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Research Paper

Studies on the Different Concentration of IBA on Hardwood Cuttings of Pomegranate (*Punica granatum* L.) cv. Wonderful

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A B S T R A C T

The present investigation entitled "Studies on the different concentration of IBA on hardwood cuttings of pomegranate (*Punica granatum* L.) cv. Wonderful" was carried out during 2016-2017 at Mata Gujri College Farm, Fathegarh Sahib. Pomegranate is most important deciduous fruit crop for both tropical and subtropical regions of our country. On the basis of result optimum present investigation, it can be concluded that IBA 3000 ppm concentration significantly increase numbers of roots, numbers of shoots, survival percentages, dry weight of roots and shoots has maximum recorded compared to concentrations of IBA in distilled and simple water. Therefore, the present study has demonstrated the IBA 1500 and 3000 quick dip were found to best in all the parameters studied.

***Key words*:** *Punica granatum* L., Wonderful, IBA, Quick dip, Cutting

Pomegranate (*Punica granatum* L.) belongs to family Punicaceae and it is a fruit bearing deciduous shrub or small tree. It is a semi-arid fruit crop. In India, it is cultivated in states of Maharashtra, Gujarat and to limited extent in Rajasthan, Uttar Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu. Pomegranate fruits can be consumed as fresh or in processed forms like bottled juice, syrup and jelly. They are highly valued in India for its dietic and medicinal properties. Pomegranate is a medicinal fruit because of some antioxidants and vitamins (Niacin and Riboflavin). The rind of the fruit and the bark of the pomegranate tree are used as a traditional remedy against diarrhea, dysentery and intestinal parasites. Pomegranate seeds are excellent source of dietary fiber. Pomegranate fruit has excellent keeping quality, fine table and therapeutic values along with considerable pharmacological properties like antimicrobial, antiviral and antimutagenic effects [1] which made this fruit more lucrative and remunerative in the market. Pomegranate is propagated by sexual and asexual means and propagation through seeds is popular in many parts of India, since it is easy but it shows a great variability with respect to tree vigour, precocity and quality of fruits due to cross pollination [2]. Therefore, vegetative method of propagation is advocated in place of seed propagation to eliminate the high degree of variability. Vegetative propagation in pomegranate is utmost desirable to propagate true to type plants. Though air layering is successful in pomegranate but it is expensive, cumbersome and it adversely affects the growth of the mother trees. Propagation of pomegranate by cuttings is the most convenient and cheapest method to obtain a fully developed and stronger trees in considerably less time [3].

Rooting medium plays an important role in rooting of cuttings and for further growth and development of cuttings. The medium should be sufficiently firm and dense to hold the cuttings in place during propagation. It also provides moisture and air to the base of cutting [4]. It should be porous to drain out excess water and permit aeration. In order to reduce the high mortality of rooted cuttings under field conditions, it is highly desirable to build a healthy and well-developed root system for enabling better field establishment of pomegranate trees by treating with suitable plant growth regulators.

Indole-3-Butyric Acid is the synthetic plant hormone. Which is active in inhibiting axillary bud break on developing shoots and stimulates the root initiation [5]. It promotes cell elongation which helped to increase in root length. It is a leading plant hormone used to generate new roots in the cloning of plants through cuttings. Some factors that affect the rooting of pomegranate cuttings are physiological condition of the parent plant, cutting type, season of cutting, rooting medium and use of rooting hormones [6]. Suitable medium for cutting establishment should have enough moisture and good aeration. Use of optimum rooting media and optimum concentration of IBA would help in rapid multiplication of pomegranate cuttings undertaken in pomegranate cv. Wonderful under shade net conditions.

MATERIALS AND METHODS

The present investigation entitled "Studies on the different concentration of IBA on hardwood cuttings of pomegranate (*Punica granatum* L.) cv. Wonderful" was carried out during 2016-2017 at Mata Gujri College Farm, Fathegarh Sahib. The details relating to materials used and metrological adapted for studies are described under following

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headings. The location of study was Experimental Farm, Mata Gujri College (Fathegarh Sahib) situated at latitude 30° 56'N and longitude 76° 40' E and at a height of 255 meters above mean sea level. The climate of Fathegarh Sahib is characterized by subtropical semi-arid type of climate with three distinct seasons namely, hot and dry summer, monsoon and cold winter. The minimum temperature may go down to 4°C in December-January while the maximum temperature may go as high as 45°C in May-June. Soil samples were collected randomly around the root zone of plants up to a depth of 20 cm from the field to judge the fertility status of soil before laying out the experiment. The composite sample was prepared which analyzed for various soil characteristics in order to get information about the nutrient status of the soil with following observations.

Table 1 Initial fertility status of soil

Particular	Value obtained	Method employed
Soil pH	7.59	1:2 soil: water suspension, with the help of digital pH meter [7].
Soil organic carbon (%)	0.51	Walkey and black method (1934)
Soil EC (dsm^{-1})	0.33	With the help of digital conductivity meter
Available N (kg ha^{-1})	220.1	With the help of Ion Chromatography
Available P_2O_5 (kg ha^{-1})	22.1	With the help of Ion Chromatography
Available K_2O (kg ha^{-1})	116.3	With the help of Ion Chromatography

Treatment details are described below:

Cultivar	:	Wonderful
Number of replications	:	Three
Experimental design	:	Randomized block design
Number of treatments	:	Eight
Number of cuttings per treatment	:	36
Method of application	:	Soaking in IBA solution for quick dip and long time

Table 2 Treatment details

Treatment code	Treatments details
T_1	IBA 3000 ppm quick dip
T_2	IBA 1500 ppm quick dip
T_3	IBA 1000 ppm quick dip
T_4	IBA 300 ppm dip for long time
T_5	IBA 200 ppm dip for long time
T_6	IBA 100 ppm dip for long time
T_7	IBA Distilled water dip long time
T_8	IBA Simple water dip for long time

Preparation of cuttings: The cuttings of pomegranate cv. Wonderful were brought from the Mangeana (Centre of Excellence for Fruit Crops) Indo Israel Forum (Haryana) Sirsa district. Cuttings were taken from properly matured one-year old shoots which were again cut in to small pieces having 4-6 nodes each. Uniform sized (20 cm in length and 0.8 to 0.9 cm thickness) cuttings were taken and the leaves were removed from the cuttings and trimmed to a manageable length by removing the portions from both ends of cutting just above and below the nodes. A slant cut was given at the basal end of the cuttings to expose maximum cambium surface area for effective rooting.

Preparation of growth regulators: The required concentrations of growth regulators IBA (3000 ppm, 1500 ppm, 1000 ppm, 300 ppm, 200 ppm and 100 ppm) was prepared by dissolving 3 g, 1.5 g, 1 g, 300 mg, 200 mg, and 100 mg of IBA in few ml of 80% methanol and the final volume was made one litre by adding distilled water in 1000 ml volumetric flasks.

Treatment of cuttings: The basal part (1-2 cm) of the cutting were dipped in growth regulator solutions of IBA (3000 ppm, 1500 ppm, 1000 pp, 300 ppm, 200 ppm and 100 ppm concentrations) for different time. Subsequently, they were air dried for 15 minutes and planted in poly bags containing respective rooting media upto a depth of 1-2 nodes. The rooting media around the base of the cutting was gently pressed to hold the cutting in right place, to eliminate air pockets and make sure that base of the cutting was in good contant with the moist rooting media. A slant cut was given at basal end of the cuttings to expose maximum cambium surface area for inducing effective rooting.

Aftercare: Sprinkler system was used for regular watering of cutting planted in polybags. The rooting medium was drenched with carbendazim (0.15%) at fortnightly intervals to check the disease incidence.

Observations recorded

Three sprouted cuttings were selected randomly from each treatment in each replication. These three cuttings were labeled for recording the observations throughout the study.

Root parameters: The planted cuttings were allowed to root for 90 days. Following observations were made at the end of 90th day by removing cuttings carefully from the polyethylene bags without any damage to the root system for recording the data. Polyethylene bags were watered profusely before removing the cuttings. Polyethylene bags were removed carefully and the cuttings along with ball of earth were placed in water to remove the soil particles and then further washed thoroughly with water to clean roots.

Percentage of rooted cuttings: This parameter was recorded at 90 days after planting by using the following formula.

$$\text{Percentage of rooted cuttings} = \frac{\text{No. of cuttings rooted}}{\text{Total no. of cuttings}} \times 100$$

Survival percentage of rooted cuttings: The total number of cuttings survived under each treatment in each replication was recorded at 90 days after planting and the survival percentage of rooted cuttings was calculated.

Number of roots per cutting: The number of adventitious roots per cutting was counted under each treatment and the mean was expressed as the number of roots per cutting. This excludes lateral roots present on the adventitious roots.

Length of the longest root per cutting (cm): The length of longest root of each rooted cutting was measured with the help of measuring scale from the base to the tip of root and length was calculated and expressed in centimeters.

Fresh weight of the roots (g): Fresh weight of the roots per cutting was taken with the help of an electronic balance and the mean values were calculated.

Dry weight of roots per cuttings (g): The roots were completely dried in hot air oven at 55°C until attain to a constant weight and then dry weights were recorded with electronic balance and the dry weight values were calculated.

Shoot characteristics

Number of days taken for first sprouting: The planted cuttings were observed daily under each treatment and the number of days to first sprouting was recorded and their mean was used to calculate the days taken for first sprout to appear.

Number of shoots per cutting: The number of sprouts was recorded on each cutting sample after 45 and 90 days after planting and their mean was calculated.

Length of the longest shoot per cutting (cm): On the 45^{th} and 90^{th} day after planting, the length of the longest shoot was measured on each cutting sample with the help of a scale and their mean was calculated.

Number of leaves per cutting: The number of leaves present on each cutting sample was counted after 45 and 90 DAP and their mean was calculated.

Leaf area per cutting (cm^2): Leaf area per sprouted cutting under each treatment and in each replication was measured with the help of leaf area meter and the mean leaf area was calculated and it was expressed in centimeter square.

Fresh weight of shoots (g): Fresh weight of the shoots per cutting was taken with the help of an electronic balance and the mean values were calculated.

Dry weight of shoots (g): The shoots were completely dried in hot air oven at 55°C for three days to arrive a constant weight and then dry weights were recorded with electronic balance and the mean shoot dry weight values were calculated.

Root to shoot ratio (dry weight basis): The root-shoot ratio is usually given as the ratio of the dry weight of the roots to the dry weight of shoot.

$$\text{Root/shoot ratio} = \frac{\text{No. of cuttings rooted}}{\text{Total no. of cuttings}}$$

Biochemical parameters: Biochemical analysis was done for starch, total sugars, carbohydrates, proteins and phenols. At the time of preparation of cuttings for planting, a sample of 100 g each of the plant material from basal 1-1.5 cm portion of hardwood cuttings was collected and oven dried, then ground to fine powder for the purpose of all biochemical estimations. Similarly, another lot of plant sample over a predetermined period of time (90 DAP) was also collected for the biochemical analysis.

Starch (%): The percentage of starch content was determined by using the method outlined by [8].

Total sugars (%): For estimation of total sugars, 500 mg of oven dried finely ground sample was extracted successively thrice using 80 per cent ethanol. A known volume (1 ml) of this extract was taken in a test tube and alcohol was evaporated on a boiling water bath. Distilled water was added and volume made up to 10 ml. The total sugar content in the alcohol-free extract with 1 N HCl on a hot water bath for 20 minutes at 50°C and after neutralizing it with 1N NaOH, the total sugars were estimated by anthrone method [9]. The results were expressed in percentage on dry weight basis.

Carbohydrates (%): The total carbohydrates were calculated by summing up the total sugars and starch. This was expressed in percentage on dry weight basis.

Statistical analysis

The data was analyzed using computer software programmed by the method of variance outlined by [10]. The mean values were calculated on various root and shoot parameters was tabulated and analyzed statistically by using Factorial Randomized Block Design. The differences among the treatmental means was statistically tested at 5% level of significance.

RESULTS AND DISCUSSION

Percentages of rooted cuttings

It is evident from the present investigation that significant variation exists among the IBA concentration with respect to various percentages of rooted cuttings. The data indicated that there were significant differences among the IBA concentration for percentage of rooting cutting. The maximum percentages of rooting were registered in cv. Wonderful 3000 ppm IBA T_1 (64.10%) and minimum was registered in treatment T_8 (distilled water) (36.11%). It could be attributed to the increased doses of IBA could encourage the rooting ability of cutting by changing the structure of root [11]. The presence of leaves on cuttings also play an important role in the initiation of roots in many plant species. Leaves considerably influence the rooting of cuttings because of their ability to produce endogenous auxin, carbohydrates by means of photosynthesis [12]. The IBA might enhanced the rooting by increase of internal free IBA, or synergistically modify the action of IAA or due to synthesis of endogenous IAA [13]. The treatment of cuttings with increasing concentrations of IBA could combined with endogenous IBA already present in the cuttings leads to optimization of IBA levels and consequently improved the percentage of rooting in cuttings [14].

Survival percentages of rooted cuttings

It is evident from the present investigation that significant variation exists among the IBA concentration with respect to survival percentages of rooted cuttings. The data indicated that there were significant differences among the IBA concentrations for survival % of rooting cutting. The maximum survival % of rooting was registered in cv. Wonderful treatment T_1 (3000 ppm) IBA (59.55%) and minimum was registered in treatment T_8 distilled water (45.46%). it might due to development of effective root system and increase in number and length of roots per cutting as influenced by the uptake of nutrients and water [15]. The survival of the sprouted cuttings might be directly linked to the formation of adventitious roots on cuttings. the results are in agreement with the earlier findings of [16] in guava, [17], [18] in pomegranate and [19] in pineapple

Number of roots per cuttings

It is evident from the present investigation that significant variation exists among the IBA concentration with respect to number of roots per cuttings. The data indicated that there were significant differences among the IBA concentration for numbers of roots per cutting. The maximum was number of roots per cutting registered in cv. Wonderful treatment T_1 3000 ppm IBA (12.28) and minimum was registered in treatment T_8 distilled water (6.41). Sandy loamy soil has a high-water holding capacity which helps in high absorption of water and nutrients [20] from the medium thereby increased the number of roots. The maximum number of roots was observed with IBA 3000 ppm which might be due to hormonal effect leading to accumulation of internal substances and their downward movement. Induction of maximum number of roots in IBA treated cuttings might be due to the fact that stimulation of cambial activity involved in root initiation by growth regulators in many species [21]. IBA promote adventitious root formation by their ability to promote the initiation of lateral roots and also enhanced the transport of carbohydrates to basal portion of the cuttings. The maximum number of roots in IBA treated cuttings at 3000 ppm might be due to its effect on cell wall plasticity, which accelerates cell division stimulates callus development and root growths [22]. The observations are in close proximity to the findings of [23] in apple, [24] in sour orange, [25] in guava, [26] in fig, [27] in pomegranate and [28] in grape.

Table 1 Effect of different IBA concentration on survival percentages of rooted cuttings, percentages of rooted cuttings and numbers of roots per cuttings of pomegranate cv. Wonderful

Treatment code	Treatments detail	Percentages of rooted cuttings (%)	Survival % of rooted cuttings	No. of roots per cuttings
T_1	IBA 3000 ppm	64.10	59.55	12.28
T_2	IBA 1500 ppm	60.16	57.55	11.35
T_3	IBA 1000 ppm	56.05	55.52	10.4
T_4	IBA 300 ppm	52.11	53.53	9.59
T_5	IBA 200 ppm	48.16	51.53	8.79
T_6	IBA 100 ppm	44.22	49.5	8.00
T_7	Simple water	40.14	47.47	7.2
T_8	Distilled water	36.11	45.46	6.41
	Mean	50.13	52.51	9.25
	CD at 5%	2.85	2.23	0.35

Table 2 Length of the longest root per cutting (cm) and fresh weight of roots per cutting of pomegranate cv. Wonderful

Treatments detail	Length of the longest root per cutting (cm)	Fresh weight of roots per cutting (g)
T_1: IBA 3000 ppm	8.79	1.72
T_2: IBA 1500 ppm	8.13	1.61
T_3: IBA 1000 ppm	7.47	1.5
T_4: IBA 300 ppm	6.81	1.38
T_5: IBA 200 ppm	6.15	1.26
T_6: IBA 100 ppm	4.96	1.15
T_7: Simple water	3.84	1.03
T_8: Distilled water	3.49	0.91
Mean	6.21	1.32
CD at 0.05%	0.39	0.12

Length of the longest root per cutting (cm)

It is evident from the present investigation that significant variation exists among the IBA concentration with respect to length of the longest root per cutting. The data indicated that there were significant differences among the IBA concentrations on the length of the longest root per cutting. The maximum length of the longest root per cutting registered in cv. Wonderful T_1 3000 ppm IBA (8.79) and minimum (3.49) was registered in treatment T_8 distilled water. The variation in length of the longest root per cuttings in different treatment may be due to cuttings grown in sandy loamy soil gave maximum length of root might be due to better texture and porosity of sandy loam, as it enables the downward movement of water and nutrients and leads to easy penetration of roots [29] in the medium and also being a well-drained media as it promoted better rooting characters [30]. The maximum root length was observed in cuttings treated with IBA 3000 ppm than in cuttings treated with dis might be distilled water due to an early initiation of roots at higher concentrations of IBA and therefore more utilization of the nutrients due to early formation of the roots [31]. The action of IBA activity, which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances at the base of cuttings, and resulted in accelerating cell elongation and cell division [32]. Similar results were reported by [33], [34] in pomegranate, [35] in wild passion fruit, [36] in grape.

Table 3 Effect of different IBA concentration on dry weight of roots per cuttings of pomegranate cv. Wonderful

Treatments detail	Dry weight of roots per cuttings (g)		Mean
	4 DAP	8 DAP	
T_1: IBA 3000 ppm	1.37	1.22	1.29
T_2: IBA 1500 ppm	1.31	1.16	1.23
T_3: IBA 1000 ppm	1.25	1.10	1.17
T_4: IBA 300 ppm	1.19	1.04	1.11
T_5: IBA 200 ppm	1.13	0.985	1.05
T_6: IBA 100 ppm	1.07	0.92	0.99
T_7: Simple water	1.00	0.86	0.93
T_8: Distilled water	0.91	0.79	0.85
Mean	1.15	1.01	1.08
CD at 0.05%	0.072	0.082	

Fresh weight of roots (g)

It is evident from the present investigation that significant variation exists among the IBA concentration with respect to fresh weight of roots per cuttings. The data indicated that there were significant differences among the IBA concentrations on the fresh weight of root per cutting. The maximum (1.72) g fresh weight of root per cutting was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (0.91) was registered in treatmentT_8 distilled water. The variation in fresh weight of root per cutting different treatment also increase in fresh weight of roots was probably

due to increased root number, length of roots which is evident from the varietal and climatic differences during the study in relation to chemical regimes were reflected in producing heavier roots which in turn increased fresh weight of roots. The increase in numbers of roots and length of roots have directly influenced the fresh weight of roots. These findings are in concurrence with the results of [37] in *Vitis rupestris*, [38] in cape gooseberry and [39] in pomegranate.

Table 4 Effect of different IBA concentration on number of days taken for first sprouting (%) of pomegranate cv. Wonderful

Treatments detail	Number of days taken for first sprouting (%)		Mean
	50%	100%	
T_1: IBA 3000 ppm	9.33	12.33	10.83
T_2: IBA 1500 ppm	10.33	13.33	11.83
T_3: IBA 1000 ppm	11.33	14.33	12.83
T_4: IBA 300 ppm	12.33	15.33	13.83
T_5: IBA 200 ppm	13.66	16.66	15.16
T_6: IBA 100 ppm	14.33	17.33	15.83
T_7: Simple water	15.33	18.33	16.83
T_8: Distilled water	16.33	19.33	17.83
Mean	12.87	15.87	14.37
CD at 0.05%	1.08	1.085	

Dry weight of roots (g)

It is evident from the present investigation that significant variation exists among the IBA concentration with respect to dry weight of roots. The data indicated that there were significant differences among the IBA concentrations on the dry weight of root per cutting. Significantly, the maximum (1.29) dry weight of root per cutting was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (0.85) was registered in treatment T_8 distilled water. The results indicate that cuttings of wonderful contained higher amounts of stored carbohydrates, when coupled with IBA increased the number of roots resulting in higher root dry matter accumulation. Cuttings of pomegranate treated with optimum concentration of IBA recorded more number of roots, which in turn increases dry weight. These results are in agreement with [40], [41] in Indian lavender, [42] in lemon, [43] in pomegranate and [44] in vanilla.

Table 5 Effect of different IBA concentration on number of shoots per cuttings of pomegranate cv. Wonderful

Treatments detail	Number of shoots per cuttings		Mean
	45 DAP	90 DAP	
T_1: IBA 3000 ppm	3.00	4.65	3.82
T_2: IBA 1500 ppm	3.49	4.99	5.90
T_3: IBA 1000 ppm	3.25	4.30	3.77
T_4: IBA 300 ppm	2.75	3.95	3.35
T_5: IBA 200 ppm	2.50	3.60	3.05
T_6: IBA 100 ppm	2.25	3.25	2.75
T_7: Simple water	2.05	2.90	2.47
T_8: Distilled water	1.75	2.55	2.15
Mean	2.63	3.77	3.20
CD at 0.05%	0.20	0.31	

Shooting parameters

Numbers of days taken for first sprouting

It is evident from the present investigation that significant variation exists among the IBA concentration with respect to numbers of days taken for first sprouting. The data indicated that there were significant differences among the IBA concentrations numbers of days taken for first sprouting. The maximum (10.83) numbers of days taken for first sprouting was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (17.83) was registered in treatment T_8 distilled water. The variation of numbers of days taken for first sprouting is due to minimum number of days to first sprouting was noticed in cuttings grown in a mixture of sandy loamy and FYM could be attributed to higher degree of fertility and water retaining capacity [45]. The minimum number of days to first sprouting was recorded in cuttings treated with higher concentration of IBA (3000 ppm) than with lower concentration of IBA (100 ppm) and distilled water. This might be due to presence of endogenous IBA in cuttings might have brought early breakage of bud dormancy and results in early bud sprouting [46]. Increase in the concentration of IBA significantly decreased the number of days to first sprouting of cuttings and earliness in sprouting might be due to better utilization of stored carbohydrates, nitrogen and other factors with the help of growth regulators [47]. Similar findings were reported by [48] in pomegranate, [49] in kiwifruit.

Table 6 Effect of different IBA concentration on length of the longest shoot per cutting (cm) of pomegranate cv. Wonderful

Treatments detail	Length of the longest shoot per cutting (cm)		Mean
	45 DAP	90 DAP	
T_1: IBA 3000 ppm	5.13	9.28	7.20
T_2: IBA 1500 ppm	4.75	8.56	6.65
T_3: IBA 1000 ppm	4.38	7.90	6.14
T_4: IBA 300 ppm	4.03	7.20	5.60
T_5: IBA 200 ppm	3.62	6.55	5.08
T_6: IBA 100 ppm	3.23	5.91	4.57
T_7: Simple water	2.88	5.20	4.04
T_8: Distilled water	2.50	4.58	3.54
Mean	3.81	6.89	5.35
CD at 0.05%	0.33	0.54	

Number of shoots per cuttings

It is evident from the present investigation that significant variation exists among the concentration with respect to number of shoots per cuttings. The data indicated that there were significant differences among the IBA concentrations on the numbers of shoots per cuttings. The maximum (3.82) numbers of shoots per cuttings was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (2.15) was registered in treatment T_8 distilled water. The maximum number of shoots which might be due to decomposition of lignins present in soil results in the formation of humic fractions [50] which imparts coco peat to retain more nutrients and helps in increasing the number of shoots per cutting. The cuttings treated with IBA 3000 ppm recorded greater number of shoots per cutting than the cuttings treated with IBA 100 ppm and distilled water which could be attributed to enhancement of physiological functions in the cuttings favourably [51] Earliness in sprouting, increase in number of sprouts and sprout length might be due to better utilization of stored carbohydrates, nitrogen and other factors with the aid of growth regulators [52].

Length of longest shoot per cutting (cm)

It is evident from the present investigation that significant variation exists among the concentration IBA with

respect to length of longest shoot per cutting. The maximum (9.28) length of longest shoot per cutting (cm) was registered in cv. Wonderful cutting treated with treatment T_1 3000 ppm IBA whereas minimum (4.58) was registered in treatment T_8 distilled water. These cuttings grown in a mixture of sandy loamy soil recorded the maximum length of sprout. It could be attributed to adequate supply of oxygen, water and nutrients by the soil for the proper functioning of root [53] which ultimately helps in absorption of more moisture and nutrients resulted in length of longest shoot. IBA activated shoot growth which might have resulted in elongation of stems and leaves through cell division accounting for more number of leaves and length of longest shoot. IBA 3000 ppm recorded the maximum number of roots per cutting enhanced the nutrient uptake and resulted in more photosynthate production. Food in the form of photosynthates provide required energy for cell division and cell elongation and it results in maximum shoot length [54].

Table 7 Effect of different IBA concentration on number of leaves per cutting of pomegranate cv. Wonderful

Treatments detail	Number of leaves per cutting		Mean
	45 DAP	90 DAP	
T_1: IBA 3000 ppm	26.80	29.71	28.21
T_2: IBA 1500 ppm	24.82	27.84	26.32
T_3: IBA 1000 ppm	22.83	25.81	24.32
T_4: IBA 300 ppm	20.75	23.80	22.27
T_5: IBA 200 ppm	18.78	21.80	20.29
T_6: IBA 100 ppm	16.98	19.90	18.43
T_7: Simple water	14.92	16.90	15.90
T_8: Distilled water	13.00	14.95	13.97
Mean	19.86	22.60	21.22
CD at 0.05%	1.27	1.25	

Numbers of leaves per cutting

It is evident from the present investigation that significant variation exists among the concentration with respect to numbers of leaves per cuttings. The data indicated that there were significant differences among the IBA concentration on the leaves numbers of leaves per cutting. The maximum (28.21) numbers of leaves per cutting was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (13.97) was registered in treatment T_8 distilled water. The maximum number of leaves was produced in cuttings grown in sand loamy soil and FYM might be due to superior root development in this medium. It could be attributed to higher moisture retention capacity, porosity and nutrient status of loamy [55]. The maximum number of leaves was produced in cuttings treated with IBA 3000 ppm might be due to activation of shoot growth which probably increased the number of nodes that leads to development of more number of leaves. The increase in number of leaves per cutting might be due to the reason that the leaves which are one of the production sites of natural IBA in the plants beside their main activities in photosynthesis, respiration and transpiration [56]. IBA at 3000 ppm produced healthier, lengthy roots which helps in absorbtion of water and nutrients that have great influence on production of more number of leaves by the cuttings. The increase in number of leaves with IBA 3000 ppm might be due to more number of roots, plant height and branches per cutting [57].

Leaf area per cutting (cm^2)

It is evident from the present investigation that significant variation exists among the concentration with respect to various shooting parameters. The data indicated that there were significant differences among the IBA concentration on the leaf area per cutting. The maximum (112.81) cm^2 leaf area per cutting was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (56.81) was registered in treatment T_8 distilled water. The cuttings treated with IBA 3000 ppm recorded the highest leaf area than the cuttings treated with IBA 100 ppm and distilled water. Ismail and Asghar (2007) reported that the cuttings treated with increasing concentrations of IBA produced more roots which increased nutrient uptake and aerial growth of the plants resulted in highest leaf area. There is a need to improve the photosynthetic rate and to produce more photosynthates by expanding their leaves and hence more leaf area was observed [58].

Table 8 Effect of different IBA concentration on fresh weight of shoots per cutting and leaf area per cutting cv. Wonderful

Treatments IBA details	Fresh weight of shoots per (g)	Leaf area (cm^2)
T_1: IBA 3000 ppm	2.93	112.81
T_2: IBA 1500 ppm	2.73	104.86
T_3: IBA 1000 ppm	2.53	96.81
T_4: IBA 300 ppm	2.30	88.81
T_5: IBA 200 ppm	2.07	80.88
T_6: IBA 100 ppm	1.87	72.84
T_7: Simple water	1.65	64.89
T_8: Distilled water	1.46	56.81
Mean	2.19	84.84
CD at 0.05%	0.20	2.99

Table 9 Effect of different IBA concentration on dry weight of shoots per cutting of pomegranate cv. Wonderful

Treatments detail	Dry weight of shoots per cutting (g)		Mean
	4 DAP	8 DAP	
T_1: IBA 3000 ppm	2.32	2.23	2.27
T_2: IBA 1500 ppm	2.15	2.05	2.10
T_3: IBA 1000 ppm	1.97	1.87	1.92
T_4: IBA 300 ppm	1.81	1.71	1.76
T_5: IBA 200 ppm	1.63	1.53	1.58
T_6: IBA 100 ppm	1.46	1.36	1.41
T_7: Simple water	1.30	1.20	1.25
T_8: Distilled water	1.13	1.03	1.08
Mean	1.72	1.62	1.67
CD at 0.05%	0.15	0.37	

Fresh weight of shoots per cuttings (g)

It is evident from the present investigation that significant variation exists among the concentration with respect to fresh weight of shoots per cuttings. The data indicated that there were significant differences among the IBA media fresh weight of shoots per cuttings. The maximum (2.93) fresh weight of shoots per cuttings was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (1.46) was registered in treatment T_8 distilled water. The variation are cuttings planted in a mixture of sandy loamy soil gave the maximum fresh weight of shoots per cutting it might increased the aeration, water holding capacity, nutrient retention found to be essential in early growth of plants [59] resulting in increased number of leaves, length and number of shoots which helps in increase in fresh weight of shoots. This could

be attributed to the increase in number of leaves, length and number of shoots per cutting.

Dry weight of shoots (g)

It is evident from the present investigation that significant variation exists among the concentration with respect to dry weight of shoots. The data indicated that there were significant differences among the IBA media dry weight of shoots per cuttings. The maximum (2.27) dry weight of shoots fresh per cuttings was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (1.08) was registered in treatment T_8 distilled water. The variation is among the cuttings planted in a mixture of sandy loamy soil recorded the maximum dry weight of shoot. It could be attributed to increase in number of leaves, length and number of shoots per cutting. Increased dry matter production in cutting of black pepper is due to sand and farmyard manure was reported by [60]. The cuttings treated with IBA 3000 ppm recorded the maximum dry weight of shoot. This might be due to reason that auxins activated shoot growth resulted in elongation of stems and leaves through cell division accounting for higher dry weight of shoot [61].

Table 10 Effect of different IBA concentration on root to shoot ratio (on dry weight basis) of pomegranate cv. Wonderful

Treatments detail	Root to shoot ratio (g)		Mean
	4 DAP	8 DAP	
T_1: IBA 3000 ppm	0.59	0.57	0.58
T_2: IBA 1500 ppm	0.65	0.63	0.64
T_3: IBA 1000 ppm	0.71	0.69	0.70
T_4: IBA 300 ppm	0.77	0.75	0.76
T_5: IBA 200 ppm	0.83	0.81	0.82
T_6: IBA 100 ppm	0.89	0.87	0.88
T_7: Simple water	0.96	0.94	0.95
T_8: Distilled water	1.20	1.00	1.10
Mean	0.83	0.78	0.78
CD at 0.05%	0.04	0.05	

Root to shoot ratio (on dry weight basis)

It is evident from the present investigation that significant variation exists among the concentration with respect to root to shoot ratio. The data indicated that there were significant differences among the IBA media root to shoot ratio. The maximum (0.59) root to shoot ratio was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (1.20) was registered in treatment T_8 distilled water.

Biochemical parameters

The physiological state of cuttings exerts a strong influence on development of roots and shoots from cuttings. This may be mainly related to starch, total sugars, and carbohydrates. Rooting cofactors which act synergistically with IBA have also been reported to promote rooting. The biochemical factors as related to the different treatments in the present work are discussed below.

Starch (%)

It is evident from the present investigation that significant variation exists among the concentration with respect to various biochemical parameters. The data indicated that there were significant differences among the IBA media starch (%). The maximum (6.95) starch (%) was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (3.06) was registered in treatment T_8 distilled water. In the present study, cuttings with more starch content bring about favourable conditions for root initiation and more rooting coupled with positive response of higher concentrations of IBA. The genetic variation in rooting response was directly related to the starch content, which varied according to the activity of the hydrolytic enzymes. IBA is thought to enhance (α-amylase) enzyme activity, thus increasing starch hydrolysis and facilitating its mobilization. The results therefore confirmed with the earlier observations that hydrolytic activities assumed to be some importance only during root development to meet the needs of the developing roots [62]. Such activities may be looked upon as aftereffects rather than direct causes of root initiation under influence of the root promoting hormones.

Table 11 Effect of different IBA concentration on starch (%), total sugers (%) and carbohydrate (%) of pomegranate cv. Wonderful

Treatments detail	Starch (%)	Total sugars (%)	Carbohydrate (%)
T_1: IBA 3000 ppm	6.95	1.86	8.81
T_2: IBA 1500 ppm	6.36	1.72	8.09
T_3: IBA 1000 ppm	5.82	1.60	7.43
T_4: IBA 300 ppm	5.26	1.48	6.74
T_5: IBA 200 ppm	4.7	1.35	6.05
T_6: IBA 100 ppm	4.16	1.23	5.39
T_7: Simple water	3.62	1.09	4.71
T_8: Distilled water	3.06	0.94	4.01
Mean	4.99	1.41	6.40
CD at 0.05%	0.622	0.128	0.21

Total sugars (%)

It is evident from the present investigation that significant variation exists among the cs with respect to various biochemical parameters. The data indicated that there were significant differences among the IBA media total sugars (%). The maximum (1.86) total sugars (%) was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (0.94) was registered in treatment T_8 distilled water. In the present investigation, reduction in total sugars content from the beginning of the rooting process until the evaluation period was observed, indicating the use of these sugars in the process. Application of IBA to the cuttings intensifies polysaccharide hydrolysis resulting in increased content of physiologically active sugar produced, which provide energy for meristematic tissues and thereby for root primordia for root formation as reported by [63] in *Tectona grandis.* The effect of IBA 3000 ppm treatment on cuttings of both cultivars in initial increment of total sugars was almost negligible due to less sensitivity of cuttings for that treatment which in turn yielded poor rooting in them.

Carbohydrate (%)

It is evident from the present investigation that significant variation exists among the cultivars with respect to various biochemical parameters. The data indicated that there were significant differences among the IBA concentration carbohydrate (%). The maximum (8.81) total carbohydrate (%) was registered in cv. Wonderful treatment T_1 3000 ppm IBA and minimum (4.01) was registered in treatment T_8 distilled water.

CONCLUSIONS

Pomegranate is most important deciduous fruit crop for both tropical and subtropical regions of our country. On the

basis of result optimum present investigation, it can be concluded that IBA 3000 ppm concentration significantly increase numbers of roots, numbers of shoots, survival percentages, dry weight of roots and shoots has maximum recorded compared to concentrations of IBA in distilled and simple water. Therefore, the present study has demonstrated the IBA 1500 and 3000 quick dip were found to best in all the parameters studied.

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