

## Studies on effect of grafting time and growing conditions on success of soft wood grafting in Mandarin (*Citrus reticulata* B.) cv. Nagpur Mandarin

Praveen Sheelavant<sup>1\*</sup>, Shivaji J. Shinde<sup>2</sup>,  
Santosh R. Barkule<sup>3</sup> and Tushar D. Belkhode<sup>4</sup>

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### Praveen Sheelavant

<sup>1</sup>M.Sc (Hort) Scholar,  
Department of Horticulture,  
VNМКV, Parbhani.

### Shivaji J. Shinde

<sup>2</sup> Professor and Incharge, BRS  
Nanded.

### Santosh R. Barkule

<sup>3</sup> Associate Professor,  
Department of Horticulture,  
VNМКV, Parbhani.

### Tushar D. Belkhode

<sup>4</sup>M.Sc (Hort) Scholar,  
Department of Horticulture,  
VNМКV, Parbhani.

### Corresponding author

#### Praveen Sheelavant

<sup>1</sup>M.Sc (Hort) Scholar,  
Department of Horticulture,  
VNМКV, Parbhani.

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### Abstract

The present investigation entitled “Studies on effect of grafting time and conditions on success of soft wood grafting in Mandarin (*Citrus reticulata* B.) cv. Nagpur Mandarin” was carried out at Central Nursery Scheme, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during the year 2024-2025. The study aimed to determine the effect of different grafting time and growing conditions on sprouting, growth and success of soft wood grafting in mandarin. The treatment combinations were the six-grafting time viz., D1: October 15, D2: October 30, D3: November 15, D4: November 30, D5: December 15 and D6: December 30 with two conditions viz., Polyhouse condition (C1) and Open field condition (C2). In case of grafting time minimum days to first sprouting of graft (19.49 days) and days to 50% sprouting of grafts (29.33 days) was recorded from D1 whereas maximum graft success (85.83%), graft survival (80.67%), plant height (45.98 cm), plant diameter (6.53 mm), number of branches per plant (6.75), number of leaves per plant (53.13) was recorded from In growing conditions minimum days to first sprouting of graft (19.94 days) and days to 50% sprouting of grafts (32.61 days) was recorded from C2 whereas maximum graft success (86.66%), graft survival (75.84%), plant height (42.04 cm), plant diameter (6.71 mm), number of branches per plant (7.10), number of leaves per plant (47.13) was recorded from C2.

**Keywords:** Nagpur mandarin, Grafting time, Growing condition, Softwood grafting, sprouting, Open field, Polyhouse.

### Introduction

Mandarin (*Citrus reticulata* Blanco), particularly the Nagpur mandarin, represents a significant citrus crop in India, comprising nearly half of the nation's citrus cultivation area and recognized globally for its quality

and flavour. While mandarins are grown throughout India, key production regions include Maharashtra's Vidarbha and Marathwada areas, the north-eastern states, parts of Central and South India, and notable cultivation in Punjab and Rajasthan

(Bhattacharyya *et al.* 2024). The Nagpur mandarin, awarded Geographical Indication status, is especially valued in domestic and export markets due to its quality, but faces challenges in propagation because traditional T-budding methods are slow and cannot meet current planting material demand and also T-budding are limited by long nursery phases and demand for planting material. Alternative rapid multiplication techniques, specifically softwood grafting and micro-budding, have emerged (Skaria and Zhang 2000), offering the potential for quicker, cost-effective, disease-free plant production, although micro-budding has not been widely adopted for Nagpur mandarin due to low graft success rates (Vijayakumari, N., & Singh, S. 2003). Soft wood grafting presents a rapid multiplication technique, requiring optimal environmental conditions and timing for maximum efficiency. This research evaluates the effect of these variables on successful propagation (Patel *et al.* 2010). This study aims to standardize softwood grafting as an enhanced propagation method, focusing on how grafting time and environmental growing conditions affect graft success, with the overarching objective of accelerating orchard establishment and yield improvement.

### Materials and Methods

A field experiment was carried out during October 2024 to March 2025, to assess the combined effect of grafting time and growing condition on sprouting, growth and success of soft wood grafting in mandarin at Central Nursery Scheme, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, India which is located at situated at 408.50 meter altitude above mean sea level and falls on 19°16' N latitude and 76°47' E longitude and has a sub-tropical climate. The experiment was laid out in Factorial Randomized Block Design comprising of 12 treatments which are replicated thrice. Treatment combination consisted of two factors, one with six different grafting time i.e., D1: October 15, D2: October 30, D3: November 15, D4: November 30, D5:

December 15 and D6: December 30 with two conditions viz., Polyhouse condition (C1) and Open field condition (C2). There were 12 treatment combinations such as C1D1, C1D2, C1D3, C1D4, C1D5, C1D6, C2D1, C2D2, C2D3, C2D4, C2D5, and C2D6. There were 20 plants in each replication. The data obtained for different parameters were statistically analysed to find out the significance difference of different grafting time and growing condition.

## Results and Discussion

### Days to first sprouting of grafts

Analysis of the results (Table 1) revealed that grafting dates had a significant effect on the time taken for the first graft to sprout. The earliest sprouting was observed on October 15 (D1) at 19.49 days, while the latest sprouting occurred on December 30 (D6) at 26.66 days. Among the growing conditions, grafts in the polyhouse (C2) sprouted earlier, averaging 19.94 days, compared to 24.72 days in the open field (C1). Similar results were reported by Nagargoje (2012). The interaction effect indicated that the fastest sprouting occurred when grafting was done on October 15 under polyhouse conditions (C2D1), taking 17.33 days, whereas the slowest sprouting was recorded on December 30 under open field conditions (C1D6), taking 29.66 days. These findings are consistent with those reported by Patel *et al.* (2010).

### Days to 50% sprouting of grafts

A statistically significant variation in the number of days required for 50% sprouting of grafts (Table 1) was observed across different grafting dates. Grafts made on October 15 (D1) exhibited the fastest sprouting, reaching 50% sprouting in 29.33 days, while those grafted on December 30 (D6) took the longest time, requiring 40.33 days. Among the growing conditions, grafts under the polyhouse (C2) reached 50% sprouting significantly earlier, averaging 32.61 days, compared to 36.16 days under open field conditions (C1). The interaction between growing conditions and grafting time revealed that the quickest

sprouting occurred under polyhouse conditions on October 15 (C2D1), taking 28.33 days. Conversely, the slowest sprouting was observed under open field conditions on December 30 (C1D6), taking 41.33 days. These results align with the findings reported by Patel et al. (2010).

#### **Graft success (%)**

A statistically significant variation in graft success (Table 1) was observed among different grafting dates. The highest graft success (85.83%) was recorded for grafts performed on October 15 (D1), while the lowest success (73.33%) occurred for grafts conducted on December 30 (D6). Similar findings were reported by Chalise et al. (2013). Among the growing conditions, grafts under the polyhouse (C2) showed significantly higher success (86.66%) compared to those under open field conditions (C1), which recorded 72.77%. These results are in agreement with the observations of Nagargoje (2012). The interaction effect revealed that the highest graft success

(93.33%) was achieved when grafting was done under polyhouse conditions on October 15 (C2D1), whereas the lowest success (68.33%) was noted under open field conditions on December 30 (C1D6). Similar trends were also reported by Patel et al. (2010).

#### **Graft survival (%)**

A statistically significant variation in graft survival (Table 1) was observed among different grafting dates. Grafts performed on October 15 (D1) showed the highest survival rate (80.67%), while those grafted on December 30 (D6) recorded the lowest survival rate (62.93%). Similar observations were reported by Chalise et al. (2013). Among the growing conditions, grafts under the polyhouse (C2) exhibited higher survival (75.84%) compared to those under open field conditions (C1), which recorded 67.97%. These findings are in agreement with those of Nagargoje (2012). The interaction between grafting time and growing conditions showed that grafts made on October 15 under polyhouse conditions (C2D1) achieved the

highest survival rate (88.38%), whereas the lowest survival (61.01%) was observed for grafts performed on December 30 under open field conditions (C1D6). Patel et al. (2010) also reported similar results.

#### **Plant height (cm)**

A statistically significant variation in plant height of mandarin grafts was observed at 30, 60, and 90 days after grafting (DAG) due to different grafting times (Table 2). The tallest plants (36.17, 40.77, and 45.98 cm at 30, 60, and 90 DAG, respectively) were recorded from grafts made on October 15 (D1). In contrast, the shortest plants (25.44, 28.22, and 33.43 cm at 30, 60, and 90 DAG, respectively) were observed from grafts made on December 30 (D6). Similar findings were reported by Chalise et al. (2013). Among the growing conditions, plants in the polyhouse (C2) exhibited greater height (32.47, 37.28, and 42.04 cm) compared to those in the open field (C1), which recorded lower heights (29.64, 33.21, and 37.98 cm) at 30, 60, and 90 DAG, respectively. These results are consistent with the observations of Nagargoje (2012). The interaction between grafting time and growing conditions revealed that the tallest plants (39.02, 43.63, and 48.36 cm) were recorded from grafts made on October 15 under polyhouse conditions (C2D1), whereas the shortest plants (25.05, 26.95, and 32.51 cm) were observed on December 30 under open field conditions (C1D6) at 30, 60, and 90 DAG, respectively. Similar trends were also reported by Chalise et al. (2013).

#### **Plant diameter (mm)**

A statistically significant variation in plant diameter of mandarin grafts was observed due to different grafting times at 30, 60, and 90 days after grafting (DAG) (Table 2). The maximum plant diameter (3.54, 5.84, and 6.53 mm at 30, 60, and 90 DAG, respectively) was recorded for grafts made on October 15 (D1), while the minimum diameter (2.53, 4.89, and 5.71 mm at 30, 60, and 90 DAG, respectively) was observed for grafts made on December 30 (D6). Similar findings were reported by Chalise et al. (2013). Among the growing

conditions, plants in the polyhouse (C2) recorded the highest diameters (3.47, 5.76, and 6.71 mm) compared to those in the open field (C1), which showed smaller diameters (2.64, 4.85, and 5.48 mm) at the respective observation periods. These results align with the observations of Nagargoje (2012). A significant interaction between grafting time and growing conditions was also noted. The largest diameter (4.09, 6.58, and 7.33 mm at 30, 60, and 90 DAG, respectively) occurred in the October 15 grafts under polyhouse conditions (C2D1), whereas the smallest (2.21, 4.56, and 5.25 mm) was recorded for the December 30 grafts under open field conditions (C1D6). Similar results were earlier reported by Patel et al. (2010).

#### **Number of branches per plant:**

Analysis of the results revealed that grafting time had a significant effect on the number of branches per plant in mandarin. A statistically significant variation in branch number was observed at 30, 60, and 90 days after grafting (DAG) (Table 2). The highest number of branches per plant (3.23, 5.55, and 6.75 at 30, 60, and 90 DAG, respectively) was recorded for grafts made on October 15 (D1), while the lowest (2.30, 4.26, and 5.95, respectively) was noted for grafts made on December 30 (D6). These findings are in agreement with the results reported by Chalise et al. (2013). Among the growing conditions, plants in the polyhouse (C2) produced the highest number of branches per plant (3.41, 5.62, and 7.10 at 30, 60, and 90 DAG, respectively), which were significantly superior to those grown under open field conditions (C1), where the number of branches recorded was 2.15, 4.20, and 5.59, respectively. A significant interaction between grafting time and growing conditions was also observed. The maximum number of branches per plant (4.00, 6.23, and 7.43 at 30, 60, and 90 DAG, respectively) was recorded for the October 15 grafts under polyhouse conditions (C2D1), while the minimum (1.80, 3.60, and 5.10) was observed for the December 30 grafts under open field conditions (C1D6). Similar results were also

reported by Patel et al. (2010).

#### **Number of leaves per plant:**

Analysis of the results revealed that grafting time had a significant effect on the number of leaves per plant in mandarin. A statistically significant variation in leaf number was observed at 30, 60, and 90 days after grafting (DAG) (Table 2). The highest number of leaves per plant (15.03, 37.66, and 53.13 at 30, 60, and 90 DAG, respectively) was recorded for grafts made on October 15 (D1), whereas the lowest (12.76, 24.80, and 39.71, respectively) was observed for grafts made on December 30 (D6). Similar findings were also reported by Chalise et al. (2013). Among the growing conditions, plants grown under polyhouse conditions (C2) produced the maximum number of leaves per plant (15.64, 32.95, and 47.13 at 30, 60, and 90 DAG, respectively), which were significantly superior to those grown under open field conditions (C1), where 12.50, 27.89, and 44.30 leaves per plant were recorded at the respective intervals. These results are in agreement with the findings of Nagargoje (2012). A significant interaction between grafting time and growing conditions was also observed. The maximum number of leaves per plant (16.40, 38.73, and 53.46 at 30, 60, and 90 DAG, respectively) was obtained from grafts made on October 15 under polyhouse conditions (C2D1), while the minimum (10.60, 21.93, and 38.70, respectively) was recorded for grafts made on December 30 under open field conditions (C1D6). Similar observations were also reported by Patel et al. (2010).

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**Table 1:** Effect of grafting time and growing conditions on days to first sprouting of graft, days to 50% sprouting of graft, graft success and graft survival in Mandarin

| Treatment                     | Days to first sprouting of graft | Days to 50% sprouting of grafts | Graft success (%) | Graft survival (%) |
|-------------------------------|----------------------------------|---------------------------------|-------------------|--------------------|
| Growing condition (C)         |                                  |                                 |                   |                    |
| Open field (C <sub>1</sub> )  | 24.72                            | 36.16                           | 72.77             | 67.97              |
| Polyhouse (C <sub>2</sub> )   | 19.94                            | 32.61                           | 86.66             | 75.84              |
| SE(m)±                        | 0.132                            | 0.209                           | 0.53              | 0.793              |
| CD at 5%                      | 0.391                            | 0.617                           | 1.56              | 2.340              |
| Grafting time (D)             |                                  |                                 |                   |                    |
| October 15 (D <sub>1</sub> )  | 19.49                            | 29.33                           | 85.83             | 80.67              |
| October 30 (D <sub>2</sub> )  | 20.00                            | 30.83                           | 83.33             | 77.22              |
| November 15 (D <sub>3</sub> ) | 21.16                            | 33.00                           | 81.66             | 72.89              |
| November 30 (D <sub>4</sub> ) | 22.16                            | 34.33                           | 79.16             | 70.60              |
| December 15 (D <sub>5</sub> ) | 24.50                            | 38.50                           | 75.00             | 67.13              |
| December 30 (D <sub>6</sub> ) | 26.66                            | 40.33                           | 73.33             | 62.93              |
| SE(m)±                        | 0.229                            | 0.362                           | 0.91              | 1.373              |
| CD at 5%                      | 0.677                            | 1.068                           | 2.70              | 4.053              |
| Condition X Date              |                                  |                                 |                   |                    |
| C <sub>1</sub> D <sub>1</sub> | 21.66                            | 30.33                           | 78.33             | 72.96              |
| C <sub>1</sub> D <sub>2</sub> | 22.33                            | 32.66                           | 75.00             | 71.99              |
| C <sub>1</sub> D <sub>3</sub> | 23.00                            | 35.33                           | 73.33             | 69.07              |
| C <sub>1</sub> D <sub>4</sub> | 24.66                            | 36.66                           | 71.66             | 67.30              |
| C <sub>1</sub> D <sub>5</sub> | 27.00                            | 40.66                           | 70.00             | 65.53              |
| C <sub>1</sub> D <sub>6</sub> | 29.66                            | 41.33                           | 68.33             | 61.01              |
| C <sub>2</sub> D <sub>1</sub> | 17.33                            | 28.33                           | 93.33             | 88.38              |
| C <sub>2</sub> D <sub>2</sub> | 17.66                            | 29.00                           | 91.66             | 82.45              |
| C <sub>2</sub> D <sub>3</sub> | 19.33                            | 30.66                           | 90.00             | 76.70              |
| C <sub>2</sub> D <sub>4</sub> | 19.66                            | 32.00                           | 86.66             | 73.91              |
| C <sub>2</sub> D <sub>5</sub> | 22.00                            | 36.33                           | 80.00             | 68.74              |
| C <sub>2</sub> D <sub>6</sub> | 23.66                            | 39.33                           | 78.33             | 64.86              |
| SE(m)±                        | 0.324                            | 0.512                           | 1.29              | 1.942              |
| CD at 5%                      | 0.957                            | 1.510                           | 3.83              | 5.731              |

**Table 2:** Effect of grafting time and growing conditions on plant height and plant diameter in Mandarin

| Treatment                     | Plant height (cm) |        |        | Plant diameter (mm) |        |        |
|-------------------------------|-------------------|--------|--------|---------------------|--------|--------|
|                               | 30 DAG            | 60 DAG | 90 DAG | 30 DAG              | 60 DAG | 90 DAG |
| <b>Growing condition (C)</b>  |                   |        |        |                     |        |        |
| Open field (C <sub>1</sub> )  | 29.64             | 33.21  | 37.98  | 2.64                | 4.85   | 5.48   |
| Polyhouse (C <sub>2</sub> )   | 32.47             | 37.28  | 42.04  | 3.47                | 5.76   | 6.71   |
| SE(m)±                        | 0.389             | 0.302  | 0.208  | 0.026               | 0.055  | 0.050  |
| CD at 5%                      | 1.148             | 0.891  | 0.614  | 0.077               | 0.163  | 0.147  |
| <b>Grafting time (D)</b>      |                   |        |        |                     |        |        |
| October 15 (D <sub>1</sub> )  | 36.17             | 40.77  | 45.98  | 3.54                | 5.84   | 6.53   |
| October 30 (D <sub>2</sub> )  | 35.13             | 39.25  | 43.56  | 3.38                | 5.53   | 6.36   |
| November 15 (D <sub>3</sub> ) | 32.44             | 36.92  | 41.20  | 3.18                | 5.37   | 6.20   |
| November 30 (D <sub>4</sub> ) | 29.43             | 35.13  | 39.02  | 2.97                | 5.22   | 5.95   |
| December 15 (D <sub>5</sub> ) | 27.77             | 31.17  | 36.87  | 2.73                | 4.99   | 5.82   |
| December 30 (D <sub>6</sub> ) | 25.44             | 28.22  | 33.43  | 2.53                | 4.89   | 5.71   |
| SE(m)±                        | 0.674             | 0.523  | 0.360  | 0.045               | 0.095  | 0.086  |
| CD at 5%                      | 1.989             | 1.543  | 1.064  | 0.133               | 0.282  | 0.254  |
| <b>Condition X Date</b>       |                   |        |        |                     |        |        |
| C <sub>1</sub> D <sub>1</sub> | 33.32             | 37.92  | 43.60  | 3.00                | 5.10   | 5.72   |
| C <sub>1</sub> D <sub>2</sub> | 32.97             | 36.18  | 41.12  | 2.82                | 5.01   | 5.60   |
| C <sub>1</sub> D <sub>3</sub> | 32.33             | 34.48  | 38.70  | 2.78                | 4.94   | 5.56   |
| C <sub>1</sub> D <sub>4</sub> | 27.25             | 33.40  | 37.08  | 2.63                | 4.83   | 5.44   |
| C <sub>1</sub> D <sub>5</sub> | 26.95             | 30.32  | 34.85  | 2.39                | 4.67   | 5.31   |
| C <sub>1</sub> D <sub>6</sub> | 25.05             | 26.95  | 32.51  | 2.21                | 4.56   | 5.25   |
| C <sub>2</sub> D <sub>1</sub> | 39.02             | 43.63  | 48.36  | 4.09                | 6.58   | 7.33   |
| C <sub>2</sub> D <sub>2</sub> | 37.29             | 42.33  | 46.00  | 3.94                | 6.05   | 7.12   |
| C <sub>2</sub> D <sub>3</sub> | 32.55             | 39.35  | 43.71  | 3.58                | 5.80   | 6.85   |
| C <sub>2</sub> D <sub>4</sub> | 31.61             | 36.85  | 40.97  | 3.31                | 5.62   | 6.47   |
| C <sub>2</sub> D <sub>5</sub> | 28.49             | 32.02  | 38.89  | 3.07                | 5.31   | 6.33   |
| C <sub>2</sub> D <sub>6</sub> | 25.84             | 29.49  | 34.34  | 2.86                | 5.23   | 6.18   |
| SE(m)±                        | 0.953             | 2.182  | 0.510  | 0.064               | 0.135  | 0.122  |
| CD at 5%                      | 2.813             | 0.739  | 1.505  | 0.188               | 0.393  | 0.359  |

**Table 3:** Effect of grafting time and growing conditions on number of branches per plant and number of leaves per plant in Mandarin

| Treatment                     | Number of branches per plant |        |        | Number of leaves per plant |        |        |
|-------------------------------|------------------------------|--------|--------|----------------------------|--------|--------|
|                               | 30 DAG                       | 60 DAG | 90 DAG | 30 DAG                     | 60 DAG | 90 DAG |
| <b>Growing condition (C)</b>  |                              |        |        |                            |        |        |
| Open field (C <sub>1</sub> )  | 2.15                         | 4.20   | 5.59   | 12.50                      | 27.89  | 44.30  |
| Polyhouse (C <sub>2</sub> )   | 3.41                         | 5.62   | 7.10   | 15.64                      | 32.95  | 47.13  |
| SE(m)±                        | 0.030                        | 0.024  | 0.031  | 0.098                      | 0.307  | 0.368  |
| CD at 5%                      | 0.088                        | 0.071  | 0.091  | 0.289                      | 0.907  | 1.085  |
| <b>Grafting time (D)</b>      |                              |        |        |                            |        |        |
| October 15 (D <sub>1</sub> )  | 3.23                         | 5.55   | 6.75   | 15.03                      | 37.66  | 53.13  |
| October 30 (D <sub>2</sub> )  | 3.10                         | 5.25   | 6.60   | 14.66                      | 33.65  | 49.45  |
| November 15 (D <sub>3</sub> ) | 2.90                         | 5.06   | 6.45   | 14.43                      | 32.16  | 46.56  |
| November 30 (D <sub>4</sub> ) | 2.70                         | 4.88   | 6.21   | 14.08                      | 28.28  | 43.68  |
| December 15 (D <sub>5</sub> ) | 2.46                         | 4.45   | 6.13   | 13.45                      | 25.96  | 41.76  |
| December 30 (D <sub>6</sub> ) | 2.30                         | 4.26   | 5.95   | 12.76                      | 24.80  | 39.71  |
| SE(m)±                        | 0.153                        | 0.042  | 0.053  | 0.170                      | 0.532  | 0.637  |
| CD at 5%                      | 0.052                        | 0.124  | 0.157  | 0.501                      | 1.572  | 1.880  |
| <b>Condition X Date</b>       |                              |        |        |                            |        |        |
| C <sub>1</sub> D <sub>1</sub> | 2.46                         | 4.86   | 6.06   | 13.66                      | 36.60  | 52.80  |
| C <sub>1</sub> D <sub>2</sub> | 2.33                         | 4.53   | 5.93   | 13.40                      | 30.73  | 47.86  |
| C <sub>1</sub> D <sub>3</sub> | 2.20                         | 4.30   | 5.76   | 13.26                      | 28.80  | 43.00  |
| C <sub>1</sub> D <sub>4</sub> | 2.13                         | 4.06   | 5.36   | 12.63                      | 26.53  | 42.66  |
| C <sub>1</sub> D <sub>5</sub> | 2.00                         | 3.83   | 5.33   | 11.43                      | 22.76  | 40.76  |
| C <sub>1</sub> D <sub>6</sub> | 1.80                         | 3.60   | 5.10   | 10.60                      | 21.93  | 38.70  |
| C <sub>2</sub> D <sub>1</sub> | 4.00                         | 6.23   | 7.43   | 16.40                      | 38.73  | 53.46  |
| C <sub>2</sub> D <sub>2</sub> | 3.86                         | 5.96   | 7.26   | 15.93                      | 36.56  | 51.03  |
| C <sub>2</sub> D <sub>3</sub> | 3.60                         | 5.83   | 7.13   | 15.60                      | 35.53  | 50.13  |
| C <sub>2</sub> D <sub>4</sub> | 3.26                         | 5.70   | 7.06   | 15.53                      | 30.03  | 44.70  |
| C <sub>2</sub> D <sub>5</sub> | 2.93                         | 5.06   | 6.93   | 15.46                      | 29.16  | 42.76  |
| C <sub>2</sub> D <sub>6</sub> | 2.80                         | 4.93   | 6.80   | 14.93                      | 27.66  | 40.73  |
| SE(m)±                        | 0.216                        | 0.053  | 0.075  | 0.240                      | 0.753  | 0.901  |
| CD at 5%                      | 0.073                        | 0.175  | 0.222  | 0.708                      | 2.223  | 2.658  |