Original Research Article

Effect of Indole-3-Butyric Acid (IBA) on Hardwood Cutting of Grapes (*Vitis vinifera* L.) cv. Pusa Navrang

Abstract

ABSTRACT:

Aims: Investigate the influence of different IBA concentration on the rooting and subsequent growth of hardwood cuttings of "Pusa Navrang" grapevine**.**

Study design: Completely randomized block design

Place and Duration of Study: Research Farm, College of Horticulture, Mandsaur, during the period November 2020- March 21.

Methodology:Filling of poly bags: Before the cutting planting the 5 X 7 inch poly bags will be filled with growing media. Five hundred sixty (500) poly bags were filled for each treatment, total 2000 poly bags were filled.

Preparation of cutting: After the filling of growing media in poly bags, the hard wood cuttings of uniform size having 4-5 functional bud will be taken from healthy plants of Grapes variety Pusa Navrang from one year matured shoots planted at the grapes orchard at research farm, College of Horticulture, Mandsaur.

Planting: The cutting about 0.75 to 1 cm thick diameter will be taken and planted in poly begs with 2-3 functional buds below the ground. Before the planting the hole should be done from planting place with the help of stick for preventing the buds to injuries.

Results: The best result was found for shoot parameter like shoot length (7.60 cm, 53.86 cm), number of nodes per shoot (7.08, 16.39), internodal length (2.68 cm, 6.11 cm), number of buds per shoot (11.35, 26.58), stem diameter (16.38 mm, 25.71 mm) at 60 and 90 DAP respectively, stem fresh weight (16.09 g), stem dry weight (6.74 g) at 90 DAP. Root Parameters like number of primary (22.54, 28.68) and secondary roots (16.66, 28.02), root length (20.56 cm, 21.86 cm), root thickness (1.85 mm and 1.98 mm), whole root volume (18.56 cm^2 and 24.69 cm^2) at 60 and 90 DAP, fresh weight of root (5.70 g), dry weight of root (2.41 g) at 90 DAP. Leaf Parameters like number of leaves per plant (10.00, 25.75) at 60 and 90 DAP, fresh weight of leaf (1.59 g), dry weight of leaf (0.68 g), leaf area (65.39 cm^2), leaf area index (3.99), specific leaf weight (23.53 $mgDw.cm^{-2}$) at 90 DAP, while minimum days taken to emergence of 1st leaf (22.20 DAP) and water content of leaf (57.21 %) found with IBA @ 6000 ppm (G3).

Conclusion: Among five growing media the application of IBA @ 6000 ppm (G3) responded well in term of rooting and shooting in hard wood cutting of grapes. In order to confirm the validity of results the experiment must be repeated over years, location and different season with more accuracy.

Keywords: Auxin, hardwood cutting, IBA and grapes

Introduction:

Grapes (*Vitis vinifera*) stand as a paramount fruit crop on the global stage due to their immense economic significance. They are cherished for their fruits and their various derivatives, which encompass wine, juice, and raisins (Piesse *et al*., 2017; Foster, 2018). The primary method for proliferating grapevines revolves around the utilization of cuttings, with a particular emphasis on hardwood cuttings. The successful establishment of new grapevine plants, crucial for expanding or replacing vineyards, hinges significantly on the successful rooting of these cuttings (Waite *et al*., 2014).

In the present day, India boasts a grape cultivation area spanning 1.62 lakh hectares, yielding a production of 34.45 lakh metric tons with a productivity rate of 21.00 metric tons per hectare. The primary grape-growing states in India, namely Maharashtra (70.67%), Karnataka (24.49%), Tamil Nadu (1.43%), Andhra Pradesh (1.34%), Madhya Pradesh (1.02%), and Mizoram (0.50%), collectively contribute to nearly 99% of the total grape production (NHB, 2022).

Seed propagation is a time-consuming method that leads to genetically diverse and slower-growing plants. In contrast, vegetative propagation through cuttings is a more efficient and quicker process, resulting in genetically identical plants that bear fruit earlier but with reduced vigor (Damar *et al*., 2014; Ausari *et al*., 2023).

Indole-3-butyric acid (IBA), a naturally occurring plant hormone with auxin-like properties, is renowned for its ability to stimulate root development in plant cuttings. It has been extensively studied in horticultural practices to enhance rooting and overall plant establishment. However, there is limited research on the application of IBA to hardwood grapevine cuttings, necessitating a comprehensive investigation to assess its potential impact on successful rooting and subsequent growth (Shriram *et al*., 2021; Rolaniya*et al*., 2018; Ghosh *et al*., 2017 and Singh and Tomar, 2015).

This study aims to assess the influence of IBA, a synthetic auxin, on the rooting capacity and growth enhancement of hardwood grapevine cuttings. Understanding the effects of IBA on grapevine cuttings is crucial not only for establishing new grapevines successfully but also for improving the efficiency and productivity of grape cultivation, thereby contributing to sustainable viticultural practices (Hartmann, 1997).

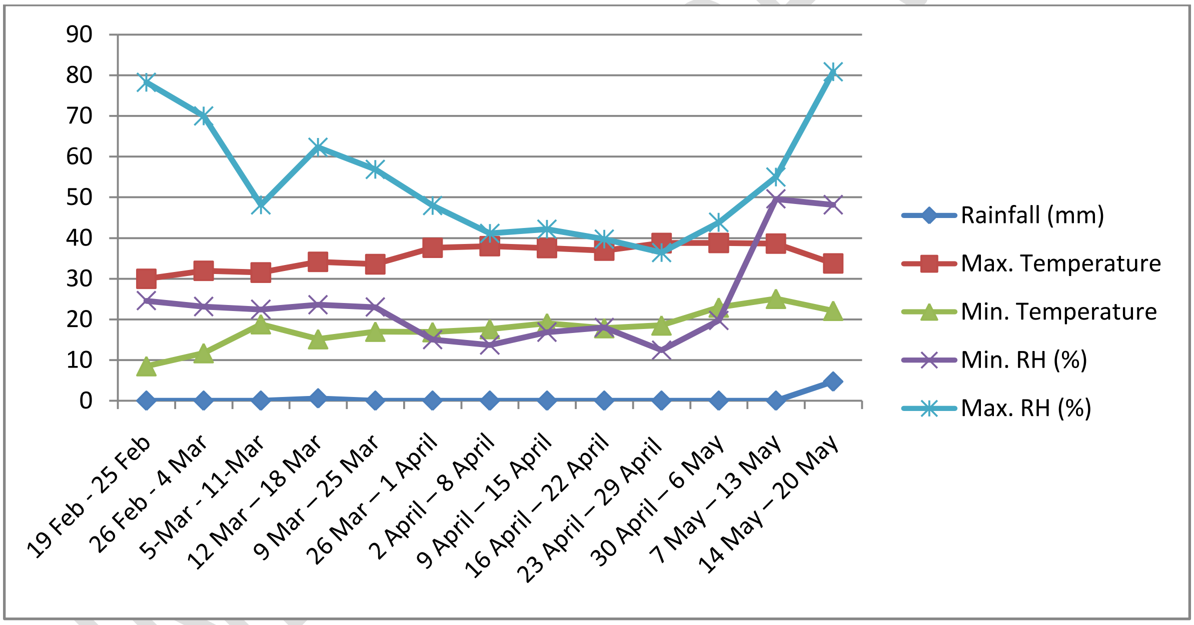
In this research, we will investigate the impact of varying concentrations of IBA on hardwood grapevine cuttings and analyze their resulting rooting performance and subsequent vegetative growth. The knowledge gained from this study will deepen our comprehension of IBA's role in grapevine propagation and provide practical recommendations for optimizing the rooting process, promoting robust growth, and ultimately enhancing grapevine cultivation methods.

Materials and Methods:

Experimental Location: The experiment took place at the Research Farm of the College of Horticulture, RVSKVV, Mandsaur (Madhya Pradesh) in the 2020-21 year. Mandsaur is situated within the Malwa plateau agro-climatic zone in the western part of Madhya Pradesh, with coordinates ranging from approximately 23.450 to 24.130 North latitude and 74.440 to 75.180 East longitude. The elevation of this region is approximately 435.02 meters above mean sea level, and it falls under Agro Climate No. 10 of the state.

Climate of the Region: Mandsaur experiences a subtropical climate characterized by hot summers and cool winters. Summer temperatures can reach as high as 46°C, while winter temperatures can drop to 3.6°C, occasionally leading to frost. The region receives an average annual rainfall of 797.6 mm, with the majority occurring from July to September, while winter and summer rains are infrequent. Meteorological data for the investigation period (2020-2021) were recorded at the Meteorological Observatory at the Bahadari Farm of the College of Horticulture in Mandsaur. Detailed meteorological information is provided in Figure - 1.

Fig.1: Weekly metrological observations during the study period



Plant Materials: The grapevine cuttings (*Vitis vinifera* L. cv. PusaNavrang) used in this study were sourced from the grape orchard at the College of Horticulture, Mandsaur, Madhya Pradesh. These plants were five years old, and the selection of branches for experimentation was based on their uniform appearance, growth habit, and vigor. Cuttings were obtained from one-year-old branches and categorized as terminal, medium, or basal.

Preparation of Hormonal Solution: In this experiment, four concentrations of Indole Butyric Acid (IBA) were utilized: 0 (zero), 2000, 4000, and 6000 ppm. To create the solutions, pure IBA crystals were dissolved in 0, 20, 40, or 60 ml of 1N NaOH, respectively, and then diluted with distilled water to a final volume of 1000 ml for each solution. Cuttings were treated by dipping them in the respective IBA solutions for 5 seconds before being planted in the rooting medium. The medium was kept moist through regular watering to maintain a humid environment around the cuttings. Liquid Dursban was applied with the initial irrigation to prevent termite infestations.

Experimental Design: The experimental design chosen for this study was a Randomized Block Design (RBD). The treatments were replicated three times, with each treatment consisting of 30 cuttings. Mean separation was performed using Duncan's multiple range test at a 5% significance level.

Treatment Details: There were four treatments in the trial: G0 (Control), G1 (IBA at 2000 ppm), G2 (IBA at 4000 ppm), and G3 (IBA at 6000 ppm).

Statistical Analysis: To assess the impact of different treatments on shoot and root characteristics, data for various parameters were recorded and statistically analyzed using the analysis of variance method as described by R. A. Fisher (1954).

Results and Discussion

1.Shoot Parameters

Under shoot parameters different observations i.e., shoot length, Number of nodes, internodal length, Number of buds per shoot, Stem diameter were recorded at 30, 60 & 90 DAP. While the fresh weight and dry weight of stem at 90 DAP, are presented below. At 30 DAP, effect of IBA found non-significant and at 60 and 90 DAP found significant effect on shoot parameters.

a. Shoot length (cm)

Shoot length was recorded at 30, 60, 90 DAP and presented in Table1. Maximum shoot length with treatment G3 (IBA @ 6000 ppm) i.e., 7.60 cm, 53.86 cm and the minimum shoot length was recorded in case of G0 (control) i.e., 2.80 cm, 11.90 cm at 60 & 90 DAP respectively and shoot length found non-significantat 30 DAP.This might be due to the application of IBA @ 6000 ppm, which raised the amount of growth promoting chemicals and accessible nutrients. Shoots length might be due to better utilization of stored carbohydrates, nitrogen and other factors with the aid of growth regulators Kaur *et al*., (2018). Similar result was reported Kaur (2016) in pomegranate cv. Ganesh, Padekar *et al*., (2018) in kartoli.

b. Number of nodes per shoot

After 60 and 90 DAP, the maximum number of nodes per shoot was found in IBA treatment IBA @ 6000 ppm (G3) i.e., 7.08, 16.39, while the lowest number of nodes per shoot was reported in treatment control (G0) i.e., 3.60, 6.04 respectively.This might be because external application of auxin promotes growth and produce favorable conditions for sprouting of dormant buds on the cutting. These results supported by Isci *et al*., (2019) in Ramsey American grapevine rootstock.

c. Internodal length (cm)

Data from Table 1 revealed that highest internodal length was observed in IBA @ 6000 ppm (G3) i.e., 2.68 cm, 6.10 cm, shortest internodal length was detected in control treatment (G0) i.e.,1.17 cm, 1.91 cm respectively.It could be due to the availability of a large amount of stored carbohydrate, which aided the rapid growth. Similar results found by Somkumar*et al*., (2009) in grapes, Chakraborty and Rajkumar (2018) in grapes

d. Number of buds per shoot

Data show in Table 1 show that the treatment IBA @ 6000 ppm (G3) i.e., 11.35, 26.58 had the most buds per shoot. Treatment control (G0) i.e., 4.59, 8.71 had the lowest number of buds per shoot at 60 and 90 days after planting, respectively.Treatments with auxin promote the hydrolysis of nutritional reserves and the mobilization of sprouting. Chakraborty and Rajkumar (2018) in grapes. The findings of this study matched those of previous studiesSingh *et al*., (2015) in lemon, Rolaniya*et al*., (2018), Siddiqua *et al*., (2018), Kumar *et al*., (2020) in pomegranate, Tanwar *et al*., (2020) in pomegranate.

e. Stem Diameter (mm)

In respect of different IBA concentration maximum stem diameter was reported with treatment IBA @ 6000 ppm (G3) i.e., 16.38 mm and 25.71 mm after 60 and 90 days after planting and the treatment control (G0) reported the minimum stem diameter per shoot i.e., 8.38 mm and 17.33 mm at 60 and 90 days after planting, respectively.It might be due to the use of growth regulators to improve the use of stored carbohydrates, nitrogen and other variables, Kaur Sukhjit (2017) in Flordaguard peach and Siddiqua *et al*., (2018) in dragon fruit, also recorded these results.

f. Stem fresh and dry weight (g)

Among the different concentration of IBA, maximum stem fresh weight and dry weight recorded with IBA @ 6000 ppm (G3) i.e., 16.09 g, 6.74 g respectively,and the minimum stem fresh weight and dry weight was found in treatment control (G0) i.e., 5.67 g and 1.81 g respectively.This could explained by the fact that auxins increased cell permeability to moisture and nutrients, resulting in cell enlargement and increased plant growth. IBA increases the number of shoots resulting in higher fresh and dry weight of shoots, Kaur *et al*. (2018) in fig. Similar results are confirmed by Kishorbhai (2014) also reported the same in fig,Singh (2017) in pomegranate,Dahale *et al.*, (2018) in Fig and Tanwar *et al*., 2020 in pomegranate.

2. Root parameters

In respect of root parameters, different observations i.e., Number of primary and secondary roots, whole root volume, root length of longest root, root thickness taken and recorded at 30, 60 & 90 DAP. While the fresh weight and dry weight of root reported at 90 DAP, are presented below. At 30 DAP, effect of IBA found non-significant and at 60 and 90 DAP found significant effect on shoot parameters.

a. Number of roots

Those stem cuttings dipping in the IBA 6000 ppm (G3) were recorded significantly maximum number of primary (22.54, 16.66) and secondary(28.68, 28.02)roots per cutting were reported in treatment G0 at 60 and 90 DAP respectively and minimum number of primary(12.03, 5.67) and secondary (15.83, 15.89) roots per cutting were reported in treatment G0 at 60 and 90 DAP respectively.IBA application resulted in a robust, fibrous root system, whereas phenoxy acetic acid application resulted in a bushy, stunted root system with bent and thick roots. Bauri *et al*., (2017) in Burmese grape, Kaur (2017) in peach, Ali *et al*., (2018) in kiwi, Kaur *et al*., (2018) in fig, Rolaniya*et al*., (2018) in grape, Siddiqua *et al*., (2018) in dragon fruit, Singh *et al*., (2019) in peach, Kumar *et al*., (2020) in pomegranate carried studies and find similar results.

b. Whole root volume

Among IBA concentration, whole root volume per cutting found maximum in treatment IBA @ 6000 ppm (G3) i.e., 18.56 cm^2 and 24.69 $cm^2$and lowest whole root volume per cutting observed in treatment control (G0) i.e., 8.63 cm^2 and 10.17 cm^2 at 60 and 90 days after planting, respectively.It may be due to higher root length which is accumulated more stored carbohydrates and more number of roots increased their volume (Hartman *et al*., 1997). Similar results also reported by Singh and Tomar (2015), Singh (2015) in Phalsa, Rolaniya*et al*., (2018) in grapes, Siddiqua *et al*., (2018) in dragon fruit, Rajamanickam and Balamohan (2019) in pomegranate.

d. Root length of longest root

In respect of different IBA concentration, maximum root length of longest root in case of treatment IBA @ 6000 ppm (G3) i.e., 20.56 cm and 21.86 cm. While, minimum root length of longest root observed in treatment IBA @ 0 ppm (G0) i.e., 7.79 cm and 8.56 cm had recorded at 60 and 90 days after planting, respectively. This may be due to increased synthesis and accumulation of growth promoting substance as well as availability of more nutrients under this treatment, which enhance the rooting in cuttings. Similar findings were also reported by Kareem *et al*., (2016) in guava, Bauri *et al*., (2017) in Burmese grape, Ali *et al*., (2018) in kiwi, Kaur *et al*., (2018) in fig, Rolaniya*et al*., (2018) in grape, Siddiqua *et al*., (2018) in dragon fruit, Rajamanickam and Balamohan (2019) in pomegranate, Singh *et al*., (2019) in peach, Kumar *et al*., (2020) in pomegranate.

e. Root thickness

As per the research data analysis, in respect of IBA concentration, highest root thickness was observed in treatment IBA @ 6000 ppm (G3) i.e., 1.85 mm and 1.98 mm. Constantly, the minimum root thickness was observed in control treatment (G0) i.e., 1.61 mm and 1.72 mm had recorded at 60 and 90 days after planting, respectively.This might because it attributes to increased synthesis and accumulation of growth-promoting substances, as well as the availability of additional nutrients, both of which improve root parameters. These conclusions are in agreement with the findings of Rolaniya*et al*., (2018) in grape, Siddiqua *et al*., (2018) in dragon fruit, Singh *et al*., (2019) in peach, Kumar *et al*., (2020) in pomegranate.

f. Root fresh and dry weight (g)

Different concentration of IBA recorded significant effect on root fresh weight at all growth stages and the maximum root fresh and dry weight recorded in treatment IBA @ 6000 ppm (G3) i.e., 5.70 g and 2.41 g respectively. While, the lowest root fresh weight observed in treatment control (G_0) i.e., 2.51 g and 0.81 g respectively at 90 days after planting.This might be due to the treatment's strong root system, which returns enhanced nutrient absorption and increases fresh and dry weight of roots. Others have reported similar findings, Narula (2016) in plum cv. Kala amritsari, Kaur *et al*., (2018) in fig, Chakraborty and Rajkumar (2018) in grapes, Rolaniya*et al*., (2018) in grapes, Siddiqua *et al*., (2018) in dragon fruit, Isci *et al*., (2019) in Ramsey American grape rootstock, Rajamanickam and Balamohan (2019) in pomegranateSingh *et al*., (2019) in peach and Kumar *et al*., (2020) in pomegranate.

3. Leaf Parameters

a. Days taken to emergence of 1st leaf

In case of different concentration of growth regulators, IBA @ 6000 ppm (G3) i.e., 22.20 DAP recorded minimum number of days to emergence of 1^{st}leaf after planting and the maximum number of days to emergence of 1^{st}leaf were found in IBA concentration control

(G0) i.e., 27.00 DAP.This might be because the higher levels of auxins resulted in the physiological processes of rooted and sprouting cuttings completed sooner. These findings are in agreement with the findings of Cleland (1973) stated that auxin has varying degree of effectiveness in promoting adventitious roots in stem cuttings of many species. This findings are also similar with findings of Kareem *et al*., (2016) in guava, Kaur (2017) in peach, Kaur *et al*., (2018) in fig, Siddiqua *et al*., (2018) in dragon fruit, Rajamanickam and Balamohan (2019) in pomegranate, Kumar *et al*., (2020) in pomegranate.

b. Number of leaves per cutting

In case different concentration of IBA, maximum number of leaves per cutting found with treatment IBA @ 6000 ppm (G3) i.e., 10.00 and 25. While the minimum number of leaves per cutting was observed in control treatment (G0) i.e., 3.98 and 8.79 had recorded at 60 and 90 days after planting, respectively.This might attributed to a higher amount of growth-promoting chemicals and accessible nutrients because of using IBA @ 6000 ppm. Similar findings were reported by Kaur (2017) in peach, Kaur *et al*., (2018) in fig, Rolaniya*et al*., (2018) in grapes, Rajamanickam and Balamohan (2019) in pomegranate, Shahzad *et al*., (2019) in grapes.

c. Fresh and dry weight per leaf (g)

Stem cuttings those dipping in the IBA 6000 ppm (G3) were recorded significantly maximum 1.59 g and 0.68 g, respectively at 90 DAP and it was minimum in IBA 0 ppm (G0) i.e., 0.95 g and 0.31 g, respectivelyat 90 DAP.This might attribute to a higher amount of growth promoting chemicals and accessible nutrients because of using IBA @ 6000 ppm. These findings are in agreement with the findings of Barde *et al*., (2010) in pomegranate, Kumawat *et al*., (2010) in pomegranate, Kaur (2017) in peach.

d. Water content per leaf (%)

In case of different IBA concentration, maximum water content per leaf was observed with IBA concentration control IBA treatment 0 ppm (G0) i.e., 67.50 % and the minimum water content per leaf was noted with IBA concentration IBA @ 6000 ppm (G3) i.e., 57.21 %.It may due to increased synthesis and accumulation of growth promoting substances as well as availability of more nutrients in this treatment. It may due to increase in dry weight per leaf which decreases water content of leaf. Supported by Barde *et al*., (2010) pomegranate, Kumawat *et al*., (2010) in pomegranate

e. Leaf area (cm^2)

Stem cuttings those dipped in the IBA 6000 ppm recorded maximum leaf area (G3) i.e., 65.39 cm^2. While, the minimum leaf area was noted under control treatment of IBA (G0) i.e., 10.98 cm^2.Same results found by Kaur (2017) in peach, Kaur *et al*., (2018) in fig, Shahzad *et al*., (2019) in grapes.

Table 1: Effect of IBA on Hardwood Cutting of Grapes for shoot parameters

Treatments	Shoot length (cm)		Number of nodes per shoot		Internodal length (cm)		Stem diameter (mm)		Number of buds per shoot		Stem fresh weight (g)	Stem dry weight (g)
	At 60 DAP	At 90 DAP	At 60 DAP	At 90 DAP	At 60 DAP	At 90 DAP	At 60 DAP	At 90 DAP	At 60 DAP	At 90 DAP	At 90 DAP	At 90 DAP
G_0- IBA@0ppm	2.80	11.90	3.60	6.04	1.17	1.91	8.38	17.33	4.59	8.71	5.67	1.81
G_1- IBA@ 2000ppm	3.54	25.28	5.08	9.00	1.61	3.80	9.90	19.99	5.67	16.94	10.38	3.93
G_2- IBA@ 4000ppm	6.95	49.08	6.78	15.67	2.56	5.90	16.00	25.18	10.43	25.37	15.61	6.47
G_3- IBA@ 6000ppm	7.60	53.86	7.08	16.39	2.68	6.11	16.38	25.71	11.35	26.58	16.09	6.74
S.Em±	**0.10**	**0.54**	**0.08**	**0.21**	**0.04**	**0.05**	**0.31**	**0.42**	**0.20**	**0.43**	**0.22**	**0.11**
CD (%)	**0.28**	**1.54**	**0.22**	**0.61**	**0.10**	**0.15**	**0.88**	**1.19**	**0.57**	**1.23**	**0.64**	**0.32**

Table 2: Effect of IBA on Hardwood Cutting of Grapes for root parameters

Treatments	Number of Primary roots		Number of Secondary roots		Root length (cm)		Root thickness (mm)		Whole root volume		Fresh weight of root (g)	Dry weight of root (g)
	At 60 DAP	At 90 DAP	At 60 DAP	At 90 DAP	At 60 DAP	At 90 DAP	At 60 DAP	At 90 DAP	At 60 DAP	At 90 DAP	At 90 DAP	At 90 DAP
IBA@0ppm	12.03	15.83	5.67	15.89	7.79	8.56	1.61	1.72	8.68	10.17	2.51	0.81
IBA@ 2000ppm	17.28	20.23	10.36	18.99	11.84	11.36	1.69	1.80	12.25	15.68	3.60	1.37
IBA@ 4000ppm	22.02	26.97	15.79	26.97	19.22	20.60	1.84	1.96	17.81	23.94	5.41	2.26
IBA@ 6000ppm	22.54	28.68	16.66	28.02	20.56	21.86	1.85	1.86	18.56	24.69	5.70	2.41
S.Em±	**0.07**	**0.53**	**0.28**	**0.42**	**0.30**	**0.36**	**0.01**	**0.01**	**0.29**	**0.40**	**0.11**	**0.04**
CD (%)	**0.19**	**1.52**	**0.80**	**1.21**	**0.87**	**1.02**	**0.04**	**0.03**	**0.83**	**1.14**	**0.30**	**0.11**

Table 3: Effect of IBA and Different Growing Media on Hardwood Cutting of Grapes for leaf parameters

Treatments	Days taken to emergence of 1st leaf	Number of leaves/plant		Fresh weight of leaf (g)	Dry weight of leaf (g)	Leaf area (cm^2)	Leaf Area Index	Water Content of Leaf (%)	Specific Leaf Weight ($mgDW.cm^2$)
		At 60 DAP	At 90 DAP	At 90 DAP	At 90 DAP	At 90 DAP	At 90 DAP	At 90 DAP	At 90 DAP
IBA@0ppm	27.00	3.98	8.79	2.51	0.81	10.98	2.33	67.50	27.26
IBA@ 2000ppm	25.67	6.92	11.73	3.60	1.37	26.18	2.95	61.63	19.04
IBA@ 4000ppm	22.73	9.31	24.25	5.41	2.26	62.61	3.83	58.06	10.57
IBA@ 6000ppm	22.20	10.00	25.75	5.70	2.41	65.39	3.99	57.21	10.56
S.Em±	0.33	0.16	0.42	0.11	0.04	0.81	0.05	0.76	0.69
CD (%)	0.94	0.510.45	1.19	0.30	0.11	2.31	0.15	2.19	1.96

f. Leaf area index

Among the different IBA concentration taken for research, maximum leaf area index was observed with IBA @ 6000 ppm (G3) i.e., 3.99 while the minimum leaf area index was noted under IBA @ 0 ppm (G0)i.e., 2.33.Similar findings recorded earlier by Barde *et al*., (2010) in pomegranate and Kumawat *et al*., (2010) in pomegranate.

h. Specific leaf weight (mgDW.cm^{-2})

Application of IBA had showed significant influence on specific leaf weight at 90 days after planting. Maximum specific leaf weight was observed with IBA concentration 6000 ppm (G3) i.e., 23.53 mgDw.cm^{-2}. While, the minimum specific leaf weight was noted under control (G0) i.e., 10.32 mgDw.cm^{-2}.

References

Ali, B.; Ali, J.; Khan, A. and Shah, M.B.A. (2018). Rooting response of Kiwi cuttings by using different concentration of IBA under greenhouse condition. *Agri Res & Tech*: Open Access J **16**(1).

Ausari, P.K.; Soni, N.; Kanpure, R.N.; Meena,K.C. and Haldar, A. (2023). Effect of Indole-3-Butyric Acid (IBA) and Different Growing Media on Hardwood Cutting of Grapes (*Vitis vinifera* L.) cv. Pusa Navrang. *Biological Forum*, **15**(9): 168-175.

Barde, P.; Tiwari, R.; Kanpure, R. N.; Baghel, B. S. and Kumawat, B. R. (2010). Effect of biofertilizers and growth regulators on rooting and growth of Pomegranate cuttings. *Ann. Pl. soil Res*., **12**(1): 46-47.

Bauri, F. K.; Dey, K.; Ghosh, A.; Chakraborti, K. and Mishra, D. K. (2017). Effects of indole butyric acid on rooting in cuttings of Burmese Grape, *Baccaureasapida*. *Food Nutr J*,**2**(6): 151.

Chakraborty, Sarmista and Rajkumar, M. (2018). Effect of growth regulators and organic substances on rooting of grapes (*Vitis vinifera* L.) cv. Muscat. *Asian Journal of Science and Technology*,**09** (07): 8418-8421.

Dahale, M.; Ningot, E.P. and Deepa, N.M. (2018). Effect of plant growth regulators on rooting and survival of hardwood cuttings in fig. *international journal of current microbiology and applied sciences*, **6**: 2386-2391.

Damar, D.; Barholia, A. K.; Lekhi, R. and Haldar, A. (2014). Effect of growth regulators and biofertilizers on survival of pomegranate (*Punica granatum* L.) Stem cuttings. *Plant Archives*, **14(**1): 347- 350.

Fisher, Ronald (1954). "The Analysis of Variance with Various Binomial Transformations". *Biometrics*. **10** (1): 130–139.

Ghosh, A.; Dey, K.; Mani, A.; Bauri, F.K. and Mishra, D.K. (2017). Efficacy of different levels of IBA and NAA on rooting of Phalsa (*Grewia asiatica* L.) cuttings. *International Journal of Chemical Studies***5**(6): 567-571.

Hartmann, H.T.; Kester, D.E.; Davis, F.T. and Geneve, R.L. (1997). Plant Propagation: Principles and Practices, Prentice Hall, Upper Saddle River, NJ, USA, 6th edition.

Isci, B.; Kacar, E. and Altindisl5, A. (2019). Effects of IBA and plant growth-promoting rhizobacteria (PGPR) on rooting of Ramsey american grapevine rootstock. *Applied Ecology And Environmental Research*, **17**(2):4693-4705.

J. D. Foster, in *Grape, Raisin, and Lily Ingestion*, Wiley, Hoboken, NJ, USA, 2018.

Kareem, A.; Manan, A.; Saeed, S.; Rehman, S.U.; Shahzad, U. and Nafees, M. (2016). Effect of different concentrations of IBA on rooting of Guava Psidium guajava L. in low tunnel under shady situation. Journal of Agriculture and Environment for International Development, 110(2): 197-203.

Kaur, A.; Kaur, K. and Kaur, A. (2018). Role of IBA and PHB on success of cuttings of fig cv. Brown turkey. *Asian Journal of Science and Technology*, **09**(05): 8237-8241.

Kaur, Sukhjit (2017). Evaluation of different doses of indole-3-butyric acid (IBA) on the rooting, survival and vegetative growth performance of hardwood cuttings of Flordaguard peach (*Prunus persica* L. Batch). *Journal of Applied and Natural Science*, **9**(1): 173-180.

Kishorbhai, B.S. (2014). Effect of plant growth regulators on propagation of fig (Ficus carica L.) by hardwood and semi hardwood cuttings. M.Sc. Thesis Navsari Agricultural University.

Kumar, S.; Prakash, S.; Prasad, Y.; Kumar, A.; Chand, P. and Dhyani, B.P. (2020). Effect of IBA and boric acid treatments on rooting and growth of stem cutting in pomegranate (*Punica granatum* L.). *Journal of Pharmacognosy and Phytochemistry*, **9**(5): 2714-2716.

Kumawat, B.R.; Kanpure, R.N.; Tiwari, R.; Baghel, B.S. and Barde, P.K. (2010). Rooting and growth of Pomegranate cuttings as influenced by environmental conditions and growth regulator. *Ann. Pl. Soil Res*., **12**(1): 30-31.

Narula, S. (2016). Effect of growth regulators on rooting of cuttings in plum cv. Kala amritsari. *Scholarly Research Journal for Humanity Science & English Language*, **5**(25): 6889-6896.

Padekar, V.J.; Garande, V.K.; Dodake, S.S.; Sawant, S.V.; Shinde, U.S.; Sonawane, P.N.; Pawar, R.D. and Dhumal, S.S. (2018). Effect of IBA, types of Cutting and Rooting Media on Sprouting, Survival Percentage and Growth of Cuttings of Kartoli* (*Momordica dioica*Roxb.). *Int.J.Curr.Microbiol.App.Sci*., **7**(10):1246-1260.

Piesse, J., Conradie, B.,Thirtle, C. and Vink,N. (2017). “Efficiency in wine grape production: comparing long-established and newly developed regions of south Africa,” *Journal of the international Association of Agricultural Economists*, vol. 49, no. 2, pp. 203–212, 2017.

Rajamanickam, C. and Balamohan, T.N. (2019). Effect of IBA on rooting of pomegranate (*Punica granatum*) stem cuttings cv. Bhagwa. *International Journal of Chemical Studies*, **7**(5): 218-220.

Rolaniya, M.K.; Bairwa, M., Khushbu and Sarvanan, S. (2018). Effect of plant growth regulators (IIA, IBA, and GA3) on rooting of hardwood cutting of Grape (*Vitis venifera* L.) cv. Thompson Seedless. *Journal of Pharmacognosy and Phytochemistry*, **1**: 398-400.

Shahzad, U.; Shahbaz, T.; Khan, A.A.; Hassan, Z.; Naqvi, S.A.; Iqbal, M.; Abbas, T. and Shahjahan, M. (2019). Effects of auxin (IBA) concentrations with different dipping time on root ability of Grape cuttings (*Vitis vinifera* L.). *The International Journal of Science & Technology*, **7**(12): 454-48.

Shriram, J.M.; Patil, R.A.;Ralebhat, B.N.; Sumitha, N.;Ghangale,T.S. and Shinde, S.B. (2021). Effect of Plant Growth Regulators on Rooting Parameters of Grape Rootstock. *Int.J.Curr.Microbiol.App.Sci.***10**(02): 738-745.

Siddiqua, A.; Thippesha, D.; Shivakumar, B.S.; Adivappar, N. and Ganapathi M. (2018). Effect of growth regulators on rooting and shooting of stem cuttings in dragon fruit [*Hylocereusundatus* (Haworth) Britton & rose]. *Journal of Pharmacognosy and Phytochemistry*, **7**(5): 1595-1598.

Singh K. R. (2017). Vegetative Propagation of Pomegranate (*Punica granatum* L.) through Cutting- A Review. *Int. J Curr. Microbiol. App. Sci*., **6**(10): 4887-4893.

Singh, G.; Kaur, S. and Kaur, A. (2019). Effect of IBA on rooting of hardwood cuttings of various Peach genotypes. *Ind. J. Pure App. Biosci*.,**7**(4), 104-109.

Singh, K.K. (2014). Effect of IBA concentrations on the rooting of pomegranate (*Punica granatum* L.) Cv. Ganesh hardwood cuttings under mist house condition. *Plant Archives*, **14**(2): 1111-1114.

Singh, K.K. and Chauhan, J.S. (2020). A review on vegetative propagation of grape (*Vitis vinifera*L.) through cutting. *G.J.B.B*, **9**(2): 50-55.

Singh, K.K. and Tomar, Y.K. (2015).Effect of planting time and indole butyric acid levels on rooting of woody cuttings of phalsa (*Grewia asiatica* L.) *HortFlora Research Spectrum*, **4**(1): 39-43.6.

Singh, V. P.; Mishra, D. S. and Ratna, R. (2015). Effect of growing season, PGRs and rooting media on survival of hard wood stem cuttings of lemon (*Citrus limon*) cv. Pant lemon-1. *Hort Flora Res Spectrum*, **4**: 347-350.

Somkumar, R.G.; Satisha, J.; Ramtekeand, S.D. and Sharma, J. (2009). Root distribution, Partitioning of dry matter and nutrient uptake in Thompson seedless grapes (*Vitis vinifera* L.) grafted on different rootstocks. *India. J.Agril.Sci.*, **79**: 669-673.

Tanwar, D.R.; Bairwa, H.L.; Lakhawat, S.S.; Mahawer, L.N.; Jat, R.K. and Choudhary, R.C.(2020). Effect of IBA and rooting media on hardwood cuttings of Pomegranate (*Punica granatum* L.) CV. Bhagwa. *International Journal of Environment and Climate Change*, **10**(12): 609-617.

Waite, H.; Whitelaw-Weckert, M.and Torley, P. (2014): Grapevine propagation:principles and methods for the production of high-quality grapevine planting material, *New ZealandJournal of Crop and Horticultural Science*, **16**(38): 1-18.

Zenginbal, H.; Haznedar, A. and Zenginbal, E. (2014). Influence of type cutting, IBA concentration and collection times on rooting of tea (*Camellia sinensis* L.).*Research in Plant Biology*, **4**(4): 01-08.