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Impact of Planting Time, Rooting Hormone and Different Media Combinations on Root Characters of Pomegranate Cuttings in Semi-Arid Conditions of India

Poonam Saini, R. K. Goyal, Hemant Saini

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ABSTRACT

The present experiment on the effect of time of planting, indole butyric acid (IBA) treatment and rooting media was carried out in open field conditions of semi-arid India during 2017. The pomegranate cuttings of Bhagwa variety were planted during February and March after treating half the cuttings with IBA at 2000 ppm and remaining half untreated in ten different combinations of rooting media. It was revealed that the cuttings planted in the month of February recorded enhanced root parameters as compared to the cuttings planted during March. Regarding the IBA treatment, the cuttings treated with IBA had better rooting and root characters. Among the rooting media, combination of cocopeat, perlite and vermicompost in ratio of 4 : 1 : 1 recorded maximum root attributes. The rooting and root characters of pomegranate cuttings were found superior with treatment combination of IBA at 2000 ppm, February and cocopeat, perlite and vermicompost combination of 4 : 1 : 1 ratio.

Keywords Pomegranate, IBA, Media, Cocopeat, Perlite.

INTRODUCTION

Pomegranate being a sub-tropical fruit also grows well in arid conditions due its hardy nature. Pomegranate (*Punica granatum* L.) belongs to the family Lythraceae and is known to be originated from Iran. India is the leading country for pomegranate production in the world occupying an area of 0.193 million hectare and annual production of 2.198 million tonnes (Saxena and Gandhi 2015). Pomegranate is commonly propagated through hardwood cuttings because it is a simple, convenient, inexpensive and rapid method for (Upadhyay and Badyal 2007) obtaining well developed and stronger plants. However, the success of this method depends upon factors like time of planting, rooting hormone and media used. Exogenous application of auxin can induce early rooting and can prevent the failure of cuttings (Kasim and Rayya 2009). The success rate of cuttings as well as number and quality of roots in cuttings of various fruit plants can be increased by exogenous application of synthetic auxin indole butyric acid (IBA). To reduce the mortality rate of cuttings plant growing media other than soil is required with properties like chemical resistance, light weight, heat balance, physical stability, source of nutrients, free from insects-pests and pathogens (Ercisli *et al.* 2003)and it should also be sufficiently firm, dense to maintain the cuttings in

Poonam Saini, R. K. Goyal, Hemant Saini*
Department of Horticulture, CCS Haryana Agricultural University, Hisar 125004, Haryana, India
Email : sainihemant721@gmail.com
*Corresponding author

place, porous to drain out excess water and permit aeration. In this way, the nutrients absorption, water consumption, oxygen maintenance and growth of plant can be improved using the different organic and inorganic substrates. The different types of rooting medium that can be used for growing pomegranate include sand, cocopeat, perlite, vermiculite, vermicompost.

Sand is chemically inert medium with neutral pH and nutrients free (Alikhani *et al.* 2011). Cocopeat, an organic material, which is porous in nature, has medium ion and high water absorption capacity (Schie 1999), provides enough aeration to roots and maintains suitable pH and electrical conductivity. Cocopeat can store and provide nutrients to cuttings for longer period and therefore, it may help to make the nutrients available to the cuttings of pomegranate (Raut *et al.* 2015). Cocopeat and perlite have the capacity to interchange elements especially inside the substrate and proper moisture distribution, which help in rooting and plant growth (Nourizadeh 2003). Perlite is considered as a substrate with excellent features in soilless cultivation since it has high water absorption capacity and increases water use efficiency (Djedidi *et al.* 1999), provides gas interchanges in media due to existence of porosity in it and improves aeration in the soil. Vermiculite improves soil aeration resulting in high moisture retention and more availability of nutrients to roots (Rajkumar *et al.* 2016). Vermicompost consists of available forms of nutrition for plant uptake such as nitrates, exchangeable phosphorus, potassium, calcium and magnesium and increased water retention capacity (Khalighi and Padasht-Dehkaee 2000).

Besides, rooting hormone and plant growing media the time of operation also governs the survival of cuttings. Successful cutting propagation has been associated with ideal planting time of cuttings. Higher rooting percentage was recorded in the cuttings planted at end of February than those planted at the beginning of October (Hambrick *et al.* 1991). Hardwood cuttings of 20 cm length will root faster and easily if planted in February or March (Sheets 2004). We report on effect of time of planting, IBA treatment and rooting media on rooting and root characters of pomegranate cuttings.

MATERIALS AND METHODS

Experimental site and details

The experiment was conducted at Center for Quality Planting Material, CCS Haryana Agricultural University, Hisar (Haryana), India. The Hisar district in Haryana state of India is situated at 215.2 meter above sea level with coordinates of 29°10′ N latitude and 75°46′ E longitudes with typical semi-arid climate having hot and dry summer and extremely cold winters. The study was carried out under open field conditions during February and March of 2017 with different combinations of rooting media viz., T_1 : Sand, T_2 : Cocopeat, T_3 : Cocopeat + sand (1:3), T_4: Cocopeat + vermicompost (4 : 1), T_5 : Cocopeat + perlite + vermicompost (4 : 1 : 1), T_6 : Cocopeat + perlite + vermicompost (6 : 1 : 1), T_7 : Cocopeat + perlite + vermicompost (8 : 1 : 1), T_8 : Cocopeat + perlite + vermiculite (4 : 1 : 1), T_9 : Cocopeat + perlite + vermiculite (6 : 1 : 1), T_{10} : Cocopeat + perlite + vermiculite (8 : 1 : 1).

Preparation of cuttings and IBA concentration

The hardwood cuttings of pomegranate cultivar Bhagwa were prepared from healthy and disease free one year old mature branches of 7.5–10 cm thickness. The cuttings of 20 cm in length with 5 to 6 buds were completely defoliated and a straight cut at basal end just below the bud and a slanting cut at the apical end above the bud was made. Indole butyric acid (IBA) of 2000 ppm concentration was prepared by dissolving 2 g IBA in small quantity of ethanol and final volume was made upto 1000 ml using distilled water.

Planting of cuttings

Poly bags of 7 : 9 inch were filled as per the treatment with rooting media on volume basis and kept replication wise for the planting of cuttings. The basal portion of half number of freshly prepared cuttings on the day of planting was treated with a solution of IBA 200 ppm for 2 minutes and remaining half of the freshly prepared cuttings was planted without IBA treatment in the polybags.

Table 1. Analysis of variance (F value) for the effects of planting time, rooting hormone and different media on root characters of pomegranate cuttings. Significance values : *ρ< 0.05 ; **ρ < 0.01.

Source	Degree of freedom	Mean sum of square Root growth characters: No. of roots generated per cutting	Root fresh weight (g)	Root dry weight (g)	Root to shoot ratio	Root diameter (mm)	Root volume (ml)	Length of longest root (cm)	No. of primary roots
Time of planting (T)	1	1179.27**	16.67**	4.44**	0.026**	1.35**	11.47**	2514.66**	39.93**
IBA Treatment (G)	1	2100.42**	33.36**	7.65**	0.053**	2.03**	13.70**	3165.68**	77.21**
Rooting media (M)	1	690.34**	27.54**	5.23**	0.009**	2.19**	18.39**	830.15**	105.80**
Interaction (T×M)	9	13.06	0.026	0.006	0.000	0.009**	0.016	9.05**	0.29
Interaction (G×M)	9	8.95	0.010	0.003	0.000	0.008**	0.004	13.17**	0.18
Interaction (T×G)	9	32.27*	0.001**	0.046*	0.013**	0.105**	0.001	26.44**	0.27
Interaction (T×G×M)	9	5.08	0.019	0.002	0.000	0.012**	0.012	4.91*	0.21
Error									
Total									

Root characters recorded

Root parameters were recorded (120 days after planting) by destructive method of uprooting the cuttings and then roots were washed with water carefully. Number of roots per cutting was counted after separating them from the cuttings with the help of secateurs. Fresh weight of roots was taken with the help of weighing balance. The roots were completely dried in hot air oven at 55°C until a constant weight was attained and then dry weight was taken on weighing balance. The root to shoot ratio was estimated as the ratio of dry weight of the roots to the dry weight of shoots. The diameter of roots of each cutting was measured with the help of *Vernier calliper*. The root volume of each cutting was measured with volume displacement method. The length of the longest root of each cutting was measured with the

Table 2. Effect of time of planting, IBA treatment and rooting media on number of roots generated per cutting, root fresh weight, root dry weight and root to shoot ratio of pomegranate.

Treatments	No. of roots generated per cutting	Root fresh weight (g)	Root dry weight (g)	Root to shoot ratio
	Time of planting			
February (T_1)	24.66±1.92	4.02±0.34	1.81±0.14	0.279±0.006
March (T_2)	20.22±1.48	3.49±0.34	1.54±0.15	0.300±0.006
CD (p=0.05)	0.67	0.05	0.02	0.004
	IBA treatment			
IBA 2000 ppm (G_1)	25.40±1.83	4.13±0.34	1.85±0.15	0.274±0.005
Without IBA (G_2)	19.48±1.51	3.39±0.33	1.49±0.15	0.304±0.007
CD (p=0.05)	0.67	0.05	0.02	0.004
	Rooting media			
M_1 : Sand	14.00±1.84	2.12±0.28	0.96±0.16	0.322±0.014
M_2 : Cocopeat	18.12±2.29	2.92±0.32	1.31±0.17	0.304±0.015
M_3 : Cocopeat + sand (1:3)	15.75±1.46	2.31±0.31	1.03±0.18	0.312±0.013
M_4 : Cocopeat + vermicompost (4:1)	19.37±2.25	3.12±0.32	1.39±0.15	0.298±0.014
M_5 : Cocopeat + perlite + vermicompost (4:1:1)	29.42±3.25	5.09±0.33	2.24±0.14	0.265±0.010
M_6 : Cocopeat + perlite + vermicompost (6:1:1)	26.33±3.00	4.66±0.30	2.08±0.14	0.273±0.011
M_7 : Cocopeat + perlite + vermicompost (8:1:1)	23.92±2.58	4.22±0.34	1.89±0.16	0.284±0.013
M_8 : Cocopeat + perlite + vermiculite (4:1:1)	28.62±3.38	4.85±0.31	2.14±0.15	0.270±0.011
M_9 : Cocopeat + perlite + vermiculite (6:1:1)	25.58±3.08	4.42±0.32	1.96±0.15	0.278±0.012
M_{10} : Cocopeat + perlite + vermiculite (8:1:1)	23.29±2.50	3.88±0.36	1.73±0.16	0.288±0.013
CD (0.05)	1.50	0.12	0.05	0.009

Table 3. Interaction effect of time of planting and rooting media (T × M) on number of roots generated per cutting, root fresh weight, root dry weight and root to shoot ratio of pomegranate.

Treatments	No. of roots generated per cutting	Root fresh weight (g)	Root dry weight (g)	Root to shoot ratio
T_1M_1	15.42	2.36	1.11	0.311
T_1M_2	20.00	3.19	1.46	0.292
T_1M_3	16.75	2.57	1.19	0.302
T_1M_4	21.33	3.39	1.52	0.287
T_1M_5	32.58	5.35	2.35	0.256
T_1M_6	28.83	4.89	2.19	0.264
T_1M_7	26.17	4.51	2.03	0.273
T_1M_8	32.00	5.09	2.27	0.262
T_1M_9	28.25	4.67	2.08	0.268
T_1M_{10}	25.25	4.23	1.89	0.276
T_2M_1	12.58	1.89	0.82	0.333
T_2M_2	16.25	2.66	1.16	0.317
T_2M_3	14.75	2.06	0.87	0.322
T_2M_4	17.42	2.84	1.26	0.309
T_2M_5	26.25	4.85	2.12	0.274
T_2M_6	23.83	4.43	1.96	0.282
T_2M_7	21.67	3.94	1.75	0.295
T_2M_8	25.25	4.61	2.01	0.279
T_2M_9	22.92	4.16	1.84	0.288
T_2M_{10}	21.33	3.54	1.57	0.300
CD (0.05)	NS	NS	NS	NS

Table 4. Interaction effect of IBA treatment and rooting media (G × M) on number of roots generated per cutting, root fresh weight, root dry weight and root to shoot ratio of pomegranate.

Treatments	No. of roots generated per curring	Root fresh weight (g)	Root dry weight (g)	Root to shoot ratio
G_1M_1	16.25	2.45	1.14	0.304
G_1M_2	20.83	3.29	1.51	0.287
G_1M_3	17.67	2.68	1.22	0.295
G_1M_4	21.92	3.49	1.57	0.28
G_1M_5	32.25	5.49	2.41	0.254
G_1M_6	29.83	5.03	2.25	0.259
G_1M_7	26.83	4.62	2.08	0.269
G_1M_8	32.00	5.22	2.30	0.258
G_1M_9	29.08	4.79	2.14	0.264
G_1M_{10}	26.33	4.26	1.89	0.273
G_2M_1	11.75	1.79	0.79	0.339
G_2M_2	15.42	2.55	1.11	0.322
G_2M_3	13.83	1.95	0.84	0.328
G_2M_4	16.83	2.75	1.21	0.316
G_2M_5	25.58	4.69	2.06	0.276
G_2M_6	22.83	4.29	1.90	0.287
G_2M_7	21.00	3.83	1.71	0.298
G_2M_8	25.25	4.48	1.98	0.283
G_2M_9	22.08	4.03	1.78	0.292
G_2M_{10}	20.25	3.50	1.57	0.303
CD (0.05)	NS	NS	NS	NS

help of scale. Number of primary roots was counted on each cutting.

Statistical analysis

The experiment was laid out in Factorial Complete Randomized Design. Each treatment was replicated six times. Statistical analysis of data collected during the study was done using STAR 2.0.1 statistical tool. The effect of rooting media, planting time and IBA treatment and their interactions were determined on shoot characters of pomegranate cuttings using a three-way analysis of variance (ANOVA) as presented in Table 1.

RESULTS

The results demonstrated that time of planting, IBA treatment and different rooting media combinations significantly enhanced the root characters of pomegranate cuttings as presented in Tables 2 and 5.

Effect of planting time on root characters

The maximum number of roots (24.66), root fresh weight (4.02 g), root dry weight (1.81g), root diameter (1.06 mm), root volume (3.28 ml), length of longest root (31.82 cm), number of primary roots (9.86) and minimum root to shoot ratio (0.279) was recorded in the cuttings planted in the month of February.

Effect of rooting hormone on root characters

The roots of the cuttings treated with IBA at 2000 ppm concentration were found more in numbers per cutting (25.40) and with maximum fresh weight (4.13 g), dry weight (1.85 g), diameter (1.07 mm), volume (3.30 ml), length (32.21 cm), number of primary roots (10.02) in comparison to the roots of untreated cuttings. Also, minimum root to shoot ratio (0.274) was observed in the cuttings treated IBA.

Table 5. Effect of time of planting, IBA treatment and rooting media on root diameter, root volume, length of the longest root and number of primary roots of pomegranate.

Treatments	Root diameter (mm)	Root volume (ml)	Length of longest root (cm)	No of primary roots
	Time of planting			
February (T_1)	1.06±0.10	3.28±0.28	31.82±2.00	9.86±0.67
March (T_2)	0.91±0.09	2.84±0.28	25.34±1.72	9.05±0.66
CD (p=0.05)	0.01	0.04	0.40	0.13
	IBA treatment			
IBA 2000 ppm (G_1)	1.07±0.10	3.30±0.27	32.21±2.01	10.02±0.68
Without IBA (G_2)	0.89±0.09	2.82±0.28	24.95±1.73	8.89±0.65
CD (p=0.05)	0.01	0.04	0.40	0.13
	Rooting media			
M_1 : Sand	0.50±0.06	1.73±0.22	19.48±2.59	6.41±0.42
M_2 : Cocopeat	0.75±0.06	2.38±0.24	25.57±2.75	7.79±0.54
M_3 : Cocopeat + sand (1:3)	0.60±0.07	1.88±0.24	21.55±2.84	6.79±0.55
M_4 : Cocopeat + vermicompost (4:1)	0.83±0.06	2.53±0.24	26.89±2.55	8.70±0.46
M_5 : Cocopeat + perlite + vermicompost (4:1:1)	1.38±0.09	4.16±0.22	39.25±3.83	12.33±0.59
M_6 : Cocopeat + perlite + vermicompost (6:1:1)	1.24±0.10	3.79±0.21	31.79±4.16	11.46±0.63
M_7 : Cocopeat + perlite + vermicompost (8:1:1)	1.06±0.09	3.44±0.24	30.22±3.85	9.45±0.71
M_8 : Cocopeat + perlite + vermiculite (4:1:1)	1.31±0.11	3.95±0.21	34.81±3.65	11.79±0.54
M_9 : Cocopeat + perlite + vermiculite (6:1:1)	1.15±0.11	3.59±0.22	28.83±4.03	10.87±0.62
M_{10}: Cocopeat + perlite + vermiculite (8:1:1)	0.99±0.10	3.16±0.25	27.41±4.10	8.95±0.63
CD (0.05)	0.03	0.09	0.89	0.29

Effect of different rooting media on root characters

Among the rooting media, the combination of cocopeat + perlite + vermicompost in the ratio of 4:1:1 produced cuttings with maximum number of roots per cutting (29.42), root fresh weight (5.09 g), root dry weight (2.24g), root diameter (1.38 mm), root volume (4.16 ml), length of longest root (39.25 cm), number of primary roots (12.33) and minimum root to shoot ratio (0.265).

Effect of interaction between planting time and different rooting media on root characters

The combined effect of planting time and rooting media did not influenced the root parameters of pomegranate cuttings significantly except root diameter and length of longest root (Tables 3 and 6). The highest diameter (1.46 mm) and length of longest root (42.95 cm) was found in the roots of cuttings planted in media combination of cocopeat + perlite + vermicompost in the ratio of 4:1:1 during February.

Effect of interaction between IBA treatment and different rooting media on root characters

Similar results were obtained in the interaction effect of IBA treatment and rooting media as in that of planting time and rooting media (Tables 4 and 7). The roots of cuttings planted in media combination of cocopeat + perlite + vermicompost in the ratio of 4:1:1 after IBA treatment had maximum diameter (1.48 mm) and length of longest root (43.20 cm).

Effect of interaction between time of planting and IBA treatment on root characters

A significant effect was noted on the root characters with the interaction of planting time and IBA treatment except root volume and number of primary roots (Figs 1 and 2). The roots were found more in numbers per cutting (27.98), with maximum fresh weight (4.39 g), dry weight (2.00 g), diameter (1.17 mm), length (35.78 cm) and with minimum root to shoot ratio (0.257) in the cuttings treated with IBA and planted in the month of February.

Table 6. Interaction effect of time of planting and rooting media (T × M) on root diameter, root volume, length of the longest root and number of primary roots of pomegranate.

Treatments	Root diameter (mm)	Root volume (ml)	Length of longest root (cm)	No of primary roots
T_1M_1	0.54	1.93	21.92	6.58
T_1M_2	0.81	2.59	28.18	8.24
T_1M_3	0.66	2.09	24.15	7.24
T_1M_4	0.89	2.76	29.39	9.08
T_1M_5	1.46	4.37	42.95	12.66
T_1M_6	1.33	3.99	35.58	11.92
T_1M_7	1.14	3.67	33.91	9.99
T_1M_8	1.41	4.15	38.27	12.16
T_1M_9	1.25	3.81	32.76	11.25
T_1M_{10}	1.08	3.44	31.05	9.49
T_2M_1	0.45	1.53	17.04	6.24
T_2M_2	0.70	2.16	22.95	7.33
T_2M_3	0.54	1.66	18.95	6.33
T_2M_4	0.77	2.30	24.39	8.33
T_2M_5	1.29	3.95	35.55	11.99
T_2M_6	1.15	3.61	28.00	10.99
T_2M_7	0.99	3.21	26.54	8.92
T_2M_8	1.22	3.75	31.34	11.41
T_2M_9	1.05	3.39	24.89	10.49
T_2M_{10}	0.90	2.88	23.76	8.41
CD (0.05)	0.04	NS	1.27	NS

Table 7. Interaction effect of IBA treatment and rooting media (G × M) on root diameter, root volume, length of the longest root and number of primary roots of pomegranate.

Treatments	Root diameter (mm)	Root volume (ml)	Length of longest root (cm)	No of primary roots
G_1M_1	0.57	1.96	22.22	6.83
G_1M_2	0.82	2.63	28.45	8.33
G_1M_3	0.67	2.14	24.62	7.33
G_1M_4	0.90	2.78	29.49	9.16
G_1M_5	1.48	4.39	43.20	12.91
G_1M_6	1.35	4.02	36.32	12.08
G_1M_7	1.16	3.69	34.24	10.16
G_1M_8	1.43	4.17	38.65	12.33
G_1M_9	1.26	3.83	32.96	11.49
G_1M_{10}	1.09	3.36	31.96	9.58
G_2M_1	0.42	1.49	16.74	5.99
G_2M_2	0.69	2.12	22.68	7.24
G_2M_3	0.52	1.62	18.48	6.24
G_2M_4	0.76	2.29	24.29	8.24
G_2M_5	1.28	3.92	35.3	11.74
G_2M_6	1.13	3.58	27.26	10.83
G_2M_7	0.97	3.19	26.2	8.74
G_2M_8	1.20	3.73	30.97	11.25
G_2M_9	1.04	3.36	24.69	10.25
G_2M_{10}	0.88	2.92	22.86	8.33
CD (0.05)	0.04	NS	1.27	NS

Effect of interaction between time of planting, IBA treatment and rooting media on root characters

The root attributes with respect to diameter and length of longest root only were significantly enhanced by the combined effect of time of planting, IBA treatment and rooting media. The cuttings planted in media combination of cocopeat + perlite + vermicompost in the ratio of 4:1:1 after IBA treatment during February had roots with increased diameter (1.62 mm) and length of longest root (47.16 cm).

DISCUSSION

The higher fresh weight of roots during February might be attributed to the increased number of roots and roots length. The amount of endogenous growth regulators, rooting cofactors and carbohydrates was different during different time of planting, thus for this reason, cuttings should be planted at right time (Hartmann *et al.* 2011). Asif *et al*. (2013) stated that root length increases under normal ecological conditions and decreases under a condition of water stress. Also, the favorable conditions activate the root promoting substances, which result in maximum root length (Hussain *et al.* 2016).

Induction of more number of roots in IBA treated cuttings might be due to cambial activity involved in root initiation stimulated by growth regulators in many species (Ullah *et al.* 2005). The increase in fresh weight of roots might be due to higher accumulation of assimilates, metabolites and nutrients with the application of growth regulators (Rajkumar *et al.* 2016). Hormones stimulate the initial meristem activities and improved the growth and development of the formed roots (Hartmann *et al.* 2011). The increase in number and length of roots has directly influenced the fresh weight of roots. The growth regulators might increase the cell division and cell elongation due to synergistic mode of action, thus, resulted in highest root growth (Kashyap 2015). Auxins improved root dry weight and higher IBA concentration resulted in higher root dry weight. Cuttings of pomegranate

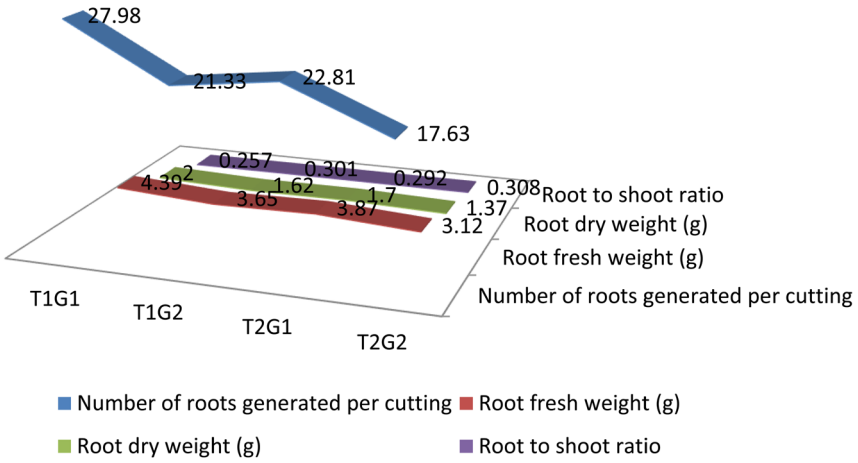

Fig. 1. Interaction effect of time of planting and IBA treatment (T × G) on number of roots generated per cutting, root fresh weight, root dry weight and root to shoot ratio of pomegranate.

treated with optimum concentration of IBA recorded more number of roots, which in turn increased the dry weight. Increase in volume associated with callus and adventitious root growth must be the result of either cell division or cell enlargement, or both and auxin is known to be involved in cell enlargement (Ansari 2013). The increase in length of roots in cuttings treated with growth regulators might be due to the enhanced hydrolysis of carbohydrates, accumulation of metabolites at the site of application of auxins, synthesis of new proteins, cell enlargement and cell division induced by the auxins (Strydem and Hartman 1960). Jadhav (2007) expressed that the increase in length of roots might be due to an early initiation of roots at higher concentration of IBA and therefore more utilization of nutrients due to early formation of the roots. The increased rooting and root length of Piper longum with IBA treatment might be attributed to the action of auxin, which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances at the base of cuttings, which resulted in accelerating cell elongation and cell division in suitable environment (Singh *et al.* 2003, Hartmann *et al.* 2007). The increase in number and length of both primary and secondary roots may be due to hormonal effect and accumulation of other internal substances and their basipetal (downward) movement (Singh 2001).

The enhanced rooting and root characters in media combination cocopeat + perlite + vermicompost in the ratio of 4:1:1 might be attributed to the fact that cocopeat is highly porous material with high quality natural rooting hormones and anti-fungal properties (Yahya *et al.* 2009). Cocopeat is an organic material with medium ion absorption capacity and it has aerial porosity and better capacity of water and nutrients maintenance (Schie 1999). Perlite has high water absorption and water use efficiency (Djedidi *et al.* 1999). Vermicompost consists of available forms of nutrition for plant uptake and also has better water retention capacity (Khalighi and Padasht-Dehkaee 2000). Dvin *et al.* (2011) reported higher rooting in cocopeat + perlite medium, which might be due to the improvement in both aeration and water holding capacity (Islam 2008). Vermiculite beside water holding capacity can release nutrients gradually that are useful for growth and development of roots (Ansari 2013). The improvement in root fresh weight, dry weight, length, diameter and volume might be due to the vigorous growth of roots, which absorbed more nutrients from the rooting media. High oxygen content of the root zone accelerates the growth of healthy and strong roots (Wiesman and Lavee 1995). The root length was the highest in perlite media, which implied that this media had better aeration properties because of its larger pore size (>30 µm) properties (Ercisli *et*

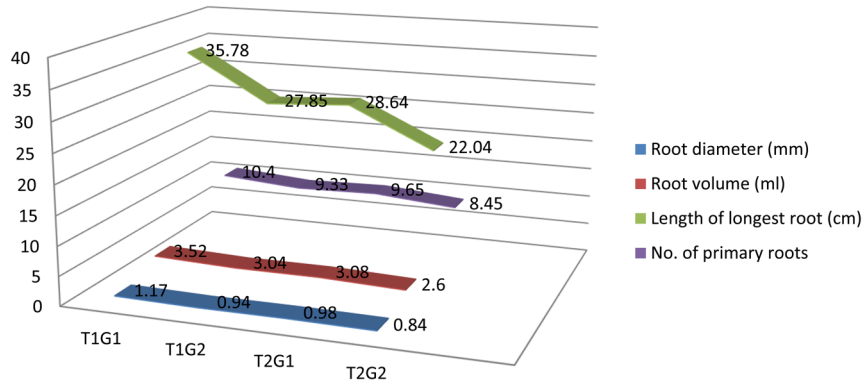

Fig. 2. Interaction effect of time of planting and IBA treatment (T × G) on root diameter, root volume, length of the longest root and number of primary roots of pomegranate.

al. 2002). The increase in primary and secondary roots might be due to the more uptake and utilization of phosphorus, nitrogen and other nutrients by the cuttings (Hakim *et al.* 2018).

The above results confirm the findings of Pal and Srivastava (1982) who observed better rooting in kinnow under IBA treatment, Panwar *et al.* (2001) who recorded maximum rooting success, number of primary roots and root length under different IBA concentrations, Verma *et al.* (2005) who reported maximum root length in citrus cuttings with the application of IBA, Upadhyay and Badyal (2007) who observed maximum number of primary roots and root length in pomegranate when IBA 2000 ppm was applied, Shirzad *et al.* (2011) who noticed that auxin promoted root formation in *Thunbergia grandiflora* and *Ficus benjamina* and Galavi *et al.* (2013) reported that IBA enhanced the number of roots, root length, root fresh and dry weight in grape cuttings.

CONCLUSION

The above study concluded that rooting and root characters of pomegranate cuttings could be enhanced by exogenous application of IBA at 2000 ppm with media combination of cocopeat + perlite + vermicompost in the ratio of 4:1:1 during February in open field conditions. Thus, quality planting material of pomegranate can be produced by combined effect of appropriate planting time, optimal growth regulator concentration and right combination of different rooting media.

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