-798.
 30. El-Gamal AS. Physiological studied on potatoes. Ph.D. Thesis. Fac. Agric., Mansoura Univ., Egypt. 1992.
 31. Tsoka O, Demo P, Nyende AB, Ngamau K. Potato seed tuber production from *In vitro* and apical stem cutting under aeroponic system. African Journal of Biotechnology. 2012;11(63):12612-12618.
DOI: <http://dx.doi.org/10.5897/AJB10.1048>.
 32. Bhatia AK, Pandita ML, Khurana SC. Plant growth substances and sprouting conditions. II Effect of tuber yield and multiplication rate in seed potato production. J. Indian Potato Assoc.1992;19 (3-4):154-156.
 33. Zaman MS, Quraishi A, Hassan G, Raziuddin, Ali S , Khabir A, Gul N. Meristem Culture of Potato (*Solanum tuberosum* L.) for production of Virus-Free plantlets. Journal of Biological Sciences. 2001; 1: 898-899.
 34. Sillu M, Patel NM, Bhadoria HS, Wankhade, VR. Effect of plant growth regulators and methods of application on growth and yield of potato (*Solanum tuberosum* L.) cv. Kufri Badshah. Advance research journal of crop improvement. 2012;3(2):144-147.

© 2022 Gul; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/93579>