**Seasonal and hormonal influence on rooting, vegetative and morphological growth of pomegranate (*Punica granatum* L.) cv. Bhagwa cuttings**

**Abstract**

A study was conducted to evaluate the response of seasons and plant growth regulators on vegetative and morphological growth of different pomegranate cuttings of cv. Bhagwa. Hardwood (C1) and semi-hardwood cuttings (C2) were taken at three different seasons viz., first fortnight of September (S1), second fortnight of September (S2), and first fortnight of October (S3), and each of the cuttings were treated with 1000 ppm IBA (T1), 1500 ppm IBA (T2), 2000 ppm IBA (T3), 1000 ppm IAA (T4), 1500 ppm IAA (T5), 2000 ppm IAA (T6), 2 % ascorbic acid (T7), and dipped in sterile water (T8 - control). The study revealed that hardwood cuttings (C1) taken during the second fortnight of September (S2) and treated with 2000 ppm IBA (T3) have superior growth at an interval of 30, 60, 90, and 120 days after planting in terms of number of leaves (48.85, 51.66, 53, and 61 respectively), number of shoots (6.16, 7, 8, and 10 respectively), shoot length (15.05, 26.44, 28.11, and 30.33 cm respectively), and height of cuttings (18.33, 18.88, 23.60, and 27 cm respectively). Moreover, the same treatment showed higher number of roots, root length, root diameter, success percentage (34.16 %), and mortality percentage (15.83 %).

**Keywords:** Hardwood cutting, indole-butyric acid, plant growth regulators, pomegranate, and semi-hardwood cuttings.

**Introduction**

Pomegranate (*Punica granatum* L.) belongs to the family Lythraceae is an important commercial fruit crop that can be grown in arid and semi-arid regions. As per PIB (2023), India ranks seventh in the production of pomegranate, and the total area under cultivation is 2,75,500 hectares, with an annual production of 62,280 metric tons.

Pomegranate can be multiplied using seeds and vegetative techniques like air layering and by cuttings. Studies have shown that fruits from orchards grown from seedlings are of low quality, give low and variable yield. Nagpal (1954), reported air layering as a commercially used technique in pomegranate, but it has a negative impact on mother plant growth. Considering this aspect, cuttings are commonly used for vegetative propagation in pomegranates. Patel *et al*. (2020) reported that vegetative plant propagation via cuttings is simpler and less time-consuming, producing true-to-type plants with precocious bearing habit, and hardwood or semi-hardwood cuttings are used for this. As per Singh. (2017) rapid multiplication of pomegranate cuttings can be achieved by using the right type of cutting, rooting hormones, and planting time. Rathwa *et al*. (2017) stated that the success rate of pomegranate cuttings is determined by various parameters, including mother plant conditions, seasons, rainfall, and temperature fluctuations. Considering this, a study was conducted to identify the type of cuttings, best season, and plant growth regulators for rooting, vegetative, and morphological growth of pomegranate (*Punica granatum* L.) cv. Bhagwa.

**Materials and methods**

The present study to evaluate the effect of season and plant growth regulators (PGRs) on different cuttings of pomegranate cv. Bhagwa was conducted at the Karunya Institute of Technology and Sciences in Coimbatore, Tamil Nadu, India during September 2024 to February 2025. Hardwood and semi-hardwood cuttings of 15-20 cm height with 3-4 nodes were taken from the vigorous, healthy plants of pomegranate cv. Bhagwa maintained at the North farm of Karunya Institute of Technology and Sciences situated at 467 meters above mean sea level at 10º 56' 25.79" North and 76º 44' 32.31" East latitudes. The basal end of the cuttings was treated with different concentrations of plant growth regulators i.e,1000ppm 1500ppm, and 2000ppm of IBA and IAA, 2% ascorbic acid, and sterile water for 2 minutes, and cuttings were planted in polybags 5х7 inch size filled with growing media. The experiment was designed as a Three-Factorial Completely Randomised Block using i.e. two types of cuttings, three seasons, and three different concentrations of growth regulators with 48 treatment combinations (Table 1). The treatments were replicated thrice with fifteen cuttings in each treatment.

**Table 1. Treatment details**

|  |  |
| --- | --- |
| Factors | Levels |
| 1. Types of cuttings | C1: Hardwood cutting |
| C2: Semi-hardwood cutting |
| 1. Seasons of cutting | S1:  First fortnight of September |
| S2: Second fortnight of September |
| S3:  First fortnight of October |
| 1. PGR and new molecules | T1: IBA – 1000ppm |
| T2: IBA – 1500ppm |
| T3: IBA – 2000ppm |
| T4: IAA – 1000ppm |
| T5: IAA – 1500ppm |
| T6: IAA – 2000ppm |
| T7: Ascorbic acid 2.0% |
| T8: Control – dipping in sterile water |

The number of leaves, number of shoots, shoot length, and height of cuttings were recorded at 30, 60, 90, and 120 days after planting (DAP), and observations on number of primary and secondary roots, length, and diameter of roots, success percentage, and mortality percentage were recorded after four months of study. The recorded data was statistically analyzed in Web Agri Stat Package (WASP) and OPSTAT.

**Results and discussion**

**Number of leaves**

The data presented in Table 2, showed significant difference between treatments on number of leaves at 120 DAP. The hardwood cuttings (C1) planted during the second fortnight of September (S2), and treated with 2000ppm IBA (T3) gave the maximum number of leaves (61), which is on par with hardwood cuttings (C1) treated with 1500ppm IAA (T3) planted during the second fortnight of September (S2) (50). The enhanced physiological conditions allow treated plants to have more leaves in the end. It might be due to the wood maturity of the cutting and likely retains a lot of sugar and starch in the cuttings at the end of the planting (Mehta *et al.*, 2018). Tanwar *et al*. (2020) stated that the cuttings treated with IBA 2000 ppm produced the most leaves because this treatment activated shoot growth, which likely increased the number of nodes that resulted in the formation of more leaves. This finding is lined up with Singh and Chouhan (2016), in phalsa.

**Number of shoots**

A significant difference between treatments was observed in the number of shoots at 120 DAP (Table 2). Hardwood cuttings (C1) treated with 2000ppm IBA (T3) planted during the second fortnight of September (S2) showed the highest number of shoots (10) and it was found to be on par with hardwood cuttings (C1) treated with 1500ppm IAA (T3) planted during the second fortnight of September (S2) with 8.50 shoots. Sabharwal *et al*. (2023) reported that hardwood cuttings have a highly developed vascular system, which helps to maintain turgor pressure and minimize water loss. Tanwar *et al*. (2020) opined that could be when auxins applied externally encouraged growth and provided more favourable conditions for dormant buds on the cutting to sprout and it is suspected that the increased physiological activities in the cuttings at this concentration are the reason why the cuttings treated with 2000 ppm IBA produced more shoots per cutting than the cuttings treated with 1500ppm IBA. Similar results were also observed in Kaur and Singh (2022), Upadhyay and Badyal. (2007), and Manila *et al*. (2017) in pomegranate.

**Shoot length (cm)**

The shoot length of pomegranate cv. Bhagwa cuttings observed on 120 DAP showed a significant significant difference between treatments (Table 2). Maximum shoot length of 30.33 cm was noted in hardwood cuttings (C1) treated with 2000ppm IBA (T3) planted during the second fortnight of September (S2), and it was on par with hardwood cuttings (C1) treated with 2000ppm IBA (T3) planted during the first fortnight of October (S3) with 27.33 cm. This may be due to a more developed vascular system, which provides the efficient transport of nutrients and water to the growing shoots (Hartmann *et al*., 2018). It facilitates the harmonious growth of roots and shoots by preserving the hormonal balance inside the cuttings, and effective nutrition and energy usage are provided for shoot growth (Ashok andRavivarman, 2020). These outcomes are similar to Alimam and Agha. (2021) in grapes, and Madhavan *et al*. (2021) in grapes.

**Height of cuttings (cm)**

Data presented in Table 2, revealed a significant difference between treatments on the height of cuttings at 60, 90, and 120 DAP. At 60, 90, and 120 DAP, a gradual increase in height of cuttings was observed in hardwood cuttings (C1) planted during the second fortnight of September (S2) treated with 2000ppm IBA (T3) (18.88, 23.60, and 27 cm respectively) which was on par with hardwood cuttings (C1) treated with 2000ppm IBA (T3) planted during the first fortnight of October (S3) (19.33, 25.33, and 20.33 respectively). Blythe *et al*. (2019) revealed that higher levels of lignification in hardwood cuttings promote structural integrity and long-term shoot elongation. The application of IBA promotes shoot elongation by speeding up root initiation, which enhances nutrient absorption and translocation, which was noted by Hartmann *et al*. (2018). Better hormonal signaling, especially auxin and gibberellin interactions, supports vertical development (Davies *et al*., 2020). Ranjangam *et al*. (2022) in acid lime reported similar findings.

**Number of primary and secondary roots**

The data of number of primary roots observed at 120 DAP showed no significant difference between treatments, whereas the number of secondary roots showed significant difference between treatments at 120 DAP (Table 3). The maximum number of secondary roots (25.66) was observed in the hardwood cuttings (C1) planted during the second fortnight of September (S2) treated with 2000ppm IBA (T3). This was found to be on par with hardwood cuttings (C1) treated with 2000ppm IBA (T3) and planted during the first fortnight of October (S3). As per Tanwar *et al*. (2020), a hormonal impact that triggers internal substances to accumulate and move downward might be responsible for the greatest number of roots seen at 2000 ppm IBA. These growth regulators additionally enhance cambial activity, which is involved in root initiation in many species. This result is in close agreement with Madhavan *et al*. (2021) in grapes, Singh and Chouhan (2016) in phalsa. The positive effect of IBA concentration usage agrees with the result obtained by Ansari. (2013), Rajkumar *et al*. (2017), Singh. (2017), and Kaur *et al*. (2022), in pomegranate.

**Root length (cm)**

Root length of hardwood and semi-hardwood cuttings of pomegranate cv. Bhagwa recorded at 120 DAP showed significant difference between treatments. The hardwood cuttings (C1) planted in the second fortnight of September (S2) treated with 2000ppm IBA (T3) had the longest roots (31.16 cm) which was found to be on par with hardwood cuttings (C1) planted in the second fortnight of September (S2) treated with 1000ppm IAA (T4). The root length has a positive effect that interacts to regulate cell division, elongation, and nutrient availability, leading to differential root growth responses. As per Strydem and Hartman. (1960), the increased hydrolysis of carbohydrates, metabolite accumulation at the auxin application site, protein synthesis, cell enlargement, and auxin-induced cell division can contribute to the longer roots in cuttings treated with growth regulators. The outcome is similar to Alimam *et al.* (2021) in grapes.

**Root diameter (mm)**

The data on root diameter presented in Table 3 showed no significant difference between the treatments at 120 DAP.

**Success percentage (%)**

A significant difference was observed between treatments on success percentage of hardwood and semi-hardwood cuttings of pomegranate cv. Bhagwa. The hardwood cuttings treated with 2000ppm IBA planted in thesecond fortnight of September (S2) (34.16 %) have a maximum success percentage (Fig 1). High reserves of carbohydrates per cutting, the right time of planting, and optimum IBA concentration might have contributed to the success percentage of cutting. According to Tanwar *et al*. (2020), the cuttings treated with 2000 ppm IBA had the highest survival rate in the polybag, mostly due to the characteristics of the roots and shoots. These results are in agreement with Beniwal *et al*. (2022) in grapes and Mehta *et al*. (2018) in pomegranate.

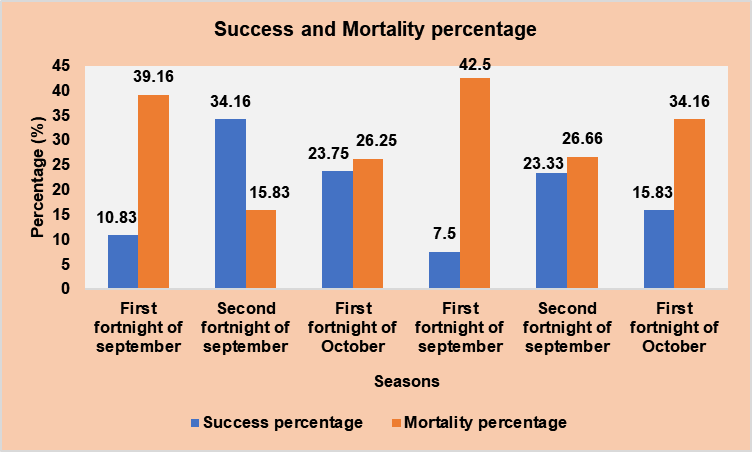
**Mortality percentage (%)**

Mortality percentagecalculated in the study showed a significant difference between treatments (Fig 1). The highest mortality rate was observed in semi-hardwood cuttings treated with sterile water and planted during the first fortnight of September (S1) (42.5 %). As per Singh. (2020), the lower amount of carbohydrates present in semi-hardwood cuttings than hardwood cuttings might have contributed to the production of less roots and shoots as they have less energy. Moreover, the presence of their partially established cuticle layers in semi-hardwood cuttings might have contributed to more transpiration, which leads to excessive water loss and desiccation (Hartmann *et al.*, 2018). Kumar *et al.* (2021) reported that reduced lignification lowers their survival rates by making them more vulnerable to environmental stress and fungal infections.

**Conclusion**

The experiment concluded that hardwood cuttings of pomegranate cv. Bhagwa treated with 2000 ppm IBA planted during the second fortnight of September and was superior to all other treatments in terms of number of leaves, number of shoots, shoot length, height of cuttings at 30, 60, 90, and 120 days after planting, and the number of primary and secondary roots, root length, root diameter, success percentage, and mortality percentage was recorded after 120 days after planting.

**Fig. 1 The effect of types of cuttings, seasons, and plant growth regulators on success and mortality percentage.**



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1.

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Table 2. Interaction effect of types of cuttings, seasons and plant growth regulators of number of leaves, shoots, shoot length, and height of cuttings in the intervals of 30, 60, 90, and 120 days of planting

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** |
|  | **Number of leaves** | | | | **Number of shoots** | | | | **Shoot length (cm)** | | | | **Height of cuttings (cm)** | | | |
| **C1S1T1** | 23.55 | 0.00 | 0.00 | 0.00 | 3.88 | 0.00 | 0.00 | 0.00 | 3.69 | 0.00 | 0.00 | 0.00 | 14.65 | 0.00 | 0.00 | 0.00 |
| **C1S1T2** | 25.77 | 4.66 | 0.00 | 0.00 | 3.66 | 1.66 | 0.00 | 0.00 | 5.11 | 2.33 | 0.00 | 0.00 | 14.05 | 14.05 | 0.00 | 0.00 |
| **C1S1T3** | 42.52 | 17.44 | 5.00 | 4.00 | 5.19 | 1.77 | 1.33 | 1.88 | 10.78 | 15.33 | 4.01 | 6.66 | 17.19 | 17.19 | 17.19 | 17.19 |
| **C1S1T4** | 27.21 | 8.00 | 1.66 | 2.00 | 3.33 | 1.33 | 0.33 | 1.00 | 4.44 | 3.66 | 1.00 | 5.33 | 14.76 | 14.76 | 14.76 | 14.76 |
| **C1S1T5** | 19.11 | 3.66 | 2.00 | 1.66 | 3.81 | 1.00 | 0.66 | 1.33 | 3.10 | 3.33 | 1.66 | 6.66 | 14.83 | 14.83 | 14.83 | 14.83 |
| **C1S1T6** | 19.44 | 3.50 | 3.00 | 3.16 | 3.33 | 0,83 | 0.83 | 1.16 | 5.83 | 3.00 | 0.66 | 2.83 | 14.77 | 14.77 | 14.77 | 14.77 |
| **C1S1T7** | 30.44 | 12.66 | 3.33 | 3.00 | 2.33 | 3.33 | 1.00 | 2.00 | 6.78 | 9.33 | 2.33 | 15.00 | 14.11 | 14.11 | 14.00 | 14.11 |
| **C1S1T8** | 37.55 | 5.33 | 0.00 | 0.00 | 4.10 | 1.00 | 0.00 | 0.00 | 6.60 | 2.33 | 0.00 | 0.00 | 14.94 | 14.94 | 0.00 | 0.00 |
| **C1S2T1** | 20.33 | 42.22 | 43.66 | 46.66 | 4.88 | 5.44 | 6.55 | 7.88 | 8.38 | 20.55 | 21.88 | 25.66 | 14.63 | 14.39 | 15.88 | 19.00 |
| **C1S2T2** | 16.22 | 28.78 | 32.94 | 35.61 | 4.22 | 4.77 | 4.99 | 6.33 | 7.77 | 17.11 | 18.66 | 23.33 | 14.46 | 15.89 | 16.22 | 20.66 |
| **C1S2T3** | 48.85 | 51.66 | 53.00 | 61.00 | 6.16 | 7.00 | 8.00 | 10.00 | 15.05 | 26.44 | 28.11 | 30.33 | 18.33 | 18.88 | 23.60 | 27.00 |
| **C1S2T4** | 17.22 | 31.89 | 35.16 | 39.16 | 4.77 | 4.66 | 5.27 | 6.94 | 6.10 | 15.89 | 17.83 | 20.5 | 13.24 | 15.11 | 17.38 | 19.88 |
| **C1S2T5** | 16.66 | 40.11 | 41.11 | 50.25 | 4.77 | 6.55 | 7.50 | 8.50 | 4.72 | 8.39 | 14.55 | 14.91 | 13.93 | 14.22 | 16.38 | 18.33 |
| **C1S2T6** | 15.77 | 21.66 | 27.00 | 31.00 | 4.66 | 3.66 | 4.99 | 7.44 | 5.16 | 9.89 | 12.44 | 14.44 | 13.66 | 14.77 | 15.55 | 20.44 |
| **C1S2T7** | 15.88 | 26.66 | 30.38 | 35.10 | 4.77 | 4.16 | 5.94 | 7.11 | 6.10 | 9.16 | 11.83 | 13.5 | 12.22 | 13.77 | 15.11 | 20.00 |
| **C1S2T8** | 14.66 | 15.22 | 25.61 | 32.22 | 4.99 | 3.33 | 5.00 | 6.66 | 5.88 | 9.94 | 13.22 | 15.66 | 14.27 | 15.14 | 16.50 | 18.00 |
| **C1S3T1** | 18.22 | 23.88 | 29.11 | 3.44 | 3.10 | 5.66 | 4.99 | 1.00 | 7.33 | 10.66 | 16.10 | 2.66 | 15.66 | 17.00 | 20.00 | 18.33 |
| **C1S3T2** | 18.33 | 23.11 | 26.66 | 12.99 | 3.22 | 4.33 | 5.11 | 2.44 | 7.99 | 19.77 | 23.37 | 7.00 | 13.88 | 16.11 | 19.22 | 16.88 |
| **C1S3T3** | 28.33 | 37.11 | 39.66 | 41.00 | 4.66 | 6.22 | 8.33 | 7.22 | 9.88 | 21.80 | 26.97 | 27.33 | 16.10 | 19.33 | 25.33 | 20.33 |
| **C1S3T4** | 13.05 | 17.50 | 20.97 | 12.18 | 2.83 | 3.83 | 5.33 | 1.00 | 8.22 | 15.94 | 18.73 | 7.33 | 13.66 | 18.77 | 21.00 | 17.33 |
| **C1S3T5** | 9.77 | 14.11 | 17.22 | 0.00 | 2.77 | 3.89 | 4.22 | 0.00 | 6.00 | 14.00 | 15.33 | 0.00 | 14.88 | 17.66 | 18.38 | 0.00 |
| **C1S3T6** | 8.22 | 13.55 | 17.66 | 19.33 | 1.94 | 3.44 | 4.44 | 5.83 | 5.44 | 8.00 | 10.33 | 9.59 | 14.22 | 15.38 | 17.44 | 15.55 |
| **C1S3T7** | 15.55 | 20.89 | 20.44 | 12.53 | 3.77 | 4.89 | 4.43 | 4.00 | 6.22 | 9.22 | 12.44 | 13.21 | 14.66 | 15.78 | 20.33 | 19.00 |
| **C1S3T8** | 16.22 | 33.55 | 21.99 | 12.99 | 5.44 | 5.55 | 6.55 | 2.00 | 7.44 | 15.78 | 16.32 | 5.83 | 16.44 | 17.22 | 19.10 | 17.00 |
| **C2S1T1** | 13.88 | 7.83 | 2.00 | 2.00 | 4.33 | 0.33 | 0.67 | 0.66 | 4.61 | 3.50 | 2.66 | 2.83 | 13.61 | 13.61 | 13.61 | 13.61 |
| **C2S1T2** | 18.22 | 0.00 | 0.00 | 0.00 | 3.16 | 0.00 | 0.00 | 0.00 | 4.27 | 0.00 | 0.00 | 0.00 | 15.65 | 0.00 | 0.00 | 0.00 |
| **C2S1T3** | 23.10 | 14.67 | 6.83 | 5.50 | 4.00 | 1.00 | 1.33 | 1.16 | 5.03 | 8.16 | 4.16 | 3.66 | 16.10 | 16.10 | 16.10 | 16.10 |
| **C2S1T4** | 16.88 | 0.00 | 0.00 | 0.00 | 3.66 | 0.00 | 0.00 | 0.00 | 3.44 | 0.00 | 0.00 | 0.00 | 14.88 | 0.00 | 0.00 | 0.00 |
| **C2S1T5** | 21.55 | 0.00 | 0.00 | 0.00 | 3.44 | 0.00 | 0.00 | 0.00 | 4.03 | 0.00 | 0.00 | 0.00 | 13.49 | 0.00 | 0.00 | 0.00 |
| **C2S1T6** | 20.22 | 0.00 | 0.00 | 0.00 | 3.33 | 0.00 | 0.00 | 0.00 | 3.28 | 0.00 | 0.00 | 0.00 | 15.50 | 0.00 | 0.00 | 0.00 |
| **C2S1T7** | 12.66 | 11.66 | 2.00 | 1.66 | 3.66 | 1.00 | 1.00 | 1.33 | 3.02 | 3.66 | 1.00 | 3.00 | 13.75 | 13.75 | 13.75 | 13.75 |
| **Treatments** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** |
|  | **Number of leaves** | | | | **Number of shoots** | | | | **Shoot length (cm)** | | | | **Height of cuttings (cm)** | | | |
| **C2S1T8** | 17.33 | 16.83 | 3.00 | 1.33 | 2.33 | 1.00 | 0.66 | 1.00 | 3.02 | 5.16 | 2.33 | 3.00 | 13.93 | 13.93 | 13.93 | 13.93 |
| **C2S2T1** | 13.66 | 26.89 | 28.22 | 25.38 | 3.33 | 3.61 | 4.61 | 5.11 | 4.22 | 10.39 | 13.11 | 14.00 | 14.10 | 15.89 | 13.85 | 18.00 |
| **C2S2T2** | 8.33 | 11.55 | 15.77 | 18.33 | 2.33 | 1.77 | 2.11 | 2.66 | 4.18 | 9.00 | 10.33 | 11.33 | 13.66 | 13.33 | 14.58 | 19.00 |
| **C2S2T3** | 27.00 | 30.00 | 32.98 | 34.94 | 3.77 | 4.66 | 6.00 | 8.00 | 10.55 | 10.88 | 14.33 | 18.66 | 17.12 | 18.00 | 20.50 | 24.00 |
| **C2S2T4** | 8.44 | 18.83 | 25.5 | 33.94 | 2.44 | 2.33 | 4.50 | 6.00 | 3.52 | 7.11 | 8.00 | 8.833 | 12.77 | 13.94 | 14.88 | 19.22 |
| **C2S2T5** | 11.44 | 16.78 | 22.77 | 26.44 | 2.44 | 2.55 | 4.44 | 6.44 | 4.72 | 8.00 | 9.11 | 13.00 | 12.10 | 12.89 | 14.44 | 18.66 |
| **C2S2T6** | 10.33 | 11.16 | 13.61 | 15.27 | 2.88 | 2.07 | 3.22 | 4.61 | 5.52 | 5.83 | 10.16 | 12.66 | 14.33 | 15.33 | 16.44 | 18.77 |
| **C2S2T7** | 14.99 | 13.00 | 15.83 | 17.83 | 2.77 | 2.50 | 3.33 | 5.00 | 4.85 | 7.33 | 8.50 | 10.33 | 12.38 | 14.00 | 14.33 | 18.33 |
| **C2S2T8** | 9.55 | 11.72 | 20.27 | 20.61 | 2.21 | 2.33 | 3.38 | 5.22 | 3.85 | 7.05 | 9.83 | 13.33 | 13.55 | 14.44 | 15.22 | 19.88 |
| **C2S3T1** | 13.66 | 21.22 | 12.33 | 0.00 | 2.33 | 3.77 | 4.55 | 0.00 | 5.70 | 11.66 | 9.63 | 0.00 | 14.66 | 15.66 | 19.00 | 0.00 |
| **C2S3T2** | 12.99 | 21.61 | 15.50 | 13.33 | 1.66 | 3.33 | 4.33 | 1.66 | 5.91 | 14.11 | 9.16 | 4.16 | 14.83 | 15.61 | 19.88 | 16.33 |
| **C2S3T3** | 14.44 | 24.07 | 26.66 | 27.55 | 2.44 | 5.33 | 6.66 | 5.00 | 7.25 | 15.00 | 18.66 | 21.00 | 15.89 | 17.33 | 21.33 | 23.44 |
| **C2S3T4** | 13.11 | 18.55 | 13.22 | 15.77 | 1.33 | 4.44 | 4.66 | 0.66 | 4.55 | 6.66 | 8.32 | 2.50 | 13.65 | 16.11 | 20.33 | 18.33 |
| **C2S3T5** | 9.10 | 13.55 | 6.77 | 18.33 | 1.99 | 4.00 | 5.00 | 2.00 | 4.44 | 9.44 | 7.44 | 8.96 | 14.66 | 15.44 | 19.44 | 20.23 |
| **C2S3T6** | 8.77 | 18.22 | 16.88 | 0.00 | 1.88 | 4.55 | 4.00 | 0.00 | 4.88 | 9.44 | 8.66 | 0.00 | 14.55 | 15.44 | 19.10 | 0.00 |
| **C2S3T7** | 9.44 | 14.00 | 14.44 | 0.00 | 1.44 | 4.33 | 3.00 | 0.00 | 4.77 | 8.11 | 8.66 | 0.00 | 13.77 | 14.66 | 17.99 | 0.00 |
| **C2S3T8** | 11.66 | 20.66 | 14.44 | 0.00 | 1.33 | 4.44 | 3.44 | 0.00 | 5.22 | 12.99 | 12.05 | 0.00 | 14.66 | 15.55 | 17.44 | 0.00 |
| **SE (d)** | NS | NS | NS | 5.41 | NS | NS | NS | 1.09 | NS | NS | NS | 3.84 | NS | 2.20 | 3.30 | 6.29 |
| **CD 5%** | NS | NS | NS | 10.75 | NS | NS | NS | 2.17 | NS | NS | NS | 7.63 | NS | 4.36 | 6.55 | 12.48 |

*(C1 - Hardwood cuttings, C2 - Semi-hardwood cuttings, S1 – First fortnight of September, S2 – Second fortnight of September, S3 – First fortnight of October,*

*T1 – 1000 ppm IBA, T2 – 1500 ppm IBA, T3 – 2000 ppm IBA, T4 – 1000 ppm IAA, T5 – 1500 ppm IAA, T6 – 2000 ppm IAA, T7 – 2% Ascorbic acid, T8 – Control – dipping in sterile water)*

Table 3. Interaction effect of types of cuttings, seasons, and plant growth regulators of the number of primary and secondary roots root length, and root diameter after 120 days of planting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Number of primary and secondary roots** | | **Root length (cm)** | **Root diameter (mm)** |
| **C1S1T1** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C1S1T2** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C1S1T3** | 2.66 | 9.33 | 5.50 | 0.60 |
| **C1S1T4** | 1.00 | 5.33 | 4.16 | 0.53 |
| **C1S1T5** | 1.66 | 4.66 | 3.30 | 0.38 |
| **C1S1T6** | 1.33 | 3.66 | 3.80 | 0.55 |
| **C1S1T7** | 1.66 | 6.00 | 4.44 | 0.55 |
| **C1S1T8** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C1S2T1** | 3.00 | 17.33 | 14.33 | 1.34 |
| **C1S2T2** | 3.66 | 13.66 | 15.33 | 1.51 |
| **C1S2T3** | 5.00 | 25.66 | 31.16 | 1.84 |
| **C1S2T4** | 1.66 | 11.66 | 24.86 | 0.94 |
| **C1S2T5** | 3.66 | 10.66 | 20.20 | 0.73 |
| **C1S2T6** | 4.00 | 9.00 | 19.00 | 1.24 |
| **C1S2T7** | 2.66 | 15.00 | 13.33 | 1.04 |
| **C1S2T8** | 2.00 | 10.33 | 6.00 | 1.22 |
| **C1S3T1** | 0.33 | 6.00 | 5.83 | 0.52 |
| **C1S3T2** | 1.66 | 13.00 | 7.60 | 0.65 |
| **C1S3T3** | 2.00 | 18.00 | 21.10 | 1.44 |
| **C1S3T4** | 1.00 | 5.66 | 4.66 | 0.55 |
| **C1S3T5** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C1S3T6** | 1.66 | 15.33 | 5.76 | 0.66 |
| **C1S3T7** | 1.00 | 5.00 | 3.00 | 0.59 |
| **C1S3T8** | 1.00 | 8.00 | 5.00 | 0.25 |
| **C2S1T1** | 0.33 | 5.00 | 2.83 | 0.33 |
| **C2S1T2** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C2S1T3** | 1.66 | 5.33 | 5.66 | 0.41 |
| **C2S1T4** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C2S1T5** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C2S1T6** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C2S1T7** | 1.33 | 3.00 | 3.43 | 0.19 |
| **C2S1T8** | 1.00 | 2.66 | 2.33 | 0.35 |
| **C2S2T1** | 2.00 | 7.00 | 7.56 | 1.26 |
| **Treatments** | **Number of primary and secondary roots** | | **Root length (cm)** | **Root diameter (mm)** |
| **C2S2T2** | 2.66 | 11.33 | 5.80 | 1.35 |
| **C2S2T3** | 4.00 | 16.66 | 18.56 | 1.73 |
| **C2S2T4** | 1.66 | 7.00 | 8.33 | 1.05 |
| **C2S2T5** | 1.66 | 4.66 | 7.03 | 0.35 |
| **C2S2T6** | 2.00 | 10.00 | 8.73 | 1.09 |
| **C2S2T7** | 3.00 | 11.66 | 13.46 | 0.96 |
| **C2S2T8** | 3.00 | 12.66 | 8.69 | 0.61 |
| **C2S3T1** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C2S3T2** | 1.00 | 7.33 | 3.66 | 0.96 |
| **C2S3T3** | 1.66 | 14.00 | 6.66 | 1.43 |
| **C2S3T4** | 1.00 | 12.33 | 3.33 | 0.30 |
| **C2S3T5** | 1.33 | 13.00 | 5.00 | 0.44 |
| **C2S3T6** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C2S3T7** | 0.00 | 0.00 | 0.00 | 0.00 |
| **C2S3T8** | 0.00 | 0.00 | 0.00 | 0.00 |
| **SE (d)** | NS | 4.30 | 3.20 | NS |
| **CD 5 %** | NS | 8.63 | 6.41 | NS |

*(C1 - Hardwood cuttings, C2 - Semi-hardwood cuttings, S1 – First fortnight of September, S2 – Second fortnight of September, S3 – First fortnight of October,*

*T1 – 1000 ppm IBA, T2 – 1500 ppm IBA, T3 – 2000 ppm IBA, T4 – 1000 ppm IAA, T5 – 1500 ppm IAA, T6 – 2000 ppm IAA, T7 – 2% Ascorbic acid, T8 – Control – dipping in sterile water)*

Table 4. Effect of types of cuttings, seasons, and plant growth regulators of number of leaves, shoots, shoot length (cm), and height of cuttings (cm) in the intervals of 30, 60, 90, and 120 days of planting

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** |
|  | **Number of leaves** | | | | **Number of shoots** | | | | **Shoot length (cm)** | | | | **Height of cuttings (cm)** | | | |
| **Types of cuttings (C)** | | | | | | | | | | | | | | | | |
| **C1** | 19.13 | 20.71 | 20.73 | 21.62 | 3.68 | 3.99 | 3.82 | 4.02 | 6.83 | 11.15 | 11.33 | 11.99 | 14.75 | 15.14 | 15.26 | 15.54 |
| **C2** | 14.20 | 14.28 | 12.89 | 11.57 | 2.69 | 2.47 | 2.95 | 2.35 | 4.78 | 7.22 | 7.36 | 6.30 | 14.31 | 12.54 | 14.00 | 12.15 |
| **SE (d)** | 0.80 | 1.20 | 0.88 | 1.10 | 0.16 | 0.22 | 0.19 | 0.22 | 0.33 | 0.84 | 0.64 | 0.78 | 0.20 | 0.44 | 0.67 | 1.28 |
| **CD 5%** | 1.59 | 2.34 | 1.75 | 2.21 | 0.33 | 0.43 | 0.39 | 0.43 | 0.66 | 1.64 | 1.28 | 1.55 | 0.41 | 0.90 | 1.35 | 2.56 |
| **Types of seasons (S)** | | | | | | | | | | | | | | | | |
| **S1** | 23.09 | 6.64 | 1.80 | 1.52 | 3.60 | 0.89 | 0.49 | 0.72 | 4.81 | 3.74 | 1.24 | 3.06 | 14.08 | 10.12 | 8.31 | 8.31 |
| **S2** | 16.83 | 24.88 | 28.99 | 32.71 | 3.84 | 3.84 | 4.99 | 6.49 | 6.28 | 11.43 | 13.90 | 16.28 | 14.76 | 14.96 | 16.30 | 19.95 |
| **S3** | 13.80 | 20.97 | 19.62 | 11.84 | 2.63 | 4.50 | 4.94 | 2.05 | 6.33 | 12.66 | 13.88 | 6.85 | 14.76 | 16.44 | 19.71 | 12.86 |
| **SE (d)** | 0.98 | 1.48 | 1.08 | 1.35 | 0.20 | 0.27 | 0.23 | 0.27 | 0.40 | 1.03 | 0.78 | 0.96 | 0.25 | 0.55 | 0.82 | 1.57 |
| **CD 5%** | 1.95 | 2.87 | 2.14 | 2.71 | 0.41 | 0.52 | 0.47 | 0.53 | 0.80 | 2.01 | 1.57 | 1.90 | 0.50 | 1.10 | 1.65 | 3.14 |
| **Plant growth regulators (T)** | | | | | | | | | | | | | | | | |
| **T1** | 17..22 | 20.34 | 19.22 | 12.91 | 3.64 | 3.13 | 3.56 | 2.44 | 5.65 | 9.46 | 10.56 | 7.52 | 14.55 | 12.75 | 13.72 | 11.49 |
| **T2** | 16.64 | 14.95 | 15.14 | 13.37 | 3.04 | 2.64 | 2.75 | 2.18 | 5.87 | 10.38 | 10.25 | 7.63 | 14.42 | 12.49 | 11.65 | 12.14 |
| **T3** | 27.35 | 28.93 | 29.16 | 30.70 | 4.33 | 4.37 | 5.27 | 5.54 | 9.75 | 16.12 | 16.26 | 17.94 | 16.88 | 17.71 | 20.67 | 21.34 |
| **T4** | 15.98 | 15.79 | 16.08 | 17.17 | 3.06 | 2.76 | 3.35 | 2.60 | 5.04 | 8.21 | 8.98 | 7.41 | 13.83 | 13.11 | 14.72 | 14.92 |
| **T5** | 14.60 | 14.70 | 14.98 | 16.11 | 3.20 | 3.00 | 3.63 | 3.04 | 4.50 | 7.19 | 8.01 | 7.25 | 13.98 | 12.50 | 13.91 | 12.01 |
| **T6** | 13.79 | 11.35 | 13.02 | 11.46 | 3.00 | 2.42 | 2.91 | 3.17 | 5.02 | 6.02 | 7.04 | 6.58 | 14.50 | 12.61 | 13.88 | 12.09 |
| **T7** | 16.49 | 16.48 | 14.40 | 11.69 | 3.12 | 3.37 | 3.12 | 3.24 | 5.29 | 7.80 | 7.46 | 9.17 | 13.48 | 14.34 | 15.92 | 14.18 |
| **T8** | 17.83 | 17.22 | 14.22 | 11.19 | 3.40 | 2.94 | 3.17 | 2.48 | 5.33 | 8.87 | 8.96 | 6.30 | 14.63 | 15.20 | 13.70 | 11.46 |
| **SE (d)** | 1.38 | 2.41 | 1.77 | 2.21 | 0.33 | 0.45 | 0.39 | 0.44 | 0.66 | 1.68 | 1.28 | 1.57 | 0.41 | 0.89 | 1.34 | 2.56 |
| **CD 5%** | 3.19 | 4.68 | 3.50 | 4.43 | 0.67 | 0.85 | 0.78 | 0.87 | 1.31 | 3.28 | 2.56 | 3.11 | 0.83 | 1.80 | 2.70 | 5.12 |
| **Cuttings х Seasons (C х S)** | | | | | | | | | | | | | | | | |
| **SE (d)** | 1.38 | 2.09 | 1.53 | 1.91 | 0.29 | 0.39 | 0.33 | 0.38 | NS | NS | 1.11 | NS | NS | 0.77 | NS | NS |
| **CD 5%** | 2.75 | 4.15 | 3.05 | 3.80 | 0.57 | 0.77 | 0.67 | 0.76 | NS | NS | 2.21 | NS | NS | 1.54 | NS | NS |
| **Cuttings х Treatments (C х T)** | | | | | | | | | | | | | | | | |
| **SE (d)** | 2.26 | NS | NS | NS | 0.47 | NS | NS | 0.63 | NS | NS | NS | NS | NS | 1.27 | 1.90 | NS |
| **CD 5%** | 4.50 | NS | NS | NS | 0.94 | NS | NS | 1.25 | NS | NS | NS | NS | NS | 2.52 | 3.78 | NS |
| **Seasons х Treatments (S х T)** | | | | | | | | | | | | | | | | |
| **SE (d)** | 2.77 | 4.18 | 3.07 | 3.83 | NS | NS | 0.67 | 0.77 | NS | NS | NS | 2.72 | 0.72 | 1.55 | 2.33 | NS |
| **CD 5%** | 5.51 | 8.31 | 6.10 | 7.60 | NS | NS | 1.34 | 1.53 | NS | NS | NS | 5.40 | 1.43 | 3.08 | 4.63 | NS |
| **Treatments** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** | **30th DAP** | **60th DAP** | **90th DAP** | **120th DAP** |
|  | **Number of leaves** | | | | **Number of shoots** | | | | **Shoot length (cm)** | | | | **Height of cuttings (cm)** | | | |
| **Cuttings х Seasons х Treatments (C х S х T)** | | | | | | | | | | | | | | | | |
| **SE (d)** | NS | NS | NS | 5.41 | NS | NS | NS | 1.09 | NS | NS | NS | 3.84 | NS | 2.20 | 3.30 | 6.29 |
| **CD 5%** | NS | NS | NS | 10.75 | NS | NS | NS | 2.17 | NS | NS | NS | 7.63 | NS | 4.36 | 6.55 | 12.48 |

*(C1 - Hardwood cuttings, C2 - Semi-hardwood cuttings, S1 – First fortnight of September, S2 – Second fortnight of September, S3 – First fortnight of October,*

*T1 – 1000 ppm IBA, T2 – 1500 ppm IBA, T3 – 2000 ppm IBA, T4 – 1000 ppm IAA, T5 – 1500 ppm IAA, T6 – 2000 ppm IAA, T7 – 2% Ascorbic acid, T8 – Control – dipping in sterile water)*

Table 5. Effect of types of cuttings, seasons, and plant growth regulators on the number of primary and secondary roots, root length (cm), and root diameter (mm) after 120 days of planting

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Number of primary and secondary roots** | | **Root length (cm)** | **Root diameter (mm)** |
| **Types of cuttings (C)** | | | | |
| **C1** | 1.77 | 8.88 | 9.10 | 0.71 |
| **C2** | 1.22 | 5.98 | 4.63 | 0.54 |
| **SE (d)** | 0.21 | 0.87 | 0.65 | 0.08 |
| **CD 5%** | 0.42 | 1.76 | 1.30 | 0.16 |
| **Types of seasons (S)** | | | | |
| **S1** | 0.79 | 2.81 | 2.21 | 0.24 |
| **S2** | 2.85 | 12.14 | 13.90 | 1.51 |
| **S3** | 0.85 | 7.35 | 4.47 | 0.48 |
| **SE (d)** | 0.25 | 1.07 | 0.80 | 0.09 |
| **CD 5%** | 0.51 | 2.15 | 1.60 | 0.19 |
| **Plant growth regulators (T)** | | | | |
| **T1** | 0.94 | 5.88 | 5.09 | 0.57 |
| **T2** | 1.50 | 7.55 | 5.40 | 0.74 |
| **T3** | 2.83 | 14.83 | 14.77 | 1.25 |
| **T4** | 1.05 | 7.00 | 7.56 | 0.56 |
| **T5** | 1.38 | 5.50 | 5.92 | 0.31 |
| **T6** | 1.50 | 6.33 | 6.21 | 0.59 |
| **T7** | 1.61 | 6.77 | 6.27 | 0.55 |
| **T8** | 1.16 | 5.61 | 3.67 | 0.42 |
| **SE (d)** | 0.42 | 1.75 | 1.30 | 0.16 |
| **CD 5%** | 0.84 | 3.52 | 2.61 | 0.32 |
| **Cuttings х Seasons (C х S)** | | | | |
| **SE (d)** | NS | NS | 1.13 | NS |
| **CD 5%** | NS | NS | 2.24 | NS |
| **Cuttings х Treatments (C х T)** | | | | |
| **SE (d)** | NS | NS | 1.85 | NS |
| **CD 5%** | NS | NS | 3.67 | NS |
| **Seasons х Treatments (S х T)** | | | | |
| **SE (d)** | NS | NS | 2.26 | NS |
| **CD 5%** | NS | NS | 4.49 | NS |
| **Cuttings х Seasons х Treatments (C х S х T)** | | | | |
| **SE (d)** | NS | 4.30 | 3.20 | NS |
| **Treatments** | **Number of primary and secondary roots** | | **Root length (cm)** | **Root diameter (mm)** |
| **CD 5%** | NS | 8.54 | 6.36 | NS |

*(C1 - Hardwood cuttings, C2 - Semi-hardwood cuttings, S1 – First fortnight of September, S2 – Second fortnight of September, S3 – First fortnight of October,*

*T1 – 1000 ppm IBA, T2 – 1500 ppm IBA, T3 – 2000 ppm IBA, T4 – 1000 ppm IAA, T5 – 1500 ppm IAA, T6 – 2000 ppm IAA, T7 – 2% Ascorbic acid, T8 – Control – dipping in sterile water)*