Response of Rootstock Planting, Scion Type and Time of Grafting on Grafting Success and Subsequent Growth of Walnut Plants

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Authors’ contributions

This work was carried out in collaboration among all authors. Author RB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. While Authors SK, MKS, SH and RM managed the analysis, literature and final manuscript.

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ABSTRACT

This was carried out in the Experimental Farm, of Division of Fruit Science, SKUAST-K- Shalimar during the years 2017 and 2018. The experiment was laid out in a Randomized Complete Block Design with three replications having 15 plants per replication. In this study rootstocks were planted at three different timings (2nd fortnight of November, 2nd fortnight of December, 2017 and 2nd fortnight of January, 2018) and were grafted with two different scion types (Middle portion of current season growth with 3-5 buds and Current season growth (3-5 buds) with small piece of 2-year old wood) on two different dates (3rd week of February and 1st week of March, 2018) under polyhouse conditions. The results obtained indicated that initial graft success (75%), leaf area (350 cm²), leaf number (11.4), scion girth (4.8 cm), shoot length (21.8 cm), final plant height (132.9 cm) and final graft success (69%) were significantly better when rootstocks were planted during 2nd fortnight of November as compared to other timings of rootstock planting. Among two different scions viz., (Middle portion of current season growth with 3-5 buds) and (Current season growth (3-5 buds) with small piece of 2-year old wood), initial graft success (63%), leaf area (309.9 cm²), leaf number.
inconsistency in their success. It has been popular for mass multiplication due to of walnut, but none of these methods became grafting and patch budding, wh necessary which can be made are well by different methods of propagation like wedge grafting and patch budding, which known in case of walnut, but none of these methods became popular for mass multiplication due to inconsistency in their success. It has been reported that most economical and practical vegetative methods for walnut propagation is grafting and budding. If the rootstock is already established then the grafting success will be more, as the plant will escape the transplanting shock making the stored food available for callus formation [5]. Immediate after transplanting, farmers go for grafting in the polyhouse due to which success is very less. This may be due to the reason that plants are in stage of transplanting shock and this time whole of the energy of plant is diverted for overcoming the transplanting shock and very little amount of energy will be diverted toward the formation of callus, thereby resulting in less success. The success in propagation is also known to be influenced by the method, time and environment conditions to which the plants are subjected to grow before and after propagation [6]. Thus, there is urgent need to standardize the environment and time for clonal multiplication of walnut in order to ensure supply of quality plant material for expansion of area, there by facilitating manifold increase in production and productivity of superior nuts and meeting the international standards of quality characters of nut and kernel. Therefore, the studies were conducted to determine the response of rootstock planting, scion type and time of grafting on the grafting success and subsequent growth of walnut plants.

1. INTRODUCTION

Walnut (Juglans regia L.) also known as persian walnut belongs to the family Juglandaceae and genus Juglan L. Walnut is believed to have been originated in Iran and its surrounding areas [1]. Walnut has wide adaptability to grow in temperate regions of the world between the elevation of 1200 to 2150 m above mean sea level [2]. The major walnut growing countries are China, USA, Iran, Ukrain, Turkey and Mexico In India, the important walnut producing states are Jammu and Kashmir, Himachal Pradesh and Uttarakhand. It is grown over an area of 108,000 ha with an annual production of 295000MT [3]. In Jammu and Kashmir the total area under walnut cultivation is 84,777 ha with a production of 2, 79,422 MT [4] and it constitutes about 85 per cent of the total production of the India. The high biological value of the walnut kernel makes it an indispensable food product and that’s why the walnut is on the FAO priority list. Therefore, only varieties/ selections with proven high nutritive value and good agro-economical indexes have to be propagated.

The existing plantation in Kashmir valley is generally of seedling in origin and majority of the trees are giant size (20-30 m), long gestation period, notably variable in production, vigor, kernel size, shape and quality that ultimately hamper the grading of nuts for export and causes of low productivity are mainly attributed due to undescribed type of seedling plant population, lack of standard propagation techniques and absence of regular orchard of known cultivar As these plants don’t begin to yield fruit until they are 10 to 12 years old as compared to grafted plants which start bearing fifth year onwards. For the production of commercial walnut crops of uniform size and quality of kernel, vegetative propagation is necessary which can be made are well by different methods of propagation like wedge grafting and patch budding, which known in case of walnut, but none of these methods became popular for mass multiplication due to inconsistency in their success. It has been
winter [4]. An experiment was laid out in a randomized block design with eight treatment combinations. There were three replications and 15 plants per replication. The percentage of sprouted graft after grafting was observed in each treatment in the month of June and was calculated with the help of following formula:

\[
\text{Initial graft success} = \frac{\text{Initial sprouted graft}}{\text{Total grafted plant}} \times 100
\]

The percentage of graft survival from sprouted grafts was observed in each treatment in the month of October and was calculated with the help of following formula:

\[
\text{Final graft success} = \frac{\text{Total graft survival}}{\text{Total grafted plant}} \times 100
\]

Shoot count was taken at the termination of growth in the month of October. All the shoots irrespective of their size were taken into count. Shoot length of the grafted plant was measured in “cm” with the help of a measuring tape from the base of the fresh growth. Total number of leaves per plant was counted during the month of August on newly emerged shoots of graft and average number of leaves on sprouted graft was calculated. Leaf area was measured in “cm²” with the help of leaf area meter (Systronics leaf area meter 211). Ten leaflets were randomly selected from a grafted plant in the month of August and leaf area was expressed in cm². The scion girth of plants was recorded 5 cm above the graft union in the month of October with the help of measuring tape and was expressed in centimeter. After the cessation of growth (October), the height was measured from the surface of soil to the terminal bud of the main axis and the data was expressed in centimeter.

3. RESULTS AND DISCUSSION

Table 1 revealed that initial graft success per cent was significantly influenced by time of rootstock planting, scion type and time of grafting. Among three rootstock planting timings, the maximum initial graft success (75%) was recorded in November planting. Minimum initial graft success was recorded when rootstock was planted in January (47%). This may be due to the reason that the plant were in stage of transplanting shock and whole energy of plant might be diverted for overcoming transplanting shock and very little amount of energy might be diverted towards the formation of callus. The results are in conformity with Singh et al., 2011.

Scion type also significantly influenced the initial graft success per cent. Maximum initial graft success per cent (63%) was obtained with scion type having middle portion of current season growth with 3-5 buds. This may be due to the presence of more reserve foods in young scion and actively growing tissues that enhanced initial graft success. These results are in conformity with Tanuja [7] who obtained similar results in sapota. Time of grafting also exhibited the significant influence on initial graft success per cent. Maximum initial graft success (65%) was recorded when the grafting was performed during 3rd week of February. The reason for minimum initial graft success in 1st week of March (59%) might be due to lower temperature and humidity which delayed the callus formation. These results are in conformity with Upadhyaya [1] who obtained similar results in walnut. The interaction between time of rootstock planting and time of grafting and scion type and time of grafting also had significant influence on initial graft success per cent. These results are in conformity with Jadia et al. [8] in guava.

The final graft success per cent was significantly influenced by time of rootstock planting, scion type and time of grafting (Table 1). Among three rootstock planting time, the maximum final graft success (69%) was obtained in November planting. This may be due to the reason that plants have escaped transplanting shock due to early planting and their stored food material got available for callus formation which resulted in early and strong union. Minimum final graft success (41%) was recorded when rootstock was planted during January and this might be due to the reason that some of the grafts were failed to survive due to weak union. These results are in line with Joshi et al. [9]. Scion type also influenced the final graft success per cent. The maximum final graft success (58%) was obtained with scion type having middle portion of current season growth with 3-5 buds. This may be due to the presence of more reserve foods in young scion and actively growing tissues that enhanced final graft success. These results are in conformity with Tanuja [7] who observed the similar results in sapota. Time of grafting also exhibited the significant influence on final graft success per cent. The maximum final graft success (63%) was obtained when the grafting was performed during 3rd week of February. It might be due to the favorable temperature and humidity which have a pronounced effect on the production of callus tissue, necessary for good graft union formation [10]. The reason for
minimum final graft success in 1st week of March (57%) might be due to lower temperature and humidity which delayed the callus formation. These results are in congruence with Hassan (2019) in walnut. Scion type also had significant influence on number of leaves per plant. Maximum number of leaves per plant (13) was obtained with the scion type having middle portion of current season growth with 3-5 buds. Interaction between time of rootstock planting and scion type showed significant effect with respect to final graft success per cent. Final graft success was highest (71%) when rootstock was planted during 2nd fortnight of November with scion type having middle portion current season growth with 3-5 buds. Interaction between time of rootstock planting and time of grafting showed significant influence on final graft success. Maximum graft success (72%) was observed when rootstock was planted during 2nd fortnight of November and grafting was performed during 3rd week of February. The interaction between time of rootstock planting, scion type and time of grafting had significant influence on final graft success. Maximum graft success (75%) was found when rootstock was planted during 2nd fortnight of November and grafting was performed during 3rd week of February with scion type having middle portion of current season growth with 3-5 buds. These results are in line with Vanaja, et al. [11] in walnut and guava, respectively.

The shoot length was significantly influenced by time of rootstock planting, scion type and time of grafting (Table 2). Among the time of rootstock plantings, the maximum shoot length (21 cm) was recorded when rootstock was planted during second fortnight of November. This might be due to early sprouting and better callus formation. Minimum shoot length (15 cm) was obtained when rootstock was planted during 2nd fortnight of January. These results are in congruence with Ahmad et al. [6] in walnut. Scion type had significant influence on shoot length. Maximum shoot length was obtained with scion type having middle portion of current season growth with 3-5 buds. This may be due to the reason that there occurs more accumulation of stored food material in this portion than the scion having current season growth with 2-year old wood. Time of grafting had significant influence on shoot length. Maximum shoot length (20 cm) was recorded when grafting was performed during 3rd week of February. This may be due to the fact that in addition to photosynthates contribution towards the growth of the scion, it may be more helpful in month of February because of optimum temperature prevalence during the respective period resulting in good growth of scion as have been emphasized by Hartmann, et al. [10].

Interaction between time of rootstock planting and time of grafting had significant influence on shoot length. Maximum shoot length (23 cm) was obtained when rootstock was planted during second fortnight of November and grafting was performed during 3rd week of February. Interaction between scion type and time of grafting and time of rootstock planting, scion type and time of grafting had significant influence on shoot length. Maximum shoot length was (24 cm) when rootstock was planted during 2nd fortnight of November with scion type having middle portion of current season growth with 3-5 buds and grafting was performed during 3rd week of February. The congenial environmental conditions (favorable relative humidity and temperature) under polyhouse might hasten the process of photosynthesis which results in higher availability of food material to the plants which supported to continue flushing of grafts till the end of the experimental period. A higher relative humidity prevented water losses from plants and higher amount of CO2 inside the polyhouse also favored the growth of plants. An early graft union formation also caused the better uptake of nutrients and water from soil. This might lead to higher growth of grafts inside the polyhouse. These results are in congruence with Dev [12].

Table 2 revealed that total number of leaves per plant was significantly influenced by time of rootstock planting, scion type and time of grafting. Among three rootstock planting timings, the maximum number of leaves per plant (11) was obtained in November planting. This might be due to the quick and strong union formation and better nutrient uptake which might have caused better plant growth and more number of leaves per plant. These results are in conformity with the findings of Hassan (2019) who obtained similar results in walnut. Time of grafting also exhibited the significant influence on total number of leaves per plant. Maximum number of leaves per plant (10) was obtained when the grafting was performed during 3rd week of February. The congenial weather conditions prevailed during this grafting period triggered cell metabolic activity in the scions. Due to the development of more number of sprouts, more meristimatic activity and better healing of grafts during this period resulted in more number of leaves per plant .These results are in congruence with Hassan (2019) in walnut. Scion type also had significant influence on number of leaves per plant. Maximum number of leaves per plant (13) was obtained with the scion type having middle portion of current season growth.
The quick and strong union formation, better nutrient uptake and ample growing period helped to increase height of plants resulting into more number of leaves due to long growing season. The results are in conformity with Chovatia and Singh [13]. The interactions between time of rootstock planting and time of grafting showed significant effect with respect to total number of leaves. The maximum number of leaves (13) was observed in November planting when grafting was performed during 3rd week of February. These results are in agreement with Srivastava [14]. The interactions between scion type, time of grafting and time of rootstock planting, scion type and time of grafting showed significant influence on number of leaves per plant. Maximum number of leaves per plant (13) was observed in November planting when grafting was performed during 3rd week of February with scion type having middle portion of current season growth with 3-5 buds. These results are in line with Zenginbal (2007).

Table 3 indicated that leaf area was significantly influenced by time of rootstock planting, scion type and time of grafting. Among three rootstock planting timings, the maximum leaf area (350 cm²) was obtained when rootstock was planted during second fortnight of November. It might be due to vigorous growth of plants as they were capable of absorbing more nutrients and prepares more photosynthates that resulted in maximum leaf area. Scion type also had significant influence on leaf area. Maximum leaf area (4.3 cm) was recorded with scion type having middle portion of current season growth. It might be due to more accumulation of stored carbohydrates causing more leaf area expansion. These results are in congruence with Chovatia and Singh [13]. Time of grafting had significant influence on leaf area. Maximum leaf area (340 cm²) was obtained when grafting was performed during 3rd week of February. It might be due to optimum temperature which played an important role in photosynthetic activity of the leaves. Optimum temperature increased the rate of photosynthesis and leads to the formation of more food materials that facilitated and improved the growth and development of the grafted plants. These results are in line with Mir and Kumar [2]. The interaction between time of rootstock planting and scion type and time of rootstock planting and time of grafting had significant influence on leaf area. Maximum leaf area (386 cm²) was obtained when rootstock was planted during 2nd fortnight of November and grafted during 3rd week of February. These results are in conformity with the findings of Upadhaya [1] in walnut.

Table 3 depicted that scion girth was significantly influenced by time of rootstock planting, scion type and time of grafting. Among three rootstock planting timings the maximum scion girth (4.8 cm) was recorded when rootstock was planted during second fortnight of November. This may be due to vigorous growth of plants as they were capable of absorbing more nutrients and prepares more photosynthates that resulted in maximum scion girth. Scion type also had significant effect on scion girth. Maximum scion girth (4.6 cm) was obtained when rootstock was planted during second fortnight of November. This may be due to vigorous growth of plants as they were capable of absorbing more nutrients and prepares more photosynthates that resulted in maximum scion girth. Scion type also had significant effect on scion girth. Maximum scion girth (4.3 cm) was recorded with scion type having middle portion of current season growth. This may be due to early bud bursting and synthesis of more photosynthates and the physiological maturity of scions which played an important role in the growth and success of grafts [7]. The quick and strong union formation, better nutrient uptake and ample growing period might have caused better plant growth and resulted in highest scion girth. These results are in line with Chovatia and Singh [13]. Time of grafting had significant influence on scion girth. Maximum scion girth (4.6 cm) was obtained when grafting was performed during 3rd week of February. The favorable conditions prevailed inside the structure might be stimulated rapid callusing and early contact of cambial layers, which enabled the graft to heal quickly and make a strong union ultimately leading to better strength and faster growth. The results are in conformity with Mir and Kumar [2]. Interaction between time of rootstock planting, scion type and time of grafting had significant influence on scion girth. Maximum scion girth (5.6 cm) was obtained when rootstock was planted during 2nd fortnight of November with middle portion of current season growth with 3-5 buds and grafting was performed during 3rd week of February. These results are in conformity with Upadhaya [1].
Table 1. Effect of rootstock planting time, scion type and grafting period on initial and final graft success (%) in walnut

| Rootstock planting time | Scion type | Time of grafting | Initial graft success (t1) | Final graft success (t2) | Factor mean (t1) | Sub mean | Factor mean (t2) | Sub mean |
|-------------------------|------------|------------------|---------------------------|--------------------------|------------------|----------|------------------|----------|
|                         | S1         | Sub mean | t1 | t2 | Sub mean | t1 | t2 | Sub mean | t1 | t2 | Sub mean | t1 | t2 | Sub mean | t1 | t2 |
| 2nd fortnight of November |            |         | 80.55 | 72.12 | 76.33 | 77.88 | 70.57 | 74.22 | 75.28 | 71.34 | 75.23 | 67.66 | 71.45 | 70.00 | 63.34 | 66.66 | 69.05 | 72.61 | 65.49 |
| 2nd fortnight of December |            |         | 67.77 | 63.03 | 65.42 | 65.53 | 61.36 | 63.44 | 64.43 | 66.65 | 62.19 | 60.53 | 58.66 | 59.60 | 60.66 | 56.67 | 58.66 | 59.13 | 64.06 | 59.07 |
| 2nd fortnight of January |            |         | 53.69 | 44.55 | 49.12 | 48.45 | 42.07 | 45.26 | 47.19 | 51.07 | 43.31 | 45.33 | 40.00 | 42.67 | 43.34 | 35.00 | 39.16 | 40.91 | 44.33 | 37.5  |
| Mean                    |            |         | 67.33 | 60.00 | 63.66 | 63.95 | 58.00 | 60.97 | 65.64 | 68.94 | 60.36 | 55.44 | 58.00 | 58.00 | 51.67 | 54.83 | 63.54 | 56.89 |

S1 = Middle portion of current season growth with 3-5 buds, S2 = Current season growth with small piece of 2-year old wood; t1 = 3rd week of February, t2 = 1st week of March; Main effects and interaction effects; C.D(P≤0.05):

Time of Rootstock planting (R.P) : 0.84  0.64
Scion type (S) : 0.69  0.52
Time of grafting (t) : NS  0.52
Time of rootstock planting × Scion type : 1.19  0.90
Time of rootstock planting × Time of grafting : 0.97  0.90
Scion type × Time of grafting : 0.37  0.73
Time of rootstock planting × Scion type × Time of grafting : NS  1.28
Table 2. Effect of rootstock planting time, scion type and grafting period on shoot length (cm) and number of leaves in walnut

| Scion type | Rootstock planting time | S1 Sub mean | S2 Sub mean | Factor mean Sub mean | S1 Sub mean | S2 Sub mean | Factor mean Sub mean |
|------------|-------------------------|------------|------------|----------------------|------------|------------|----------------------|
|            |                         | t1         | t2         | t1                  | t2         | t1         | t2                  |
| 2\textsuperscript{nd} fortnight of November | 24.24 | 20.39 | 22.31 | 22.77 | 19.70 | 21.23 | 21.77 | 23.50 | 20.04 | 13.29 | 10.42 | 11.85 | 12.64 | 9.03 | 10.83 | 11.34 | 12.96 | 9.72 |
| 2\textsuperscript{nd} fortnight of December | 22.34 | 17.17 | 19.75 | 18.32 | 16.71 | 17.51 | 18.63 | 20.33 | 16.94 | 11.29 | 8.45 | 9.87 | 9.10 | 7.71 | 8.40 | 9.13 | 10.19 | 8.08 |
| 2\textsuperscript{nd} fortnight of January | 17.16 | 14.70 | 15.93 | 15.60 | 13.96 | 14.78 | 15.35 | 16.38 | 14.33 | 9.74 | 7.00 | 8.37 | 7.31 | 6.52 | 6.91 | 7.64 | 8.52 | 6.76 |
| Mean       | 17.16 | 8.62  | 12.89 | 9.68  | 7.75  | 8.71  | 10.55 | 8.18  |

S\textsubscript{1} = Middle portion of current season growth with 3-5 buds, S\textsubscript{2} = Current season growth with small piece of 2-year old wood; t\textsubscript{1} = 3\textsuperscript{rd} week of February, t\textsubscript{2} = 1\textsuperscript{st} week of March; Main effects and interaction effects; C.D(P≤0.05)

- Time of Rootstock planting(R.P) : 0.59  0.41
- Scion type(S) : 0.48  0.33
- Time of grafting(t) : 0.48  0.33
- Time of rootstock planting\times Scion type : NS  NS
- Time of rootstock planting\times Time of grafting : 0.63  0.58
- Scion type\times Time of grafting : 0.68  0.47
- Time of rootstock planting\times Scion type\times Time of grafting : 1.17  0.82
Table 3. Effect of rootstock planting time, scion type and grafting period on leaf area (cm$^2$) and scion girth (cm) in walnut

| Time of grafting | Rootstock planting | Scion type | S1 | Sub mean | S2 | Sub mean | Factor mean | S1 | Sub mean | S2 | Sub mean | Factor mean | Sub mean |
|------------------|--------------------|------------|----|----------|----|----------|-------------|----|----------|----|----------|-------------|----------|
| 2$^{nd}$ fortnight of November | t1 | 391.22 | 315.74 | 353.48 | 382.07 | 311.05 | 346.56 | 350.02 | 386.64 | 313.39 | 5.58 | 4.33 | 4.95 | 5.25 | 4.15 | 4.78 | 4.82 | 5.41 | 3.99 |
| t2 | 380.15 | 301.47 | 340.81 | 378.59 | 298.08 | 338.33 | 339.57 | 299.77 | 5.17 | 4.06 | 4.61 | 4.99 | 3.65 | 4.32 | 4.46 | 5.08 | 3.85 |
| 2$^{nd}$ fortnight of December | t1 | 257.74 | 213.45 | 235.59 | 250.63 | 205.18 | 227.91 | 231.75 | 254.18 | 209.31 | 3.60 | 3.14 | 3.37 | 3.12 | 3.01 | 3.06 | 3.21 | 3.36 | 3.07 |
| t2 | 343.03 | 276.88 | 309.95 | 337.10 | 271.43 | 304.26 | 340.06 | 274.16 | 4.78 | 3.84 | 4.45 | 3.60 | 4.02 | 4.61 | 3.63 |
| 2$^{nd}$ fortnight of January | Mean | 343.03 | 276.88 | 309.95 | 337.10 | 271.43 | 304.26 | 340.06 | 274.16 | 4.78 | 3.84 | 4.45 | 3.60 | 4.02 | 4.61 | 3.63 |

S$_1$ = Middle portion of current season growth with 3-5 buds; S$_2$ = Current season growth with small piece of 2-year old wood; t$_1$ = 3$^{rd}$ week of February; t$_2$ = 1$^{st}$ week of March; Main effects and interaction effects; C.D(P<0.05)

Time of Rootstock planting (R.P) : 1.57 0.09
Time of grafting (t) : 0.62 0.07
Time of rootstock planting × Scion type : 2.22 NS
Time of rootstock planting × Time of grafting : 2.22 0.13
Scion type × Time of grafting : NS NS
Time of rootstock planting × Scion type × Time of grafting : NS 0.18
Table 4. Effect of rootstock planting time, scion type and grafting period on final plant height (cm) in walnut

| Scion type | Time of grafting | S1 | Sub mean | S2 | Sub mean | Mean | Factor mean |
|------------|-----------------|----|----------|----|----------|------|-------------|
|            | Time of rootstock planting | t1 | t2 | t1 | t2 | t1 | t2 | t1 | t2 |
| Rootstock planting time | 2nd fortnight of November | 138.03 | 130.30 | 134.17 | 135.25 | 128.33 | 131.79 | 135.14 | 129.31 |
| | 2nd fortnight of December | 125.27 | 118.13 | 121.70 | 120.12 | 110.08 | 115.10 | 118.40 | 122.69 | 114.10 |
| | 2nd fortnight of January | 105.27 | 101.66 | 103.47 | 100.30 | 95.00 | 97.62 | 100.56 | 102.78 | 98.33 |
| Mean | 122.85 | 116.69 | 119.78 | 118.55 | 111.13 | 114.85 | 120.20 | 113.92 |

S1 = Middle portion of current season growth with 3-5 buds, S2 = Current season growth with small piece of 2-year old wood; t1 = 3rd week of February, t2 = 1st week of March; Main effects and interaction effects; C.D(P≤0.05)

- Time of rootstock planting (r.p) : 0.33
- Scion type(s) : 0.27
- Time of grafting(t) : 0.27
- Time of rootstock planting × scion type : 0.46
- Time of rootstock planting × time of grafting : 0.46
- Scion type × time of grafting : 0.38
- Time of rootstock planting × scion type × time of grafting : 0.66
Data presented in Table 4 recorded that final height of grafted plant was significantly influenced by time of rootstock planting, scion type and time of grafting. Among time of rootstock plantings, the maximum plant height (133cm) was obtained when rootstock was planted during second fortnight of November. This might be due to early sprouting and better callus formation. Minimum plant height (100cm) was obtained when rootstock was planted during 2nd fortnight of January. These results are in conformity with Srivastava [14]. Scion type had significant influence on final plant height. Maximum final plant height (119cm) was obtained with scion type having middle portion of current season growth with 3-5 buds. This may be due to more accumulation of stored food material in this portion than current season growth with 3-5 buds having 2-year old growth. Time of grafting had significant influence on final plant height. Maximum plant height (120cm) was obtained when grafting was performed during 3rd week of February. This may be due to the rapid regeneration of cambium tissue due to activation of scion and rootstocks coupled with ideal temperature in February. These findings are in conformity with findings of Ahmed et al [6]. Interaction between time of rootstock planting and scion type and time of rootstock planting and time of grafting significantly influenced the final height of grafted plants. Interaction between scion type and time of grafting and time of rootstock planting, scion type and time of grafting had significant influence on final height of grafted plant. This might be due to good sap flow in the rootstock along with favorable temperature and relative humidity available for a comparatively longer period which was responsible for the increase in the final plant height. Similar findings were described by Srivastava [14].

Temperature and relative humidity had pronounced effect on walnut grafting success because temperature and relative humidity effect on the production of callus tissue which is essential for graft union formation. High environmental moisture is needed for walnut grafting, because the parenchyma cells of callus have soft walls and they lose their moisture in dry places [15]. Both these parameters were regulated under polyhouse conditions.

4. CONCLUSION

The study revealed that among the different timings of rootstock planting, rootstocks planted during 2nd fortnight of November proved significantly better in comparison to other timings. Scion type having middle portion of current season growth with 3-5 buds grafted during 3rd week of February on the rootstock which was planted during 2nd fortnight of November took minimum days to bud swell and bud bursting and had higher graft success per cent, more number of leaves, higher leaf area and shoot length and greater final height of grafted plants. Thus, rootstock planting during 2nd fortnight of November and grafted during 3rd week of February with scion type having middle portion of current season growth with 3-5 buds should be practiced for large scale multiplication of walnuts under polyhouse conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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