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Effect of various media composition and rooting hormone concentrations on success of phalsa cuttings

Gul-e-Khanda[1], Muhammad Shafique[1]*, Ahsan Akram[2], Irfan Ali[3], Madiha Butt[4] and Abdul Mannan[4]

[1]University of Agriculture Faisalabad, Sub-Campus Burewala-Vehari, Pakistan
[2]Institute of Horticultural Sciences, University of Agriculture Faisalabad, Pakistan
[3]Department of Horticulture, Pir Mehr Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan
[4]Department of Horticulture, Ghazi University, Dera Ghazi Khan, Pakistan

*****Corresponding author: Muhammad Shafique (shafiqhort@hotmail.com)

Abstract

Phalsa is a promising small fruit of Pakistan which is cherished in summer season. It is a hardy plant which can be propagated by sexual and asexual methods. Current experimental trial was conducted to assess different concentrations of rooting hormone (IBA) and various compositions of growing media on off-season hardwood phalsa cuttings under lathhouse. Eight different composite growing mixtures consisting of bagasse, silt, compost, sand, peatmoss along with their combinations were evaluated for phalsa cuttings that were dipped in four different concentrations of IBA i.e., control, 300 mg L^{-1}, 600 mg L^{-1} and 900 mg L^{-1}. The results suggested that phalsa cuttings dipped in 900 mg L^{-1} IBA concentration and grown in media comprising of sand + silt + peatmoss took minimum days to first sprouting (17.33). Cuttings treated with IBA at 900 mg L^{-1} and planted in a mixture of silt + compost + peatmoss showed maximum number of buds sprouted (4), sprouting percentage (88.88%), number of sprouts (7), number of leaves (18), leaf area (15.45 cm^2), length of longest sprout (12.4 cm), diameter of thickest sprout (10.67 mm), fresh weight of shoots (17.82 g), dry weight of shoots(8.92 g), number of roots (18), length of longest root (11.31 cm), diameter of thickest root (20.81 mm), fresh weight of roots (6.67 g), dry weight of roots (3.19) and survival percentage (100%). Conclusively, dipping of phalsa cuttings in 900 mg L^{-1} IBA concentration followed by planting in rooting media comprising of Silt + Compost + Peatmoss was the suitable treatment for propagation of hardwood phalsa.

Keywords: Cuttings, Growing media, IBA, Phalsa

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Introduction

Phalsa (*Grewia asiatica* L.) is a small berry fruit of tropical regions of South Asia including Pakistan and belongs to the Tiliaceae family (Wani et al., 2015; Dave et al., 2016). It is one of the most cherished small fruits in Pakistan cultivated on an area of 1241 hectares with 4209 tonnes annual production (GOP, 2019). It is highly nutritious and contains several bioactive compounds like tannins, anthocyanins, phenols and flavonoids. It is sub acidic, containing vitamin C, A and also a good source of iron and phosphorus; whereas, ripened fruit contains 50-60% juice content, 10-11% sugar and 2.0-2.5% acid (Wani et al., 2015; Dave et al., 2016). Phalsa also contains amino acids such as glutaric acid, lysine, proline and carbohydrates like glucose, arabinose and xylose (Sharma & Sisodia, 2010). Moisture content present in fruit is 80% and edible portion is 69%; while, 100 g pulp contains 1.3 g protein, 0.9 g fat, 14.7 g carbohydrates, 1.2 g fiber and 1.1 g minerals. Phalsa plant is usually propagated through seed; whereas, asexually it is propagated through hardwood cutting and layering (Ghosh et al., 2017). Unripe phalsa fruit is used to cure respiratory problems, heart diseases, blood disorders, fever reduction and effective for treatment of anemia while ripe fruit is used as fresh, desserts or can be processed into juice which is consumed during hot summers to overcome thirst (Khemiss et al., 2006; Singh et al., 2015). Commercially, phalsa is propagated through seeds but seeds lose their viability within three months at room temperature so fresh seeds taken from fully ripened fruit have to be sown earlier (Singh & Bahadur, 2015). Plants raised from seeds show a great variability in terms of plant vigor, precocity and fruit quality (Hartmann & Kester, 1983).

Propagation of phalsa through stem cutting is a very easy and less expensive technique to get true to type plant (Ghosh et al., 2017). Stem is hard and woody, non-hairy and circular with rough grey colored bark. Propagation through stem cutting is particularly important to produce improved plant materials in a large quantity within a short time period and to perpetuate the features of the mother plant. Rooting ability of cuttings differ from variety to variety, season to season, site to site and age of limb; whereas, hardwood cuttings of phalsa produce a greater number of primary roots as compared to semi-hardwood cuttings (Hartmann & Kester, 1983; Kathortia & Singh, 1995). Rooting of cuttings mostly depends on factors like growing conditions, treatment applied and environmental elements

which enhance the regeneration capability of cuttings (Kumar & Jadhav, 2007). Growth regulators like auxin, cytokinin, gibberellin, and ethylene influences root development in cuttings. In woody plants, indole butyric acid is mostly used for inducing root formation in cuttings and those roots which are induced by IBA show increased number of vascular strands in relation to its concentration (Singh & Bahadur, 2015). Chrysanthemum cuttings treated with combination of IBA and NAA resulted in early rooting, increased root as well as shoot length, fresh weight and dry weight and showed maximum rooting percentage (Manjunath et al., 2022). IBA being a stable and non-toxic compound to plants and effective for root promotion has been used in a wide range of plant species (Mehra et al., 2019). IBA enhances rooting potential by increasing internal IBA level or by the modification of action of IAA, or by starting internal synthesis of IAA (Kreiken et al., 1993). Likewise, IBA increased the number of leaves, root length, root thickness, average number of roots and buds in treated "Thompson Seedless" grape cuttings (Beniwal et al., 2022). While semi-hardwood cuttings of acid lime treated with 2000 ppm gave encouraging results for mass multiplication (Rajangam et al., 2022).

Likewise, growing media holds significant importance for successful rooting of phalsa cuttings. Use of good growing media along with rooting hormones increases root induction. Growing media should be well drained, porous, hold sufficient moisture and uniform in texture (Sardoei et al., 2014; Leonardi et al., 2001). Suitability of growing medium varies with species, type of cutting, propagation technique used, season, price and accessibility (Sardoei, 2014). Combination of appropriate rooting components is very necessary to provide proper ventilation and removal of extra water to get roots of better quality (Raviv, 2005). The results showed that the application of treatment G3M3 (Khirni seeds are sowed in Soil + FYM after soaking in GA3 300 ppm for 24 hours) was found better for early germination, highest germination percentage, maximum shoot length, number of leaves, stem diameter, fresh and dry weight of seedling as well as highest leaf area and survival percentage of Khirni seedling (Sejal et al., 2022).

Keeping in view the importance of growth promoting hormone and potting media, a study was conducted at UAF Sub campus Burewala-Vehari during winter 2020-2021. An experiment was conducted to assess the effect of different media compositions and rooting hormone concentrations on phalsa cuttings. Objective of this study was to evaluate suitability of different growing media for root growth of phalsa cutting. Evaluation of various IBA concentrations on successful rooting of phalsa cutting and evaluation of different combinations of IBA and media on success of phalsa cuttings.

Materials and Methods

Current research experiment was carried out at Horticulture nursery, UAF Sub-campus Burewala-Vehari during winter 2020 on phalsa cutting. Hardwood phalsa cuttings were obtained from 8-9 months old plant of phalsa with the help of a cutter. The size of each cutting was 30 cm long, having 3-4 buds. The hardwood phalsa cuttings treated with different concentrations of Indole-butyric acid (IBA) were planted in black-colored bags of 5x12'' size that were filled with different media compositions of peat moss, bagasse, compost, silt and sand.

Table 1 Treatment detail of growing media and IBA concentrations

Treatments	Growing media	IBA concentration
GM1 + Undipped	Sand	Control
GM1 + IBA 300 mg L^{-1}	Sand	300 mg L^{-1}
GM1 + IBA 600 mg L^{-1}	Sand	600 mg L^{-1}
GM1 + IBA 900 mg L^{-1}	Sand	900 mg L^{-1}
GM2 + Undipped	Compost	Control
GM2 + IBA 300 mg L^{-1}	Compost	300 mg L^{-1}
GM2 + IBA 600 mg L^{-1}	Compost	600 mg L^{-1}
GM2 + IBA 900 mg L^{-1}	Compost	900 mg L^{-1}
GM3 + Undipped	Silt	Control
GM3 + IBA 300 mg L^{-1}	Silt	300 mg L^{-1}
GM3 + IBA 600 mg L^{-1}	Silt	600 mg L^{-1}
GM3 + IBA 900 mg L^{-1}	Silt	900 mg L^{-1}
GM4 + Undipped	Sand + Compost + Silt	Control
GM4 + IBA 300 mg L^{-1}	Sand + Compost + Silt	300 mg L^{-1}
GM4 + IBA 600 mg L^{-1}	Sand + Compost + Silt	600 mg L^{-1}
GM4 + IBA 900 mg L^{-1}	Sand + Compost + Silt	900 mg L^{-1}
GM5 + Undipped	Sand + Compost + Bagasse	Control
GM5 + IBA 300 mg L^{-1}	Sand + Compost + Bagasse	300 mg L^{-1}
GM5 + IBA 600 mg L^{-1}	Sand + Compost + Bagasse	600 mg L^{-1}
GM5 + IBA 900 mg L^{-1}	Sand + Compost + Bagasse	900 mg L^{-1}
GM6 + Undipped	Sand + Compost + Peat moss	Control

GM6 + IBA 300 mg L^{-1}	Sand + Compost + Peatmoss	300 mg L^{-1}
GM6 + IBA 600 mg L^{-1}	Sand + Compost + Peatmoss	600 mg L^{-1}
GM6 + IBA 900 mg L^{-1}	Sand + Compost + Peatmoss	900 mg L^{-1}
GM7 + Undipped	Silt + Compost + Peatmoss	Control
GM7 + IBA 300 mg L^{-1}	Silt + Compost + Peatmoss	300 mg L^{-1}
GM7 + IBA 600 mg L^{-1}	Silt + Compost + Peatmoss	600 mg L^{-1}
GM7 + IBA 900 mg L^{-1}	Silt + Compost + Peatmoss	900 mg L^{-1}
GM8 + Undipped	Silt + Compost + Bagasse	Control
GM8 + IBA 300 mg L^{-1}	Silt + Compost + Bagasse	300 mg L^{-1}
GM8 + IBA 600 mg L^{-1}	Silt + Compost + Bagasse	600 mg L^{-1}
GM8 + IBA 900 mg L^{-1}	Silt + Compost + Bagasse	900 mg L^{-1}

Eight different kinds of growing mixtures were prepared i.e., Sand, Silt, Compost, Sand + Compost + Silt (1:1:1), Sand + Compost + Bagasse (1:1:1), Sand + Compost + Peat moss (1:1:1), Silt + Compost + Peat moss (1:1:1) and Silt + Compost + Bagasse (1:1:1) were prepared as experimental treatments. The basal part of hardwood phalsa cuttings up to 10 cm was dipped in different concentrations (300, 600 and 900 mg L^{-1}) of rooting hormone IBA for 30 mins and subsequently inserted up to two third of its length in growing media already filled in polybags. After planting bags were placed in the lath house carefully and irrigation was applied as per requirement. Low height tunnel was made with sticks and covered with a polythene sheet to maintain internal temperature during the winter season.

Analysis of growing media

Parameters like water holding capacity (WHC), pH, electrical conductivity, organic matter, NPK were determined from different growing media and presented in Table 2. WHC was determined in g water/g dry material by the method elaborated by Ahn et al., (2008); while organic matter contents were estimated using the method of Moodie et al. (1959). Electrical conductivity was determined in dS m^{-1} using a conductivity meter and pH was determined by using digital ion analyzer. Nitrogen was determined by Kjeldhal's method where $H2SO_4$ was used for digestion; whereas boric acid (H_3BO_3) and methylene blue were used as indicators (Jackson 1962). Phosphorus from different growing media compositions was determined by adopting the method given by Olsen et al. (1954); potassium was estimated using a flame photometer (Model M360 Sherwood Scientific Ltd, UK) by United States Salinity Laboratory Staff method (1954).

Table 2 Properties of growing media

	OMC (%)	EC ds/m	pH	N %	P %	K %
Sand	0.98 ± 0.04	0.09 ± 0.01	5.88 ± 0.14	0.62 ± 0.03	0.29 ± 0.04	0.16 ± 0.02
Compost	46 ± 2.26	5.02 ± 0.07	7.5 ± 0.14	2.02 ± 0.03	0.69 ± 0.04	0.98 ± 0.09
Silt	0.78 ± 0.06	0.69 ± 0.05	6.28 ± 0.10	0.64 ± 0.07	0.52 ± 0.04	0.61 ± 0.04
Sand + Compost + Silt	47.31 ± 2.23	2.05 ± 0.05	7.05 ± 0.14	2.22 ± 0.13	1.01 ± 0.03	1.01 ± 0.09
Sand + Compost + Baggasse	56.18 ± 1.94	2.47 ± 0.08	5.53 ± 0.17	2.99 ± 0.06	0.82 ± 0.05	1.34 ± 0.04
Sand + Compost + Peatmoss	68.28 ± 1.25	3.21 ± 0.08	5.65 ± 0.22	3.70 ± 0.22	1.62 ± 0.05	1.93 ± 0.04
Silt + Compost + Peatmoss	73.28 ± 0.44	3.54 ± 0.04	6.28 ± 0.14	5.59 ± 0.27	2.00 ± 0.05	2.20 ± 0.04
Silt + Compost + Baggasse	59.24 ± 1.36	2.87 ± 0.07	5.68 ± 0.13	3.23 ± 0.12	1.14 ± 0.07	1.61 ± 0.07

Sand, Compost, Silt, Sand + Compost+ Silt, Sand + Compost+ Bagasse, Sand + Compost+ Peat moss, Silt + Compost + Peatmoss, Silt + Compost + Baggasse [n=3], OMC = Organic matter content, EC = Electrical conductivity

Pre-rooting attributes

No. of days taken for sprouting, no. of buds sprouted, no. of sprouts, sprout percentage (%)

Phalsa cuttings dipped in different concentrations of IBA and placed in different media compositions were noticed daily for their sprouting and total days taken by cuttings for first sprouting was counted. Treated cuttings were observed on a daily basis and total buds sprouted was counted and average was calculated. Total number of sprouts emerging from a single bud in each treated cutting with different levels of IBA and placed in different media was counted and the mean was calculated. Sprouting percentage of phalsa cuttings was calculated using given formula:

$$\text{Sprouting percentage} = \text{No. of cuttings sprouted x } 100/\text{Total number of cuttings planted}$$

Number of leaves, leaf area (cm^2), length of longest sprout (cm) and diameter of thickest sprout (mm)

Total number of new leaves emerged per cutting was recorded after removal of cuttings (190^{th} day) in each treatment and average was calculated. Three leaves from each cutting were taken after removal of cuttings (190^{th} day) and leaf area was measured with the help of scale, average was calculated and expressed in centimeter square. Sprout length of each cutting which was soaked in various IBA solutions was measured by using scale on 190^{th} day after inserting in different growing media compositions and the average was calculated. Diameter of thickest sprout per cutting in each treatment was calculated by using stainless hardened digital vernier caliper (Metr. ISO, Part #5900601, Spain) after removal of cuttings on 190^{th} day and average was calculated.

Fresh weight of shoots (g) and dry weight of shoots (g)

Fresh weight of shoots per cutting was taken immediately after removal of cutting (on 190^{th} day) from polythene bags in each treatment with the help of electronic balance, average was calculated and expressed in grams. Shoots of cuttings of each treatment were kept in an oven at 55^oC for 6 hours to dry them. After that, dry weight with the help of electronic balance was weighted, mean was calculated and expressed in grams on 190^{th} day after planting.

Post-rooting attributes

Number of roots, root length (cm), diameter of thickest root (mm), fresh weight (g), dry weight (g) and survival percentage (%)

Total roots formed in each treated cutting were counted on 190^{th} day after planting and the average was calculated. The root length of each cutting sunk in IBA solutions and inserted in different growing mixtures was measured by using scale on 190^{th} day after planting and the mean was calculated. Diameter of the thickest root was expressed in millimeters (mm) by using a digital vernier caliper on 190^{th} day after planting. For fresh weight determinations cuttings removed from polythene bags (190^{th} day) were weighed using electronic balance and expressed in grams. Dry weight of cuttings was determined by oven drying at 55^oC for 6 hours and dry weight was calculated using electronic balance and expressed in grams. Survival percentage of phalsa cuttings was calculated using following formula:

$$\text{Survival percentage} = \text{No. of plants survived x } 100/\text{Total no. of plants}$$

Statistical analysis

The experiment was carried out in CRD design, two factor factorial with three replicates. In the first factor rooting hormone IBA was used with different concentrations. In the second factor different types of media composition were used as shown in Table 1. Data was subjected to analysis of variance techniques to observe the difference among all treatments and their interactions. Mean values of significant results were further processed for difference through Tukey's (HSD) test at 0.05 probability by using Statistics 8.1 (Abdi & Williams, 2010).

Results and Discussion

No. of days taken for sprouting, no. of buds sprouted, no. of sprouts, sprout percentage (%), sprout length (cm) and thickest sprout (mm)

Various media compositions and different IBA concentrations significantly affected the success of phalsa cuttings. Results revealed that 900 mg L^{-1} IBA-treated hardwood cuttings and planted in sand + compost + peat moss took minimum days (17.33) for sprouting followed by GM7. On the other hand, maximum days (58) were taken in control with silt medium (Table 3). Our results for number days taken for sprouting can be correlated with the findings of Damar et al., 2014 where hardwood cuttings immersed in IBA showed early sprouting. Early sprouting could be related to better use of nitrogen and carbohydrates due to increased internal auxin level that might have promoted rapid cell division and fast callus formation (Chandramouli, 2001). Similarly, combination of different media compositions and IBA concentrations significantly influenced significantly affected number of buds sprouted per cutting as significantly increased number of buds as 4 buds were sprouted in cuttings that were treated with 900 mg L^{-1} IBA and planted in GM7 followed by GM8 that exhibited 3 sprouted buds. Results also revealed low bud sprouting percentage in cuttings treated with lower concentrations of IBA (Table 3). Addition of compost and peat moss in silt medium might have improved all physical as well as biological properties of soil and provided sufficient nutrients to the *Dracaena deremensis* cuttings as reported by Wazir et al. (2003). Pomegranate cuttings dipped in higher concentrations of IBA showed maximum bud sprouting as compared to untreated cuttings Singh et al. (2011).

Number of sprouts emerged from single bud also significantly in all treatments as maximum up to 7 sprouts from single bud were obtained from 900 mg L^{-1} IBA-treated phalsa cuttings planted in silt + compost + peat moss; while phalsa cuttings treated with 300 mg L^{-1} of IBA and planted in sand could not sprout at all. Similarly untreated hardwood phalsa cuttings planted sand as well as in compost media did not exhibit any sprouting (Table 3). Our results for number of sprouts per cutting are in confirmation with the findings of Singh and Tomar (2015), who recorded increased number of sprouts of phalsa cuttings with higher dose of IBA and decreased number of sprouts from untreated cuttings. Variation in number of sprouts under different levels of IBA might be due the variation of auxin mobility in cuttings and its effect on

hydrolysis of stored food into reducing and non-reducing sugars and metabolites (Patel et al., 2017).

Meanwhile, significant variations were observed among different treatments for the sprouting percentage of hardwood phalsa cuttings. Dipping hardwood phalsa cutting in 900 mg L^{-1} IBA followed by planting in silt + compost + peat moss growing resulted in 88.88% sprouted cuttings; while, absolutely zero sprouting percentage was recorded in non-IBA treated phalsa cuttings planted in sand and compost media. Sprouting percentage of phalsa cuttings was decreased at lower concentrations of IBA as 300 mg L^{-1} IBA + compost showed zero sprouting percentage (Table 3). The increase in sprouting percentage might be due to the fact that when auxin level increased in cuttings, the physiological process completed earlier. IBA also improved the consumption of stored nitrogen and carbohydrates present in hardwood cuttings (Sinha et al., 2014). Previously, Yusnita et al. (2017) reported maximum sprouting percentage when apple cuttings were treated with IBA at higher concentration. In another study, the highest sprouting percentage was observed from shoot cuttings of peaches which were dipped in IBA (Gill et al., 2014).

Our results revealed that longest sprouts of 12.4 cm in phalsa cuttings which were treated with IBA @ 900 mg L^{-1} and planted in GM7; while shortest sprout length (3.40 cm) was recorded under 600 mg L^{-1} IBA with sand (Table 3). Previously increased sprout length has been recorded in phalsa cuttings planted in compost media and guava cuttings planted in peat moss media (Singh and Singh et al. 2018; Qadri et al. 2018). This increase in sprout length might be due to nutritional mixture with good water retention and nutrients holding capacity resulting in better root and shoot system. Dipping in IBA might have further enhanced nutrients uptake and provided energy for cell division and cell elongation (Shahab et al., 2013).

Sprout thickness was also affected significantly due different media compositions and IBA concentrations. Thickest sprout diameter of phalsa cuttings (10.67 mm) was observed in GM7 with 900 mg L^{-1} of IBA; while minimum sprout thickness (1.25 mm) was recorded from phalsa cuttings inserted in sand treated with 600 mg L^{-1} of IBA (Table 3). These results are in line with Thota et al. (2012) where thickest sprout diameter was recorded in IBA dipped fig cuttings. Increase in sprout thickness could be due to auxins promote cell division and cell elongation that resulted in better shoot system with more shoot diameter as reported in fig cuttings as reported by Kaur et al. (2018).

Table 3 Effect of different media compositions and IBA concentrations on day taken to sprouting, no. of buds, no. of sprouts and cutting sprouting percentage

Treatment	Days taken for sprouting	No. of buds sprouted	No. of sprouts	Sprout percentage (%)	Sprout length (cm)	Thickest sprout (mm)
GM1 + Undipped	0.00 p	0.00 g	0.00 j	0.00 d	0.00 m	0.00 q
GM1 + IBA 300 mg L^{-1}	0.00 p	0.00 g	0.00 j	0.00 d	0.00 m	0.00 q
GM1 + IBA 600 mg L^{-1}	45.00 e-h	1.00 f	1.00 ij	33.33 c	3.4 l	1.25 p
GM1 + IBA 900 mg L^{-1}	37.00 i-k	1.00 f	2.00 hi	33.33 c	4.50 i-l	2.15 op
GM2 + Undipped	0.00 p	0.00 g	0.00 j	0.00 d	0.00 m	0.00 q
GM2 + IBA 300 mg L^{-1}	47.00 d-g	1.00 f	1.00 ij	33.33 c	3.43 kl	2.63 m-o
GM2 + IBA 600 mg L^{-1}	42.33 f-i	1.00 f	2.00 hi	33.33 c	4.40 i-l	3.37 l-n
GM2 + IBA 900 mg L^{-1}	37.67 i-j	2.00 de	2.67 gh	66.66 b	5.50 hi	4.05 kl
GM3 + Undipped	58.00 a	1.00 f	2.00 hi	33.33 d	3.43 kl	2.24 n-p
GM3 + IBA 300 mg L^{-1}	56.00 ab	1.00 f	2.00 hi	33.33 c	4.40 i-l	4.31 j-l
GM3 + IBA 600 mg L^{-1}	53.00 a-d	2.00 de	2.33 h	33.33 c	5.43 h-j	4.95 h-k
GM3 + IBA 900 mg L^{-1}	49.00 c-f	2.00 de	3.00 f-h	66.66 b	6.50 f-h	5.67 f-i
GM4 + Undipped	55.33 a-c	1.00 f	2.00 hi	33.33 c	4.70 i-k	3.49 lm
GM4 + IBA 300 mg L^{-1}	51.00 b-e	2.67 b-d	2.67 gh	33.33 c	6.30 gh	4.88 i-k
GM4 + IBA 600 mg L^{-1}	50.00 b-e	2.00 de	3.67 e-g	66.66 b	7.10 e-g	6.05 e-i
GM4 + IBA 900 mg L^{-1}	47.67 d-g	1.00 f	4.67 c-e	66.66 b	8.40 c-d	7.09 de
GM5 + Undipped	50.67 b-e	1.67 ef	2.00 hi	33.33 c	4.20 j-l	2.83 m-o
GM5 + IBA 300 mg L^{-1}	48.00 d-g	1.67 ef	2.33 h	44.44 c	5.33 h-j	4.66 i-k
GM5 + IBA 600 mg L^{-1}	47.00 d-g	2.00 de	3.00 f-h	33.33 c	6.47 f-h	5.46 g-j
GM5 + IBA 900 mg L^{-1}	42.00 g-i	2.33 c-e	4.33 de	66.66 b	7.70 d-f	6.39 e-g
GM6 + Undipped	30.00 lm	2.00 de	3.00 f-h	33.33 c	5.50 hi	4.52 i-l
GM6 + IBA 300 mg L^{-1}	23.67 m-o	2.00 de	3.67 e-g	33.33 c	7.37 d-g	6.11 e-h
GM6 + IBA 600 mg L^{-1}	22.00 no	2.33 c-e	5.00 b-d	66.66 b	8.57 cd	7.71 cd
GM6 + IBA 900 mg L^{-1}	17.33 o	3.33 ab	5.67 bc	77.77 b	10.46 b	9.74 ab
GM7 + Undipped	30.33 k-m	2.00 de	3.00 f-h	33.33 c	6.57 f-h	5.35 g-j
GM7 + IBA 300 mg L^{-1}	28.33 l-n	3.00 bc	5.00 b-d	66.66 b	8.50 cd	6.82 d-f

GM7 + IBA 600 mg L^{-1}	27.33 mn	3.00 bc	6.00 ab	66.66 b	10.00 b	8.84 bc
GM7 + IBA 900 mg L^{-1}	22.33 no	4.00 a	7.00 a	88.88 a	12.40 a	10.67 a
GM8 + Undipped	40.00 h-j	2.00 de	2.67 gh	33.33 c	5.50 hi	4.35 j-l
GM8 + IBA 300 mg L^{-1}	34.00 j-l	2.00 de	3.00 f-h	33.33 c	7.33 d-g	5.19 h-k
GM8 + IBA 600 mg L^{-1}	30.00 lm	2.00 de	4.00 d-f	33.33 c	8.33 c-e	6.36 e-g
GM8 + IBA 900 mg L^{-1}	28.33 l-n	3.00 bc	5.00 b-d	66.66 b	9.50 bc	7.57 d

HSD ($P \leq 0.05$) for Days taken for sprouting = 6.8833, No. of buds sprouted = 0.8075, No. of sprouts = 1.0424, Sprouting percentage = 19.03, Sprout length = 1.2953, Thickest Sprout = 1.1591. * Means not sharing a same letter are significantly different at $P \leq 0.05$.

No. of leaves, leaf area (cm^2), fresh weight of shoots (g), dry weight of shoots (g) and no. of roots

Hardwood cuttings of phalsa immersed in a solution of 900 mg L^{-1} of IBA and implanted in silt + compost + peat moss produced maximum (18) number of leaves as compared to those cuttings which were dipped in lower concentrations of IBA or planted in sand, silt, or compost media. On the other hand, non-IBA treated phalsa cuttings did not exhibit any leaf (Table 4). Previously dipping guava and grape cuttings in IBA solutions has been reported to exhibit increased number of leaves (Wahab et al. 2001; Abebe 2017). This increase in leaf number might be due to the external treatment of IBA which helped to produce healthy and longer roots to absorb water and nutrients from growing substrate inducing shoot growth and increased number of new leaves (Babaie et al., 2014). Likewise, leaf area was also increased in phalsa cuttings planted in combined media of Silt + Compost + Peat Moss at higher concentration of IBA i.e., 900 mg L^{-1} that resulted highest leaf area 15.45 cm^2; while minimum leaf area 4.62 cm^2 was recorded with 600 mg L^{-1} of IBA in cuttings inserted sand (Table 4). Our results for leaf area are in confirmation with Mehta et al. (2016) who reported maximum leaf area in stem cuttings of pear under IBA treatment. Similarly, Navjot and Kahlon (2002) obtained maximum leaf area per cutting when pomegranate cuttings were treated with IBA.

Growing media composition coupled with different IBA concentration exhibited significant effects on fresh weight of shoots, dry weight of shoots. Hardwood phalsa cuttings treated with IBA @ 900 mg L^{-1} and grown in GM7 (silt + compost + peat moss) retained significantly higher fresh weight (17.82 g), dry weight of shoots (8.92 g) and number of roots (18); while lowest values for fresh weight/dry weight of shoots and number of roots were from phalsa cuttings grown in sand media (GM1) and soaked in 600 mg L^{-1} IBA (Table 4). Similar findings were reported by Hakim et al. (2018) where IBA soaked pomegranate cuttings exhibited maximum fresh weight of shoots. Increased dry weight of shoots recorded in peat moss medium could be due to high concentration of potassium, phosphorus and nitrogen that resulted in vigorous vegetative growth (Mousa et al., 2015). Similar results were reported by Dhatrika et al. (2018) where significant increase in dry weight of shoots was obtained from hardwood guava cuttings soaked in IBA. Our results for number of roots are in conformity with Reddy et al. (2008) and Diwaker and Katiyar (2013) as they reported maximum number of roots in IBA soaked fig and lime cuttings, respectively.

Table 4 Effect of different media compositions and IBA concentrations on number of leaves, leaf area, fresh weight of shoots, dry weight of shoots and number of roots

Treatment	No. of leaves	Leaf area (cm^2)	Fresh weight of shoots (g)	Dry weight of shoots (g)	No. of roots
GM1 + Undipped	0.00 m	0.00 o	0.00 q	0.00 p	0.00 i
GM1 + IBA 300 mg L^{-1}	0.00 m	0.00 o	0.00 q	0.00 p	0.00 i
GM1 + IBA 600 mg L^{-1}	3.33 l	4.62 mn	2.00 p	1.00 o	1.67 kl
GM1 + IBA 900 mg L^{-1}	5.00 i-l	6.51 kl	5.00 mn	2.55 lm	3.33 i-k
GM2 + Undipped	0.00 m	0.00 o	0.00 q	0.00 p	0.00 i
GM2 + IBA 300 mg L^{-1}	4.67 j-l	5.51 l-n	2.66 op	1.20 no	2.33 jk
GM2 + IBA 600 mg L^{-1}	5.67 g-k	7.17 jk	5.00 mn	2.42 lm	3.67 h-k
GM2 + IBA 900 mg L^{-1}	7.33 e-h	9.25 g-i	8.00 j-l	4.57 h-j	5.33 g-i
GM3 + Undipped	4.33 kl	4.48 n	4.17 no	2.00 mn	4.33 h-j
GM3 + IBA 300 mg L^{-1}	5.33 h-l	7.19 jk	7.48 kl	3.60 i-k	5.33 g-i
GM3 + IBA 600 mg L^{-1}	5.67 g-k	8.25 h-j	8.50 i-k	4.30 hi	7.33 fg
GM3 + IBA 900 mg L^{-1}	7.67 d-g	10.14 fg	11.44 f-h	5.67 fg	8.67 f
GM4 + Undipped	5.67 g-k	5.10 k-m	6.47 lm	3.17 j-l	5.33 cd
GM4 + IBA 300 mg L^{-1}	5.67 g-k	9.04 ghi	9.70 h-j	4.80 gh	9.33 ef
GM4 + IBA 600 mg L^{-1}	8.33 d-f	10.11 fg	11.58 e-g	5.75 e-g	11.33 de
GM4 + IBA 900 mg L^{-1}	9.67 d	12.03 de	13.46 c-e	6.71 c-e	13.33 cd
GM5 + Undipped	5.33 h-l	5.14 l-n	5.50 mn	2.90 k-m	4.67 hi
GM5 + IBA 300 mg L^{-1}	5.33 h-l	8.22 h-j	8.52 ijk	4.16 h-j	7.33 fg

GM5 + IBA 600 mg L^{-1}	6.67 f-j	9.06 g-i	9.18 ijk	4.47 hi	8.33 f
GM5 + IBA 900 mg L^{-1}	8.33 d-f	11.17 ef	11.57 f-h	5.71 fg	11.67 d
GM6 + Undipped	8.33 d-f	7.97 ij	8.84 i-k	4.43 hi	7.33 fg
GM6 + IBA 300 mg L^{-1}	9.67 d	11.30 ef	13.77 cd	6.87 cd	11.33 de
GM6 + IBA 600 mg L^{-1}	12.33 c	12.88 cd	14.66 b-d	7.32 b-d	13.33 cd
GM6 + IBA 900 mg L^{-1}	14.33 bc	14.37 ab	15.99 ab	7.95 ab	16.67 ab
GM7 + Undipped	9.33 de	9.44 gh	9.95 g-i	4.95 gh	8.33 f
GM7 + IBA 300 mg L^{-1}	14.33 bc	12.28 de	14.59 b-d	7.29 b-d	13.33 cd
GM7 + IBA 600 mg L^{-1}	15.67 b	13.75 bc	15.76 b	7.87 b	14.68 bc
GM7 + IBA 900 mg L^{-1}	18.00 a	15.45 a	17.82 a	8.92 a	18.00 a
GM8 + Undipped	7.00 f-i	7.43 jk	7.52 kl	3.80 i-k	5.67 gh
GM8 + IBA 300 mg L^{-1}	8.00 d-f	9.72 g	12.86 d-f	6.64 d-f	9.33 ef
GM8 + IBA 600 mg L^{-1}	8.33 d-f	11.29 ef	13.72 cd	6.81 cd	11.67 d
GM8 + IBA 900 mg L^{-1}	13.00 c	13.43 b-d	14.77 bc	7.36 bc	15.00 bc

HSD ($P \leq 0.05$) for No. of leaves =2.1364, Leaf area = 1.4522, Fresh weight of shoots = 1.879, Dry weight of shoots = 0.993, No. of roots = 2.0587. * Means not sharing a same letter are significantly different at $P \leq 0.05$.

Root length (cm), root thickness (mm), fresh weight of roots, dry weight of roots (mm) and survival percentage (%)

Roots of phalsa cuttings planted in different media and dipped in different concentrations of IBA showed significant variation in root length, thickness, fresh weight, dry weight and overall survival percentage. Maximum root length (15.47 cm) was recorded in hardwood phalsa cuttings dipped in 900 mg L^{-1} solution of IBA and inserted in GM7; while, phalsa cuttings planted in GM1 and dipped in 600 mg L^{-1} IBA result in shortest roots that with average root length of 3.5 cm. While roots diameter was also increased in phalsa cuttings that were soaked with 900 mg L^{-1} IBA and planted in GM7 (Table 5). These results are correlated with the findings of Ismail and Hussain (2007) who found lengthy and healthier roots in ficus cuttings treated with IBA at a higher concentration. Similar observation was recorded when tomato and ficus cuttings were planted in peat moss and silt media (Waheed et al. 2015; Shah et al. 2006). Increased length and diameter of hardwood phalsa cutting could be owed to IBA might induce rapid cell division and cell elongation that might have increased root growth. While absorbance of water and nutrients facilitated by nutrient media might also have increased root thickness (Geiss et al., 2009).

Meanwhile, growing media and rooting hormone significantly increased fresh and dry weight of roots. Hardwood phalsa cuttings soaked in 900 mg L^{-1} IBA solution and planted in GM7 gave maximum fresh weight and dry weight of roots i.e 6.67 g and 3.19 g, respectively. While lowest fresh and dry weight was recorded in phalsa cuttings dipped in 600 mg L^{-1} and planted in GM1 (Table 5). Increase in fresh and dry weight of roots might be due to the higher number of roots induced by auxins and root length. Absorbance of more water and nutrients might have resulted in increased fresh weight of roots (Ingle and Venugopal, 2009; Adugna et al. 2015). These results are similar with the findings of Verma and Chauhan (2015) who recorded maximum fresh weight of roots with IBA treated apple cuttings. Our results for root dry weight are in confirmation with Deb et al. (2009) who found maximum dry weight of roots in lemon cuttings treated with IBA. Similar findings were also reported in olive cuttings treated with IBA placed in sand peat medium (Porghorban et al., 2014).

Likewise, survival percentage of hardwood phalsa cuttings showed significant variation due IBA concentration and type of growing media. Survival percentage was 100% in phalsa hardwood cutting dipped in 900 mg L^{-1} IBA and dipped in GM7 while, 0% survival percentage was recorded in non-IBA treated phalsa cuttings (Table 5). Cuttings treated with IBA survived better might be due better root and shoot growth because better roots absorbed water and nutrients more efficiently from growing media (Ram et al., 2005). These results are in agreement with Kishorbhai (2014) where fig cuttings dipped in IBA solution survived for a longer period of time.

Conclusion

Various concentrations of IBA and growing medium compositions significantly improved growth and vigor of phalsa cuttings. Hardwood cuttings of phalsa treated with 900 mg L^{-1} of IBA and grown in GM7 (silt + compost + peat moss) gave better results regarding root and shoot parameters. Conclusively, GM7 was the most promising media composition along with 900 mg L^{-1} IBA dipping for successful propagation of phalsa through hardwood cutting.

Table 5 Effect of different media compositions and IBA concentrations on number of root length, root thickness, fresh weight of roots, dry weight of roots and survival percentage

Treatment	Root length cm	Root thickness (cm^2)	Fresh weight of roots (g)	Dry weight of roots (g)	Survival (%)
GM1 + Undipped	0.00 n	0.00 p	0.00 q	0.00 m	0.00 c
GM1 + IBA 300 mg L^{-1}	0.00 n	0.00 p	0.00 q	0.00 m	0.00 c
GM1 + IBA 600 mg L^{-1}	3.50 lm	1.33 p	0.54 pq	0.28 lm	33.33 c
GM1 + IBA 900 mg L^{-1}	4.50 k-m	3.58 o	1.12 n-p	0.56 j-l	0.00 c
GM2 + Undipped	0.00 n	0.00 p	0.00 q	0.00 m	0.00 d
GM2 + IBA 300 mg L^{-1}	3.57 lm	5.35 no	1.03 op	0.53 j-l	33.33 c
GM2 + IBA 600 mg L^{-1}	5.00 j-l	8.69 kl	1.63 m-o	0.79 i-l	33.33c
GM2 + IBA 900 mg L^{-1}	7.00 g-i	12.14 ij	2.82 i-k	1.37 f-h	0.00 d
GM3 + Undipped	3.13 m	4.78 no	0.84 o-q	0.45 k-m	33.33 c
GM3 + IBA 300 mg L^{-1}	5.60 i-k	11.14 j	1.35 m-p	0.64 j-l	33.33 c
GM3 + IBA 600 mg L^{-1}	7.67 gh	14.16 g-i	1.91 l-n	0.87 h-k	33.33 c
GM3 + IBA 900 mg L^{-1}	9.63 ef	16.35 d-g	3.33 g-j	1.68 e-g	66.66 b
GM4 + Undipped	7.77 k-m	6.04 mn	1.58 m-o	0.82 i-k	33.33 c
GM4 + IBA 300 mg L^{-1}	7.53 gh	14.53 f-h	2.72 i-l	1.30 f-i	33.33 c
GM4 + IBA 600 mg L^{-1}	9.53 ef	16.21 d-g	3.30 g-j	1.64 e-g	66.66 b
GM4 + IBA 900 mg L^{-1}	12.50 cd	17.40 c-e	4.72 de	2.30 cd	66.66 b
GM5 + Undipped	3.60 lm	5.49 no	1.02 op	0.47 k-m	0.00 d
GM5 + IBA 300 mg L^{-1}	6.73 hi	13.45 hi	2.04 k-m	0.95 h-k	33.33 c
GM5 + IBA 600 mg L^{-1}	8.57 fg	14.90 f-h	2.58 j-l	1.21 ghi	33.33 c
GM5 + IBA 900 mg L^{-1}	11.17 de	16.34 d-g	3.92 e-g	1.82 d-f	33.33 c
GM6 + Undipped	6.47 h-j	7.75 k-m	2.96 h-j	1.31 f-i	33.33 c
GM6 + IBA 300 mg L^{-1}	9.50 ef	16.24 d-g	4.27 ef	2.02 de	66.66 b
GM6 + IBA 600 mg L^{-1}	12.43 cd	17.63 b-e	5.24 cd	2.21 cd	88.88 a
GM6 + IBA 900 mg L^{-1}	14.50 ab	19.69 ab	6.30 ab	2.98 ab	100.00 a
GM7 + Undipped	7.07 g-i	8.82 k	3.79 f-h	1.78 d-f	66.66 b
GM7 + IBA 300 mg L^{-1}	10.10 ef	16.70 c-f	4.72 de	2.25 cd	66.66 b
GM7 + IBA 600 mg L^{-1}	12.60 cd	17.77 a-c	5.72 bc	2.67 a-c	88.88 a
GM7 + IBA 900 mg L^{-1}	15.47 a	20.81 a	6.67 a	3.19 a	100.00 a
GM8 + Undipped	6.03 h-k	6.56 l-n	2.07 k-m	1.01 h-j	0.00 d
GM8 + IBA 300 mg L^{-1}	8.67 fg	15.54 e-h	3.51 f-i	1.61 e-g	33.33 c
GM8 + IBA 600 mg L^{-1}	10.97 de	17.15 c-e	4.32 ef	2.02 de	33.33 c
GM8 + IBA 900 mg L^{-1}	13.50 bc	18.40 b-d	5.41 cd	2.55 bc	66.66 b

HSD ($P \leq 0.05$) for root length = 1.6809; Root thickness = 0.5678; Fresh weight of roots = 0.8702; Dry weight of roots = 0.1316; Survival percentage = 15.54; * Means not sharing a same letter are significantly different at $P \leq 0.05$.

References

Abdi, H., & Williams, L. J. (2010). Tukey's Honestly Significant Difference (HSD) Test. In: J.S. Neil (Eds.). Encyclopedia of Research Design. California, USA: Thousand Oaks.

Abebe, H. (2017). Effect of cane length and rooting media on rooting and shoot growth of grape (*Vitis vinifera* L.) stem cuttings at Raya valley, Ethiopia (Unpublished Master's thesis) Hawassa University College of Agriculture, Ethiopia.

Adugna, M., Belew, D., & Tilahun (2015). Influence of rooting media and number of nodes per stem cutting on nursery performance of vanilla (*Vanilla planifolia* syn. fragrans). *Journal of Horticulture and Forestry, 7*(3), 48–56.

Ahn, H. K., Richard, T. L., & Glanville, T. D. (2008). Laboratory determination of compost physical parameters for modeling of airflow characteristics. *Waste Management, 28*(3), 660–670.

Babaie, H., Zarei, H., Nikdel, K., & Firrozjai, M. N. (2014). Effect of different concentrations of IBA and time of taking cutting on rooting, growth and survival of Ficus binnendijkii Amstel Queen cuttings. *Notulae Scientia Biologicae*, *6*(2), 163–166.

Beniwal, B., Kumar, N., Kour, H., Pathlan, N., & Chhabra, A. (2022). The influence of plant growth regulators on the rooting of Grapes (*Vitis venifera*) wood cutting cv. Thompson Seedless. *The Pharma Innovation Journal, 11*(5), 1119–1122.

Chandramouli, H. (2001). Influence of growth regulators on the rooting of different types of cuttings in *Bursera*

penicilliatai DC (Unpublished Master's thesis) University of Agriculture Sciences, Banglore, India.

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

Dave, R., Rao, T., & Nandane, A. (2016). RSM-Based optimization of edible-coating formulations for preserving post-harvest quality and enhancing stability of Phalsa (*Grewia asiatica* L.). *Journal of Food Processing and Preservation*, *40*(3), 509–520.

Deb, P., Bhowmick, N., Ghosh, S. K., & Suresh, C. P. (2009). Effect of different concentrations of naphthalene acetic acid (NAA) and indole butyric acid (IBA) on success and growth of semi hardwood cutting of lemon (*Citrus limon*). *Environment and Ecology*, *27*, 1130–1131.

Dhatrika, R. T., Srihari, D., Dorajeerao, A. V. D., & Subbaramamma, P. (2018). Effect of rooting media and IBA treatments on success of propagation through terminal cuttings in guava (*Psidium guajava* L.) cv. Taiwan pink. *Journal of Pharmacognosy and Phytochemistry*, *7*(5), 2953–2959.

Diwaker & Katiyar, P. N. (2013). Regeneration of kaghzi lime (*Citrus aurantifolia* Swingle) through stem cuttings with the aid of IBA and PHB. *Hortiflora Research Spectrum*, *2*, 271–273.

Geiss, G., Gutierrez, L., & Bellini, C. (2009). Adventitious root for rotation: New insight and perspective. *Annual Plants Review*, *37*, 48–56.

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

Gill, J. K., Singh, H, Thakur, A., & Jawandha, S. K. (2014). Studies on simultaneous grafting and rooting of peach on Florda guard rootstock. *HortFlora Research Spectrum*, *3*(3), 259–262.

GOP. (2019). Fruit, Vegetables and Condiments Statistics of Pakistan. Ministry of National Food Security and Research, Islamabad.

Hakim, A., Jaganath, S., Honnabyraiah, M. K., Kumar, S. M., Kumar, S. A., & Dayamani, K. J. (2018). Influence of biofertilizer and auxin on growth and rooting of pomegranate (*Punica granatum* L.) cuttings. *International Journal of Current Microbiology and Applied Sciences*, *7*(2), 1187–1193.

Hartmann, H. T., & Kester, D. E. (1983). Plant propagation. Principles and Practices (5th Eds.). New Jersy, USA: Prentice-Hill, INC Engleood Cliffs.

Ingle, M. R., & Venugopal, C. K. (2009). Effect of different growth regulators on rooting of stevia (*Stevia rebaudiana* Bertoni) cuttings. *Karnataka Journal of Agricultural Sciences*, *22*, 460–461.

Ismail, S. M., & Hussain, I. A. (2007). Effect of indole butyric acid and types of cuttings on the root initiation of *Ficus hawaii*. *Sarhad Journal of Agriculture*, *23*(4), 919–925.

Jackson, D. I. (1962). The response of *Oxalis latifolia* to hormone herbicides. *Weeds*, *10*, 23–25.

Kathortia, R. K., & Singh, S. (1995). Regeneration of roots in phalsa (*Grewia asiatica* L.) stem cuttings as influenced by maturity of wood and root promoters. *Advances of Horticulture Forestry*, *4*, 35–44.

Kaur, A., Kaur, K., & Kaur, A. (2018). Role of IBA and PHB on success of cuttings of fig cv. brown Turkey. *Asian Journal of Science and Technology*, *9*(5), 8237–8241.

Khemiss, F., Mazgar, G., Moshtaghie, A. A., & Saidane, D. (2006). Study of the effect of aqueous extract of Grewia tenax fruit on iron absorption by everted gutsac. *Journal of Ethnopharmacology*, *103*(1), 90–98.

Kishorbhai, B. S. (2014). Effect of plant growth regulators on propagation of fig (*Ficus carica* L.) by hardwood and semi hardwood cuttings. (Unpublished Master's thesis) Navsari Agriculture University.

Kreiken, W. H., Breteler, H., Visser, M. H. M., & Mavridou, D. (1993). Role of the conversion of IBA into IAA on root generation in apple: Introduction of a test system. *Plant Cell Reproduction*. *12*, 203–206.

Kumar, A., & Jadhav, S. (2007). Studies on propagation of phalsa (*Grewia asiatica* L.) by cutting. (Unpublished Master's thesis) University of Agriculture Sciences, Dharwad, Karnataka, India.

Leonardi, C., Ruggeri, A., & Malta, S. (2001). Hormone effects on *in vitro* proliferation and rooting of Grevillea explants. *Scientia Horticulturae*, *90*, 335–341.

Manjunath, D. R., Patil, R. T., BC, P., & Mukund Shiragur, S. K. T. (2022). Effect of auxins on rooting of terminal cuttings of chrysanthemum (*Dendranthema grandiflora*). *The Pharma Innovation Journal*, *11*(3), 1436–1439.

Mehra, U., Negi, M., & Awasthi, M. (2019). Effect of rooting media and indole-3-butyric acid on rooting of cuttings in persimmon (*Diosyros kaki* L.) cv. Fuyu. *Journal of Pharmacognosy and Phytochemistry*, *8*(3), 400–403.

Mehta, N. S., Bhatt, S. S., Kumar, J., Kotiyal, A., & Dimri, D. C. (2016). Effect of IBA on vegetative growth and multiplication rate in stem cuttings of pear rootstocks. *HortFlora Research Spectrum*, *5*(3), 242–245.

Moodie, D., Smith H. W., & Mc-Creary, R. A. (1959). *Laboratory Manual for Soil Fertility*. Washington State College Press, Pullman, Washington. pp. 31-39.

Mousa, G. T., Abdul-Hafeez, E. Y., & Ibrahim, O. H. M. (2015). Response of gardenia plants grown under various growth media and ferrous sulphate application. *Pakistan Journal of Agricultural Sciences*, *52*(3), 651–658.

Navjot, S., & Kahlon, P. S. (2002). Effect of type of cuttings and IBA on rooting in cuttings and plant growth in pomegranate (*Punica granatum* L.) cv. Kandhari. *Horticultural Journal*, *15*(3), 9–16.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Department of Agriculture, 939.

Patel, H. R., Patel, M. J., & Singh, S. (2017). Effect of different levels of IBA and NAA on rooting of hardwood and semi hardwood cutting in fig. *International Journal of Agricultural Science and Research*, *7*(4), 519–524.

Porghorban, M., Moghadam, E. G., & Asgharzadeh, A. (2014). Effect of media and indole butyric acid (IBA) concentrations on rooting of Russian olive (*Elaeagnus angustifolia* L.) semi-hardwood cuttings. *Indian Journal of Fundamental and Applied Sciences*, *4*(3), 517–522.

Qadri, R., Azam, M., Khan, S. B., Khan, Imran-ul-Haq, I., Yang, Y., Jahangir, M. M., Ghani, M. A., & Moazzam, M. (2018). Growth performance of guava cutting under different growing media and plant cutting taking height. *Bulgarian Journal of Agricultural Science*, *24*(2), 236–243.

Rajangam, J., Sankar, C., & Kavino, M. (2022). Effect of IBA on rooting of Acid lime (*Citrus aurantifolia*) stem cuttings cv. PKM1. *The Pharma Innovation Journal*, *11*(2), 13–17.

Ram, R. B., Kumar, P., & Kumar, A. (2005). Effect of IBA and PHB on regeneration of pomegranate (*Punica granatum* L.) through stem cuttings. *New Agriculturist*, *16*, 113–122.

Raviv, M. (2005). Production of high-quality composts for horticultural purposes. A mini-review. *Horticulture Technology*, *15*, 52–57.

Reddy, R.V. K., Reddy, C. P., & Goud, P. V. (2008). Effect of auxins on the rooting of fig (*Ficus carica* L.) hardwood and semi hardwood cuttings. *Indian Journal of Agriculture and Research*, 42, 75–78.

Sardoei, A. S. (2014). Effect of different media of cuttings on rooting of guava (*Psidium guajava* L.). *European Journal of Experimental Biology*, *4*(2), 88–92.

Sardoei, A. S., Fahraji, S. S., & Ghasemi, H. (2014). Effect of different growing media on growth and flowering of zinnia (*Zinnia elegans*). *International Journal of Advanced Biological and Biomedical Research*, *2*(6), 1894–1899.

Sejal, B., Kanzaria, D. R., Parasana, J. S., Patel, H. N., & Patel, S. (2022). Impact of GA_3 and growing media on seed germination and seedling parameters of Khirni (*Manilkara hexandra* Roxb.). *The Pharma Innovation Journal*, *11*(2), 1907–1911.

Shah, M., Khattak, A. M., & Amin, N. U. (2006). Effect of different growing media on the rooting of ficus binnendijkii 'amstel queen'cuttings. *Journal of Agriculture and Biological Sciences*, *1*(3), 15–17.

Shahab, M., Ayub, G., Rehman, A., Rashid, A., Jamal, A., & Ali, J. (2013). Assessment of IBA (Indole butyric acid) levels and planting time for rooting and growth of alstonia cuttings. *Journal of Natural Sciences and Research*, *3*, 59–67.

Sharma, K.V., & Sisodia, R. (2010). Radio-protective potential of *Grewia asiatica* (Phalsa) fruit extract in mice testis. *PharmacologyOnLine*, *1*, 487–495.

Singh, A. K., & Bahadur V. (2015). Effect of NAA and IBA on rooting and establishment of hardwood cutting in Phalsa (*Grewia asiatica* L.). *The Allahabad Farmer*, *2*, 199–201.

Singh, B., Singh, S., & Singh, G. (2011). Influence of planting time and IBA on rooting and growth of pomegranate (*Punica granatum* L.) Ganesh cutting. *Acta Horticulturae*, *890*, 183–188.

Singh, K. K., & Singh, S. P. (2018). Cultivation and utilization in phalsa (*Grewia asiatica* L.) under Garwhwal Himalyas region. *Journal of Medical Plant Studies*, *6*(1), 254–256.

Singh, K. K., & 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.

Sinha, N. K., Kumar, S., Santra, P., Raja, P., & Mertia, D. (2014). Temporal growth performance of Indian myrrh (*Commiphora wightii*) raised by seedlings and cuttings from same genetic stocks in the extremely arid Thar dessert of India. *The Ecoscan*, *8*, 241–244.

Thota, S., Madhavi, K., & Vani, V. S. (2012). Effect of type of cuttings and IBA concentrations on the propagation of fig. *International Journal of Tropical Agriculture*, *32*, 89–94.

Verma, P., & Chauhan, P. S. (2015). Effect of storage conditions (growth chambers) and IBA treatments on rooting of cuttings of apple clonal rootstocks merton 793 in net house conditions. *The Bioscan*, *10*, 1049–1052.

Wahab, F., Nabi, G., Ali, N., & Shah, M. (2001). Rooting response of semi hardwood cuttings of guava (*Psidium guajava* L.) to various concentrations of different auxins. *Online Journal of Biological Sciences*, *1*(4), 184–187.

Waheed, A., Hameed, F. S., Abbasi, F. M., Alam, S., Shah, A. H., Ahmad, N., Naheed, Z., Ali, H., & Khan, N. (2015). Effect of indole butyric acid on early root formation (Tomato "Sahil" hybrid) cuttings. *Journal of Material and Environmental Sciences*, *6*(1), 272–279.

Wani, T. A., Pandith, S. A., Rana, S., Bhat, W. W., Dhar, N., Ranzdan, S., Chandra, S., Kitchlu, S., Sharma, N., & Lattoo, S. K. (2015). Promiscuous breeding behavior in relation to reproductive success in *Grewia asiatica* L. *Flora-Morphology, Distribution, Functional Ecology of Plants*, *211*, 62–71.

Wazir, M. G., Amin, N. U., Ishtiaq, M., Aziz, A., & Khan, I. A. (2003). Effects of different soil media on the growth of *Dracaena dermensis* var. Janet craige cuttings. *Sarhad Journal of Agriculture*. *19*, 31–40.

Yusnita, Y., Jamaludin, J., Agustiansyah, A., & Hapsoro, D. (2017). A combination of IBA and NAA resulted in better rooting and shoot sprouting than single auxin on malay apple (*Syzgium malaccense* L.) stem cuttings. *AGRIVITA, Journal of Agricultural Science*, *40*(1), 80–90.