International Journal of Agricultural Sciences
Volume **17** | AAEBSSD | 2021 | 51-60
DOI:10.15740/HAS/IJAS/17-AAEBSSD/51-60
ISSN : 0973-130X
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*RESEARCH PAPER*

# Effect of different concentrations of Indole-3-butyric acid (IBA) concentrations and cutting size (length and diameter) on root growth of pomegranate (*Punica granatum* L.) cuttings

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**Abstract :** The experiment was carried out during the year 2017-18 at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani on pomegranate (*Punica granatum* L.) cv. Bhagwa. The cuttings were taken from hardwood cuttings arising on trees of pomegranate cv. Bhagwa during the month of July. Experiment was laid out in Factorial Randomized Block Designed(FRBD) with 18 treatments and 3 factors which are replicated trice and no. of cuttings per treatment are 40. Result revealed that significantly maximum number of roots, highest length of roots, rooting percentage and weight of roots was recorded with treatment $D_2$ *i.e.* (1.5 cm) and lowest values in $D_1$ *i.e.* (1 cm diameter). Significantly maximum number of roots, highest length of roots, rooting percentage and weight of roots was recorded with treatment $L_3$ *i.e.* (20 cm) and minimum values in $L_1$ *i.e.* (10 cm length) and maximum number of roots, highest length of roots, rooting percentage and weight of roots of pomegranate cutting were recorded with treatment $T_3$ *i.e.* (IBA 5000 ppm) and minimum values were found in $T_1$ *i.e.* (IBA 3000 ppm).

**Key Words :** Root, Indole-3-butyric acid, Length pomegranate, Cutting, Diameter

**View Point Article :** Ahmadi, Basir Ahmad, Waghmare, G. M. and Bhosale, A. M. (2021). Effect of different concentrations of Indole-3-butyric acid (IBA) concentrations and cutting size (length and diameter) on root growth of pomegranate (*Punica granatum* L.) cuttings. *Internat. J. agric. Sci.*, **17** (AAEBSSD) : 51-60, **DOI:10.15740/HAS/IJAS/17-AAEBSSD/51-60.** 

**Article History : Received :** 10.07.2021; **Accepted :** 15.07.2021

## INTRODUCTION

Pomegranate (*Punica granatum* L.) belongs to family Punicaceae is native to Asia especially to Iran, Afghanistan and Himalayan region. It is one of the oldest known edible fruit of tropical and sub-tropical region, known for its gustative, medicinal and ornamental. The tree is quite resistant to cold when dormant, withstanding temperatures down to $10^{o}$ F. However, it is very sensitive to frost before it reaches full dormancy in late fall and after buds have begun to swell in early spring. The best quality pomegranate fruits are produced in regions with cool winters and hot, dry summers.

Pomegranate is a shrub that naturally tends to develop multiple trunks and has a bushy appearance. When domesticated, it is grown as a small tree that grows up to 5m, leaves have an oblanceolate shape with an apex and acuminate base. Mature leaves are green, entire, smooth and hairless; the flowers can appear

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solitary, pairs or cluster. In the most cases, the solitary flowers will appear as spurs along the branches while the clusters are terminal (Levin, 2006). Fruit is globular, possessing a smooth outer rind with juicy arils (Mars, 2000).

Pomegranate could be propagated either sexually by seeds or vegetatively using stem cuttings and sometimes as layers or suckers or by grafting (Hartmann *et al.,* 1997). However, in commercial propagation stem cuttings are widely used. (Antakya Hatay, 2009).

The length and diameter of stem cuttings have an impact on rooting rate and subsequent survival in the field after transplanting, determining optimal cutting length is essential as (1) a very long cutting larger than 12 cm will be waste of valuable coppice material, with limited or no benefit in rooting percentage, whereas, (2) a short cutting may not result in the development of sufficient roots (possibly due to lack of sufficient storage reserves) (Leakey, 2004).

Sprouting and rooting ability of cuttings is mainly depends upon the physiological maturity of the shoot and conditions where cuttings have been planted for sprouting and subsequent rooting (Purohit and Shekrappa, 1985) and various internal and external factors like seasons and concentration of endogenous and exogenous phytohormones (Arya *et al*., 1994). Plant growth regulators improve the rooting of cutting by stimulating the production of adventitious roots. Went (1934) first postulated that auxins initiate adventitious root formation in stem cuttings.

IBA is the most promising growth regulator inducing rooting quickly. Exogenous application of IBA accelerates the rate of rooting, increases final rooting percentage and number of roots. However, relatively high concentrations of IBA have been reported to be inhibitory to rooting (Leakey, 1990). It promotes root initiation, number of roots and shoots growth in number of ornamental and fruits plants. The rooting medium can have a major influence on the rooting capacity of cuttings (Hartmann *et al*., 2002).

## MATERIAL AND METHODS

The experiment was carried out during the year 2017-18 at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani on pomegranate (*Punica granatum* L.) cv. Bhagwa". The cuttings were taken from hardwood cuttings arising on trees of pomegranate cv. Bhagwa during the month of July. Experiment was laid out in Factorial Randomized Block Designed (FRBD) with 18 treatments and 3 factors which are replicated trice and no. of cuttings per treatment are 40. Treatment Details:

| **Factors:** | | | | | |
|---|---|---|---|---|---|
| Factor A: Length of cutting | | Factor B: Diameter of cutting | | Factor C: IBA concentration | |
| $L_1$: | 10 cm | $D_1$: | 1 cm | $T_1$: | 3000 ppm |
| $L_2$: | 15 cm | $D_2$: | 1.5 cm | $T_2$: | 4000 ppm |
| $L_3$: | 20 cm | | | $T_3$: | 5000 ppm |

### Observation recorded:

*Root observation*:

Number of primary and secondary roots per cutting:

The five cuttings from each treatment were uprooted carefully after heavy irrigation and washed under the tap water gently and number of primary and secondary roots per cuttings was counted and mean number of roots per cuttings was calculated.

Length of root:

The length of longest root of fifteen labeled rooted cutting was measured by measuring scale in (cm) from the base to the tip of root and the mean length of root was calculated.

Percentage of cuttings rooted:

This parameter was calculated at 60 days after planting by taking the ratio of number of rooted cuttings to total number of cuttings planted and was multiplied by 100.

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

Fresh and dry weight of roots:

All the roots of each selected fifteen cuttings from three replications were removed with the help of stainless steel knife. The separate roots were placed in brown paper bags, properly labeled, dried in oven at 60c° and after stabilization of weight, this stabilized weight (g) was recorded. From the fresh weight of root, we can find out the dry weight of root by using the following formula.

$$\text{Dry matter of root} = \frac{\text{Fresh weight - Dry weight}}{\text{Fresh weight}} \times 100$$

## RESULTS AND DISCUSSION

The results obtained during the experiment were recorded and analysed statistically, presented under appropriate headings, sub-headings and discussed with available literature.

## Root parameters:

*Number of primary roots per cutting at 90DAP* :

Data on number of primary roots per cutting of pomegranate as influenced by diameter of cutting (D), length of cutting (L), IBA concentrations (T) and their interaction are presented in Table 1.

*Effect of cutting diameter (D):*

Significantly highest number of primary roots (19.03) was recorded in treatment $D_2$ *i.e.* (1.5 cm diameter), while minimum number of roots (16.50) were observed in $D_1$ *i.e.* (1 cm diameter).

*Effect of cutting length (L):*

Among the length of cuttings, the highest number of primary roots (20.83) per cutting was recorded in $L_3$ *i.e.* (20 cm length) and minimum number of primary roots (15.11) per cutting was found in $L_1$ *i.e.* (10 cm length). Highest diameter and length of cuttings have maximum roots because cuttings are prepared from mature stem and they provide sufficient food material for initiation of roots. Kaur and Kaur (2018).

*IBA concentration (T):*

In the present investigation the highest number of primary roots per cutting (20.86) was recorded in $T_3$ *i.e.* (IBA 5000 ppm) and minimum number (15.16) of primary roots was registered in $T_1$ *i.e.* (IBA 3000 ppm). IBA 5000 ppm produce maximum roots due to cell division and cell elongation, differentiation of cambial initial into root primordia and mobilization of reserve food material to sites of root initiation which increase number of primary roots. These results are in conformity with the findings of Sharma (1999) and Kamboj *et al.* (2017).

*Interaction effect of (L×D):*

Significant interaction between length and diameter of cutting was observed regarding number of primary roots per cutting. Highest number of primary roots (23.38) per cutting was observed in interaction of $L_3D_2$ *i.e.* (length 20 cm and 1.5 cm diameter). However, lowest number of primary root (13.88) was observed in interaction of $L_1D_1$ *i.e.* (length 10 cm and 1 cm diameter).

**Table 1: Effect of cutting size and IBA concentration on number of roots per cutting in pomegranate**

| Treatments | Number of primary roots per cutting | Number of secondary roots per cutting |
|---|---|---|
| | 90DAP | 90DAP |
| Diameter of cutting (D) | | |
| $D_1$ | 16.50 | 45.00 |
| $D_2$ | 19.03 | 47.53 |
| S.E N± | 1.02 | 1.02 |
| C.D. at 5% | 2.82 | 2.82 |
| Length of cutting (L) | | |
| $L_1$ | 15.11 | 43.61 |
| $L_2$ | 17.36 | 45.86 |
| $L_3$ | 20.83 | 49.33 |
| S.E N± | 1.25 | 1.25 |
| C.D. at 5% | 3.46 | 3.46 |
| IBA concentration (T) | | |
| $T_1$ | 15.16 | 43.63 |
| $T_2$ | 17.27 | 45.77 |
| $T_3$ | 20.86 | 49.35 |
| S.E N± | 1.25 | 1.25 |
| C.D. at 5% | 3.46 | 3.46 |
| Interaction (L x D) | | |
| $L_1D_1$ | 13.88 | 40.58 |
| $L_2D_1$ | 14.33 | 42.52 |
| $L_3D_1$ | 14.88 | 43.58 |
| $L_1D_2$ | 15.27 | 44.25 |
| $L_2D_2$ | 18.38 | 46.86 |
| $L_3D_2$ | 23.38 | 51.25 |
| S.E N± | 1.76 | 1.76 |
| C.D. at 5% | 4.89 | 4.89 |
| Interaction (T x D) | | |
| $T_1D_1$ | 11.94 | 40.25 |
| $T_1D_2$ | 18.38 | 46.36 |
| $T_2D_1$ | 17.61 | 47.39 |
| $T_2D_2$ | 16.94 | 45.25 |
| $T_3D_1$ | 19.94 | 48.44 |
| $T_3D_2$ | 21.77 | 50.27 |
| S.E N± | 1.76 | 1.76 |
| C.D. at 5% | 4.89 | 4.89 |
| Interaction (L x T) | 90DAP | 90DAP |
| $T_1L_1$ | 13.91 | 41.36 |
| $T_1 L_2$ | 15.55 | 44.02 |
| $T_1 L_3$ | 17.00 | 45.50 |
| $T_2 L_1$ | 20.83 | 49.37 |
| $T_2 L_2$ | 16.33 | 44.29 |
| $T_2L_3$ | 14.66 | 43.86 |
| $T_3L_1$ | 17.75 | 45.50 |
| $T_3 L_2$ | 20.16 | 48.72 |
| $T_3 L_3$ | 24.66 | 53.89 |
| S.E N± | 2.16 | 2.16 |
| C.D. at 5% | 5.99 | 5.99 |

*Table 1: Contd………..*

Table 1: Contd……………

| Interaction (T x D x L) | | |
|---|---|---|
| $T_1D_1L_1$ | 11.16 | 37.66 |
| $T_1D_1L_2$ | 13.83 | 42.33 |
| $T_1D_1L_3$ | 12.83 | 41.25 |
| $T_1D_2L_1$ | 20.16 | 48.66 |
| $T_1D_2L_2$ | 22.00 | 50.50 |
| $T_1D_2L_3$ | 13.00 | 41.25 |
| $T_2D_1L_1$ | 20.50 | 49.00 |
| $T_2D_1L_2$ | 17.66 | 46.61 |
| $T_2D_1L_3$ | 14.66 | 43.85 |
| $T_2D_2L_1$ | 21.83 | 49.66 |
| $T_2D_2L_2$ | 15.00 | 43.50 |
| $T_2D_2L_3$ | 14.66 | 42.69 |
| $T_3D_1L_1$ | 20.50 | 49.00 |
| $T_3D_1L_2$ | 22.16 | 50.06 |
| $T_3D_1L_3$ | 17.16 | 45.09 |
| $T_3D_2L_1$ | 18.33 | 42.00 |
| $T_3D_2L_2$ | 18.16 | 45.82 |
| $T_3D_2L_3$ | 28.83 | 57.25 |
| S.E N± | 3.06 | 3.06 |
| CD at 5% | 8.48 | 8.48 |
| Treatment details | | |
| $D_1$-Diameter 1 cm | $L_1$- Length 10 cm | $T_1$- 3000 ppm IBA |
| | $L_2$- Length 15 cm | $T_2$- 4000 ppm IBA |
| $D_2$-Dimeter 1.5 cm | $L_3$- Length 20 cm | $T_3$- 5000 ppm IBA |

*Interaction effect of (T×D):*

Significantly maximum number of primary roots (21.77) of pomegranate cuttings was observed in interaction of $T_3D_2$ *i.e.* (IBA 5000 ppm and 1.5 cm diameter) which was followed by interactions of $T_3D_1$ (19.94) and $T_1D_2$ (18.38). However, minimum number of primary roots (11.94) were observed in interaction of $T_1D_1$ *i.e.* (IBA 3000 ppm and 1 cm diameter).

*Interaction effect of (T×L):*

The interaction effect of length of cutting and IBA concentration on number of primary roots shows significant variation among the interactions. Interaction of $T_3L_3$ *i.e.* (IBA 5000 ppm and 20 cm length) recorded significantly highest number of primary roots (24.66), which was at par with interactions of $T_2L_1$ (20.83), $T_3L_2$ (20.16) and lowest number of primary roots (13.91) was observed in interaction of $T_1L_1$ *i.e.* (IBA 3000 ppm and 10 cm length), whereas the Interaction effect of IBA concentrations, diameter and length of cuttings (T×D×L) do not show significant variation on number of primary roots per cutting.

**Number of secondary roots per cutting at 90DAP:**

The effect of diameter of cutting (D), length of cutting (L), IBA concentrations (T) and their interactions on number of secondary roots per cutting presented in Table 1.

*Effect of cutting diameter (D):*

It has been reported that, the highest number of secondary roots per cutting (47.53) was recorded in $D_2$ *i.e.* (1.5 cm diameter) and lowest number of secondary roots (45.00) per cutting was observed in $D_1$ *i.e.* (1 cm diameter).

*Effect of cutting length (L):*

Significantly maximum number of secondary roots per cutting (49.33) was recorded in $L_3$ *i.e.* (20 cm length) and minimum number of secondary roots per cutting (43.61) was observed in $L_1$ *i.e.* (10 cm length). Significantly maximum number of secondary roots may be due to large size of cuttings which perform better in terms of all the rooting parameters examined in this study. This could be attributed to the fact that longer cuttings probably have higher food reserves, Islam *et al.* (2010).

*IBA concentration (T):*

With respect to IBA concentration significantly maximum number of secondary roots (49.35) for pomegranate cuttings was observed in treatment $T_3$ *i.e.* (5000 ppm IBA) and minimum number of secondary roots (43.63) was observed in $T_1$ *i.e.* (IBA 3000 ppm). It might be due to increased cell division and their differentiation under the influence of rooting chemicals and enhanced hydrolysis of nutritional reserves resulting into increased root formation zone. (Kaur and Kaur 2016). These findings are in agreement with the research work of Tripathi and Shukla (2004) in pomegranate.

*Interaction effect of (L×D):*

The interaction of length and diameter of cutting shows significant effect on number of secondary roots per cutting. Significantly highest number of secondary roots (51.25) per cutting was observed in interaction of $L_3D_2$ *i.e.* (length 20 cm and 1.5 cm diameter), whereas minimum number of secondary roots (40.58) were observed in interaction of $L_1D_1$ *i.e.* (length 10 cm and 1 cm diameter).

*Interaction effect of (T×D):*

Significantly maximum number of secondary roots (50.27) per cutting in pomegranate was observed in interaction of $T_3D_2$ *i.e.* (IBA 5000 ppm and 1.5 cm diameter) which was followed by interaction of $T_3D_1$ (48.44), while minimum number of secondary roots (40.25) were observed in interaction of $T_1D_1$ *i.e.* (IBA 3000 ppm and 1 cm diameter).

*Interaction effect of (T×L):*

The interaction effect of length of cutting and IBA concentration on number of secondary roots shows significant variation. The interaction of $T_3L_3$ *i.e.* (IBA 5000 ppm and 20 cm length) was recorded significantly maximum number of secondary roots (53.89) per cutting, which was statistically at par with interactions of $T_3L_2$ (48.72) and $T_2L_1$ (49.37) whereas minimum number of secondary roots (41.36) was observed in interaction of $T_1L_1$ *i.e.* (IBA 3000 ppm and 10 cm length). However, the interaction of IBA concentration, length and diameter of cuttings (T×D×L)wasfound to be non significant on number of secondary roots per cutting in pomegranate.

**Root length (cm) at 90DAP:**

The effect of diameter of cutting (D), length of cutting (L), IBA concentrations (T) and their interactions on root length per cutting of pomegranate are presented in Table 2.

*Effect of cutting diameter (D):*

The perusal of data in Table 10 reveals that, significantly maximum root length (19.24 cm) was recorded in $D_2$ *i.e.* (1.5 cm diameter), while minimum root length (16.00 cm) was observed in $D_1$ *i.e.* (1 cm diameter).

*Effect of cutting length (L):*

Significantly maximum root length (20.61 cm) was recorded with treatment $L_3$ *i.e.* (20 cm length) and minimum root length (15.63 cm) was observed in $L_1$ *i.e.* (10cm length). A reduction in root length was observed with reduction in cutting size due to inadequate supply of nutrients and leaching of nutrients in shorter cuttings resulted in poor performance in rooting. The length of longest root may be due to better physiological maturity of the cuttings along with the mobilization of secondary

**Table 2: Effect of cutting size and IBA concentration on length of root in pomegranate**

| Treatments | Length of root (cm) |
|---|---|
| | 90DAP |
| Diameter of cutting (D) | |
| $D_1$ | 16.00 |
| $D_2$ | 19.24 |
| S.E N± | 0.46 |
| C.D. at 5% | 1.28 |
| Length of cutting (L) | |
| $L_1$ | 15.63 |
| $L_2$ | 16.61 |
| $L_3$ | 20.61 |
| S.E N± | 0.56 |
| C.D. at 5% | 1.57 |
| IBA concentration (T) | |
| $T_1$ | 16.30 |
| $T_2$ | 17.63 |
| $T_3$ | 18.91 |
| S.E N± | 0.56 |
| C.D. at 5% | 1.57 |
| Interaction (L x D) | |
| $L_1D_1$ | 13.55 |
| $L_2D_1$ | 16.66 |
| $L_3D_1$ | 17.77 |
| $L_1D_2$ | 15.72 |
| $L_2D_2$ | 16.55 |
| $L_3D_2$ | 23.44 |
| S.E N± | 0.80 |
| C.D. at 5% | 2.22 |
| Interaction (T x D) | |
| $T_1D_1$ | 14.72 |
| $T_1D_2$ | 17.05 |
| $T_2D_1$ | 15.55 |
| $T_2D_2$ | 19.55 |
| $T_3D_1$ | 17.72 |
| $T_3D_2$ | 20.69 |
| S.E N± | 0.80 |
| C.D. at 5% | 2.22 |
| Interaction (L x T) | 90DAP |
| $T_1L_1$ | 14.25 |
| $T_1 L_2$ | 16.33 |
| $T_1 L_3$ | 18.33 |
| $T_2 L_1$ | 20.33 |
| $T_2 L_2$ | 17.25 |
| $T_2L_3$ | 15.33 |
| $T_3L_1$ | 17.33 |
| $T_3 L_2$ | 16.25 |
| $T_3 L_3$ | 23.16 |
| S.E N± | 0.98 |
| C.D. at 5% | 2.72 |

*Table 2: Contd....*

Table 2: Contd……...

| Interaction (T x D x L) | | |
|---|---|---|
| $T_1D_1L_1$ | | 12.16 |
| $T_1D_1L_2$ | | 18.16 |
| $T_1D_1L_3$ | | 16.33 |
| $T_1D_2L_1$ | | 20.33 |
| $T_1D_2L_2$ | | 14.50 |
| $T_1D_2L_3$ | | 16.33 |
| $T_2D_1L_1$ | | 15.66 |
| $T_2D_1L_2$ | | 15.00 |
| $T_2D_1L_3$ | | 13.50 |
| $T_2D_2L_1$ | | 23.08 |
| $T_2D_2L_2$ | | 19.50 |
| $T_2D_2L_3$ | | 17.16 |
| $T_3D_1L_1$ | | 23.08 |
| $T_3D_1L_2$ | | 16.83 |
| $T_3D_1L_3$ | | 15.00 |
| $T_3D_2L_1$ | | 17.66 |
| $T_3D_2L_2$ | | 15.66 |
| $T_3D_2L_3$ | | 25.00 |
| S.E N± | | 1.39 |
| CD at 5% | | 3.86 |
| **Treatment details** | | |
| $D_1$-Diameter 1 cm | $L_1$- Length 10 cm | $T_1$- 3000 ppm IBA |
| | $L_2$- Length 15 cm | $T_2$- 4000 ppm IBA |
| $D_2$-Dimeter 1.5 cm | $L_3$- Length 20 cm | $T_3$- 5000 ppm IBA |

metabolites towards better root formation and hence, more number of roots and highest root length, Pooja *et al.* (2013).

*IBA concentration (T):*

The data presented in Table 2 indicated that, length of root was significantly influenced by IBA concentration. Significantly maximum root length (18.91 cm) was observed in treatment $T_3$ *i.e.* (IBA 5000 ppm). However, minimum root length (16.30 cm) was observed in treatment $T_1$ *i.e.* (IBA 3000 ppm). The increased in length of roots might be due to auxin hormone which plays an important role in metabolic activity and cell division process of cuttings, resulting into increased growth of roots. Edmond *et al.* (1997).

*Interaction effect of (L×D):*

The interaction of length and diameter of cutting shows significant effect on root length. Significantly highest root length (23.44 cm) was observed in interaction of $L_3D_2$ *i.e.* (length 20 cm and 1.5 cm diameter). However, lowest root length (13.55cm) was observed in interaction of $L_1D_1$ *i.e.* (length 10 cm and 1 cm diameter).

*Interaction effect of (T×D):*

Significantly maximum root length (20.55 cm) of pomegranate cuttings was observed in interaction of $T_2D_2$ *i.e.* (IBA 4000 ppm and 1.5 cm diameter) which was followed by interaction of $T_3D_2$ (20.11 cm), $T_3D_1$ (17.72 cm) and minimum root length (14.72 cm) was observed in interaction of $T_1D_1$ *i.e.* (IBA 3000 ppm and 1 cm diameter).

*Interaction effect of (T×L):*

The interaction effect of length of cutting and IBA concentration on root length shows significant variation. The interaction $T_3L_3$ *i.e.* (IBA 5000 ppm and 20 cm length) was recorded significantly highest root length (23.16 cm) which was statistically at par with the interactions of $T_2L_1$ (20.33 cm), $T_1L_3$ (18.33 cm) and lowest root length (14.25 cm) was observed in interaction of $T_1L_1$ *i.e.* (IBA 3000 ppm and 10 cm length).

*Interaction effectof (T×D×L):*

The data presented in Table 2 indicate that, length of root was significantly influenced by IBA concentration, diameter and length of cuttings. The data in respect to root length per cutting was recorded significantly maximum (25.00 cm) in interaction of $T_3D_2L_3$ which was followed by interactions of $T_2D_2L_1$ (23.08 cm) and $T_1D_2L_1$ (20.33 cm). However, minimum root length (12.16 cm) was observed under interaction of $T_1D_1L_1$.

**Rooting percentage :**

The effect of cutting diameter (D), length of cutting (L), IBA concentrations (T) and their interactions on rooting percentage of pomegranate cutting are presented in Table 3.

*Effect of cutting diameter (D):*

With respect to diameter, highest percentage of rooting (68.79 %) was recorded in treatment $D_2$ *i.e.* (1.5 cm diameter) and lowest rooting percentage (62.37 %) was observed in treatment $D_1$. *i.e.* (1 cm diameter). This might be due to maximum storage food for root initiation as compared to small cutting size. These results are in conformity with the findings of Naidu and Jone (2009).

*Effect of cutting length (L):*

The length of cutting has significant effect on rooting percentage. The highest rooting percentage (69.47 %) was observed in $L_3$ *i.e.* (20 cm length), whereas the lowest rooting percentage (60.75 %)was observed in $L_1$ *i.e.* (10 cm length). It might be due to better physiological maturity of the stem cuttings along with the mobilization of secondary metabolites towards better root formation and hence, more number of roots and highest root length. Pooja *et al.*(2013). These results coincide with the findings of Nicoloso *et al.* (2001) in Pfaffia glomerata and Jadhav *et al.* (2003) in patchouli.

*IBA concentration (T):*

The result from the study indicate that IBA concentration have positive effect on rooting percentage of pomegranate cutting. The highest rooting percentage (66.02 %) was recorded in treatment $T_3$*i.e.* (IBA 5000 ppm) and lowest rooting percentage (62.58 %) was observed in treatment $T_1$ *i.e.* (IBA 3000 ppm).

It might be due to increase in cell division and their differentiation under the influence of rooting chemicals, enhanced hydrolysis of nutritional reserves resulting into increased root formation zone. Shukla *et al.*(2010). These findings are in agreement to the report of Prati *et al.* (1999) in lime and Tripathi and Shukla (2004) in pomegranate.

*Interaction effect of (L×D):*

The interaction of length and diameter of cutting shows significant effect on rooting percentage. Significantly highest rooting percentage (74.55 %) was observed in interaction of $L_3D_2$*i.e.* (length 20 cm and diameter 1.5 cm) and lowest rooting percentage (57.31 %) was observed in interaction of $L_1D_1$*i.e.* (10 cm length and 1 cm diameter).

*Interaction effect of (T×D):*

Significantly highest rooting percentage (69.77 %) of pomegranate cutting was observed in interaction of $T_3D_2$*i.e.* (IBA 5000 ppm and 1.5 cm diameter) which was closely followed by interactions of $T_1D_2$ (66.22 %) and $T_2D_2$ (65.40 %). However, lowest rooting percentage (57.55 %) was observed in interaction of $T_1D_1$ *i.e.* (IBA 3000 ppm and 1 cm diameter).

*Interaction effect of (T×L):*

The interaction effect of length of cutting and IBA concentration on rooting percentage shows significant variation. Significantly highest rooting percentage of cutting (70.75 %) was recorded by interaction of $T_3L_3$*i.e.* (IBA 5000 ppm and 20 cm length) which was statistically at par with interactions of $T_1L_2$ (67.00 %) and $T_2L_2$ (66.50 %) and lowest rooting percentage (56.50 %) of cuttings was observed in $T_1L_1$*i.e.* (IBA 3000 ppm and 10 cm length). However, the interaction of IBA concentrations, length and diameter of cuttings (T×D×L)shows non significant effect on rooting percentage of pomegranate cuttings.

**Fresh weight of root (g):**

Data regarding fresh weight of root per cutting in pomegranate as influenced by diameter of cutting (D), length of cutting (L), IBA concentrations (T) and their interaction are presented in Table 4 and graphically illustrated in Fig. 29 and 30.

*Effect of cutting diameter (D):*

Significantly, maximum weight of fresh root (0.50g) was recorded in treatment $D_2$*i.e.* (1.5cm diameter) and minimum weight of fresh root (0.38g) was observed in $D_1$ *i.e.* (1cm diameter). This might be due to reserve food material available for rooting and development of roots at initial stage. Early rooting helps to absorbs nutrients from media and used for growth and development. Similar results were also observed by Singh *et al.* (2014).

*Effect of cutting length (L):*

The results clearly indicated that, maximum weight of fresh root (0.53g) was recorded with treatment $L_3$*i.e.* (20 cm length) and minimum weight of fresh root (0.35g) was observed in $L_1$*i.e.* (10 cm length). Significantly maximum weight of fresh roots might be due to highest length and maximum number of roots per cuttings. Zhang *et al.* (2010).

*IBA concentration (T):*

There was significant variation in the application of IBA concentration. As per data, weight of fresh root per cutting was recorded maximum (0.56g) in $T_3$*i.e.* (IBA 5000 ppm) and minimum weight of fresh root (0.34g) was observed in $T_1$*i.e.* (IBA 3000 ppm). Maximum weight of roots might be due to the fact that Auxin is for initiation and growth of roots. This might be also due to the reserved food in the cuttings. Kamboj (2017).

**Table 3 : Effect of cutting size and IBA concentration on rooting percentage of pomegranate cuttings**

| Treatments | Rooting percentage 90DAP |
|---|---|
| Diameter of cutting (D) | |
| $D_1$ | 62.37 (38.77) |
| $D_2$ | 68.79 (43.64) |
| S.E N± | 1.13 |
| C.D. at 5% | 3.39 |
| Length of cutting (L) | |
| $L_1$ | 60.75 (37.64) |
| $L_2$ | 66.19 (41.98) |
| $L_3$ | 69.47 (43.99) |
| S.E N± | 0.75 |
| C.D. at 5% | 2.35 |
| IBA concentration (T) | |
| $T_1$ | 62.58 (38.56) |
| $T_2$ | 64.50 (40.48) |
| $T_3$ | 66.02(41.12) |
| S.E N± | 1.15 |
| C.D. at 5% | 3.45 |
| Interaction (L x D) | |
| $L_1D_1$ | 57.31 (35.61) |
| $L_2D_1$ | 65.11 (41.32) |
| $L_3D_1$ | 63.38 (39.37) |
| $L_1D_2$ | 63.88 (39.67) |
| $L_2D_2$ | 67.27 (42.63) |
| $L_3D_2$ | 74.55 (48.62) |
| S.E N± | 1.48 |
| C.D. at 5% | 4.44 |
| Interaction (T x D) | |
| $T_1D_1$ | 57.55 (35.40) |
| $T_1D_2$ | 66.00 (41.08) |
| $T_2D_1$ | 64.27 (40.48) |
| $T_2D_2$ | 65.40 (41.65) |
| $T_3D_1$ | 63.89 (39.72) |
| $T_3D_2$ | 69.77 (43.40) |
| S.E N± | 1.48 |
| C.D. at 5% | 4.45 |
| Interaction (L x T) | 90DAP |
| $T_1L_1$ | 56.50 (34.10) |
| $T_1 L_2$ | 67.00 (42.89) |
| $T_1 L_3$ | 65.25 (41.56) |
| $T_2 L_1$ | 63.00 (39.00) |
| $T_2 L_2$ | 66.50 (42.75) |
| $T_2L_3$ | 58.12 (36.25) |
| $T_3L_1$ | 60.23 (39.25) |
| $T_3 L_2$ | 65.50 (42.02) |
| $T_3 L_3$ | 70.75 (45.38) |
| S.E N± | 2.04 |
| C.D. at 5% | 4.48 |

*Table 3 : Contd……….*

Table 3 : Contd……

| Interaction (T x D x L) | | |
|---|---|---|
| $T_1D_1L_1$ | | 50.83(33.18) |
| $T_1D_1L_2$ | | 67.33 (43.45) |
| $T_1D_1L_3$ | | 68.16 (44.00) |
| $T_1D_2L_1$ | | 69.85 (44.70) |
| $T_1D_2L_2$ | | 65.66 (41.80) |
| $T_1D_2L_3$ | | 63.33 (39.01) |
| $T_2D_1L_1$ | | 64.16 (40.69) |
| $T_2D_1L_2$ | | 65.15 (41.79) |
| $T_2D_1L_3$ | | 62.66 (38.41) |
| $T_2D_2L_1$ | | 60.83 (37.38) |
| $T_2D_2L_2$ | | 73.16 (47.96) |
| $T_2D_2L_3$ | | 71.16 (46.75) |
| $T_3D_1L_1$ | | 68.83 (44.92) |
| $T_3D_1L_2$ | | 65.00 (41.02) |
| $T_3D_1L_3$ | | 67.83 (43.26) |
| $T_3D_2L_1$ | | 60.16 (39.85) |
| $T_3D_2L_2$ | | 73.00 (48.12) |
| $T_3D_2L_3$ | | 78.33 (52.48) |
| S.E N± | | 4.30 |
| CD at 5% | | NS |
| **Treatment details** | | |
| $D_1$-Diameter 1 cm | $L_1$- Length 10 cm | $T_1$- 3000 ppm IBA |
| | $L_2$- Length 15 cm | $T_2$- 4000 ppm IBA |
| $D_2$-Dimeter 1.5 cm | $L_3$- Length 20 cm | $T_3$- 5000 ppm IBA |

* figures in parenthesis indicate the arc sine values

*Interaction effect of (L×D):*

The interaction of length and diameter of cutting shows significant effect on weight of fresh root. Highest weight of fresh root (0.60g) per cutting was observed in interaction of $L_3D_2$ *i.e.* (length 20 cm and diameter 1.5 cm) and lowest weight of fresh root (0.33g) was observed in interaction of $L_1D_1$ *i.e.* (length 10 cm and diameter 1 cm). However, Application of IBA and cutting diameter have not affected significantly on weight of fresh root.

*Interaction effect of (T×L):*

The interaction of $T_3L_3$ *i.e.* (IBA 5000 ppm and 20 cm length) was recorded significantly maximum weight of fresh root (0.59g), which was statistically at par with interaction of $T_3L_2$ (0.52g). However, minimum weight of fresh root (0.32g) was observed in $T_1L_1$ *i.e.* (IBA 3000 ppm and 10 cm length). The weight of fresh root was found to be non significant as influenced by IBA concentrations, diameter and length of cutting (T×D×L).

## Dry weight of root (g):

The effect of cutting diameter (D), length of cutting (L), IBA concentrations (T) and their interactions on weight of dry root per cutting of pomegranate are presented in Table 4.

*Effect of cutting diameter (D):*

The maximum weight of dry root (0.30g) was recorded in $D_2$ *i.e.* (1.5 cm diameter) and minimum weight of dry root (0.23g) was observed in $D_1$ *i.e.* (1 cm diameter). A significant increase in root biomass is correlated with increase in diameter of cuttings in Feijoa sellowiana. This was possibly because of early root initiation in large sized cuttings which provided longer time for their growth and development. Zhang *et al.* (2010)

*Effect of cutting length (L):*

Maximum weight of dry roots (0.32g) was recorded with treatment of $L_3$ *i.e.* (20 cm length) and minimum weight of dry roots (0.210g) in $L_1$ *i.e.* (10 cm length). The higher food reserve in large sized cuttings could be a reason for their better growth and development of the cuttings. Kaur and Kaur (2018).

*IBA concentration (T):*

Significantly highest weight of dry root (0.33g) per cutting was recorded in treatment $T_3$ *i.e.* (IBA 5000 ppm) and lowest weight of dry root (0.21g) was observed in treatment $T_1$ *i.e.* (IBA 3000 ppm). Themaximum root weight was attributed to the fact that auxins naturally occuring or exogeneously applied are for initiation and growth of roots. Low auxin activity and its slow degradation by Auxin destroying enzyme lead to the growth and vigour of roots. This might also be due to the reserved food in the cuttings Singh *et al.* (2013).

*Interaction effect of (L×D):*

Significantly maximum weight of dry root (0.31g) was observed in interaction of $L_3D_2$ *i.e.* (length 20 cm and diameter 1.5 cm) and minimum weight of dry root (0.19g) was observed in interaction of $L_1D_1$ *i.e.* (length 10 cm and diameter 1 cm). However, interaction effectof IBA concentration and cutting diameteron dry weight of root was found to be non significant.

*Interaction effect of (T×L):*

The interaction of $T_3L_3$ *i.e.* (IBA 5000 ppm and 20

**Table 4: Effect of cutting size and IBA concentration on weight of roots per cutting of pomegranate**

| Treatments | Fresh weight of root (g) | Dry weight of root (g) |
|---|---|---|
| | 90DAP | 90DAP |
| Diameter of cutting (D) | | |
| $D_1$ | 0.38 | 0.23 |
| $D_2$ | 0.50 | 0.30 |
| S.E N± | 0.032 | 0.021 |
| C.D. at 5% | 0.090 | 0.059 |
| Length of cutting (L) | | |
| $L_1$ | 0.35 | 0.21 |
| $L_2$ | 0.44 | 0.26 |
| $L_3$ | 0.53 | 0.32 |
| S.E N± | 0.040 | 0.026 |
| C.D. at 5% | 0.11 | 0.072 |
| IBA concentration (T) | | |
| $T_1$ | 0.34 | 0.21 |
| $T_2$ | 0.42 | 0.26 |
| $T_3$ | 0.56 | 0.33 |
| S.E N± | 0.040 | 0.026 |
| C.D. at 5% | 0.11 | 0.072 |
| Interaction (L x D) | | |
| $L_1D_1$ | 0.33 | 0.19 |
| $L_2D_1$ | 0.42 | 0.24 |
| $L_3D_1$ | 0.36 | 0.21 |
| $L_1D_2$ | 0.35 | 0.22 |
| $L_2D_2$ | 0.51 | 0.29 |
| $L_3D_2$ | 0.60 | 0.31 |
| S.E N± | 0.056 | 0.036 |
| C.D. at 5% | 0.15 | 0.10 |
| Interaction (T x D) | | |
| $T_1D_1$ | 0.30 | 0.18 |
| $T_1D_2$ | 0.38 | 0.24 |
| $T_2D_1$ | 0.36 | 0.22 |
| $T_2D_2$ | 0.48 | 0.28 |
| $T_3D_1$ | 0.48 | 0.26 |
| $T_3D_2$ | 0.55 | 0.31 |
| S.E N± | 0.056 | 0.036 |
| C.D. at 5% | NS | NS |
| Interaction (L x T) | 90DAP | 90DAP |
| $T_1L_1$ | 0.32 | 0.18 |
| $T_1L_2$ | 0.33 | 0.20 |
| $T_1L_3$ | 0.36 | 0.23 |
| $T_2L_1$ | 0.43 | 0.23 |
| $T_2L_2$ | 0.46 | 0.26 |
| $T_2L_3$ | 0.37 | 0.23 |
| $T_3L_1$ | 0.36 | 0.21 |
| $T_3L_2$ | 0.52 | 0.24 |
| $T_3L_3$ | 0.59 | 0.29 |
| S.E N± | 0.069 | 0.045 |
| C.D. at 5% | 0.19 | 0.12 |

*Table 4: Contd……..*

Table 4 : Contd……….

| Interaction (T x D x L) | | |
|---|---|---|
| $T_1D_1L_1$ | 0.21 | 0.13 |
| $T_1D_1L_2$ | 0.25 | 0.14 |
| $T_1D_1L_3$ | 0.43 | 0.27 |
| $T_1D_2L_1$ | 0.50 | 0.04 |
| $T_1D_2L_2$ | 0.41 | 0.26 |
| $T_1D_2L_3$ | 0.23 | 0.15 |
| $T_2D_1L_1$ | 0.41 | 0.23 |
| $T_2D_1L_2$ | 0.31 | 0.22 |
| $T_2D_1L_3$ | 0.36 | 0.20 |
| $T_2D_2L_1$ | 0.46 | 0.25 |
| $T_2D_2L_2$ | 0.61 | 0.26 |
| $T_2D_2L_3$ | 0.38 | 0.24 |
| $T_3D_1L_1$ | 0.62 | 0.29 |
| $T_3D_1L_2$ | 0.52 | 0.28 |
| $T_3D_1L_3$ | 0.29 | 0.16 |
| $T_3D_2L_1$ | 0.44 | 0.28 |
| $T_3D_2L_2$ | 0.51 | 0.22 |
| $T_3D_2L_3$ | 0.71 | 0.32 |
| S.E N± | 0.098 | 0.064 |
| CD at 5% | NS | NS |
| **Treatment details** | | |
| $D_1$-Diameter 1 cm | $L_1$- Length 10 cm | $T_1$- 3000 ppm IBA |
| | $L_2$- Length 15 cm | $T_2$- 4000 ppm IBA |
| $D_2$-Dimeter 1.5 cm | $L_3$- Length 20 cm | $T_3$- 5000 ppm IBA |

cm length) was recorded significantly maximum weight of dry root (0.29g) which was statistically at par with the interactions of $T_2L_2$ (0.26g) and $T_3L_2$ (0.24g) while, minimum weight of dry root (0.18g) was observed with interaction of $T_1L_1$ *i.e.* (IBA 3000 ppm and 10 cm length). However, interaction effect ofIBA concentrations, diameter and length of cutting (T×D×L)on weight of dry root was found to be non significant.

Significantly maximum weight of dry roots is due to maximum length and highest number of roots. This might be due to reserve food material available for rooting and development of roots, shoots. Similar results were also reported by Singh *et al.* (2014).

## Conclusion:

Pomegranate cuttings when treated with treatment combination of $T_3D_2L_3$ *i.e.* (IBA 5000 ppm, 1.5 cm diameter and 20 cm length) was found better on root parameters in respect tomaximum number of roots, highest length of roots, rooting percentage and weight of roots of pomegranate cutting.

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