

## SPROUTING AND GROWTH RESPONSES OF POMEGRANATE (*PUNICA GRANATUM* L.) CUTTINGS TO DIFFERENT PRE-PLANTING TREATMENTS

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### Abstract

Pomegranate is commonly propagated through cuttings; however, this method often lacks standardized protocols and thorough documentation. Moreover, untreated cuttings frequently result in suboptimal rooting and less vigorous saplings. To improve rooting efficiency and enhance propagation success, modern techniques increasingly utilize synthetic root-promoting growth regulators. This experiment was conducted during the winter of 2024 to evaluate the sprouting and growth responses of *Punica granatum* L. cuttings to different pre-planting treatments. A container-based trial was conducted at the nursery of the Department of Horticulture, Sindh Agriculture University, Tandojam, using a Completely Randomized Design (CRD) with three replications. The treatments were: T = Control, T2 = Auxin + NPK fertilizer + Topsin-M, T3 = Auxin + NPK fertilizer, T4 = Auxin + Topsin-M, and T5 = Auxin. Two pomegranate varieties were tested: V = Aab-e-Dandaan and V2 = Qandhari. Results revealed significant effects of treatments and varieties on sprouting percentage, number of sprouts, rooting, biomass, chlorophyll content, sturdiness quotient, collar diameter, and seedling quality index. Auxin alone (T5) resulted in the highest values for most parameters, followed by Auxin + Topsin-M (T4), except for the number of sprouts, which was highest in T2 (Auxin + NPK fertilizer + Topsin-M). Among the varieties, Aab-e-Dandaan outperformed Qandhari in most measured traits. It is concluded that Auxin application alone can significantly enhance rooting and growth of pomegranate cuttings, with the Aab-e-Dandaan variety showing superior performance under the given conditions.

### INTRODUCTION

Pomegranate (*Punica granatum* L.), a fruit-bearing shrub or small tree belonging to the Punicaceae family, is native to regions encompassing Iran and northern India. It is now widely cultivated and highly valued across the globe for its flavorful arils (juicy seed sacs) and numerous health benefits. Beyond its culinary appeal, pomegranate holds traditional medicinal and cultural significance. It is a rich source of vitamins—particularly B-complex and vitamin C—minerals such as potassium, and dietary fiber. Its most

notable nutritional feature is the abundance of potent antioxidants, including punicalagins and anthocyanins (Proestis, 208; Yahia et al., 209).

The fruit is renowned for its nutritional and therapeutic properties, including antioxidant, antimicrobial, anticancer, antiviral, anti-mutagenic, and cardioprotective effects. Pomegranate contains approximately 68% edible content. On a per 100g basis, it comprises 78% moisture, .6% protein, 4.5% carbohydrates, 0 mg calcium, 70 mg phosphorus, 0.3–

0.7 mg iron, 6 mg vitamin C, and 0.0 mg riboflavin (Negi et al., 2003). Successful propagation from cuttings is influenced by several factors, including growth medium, plant hormones, parent plant vigor, and cutting type and size (Yoon et al., 202).

Cutting propagation is a cost-effective method to produce healthy pomegranate seedlings. (Pawar & Singh, 2020). The use of plant growth stimulators—particularly auxins like IBA and NAA—plays a critical role in enhancing sprouting, rooting, and disease resistance. (Singh et al., 20). Auxins promote adventitious root development by regulating root meristem activity, root hair growth, and lateral root formation.

Poor rooting in cuttings is often due to inadequate nutrition (Gibson et al., 2005). Macronutrients like nitrogen, phosphorus, and potassium significantly improve rooting efficiency. Nitrogen supports chlorophyll production and protein synthesis, while phosphorus—when moderately limited—can enhance root development. Proper nutrient management is essential to promote healthy root and shoot growth during propagation (Ohyama, 200; Alvarado, 205). Potassium is involved in enzyme activation, stomatal regulation, and charge balance within plant cells (Bhatla et al., 208).

A strong root system is fundamental for water and nutrient uptake, plant vigor, and overall productivity. Healthy roots serve as the foundation for optimal vegetative growth and successful reproduction. Weak root development negatively impacts plant growth, fruit set, and final yield (Grace & Simmonds, 2008). Patil et al. (2002) observed significant variation in growth and yield performance among plants propagated through cuttings. In modern orchard systems, propagation via stem cuttings is now the preferred method, offering greater consistency and reliability compared to traditional seed propagation (Levin, 2006). The economic importance of pomegranate cultivation is increasing due to rising market demand for the fruit and its processed products. Achieving high productivity depends on effective soil management, irrigation, and nutrient application (Kahramanoglu & Usanmaz, 206).

Given the role of auxins, nutrients, and fungicides in enhancing rooting and reducing disease incidence, the present study was designed to evaluate the sprouting and growth responses of pomegranate

cuttings subjected to different pre-planting treatments.

## Materials and Methods

### Experimental Site and Duration

A container-based study was conducted during the winter of 2024 at the nursery of the Department of Horticulture, Sindh Agriculture University (SAU), Tandojam, Pakistan. The objective was to evaluate the sprouting and growth responses of *Punica granatum* L. cuttings subjected to different pre-planting treatments.

### Experimental Design and Layout

The experiment followed a Completely Randomized Design (CRD) with three replications. Each replication comprised 20 uniform hardwood cuttings. Two pomegranate varieties—Aab-e-Dandaan and Qandhari—were tested under five treatment combinations.

### Pre-Planting Treatments

The following treatments were applied before planting:

T = Control, T2 = Auxin + NPK fertilizer + Topsin-M,

T3 = Auxin + NPK fertilizer

T4 = Auxin + Topsin-M, T5 = Auxin alone

Cuttings were soaked in the respective treatment solutions before being planted in containers filled with a uniform potting mix.

### Observations and Data Collection

Data were collected from 50% of randomly selected cuttings in each replication. The parameters recorded included sprouting percentage, number of sprouts per cutting, days to sprouting, rooting percentage, root depth, fresh shoot and root biomass, chlorophyll content (SPAD value), sturdiness quotient, collar diameter, and quality index. Sprouting and rooting percentages were calculated from total cuttings. Root depth was measured with a scale, fresh biomass with a digital balance, and chlorophyll content using a SPAD meter. Collar diameter was recorded with a vernier caliper. Sturdiness quotient was the shoot height-to-collar diameter ratio. A composite quality index integrated biomass, rooting, and sturdiness to assess seedling vigor

### Statistical Analysis

All collected data were subjected to analysis of variance (ANOVA) using Statistix 8. software (Statistics, 2006). Where significant differences occurred, treatment means were compared using the Least Significant Difference (LSD) test at a 5% probability level.

### Results

The present study was carried out during the winter of 2024 to evaluate the effects of different pre-planting treatments on the sprouting and early growth of pomegranate (*Punica granatum* L.) cuttings under controlled conditions. A Completely Randomized Design (CRD) with three replications was employed, testing five treatments (T-T5) on two cultivars: Aab-e-

Dandaan and Qandhari. The treatments were: T = Control, T2 = Auxin + NPK Fertilizer + Topsin-M, T3 = Auxin + NPK Fertilizer, T4 = Auxin + Topsin-M, and T5 = Auxin alone. Detailed results and statistical analyses (Appendices -) are presented in the following sections.

### 4. Sprouting Percentage

The sprouting percentage was significantly affected by pre-planting treatments and cultivar type ( $P < 0.05$ ), with no significant interaction between the two factors (Table 4.; Appendix ). T2 (Auxin + NPK + Topsin-M) showed the highest sprouting (00%), while T3 (Auxin + NPK) recorded the lowest (75%). Aab-e-Dandaan outperformed Qandhari, with 96.66% vs. 86.66% sprouting, respectively.

**Table 4.** Sprouting percentage (%) of different varieties under various treatments

| Pre-Planting Treatments                | Aab e Dandaan | Qandhari | Mean    |
|----------------------------------------|---------------|----------|---------|
| T = Control                            | 00            | 9.67     | 95.83 A |
| T2 = Auxin + NPK fertilizer + Topsin-M | 00            | 00       | 00.00 A |
| T3 = Auxin + NPK + Fertilizer          | 9.67          | 58.33    | 75.00 B |
| T4 = Auxin + Topsin-M                  | 9.67          | 9.67     | 9.67 A  |
| T5 = Auxin                             | 00            | 9.67     | 95.83 A |
| Mean                                   | 96.66 A       | 86.66 B  |         |

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SE ( $\pm$ ): Treatment = 7.40; Variety = 4.68; Interaction = 0.47  
 LSD (0.05): Treatment = 5.55; Variety = 9.83; Interaction = 2.99  
 P-values: Treatment = 0.0282; Variety = 0.0466; Interaction = NS

### 4.2 Number of Sprouts per Cutting

The number of sprouts per cutting was significantly influenced by treatments and varieties ( $P < 0.05$ ), with no significant interaction (Table 4.2; Appendix 2).

The highest sprouting (8.9) occurred in T (Control) for Aab-e-Dandaan, while the lowest (2.9) was under T3 for Qandhari. Overall, Aab-e-Dandaan produced more sprouts (6.28) than Qandhari (4.35).

SE ( $\pm$ ): Treatment = 0.93; Variety = 0.59; Interaction = .32

LSD (0.05): Treatment = .96; Variety = .24; Interaction = NS

P-values: Treatment = 0.0264; Variety = 0.0040; Interaction = 0.375 (NS)

**Table 4.2** Number of sprouts cutting<sup>-1</sup> under different treatments and varieties

| Pre-Planting Treatments                | Aab e Dandaan | Qandhari | Mean    |
|----------------------------------------|---------------|----------|---------|
| T = Control                            | 8.9           | 4.75     | 6.83 A  |
| T2 = Auxin + NPK fertilizer + Topsin-M | 5.75          | 4.33     | 5.04 AB |
| T3 = Auxin + NPK + Fertilizer          | 4.00          | 2.9      | 3.45 B  |
| T4 = Auxin + Topsin-M                  | 6.6           | 5.50     | 5.83 A  |
| T5 = Auxin                             | 6.58          | 4.25     | 5.4 A   |
| Mean                                   | 6.28 A        | 4.35 B   |         |

### 4.3 Days to Sprouting

Significant differences ( $P < 0.05$ ) were found in days to sprouting across treatments and varieties, while their interaction was not significant (Table 4.3; Appendix 3). The earliest sprouting (5.33 days) occurred in T2. Aab-e-Dandaan sprouted significantly earlier (5.46 days) than Qandhari (7.59 days),

indicating stronger initial vigor or greater auxin responsiveness.

SE ( $\pm$ ): Treatment = 0.83; Variety = 0.52; Interaction = .7

LSD (0.05): Treatment = .74; Variety = .0; Interaction = 2.46

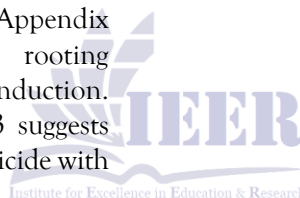
P-values: Treatment = 0.0329; Variety = 0.0007; Interaction = NS

**Table 4.3 Days to sprouting of different varieties under various treatments**

| Pre-planting treatments                | Aab e dandaan | Qandhari | Mean    |
|----------------------------------------|---------------|----------|---------|
| T = Control                            | 4.66          | 7.33     | 6.00 B  |
| T2 = Auxin + NPK fertilizer + Topsin-M | 5.33          | 9.33     | 7.33 AB |
| T3 = Auxin + NPK + Fertilizer          | 6.66          | 9.33     | 8.00 B  |
| T4 = Auxin + Topsin-M                  | 5.33          | 6.00     | 5.66 B  |
| T5 = Auxin                             | 5.33          | 6.00     | 5.66 B  |
| Mean                                   | 5.46 B        | 7.59 A   |         |

### 4.4 Rooting Percentage

Rooting percentage was significantly influenced by treatments ( $P < 0.05$ ), while variety and treatment  $\times$  variety interaction had no effect (Table 4.4; Appendix 4). T5 (Auxin) produced the highest rooting (95.83%), underscoring auxin's role in root induction. The lowest rooting (8.33%) in T2 and T3 suggests possible antagonism between NPK and fungicide with auxin.



**Table 4.4 Rooting percentage under different treatments and varieties**

| Pre-planting treatments                | Aab e Dandaan | Qandhari | Mean    |
|----------------------------------------|---------------|----------|---------|
| T = Control                            | 58.33         | 50.00    | 54.6 B  |
| T2 = Auxin + NPK fertilizer + Topsin-M | 8.33          | 8.33     | 8.33 C  |
| T3 = Auxin + NPK + Fertilizer          | 6.66          | 0.00     | 8.33 C  |
| T4 = Auxin + Topsin-M                  | 66.66         | 58.33    | 62.50 B |
| T5 = Auxin                             | 9.66          | 00.00    | 95.83 A |
| Mean                                   | 48.33 A       | 43.33 A  |         |

SE ( $\pm$ ): Treatment = 2.7; Variety = 7.70; Interaction = 7.2

LSD (0.05): Treatment = 25.57; Variety = 6.7; Interaction = 36.6

P-values: Treatment = 0.0000; Variety = NS; Interaction = NS

### 4.5 Root Depth

Root depth was significantly influenced by treatments ( $P < 0.05$ ), while the effects of variety and their

interaction with treatments were non-significant (Table 4.5; Appendix 5). The deepest root growth was observed in T5 (Auxin), with a mean depth of 26.25 cm, followed by T4 (2.50 cm). The shallowest roots (.66 cm) were recorded under T3, indicating poor root establishment.

Table 4.5 Depth of root (cm) of different varieties under various treatments

| Pre-planting treatments                            | Varieties     |          | Mean    |
|----------------------------------------------------|---------------|----------|---------|
|                                                    | Aab e dandaan | Qandhari |         |
| T = Control                                        | 3.6           | 3.66     | 3.4 BC  |
| T <sub>2</sub> = Auxin + NPK fertilizer + Topsin-M | 6.00          | 2.00     | 4.50 CD |
| T <sub>3</sub> = Auxin + NPK + Fertilizer          | 3.33          | 0.00     | .66 D   |
| T <sub>4</sub> = Auxin + Topsin-M                  | 22.00         | 2.00     | 2.50 AB |
| T <sub>5</sub> = Auxin                             | 24.83         | 27.66    | 26.25 A |
| Mean                                               | 3.86 A        | 3.06 A   |         |

SE (±): Treatment = 4.48; Variety = 2.83; Interaction = 6.34

LSD (0.05): Treatment = 9.42; Variety = 5.96; Interaction = 3.32

P-values: Treatment = 0.000; Variety = NS; Interaction = NS

#### 4.6 Fresh Biomass of Shoot

Treatments significantly influenced fresh shoot biomass ( $P < 0.05$ ), whereas variety and treatment × variety interaction showed no significant effects (Table 4.6; Appendix 6). The highest biomass (6.57 g) was recorded in T<sub>5</sub> (Auxin), highlighting auxin's role in promoting shoot growth. The lowest (.6 g) in T<sub>2</sub> suggests potential phytotoxicity from combined fertilizer and fungicide application.

Table 4.6 Fresh biomass of shoot (g) of different varieties under various treatments

| Pre-planting treatments                            | Varieties     |          | Mean    |
|----------------------------------------------------|---------------|----------|---------|
|                                                    | Aab e dandaan | Qandhari |         |
| T = Control                                        | 2.88          | 2.62     | 2.75 BC |
| T <sub>2</sub> = Auxin + NPK fertilizer + Topsin-M | .             | .2       | .6 C    |
| T <sub>3</sub> = Auxin + NPK + Fertilizer          | .48           | 2.70     | 2.09 BC |
| T <sub>4</sub> = Auxin + Topsin-M                  | 3.97          | 4.04     | 4.00 B  |
| T <sub>5</sub> = Auxin                             | 5.09          | 8.06     | 6.57 A  |
| Mean                                               | 2.90 A        | 3.73 A   |         |

SE (±): Treatment = .0; Variety = 0.64; Interaction = .43

LSD (0.05): Treatment = 2.3; Variety = .34; Interaction = 3.0

P-values: Treatment = 0.0005; Variety = NS; Interaction = NS

(Table 4.7; Appendix 7). The highest biomass (4.45 g) was recorded in T<sub>4</sub> × Qandhari, while the lowest (0.05 g) occurred in T<sub>2</sub> × Aab-e-Dandaan. Despite lower sprouting, Qandhari showed greater root biomass (.6 g), indicating stronger root establishment under favorable conditions.

#### 4.7 Fresh Biomass of Root

Fresh root biomass was significantly influenced by treatments, varieties, and their interaction ( $P < 0.05$ )

Table 4.7 Fresh biomass of root (mg) of different varieties under various treatments

| Pre-planting treatments | Varieties     |          | Mean |
|-------------------------|---------------|----------|------|
|                         | Aab e dandaan | Qandhari |      |

|                                                    |        |        |        |
|----------------------------------------------------|--------|--------|--------|
| T = Control                                        | 0.34 d | 0.9 d  | 0.26 B |
| T <sub>2</sub> = Auxin + NPK fertilizer + Topsin-M | 0.05 d | 0.05 d | 0.05 B |
| T <sub>3</sub> = Auxin + NPK + Fertilizer          | 0.5 d  | 0.00 d | 0.07 B |
| T <sub>4</sub> = Auxin + Topsin-M                  | 0.8 cd | 4.45 a | 2.63 A |
| T <sub>5</sub> = Auxin                             | .55 c  | 3.37 b | 2.46 A |
| Mean                                               | 0.58 B | .6 A   |        |

SE (±): Treatment = 0.32; Variety = 0.20; Interaction = 0.45

LSD (0.05): Treatment = 0.67; Variety = 0.42; Interaction = 0.94

P-values: Treatment = 0.0000; Variety = 0.000; Interaction = 0.0000

by treatments alone (Table 4.8; Appendix 8). The highest chlorophyll value (63.69 SPAD) was noted in T<sub>5</sub> × Qandhari, while the lowest (32.3 SPAD) was in T<sub>2</sub> × Aab-e-Dandaan. Qandhari showed superior chlorophyll content overall, indicating better photosynthetic performance and adaptability.

#### 4.8 Chlorophyll Content

Chlorophyll content was significantly affected by variety and the treatment × variety interaction, but not

**Table 4.8 Days to Sprouting under Different Pre-Planting Treatments and Varieties**

| Pre-planting Treatments                            | Aab-e-Dandaan | Qandhari   | Mean    |
|----------------------------------------------------|---------------|------------|---------|
| T = Control                                        | 39.02 ef      | 54.72 abc  | 46.87 B |
| T <sub>2</sub> = Auxin + NPK fertilizer + Topsin-M | 32.3 f        | 59.87 ab   | 46.00 B |
| T <sub>3</sub> = Auxin + NPK + Fertilizer          | 52.85 abcd    | 42.57 def  | 47.72 B |
| T <sub>4</sub> = Auxin + Topsin-M                  | 43.8 cdef     | 48.48 bcde | 45.83 B |
| T <sub>5</sub> = Auxin                             | 48.8 cde      | 63.69 a    | 55.94 A |
| Mean                                               | 43.07 B       | 53.87 B    |         |

SE (±): Treatment = 3.9024; Variety = 2.468; Interaction = 5.588

LSD (0.05): Treatment = 8.987; Variety = 5.853; Interaction = .595

P-values: Treatment = 0.098; Variety = 0.0004; Interaction = 0.008

#### 4.9 Sturdiness Quotient

The sturdiness quotient was not significantly affected by treatments, varieties, or their interaction ( $P > 0.05$ ) (Table 4.9; Appendix 9). This indicates that neither the pre-planting treatments nor varietal differences had a measurable impact on sturdiness. Overall values ranged from .4 to .6, suggesting uniform seedling sturdiness across treatments and cultivars.

| Pre-Planting Treatments                            | Aab-e-Dandaan | Qandhari | Mean |
|----------------------------------------------------|---------------|----------|------|
| T = Control                                        | .3            | .3       | .3   |
| T <sub>2</sub> = Auxin + NPK Fertilizer + Topsin-M | .37           | .46      | .4   |
| T <sub>3</sub> = Auxin + NPK Fertilizer            | .6            | .49      | .55  |
| T <sub>4</sub> = Auxin + Topsin-M                  | .05           | .35      | .20  |
| T <sub>5</sub> = Auxin                             | .39           | .4       | .26  |
| Mean                                               | .35           | .35      |      |

SE (±): Treatment = 0.892; Variety = 0.96; Interaction = 0.2675

LSD (0.05): Treatment = 0.253; Variety = 0.253; Interaction = 0.5620

P-values: Treatment = NS; Variety = NS; Interaction = NS

#### 4.0 Collar Diameter

The collar diameter was significantly influenced by treatments but not by varieties or their interaction (Table 4.0; Appendix 0). The maximum collar diameter (9.68 mm) was observed in T<sub>4</sub> (Auxin +

Topsin-M), while the minimum (3.85 mm) was recorded in T<sub>3</sub>. Although non-significant, Aab-e-Dandaan showed a marginally thicker collar (6.04 mm) than Qandhari (5.46 mm), reflecting slightly stronger early growth.

**Table 4.0 Collar diameter under different treatments and varieties**

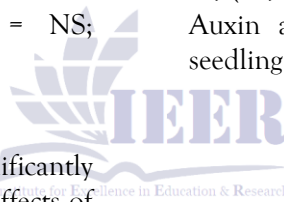
| Pre-planting treatments                            | Varieties     |          | Mean   |
|----------------------------------------------------|---------------|----------|--------|
|                                                    | Aab e dandaan | Qandhari |        |
| T = Control                                        | 6.7           | 5.82     | 5.99 A |
| T <sub>2</sub> = Auxin + NPK fertilizer + Topsin-M | 5.62          | 4.       | 4.87 A |
| T <sub>3</sub> = Auxin + NPK + Fertilizer          | 3.34          | 4.37     | 3.85 B |
| T <sub>4</sub> = Auxin + Topsin-M                  | 9.68          | 4.88     | 7.28 A |
| T <sub>5</sub> = Auxin                             | 5.39          | 8.4      | 6.77 A |
| Mean                                               | 6.04          | 5.46     |        |

SE (±): Treatment = .9554; Variety = .2367;  
Interaction = 2.7653  
LSD (0.05): Treatment = 4.08; Variety = 2.5982;  
Interaction = 5.8098  
P-values: Treatment = 0.0422; Variety = NS;  
Interaction = NS

variety and treatment-variety interaction were non-significant (Table 4.; Appendix ). The highest quality index (0.76) was achieved in T<sub>5</sub> (Auxin), followed by T<sub>4</sub> (0.45), with the lowest (0.08) in both T<sub>2</sub> and T<sub>3</sub>. Auxin alone proved most effective in enhancing seedling vigor.

#### 4. Quality Index of Seedlings

The quality index of seedlings was significantly affected by treatments ( $P < 0.05$ ), while the effects of



**Table 4. Quality index of seedlings under different treatments and varieties**

| Pre-planting treatments                            | Varieties     |          | Mean   |
|----------------------------------------------------|---------------|----------|--------|
|                                                    | Aab e dandaan | Qandhari |        |
| T = Control                                        | 0.26 bcd      | 0.2 cd   | 0.24 C |
| T <sub>2</sub> = Auxin + NPK fertilizer + Topsin-M | 0.08 d        | 0.09 d   | 0.08 C |
| T <sub>3</sub> = Auxin + NPK + Fertilizer          | 0.0 d         | 0.06 d   | 0.08 C |
| T <sub>4</sub> = Auxin + Topsin-M                  | 0.44 bc       | 0.47 bc  | 0.45 B |
| T <sub>5</sub> = Auxin                             | 0.5 b         | .0 a     | 0.76 A |
| Mean                                               | 0.28 A        | 0.37 A   |        |

SE (±): Treatment = 0.09; Variety = 0.0576;  
Interaction = 0.288  
LSD (0.05): Treatment = 0.93; Variety = 0.20;  
Interaction = 0.2706  
P-values: Treatment = 0.0000; Variety = NS;  
Interaction = 0.0358

#### Discussion

The establishment and early growth of cuttings in controlled propagation systems are profoundly influenced by both environmental and physiological factors. Pomegranate (*Punica granatum* L.), a commercially important fruit crop with notable nutritional and medicinal value, relies significantly on vegetative propagation techniques such as hardwood and semi-hardwood cuttings. These methods are

considered efficient, practical, and widely adopted in commercial propagation (Sharma et al., 2009). Among these, the application of plant growth regulators, particularly auxins, and supplementary inputs such as nutrient solutions and fungicides, plays a pivotal role in promoting successful rooting and shoot development.

Auxins are the most widely recognized group of plant growth regulators used to enhance adventitious root formation. Their application, both in natural and synthetic forms, has consistently been shown to increase rooting percentage and root quality (Damar et al., 204). In the current study, treatments involving auxin alone (T5) or in combination with other inputs demonstrated significant improvements in rooting and shoot growth attributes. The results align with findings by Owais (200), who reported that rooting hormones increased the rooting percentage of pomegranate cuttings by 49–73%, and Melgarejo et al. (2008), who observed a threefold increase in both root number and rooting success following auxin application.

In terms of sprouting percentage, the application of auxin combined with NPK fertilizer and Topsin-M (T2) produced the highest response (100%), supporting the hypothesis that a synergistic effect of hormones, nutrition, and disease prevention promotes superior sprouting. These findings are in agreement with Singh (200), who demonstrated that IBA-treated cuttings exhibited enhanced nutrient uptake and translocation due to improved root development. Similarly, Elgimabi (2009) emphasized the critical role of environmental parameters such as temperature, humidity, and light in supporting early sprouting and root initiation.

Furthermore, treatments containing auxin (T5) significantly influenced root and shoot biomass accumulation. Auxin promotes hydrolysis and translocation of carbohydrates and nitrogenous compounds to the base of the cuttings, thus enhancing cellular division and elongation under optimal environmental conditions (Barde et al., 200; Damar et al., 204). These physiological effects likely contributed to the increased shoot biomass and chlorophyll content observed in auxin-treated cuttings in this experiment.

The increased rooting percentage and root depth in auxin-treated cuttings align with the findings of

Melgarejo et al. (2000), who documented the beneficial effects of auxin on root system architecture. Similarly, Nageswari et al. (1999) reported improved root initiation and elongation in cinnamon cuttings treated with phosphobacteria, emphasizing the importance of biological and chemical amendments in propagation success. The findings of Naidu and Jone (2009) and Koyuncu and Senel (2003) further support the idea that larger cutting size and nutrient reserves enhance rooting capacity and development of secondary roots.

Medium composition also plays a crucial role in propagation success. Ansari (203) highlighted that a sand-vermiculite mixture significantly improved rooting percentages and root numbers in pomegranate cuttings. This was attributed to better moisture retention and nutrient availability, key factors that influence the rooting environment.

The role of environmental conditions, particularly light, cannot be overlooked. As reported by Runkle (206), light quality, intensity, and duration affect photomorphogenic responses in plants, including root formation and shoot elongation. Our results showed variations in growth parameters under different treatments, further suggesting that light conditions during propagation influence auxin efficacy and plant vigor.

Rooting hormones have also shown consistent positive results in other crops. For instance, Shirzadi (2007) and Moradnezhad (2002) reported maximum rooting percentages in pomegranate cuttings treated with IBA concentrations ranging from 500–4000 ppm. Likewise, Poudel (208), Kumari (202), and Panwar et al. (200) observed enhanced vegetative growth and rooting in stem cuttings of various fruit crops following auxin treatments. In fig, Kaur and Kaur (207) found that higher concentrations (3000 ppm) of IBA significantly increased shoot growth, reinforcing the applicability of auxins across diverse horticultural species.

## Conclusion

In conclusion, the current study substantiates the critical role of auxin and its combinations in enhancing sprouting, rooting, and biomass accumulation in pomegranate cuttings. Treatments T5 (Auxin alone) and T2 (Auxin + NPK + Topsin-M) emerged as the most effective across multiple

parameters, depending on varietal response. These findings underscore the need for optimized pre-planting treatments to improve the efficiency of pomegranate propagation under nursery conditions. Further studies are recommended to explore genotype-specific responses and the long-term performance of propagated plants under field conditions.

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