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Exploring Combinations of Rootstock Planting Time, Scion type and time of Grafting on Grafting Success of Walnut Plants

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ABSTRACT: The success in propagation is known to be influenced by the method, time and environment conditions to which the plants are subjected to grow before and after propagation. So 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. Since, no systematic work has been carried out to see the combined influence of the rootstock planting time, scion type and time of grafting. Therefore, the present investigation entitled "Exploring combinations of rootstock planting time, scion type and time of grafting on grafting success of walnut plants" 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 rootstock 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 (3-5buds) 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 (75.28%), leaf area (350.02cm^2), leaf number (11.34), scion girth (4.78cm), shoot length (21.77cm), final plant height (132.98cm) and final graft success (69.05%) 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 (63.66%), leaf area (309.95 cm^2), leaf number (12.89), scion girth (4.31cm) and shoot length (19.33cm), final plant height (119.78cm) and final graft success (58.00%) were observed better with scion type having middle portion of current season growth with 3-5 buds. Time of grafting significantly influenced all the recorded parameters and best results were obtained when grafting was performed during 3rd week of February as compared to 1st week of March.

Keywords: Rootstock planting, scion type, grafting, walnut, sulaiman.

INTRODUCTION

Persian walnut (*Juglans regia* L.) is the only walnut grown in India. Currently, its annual production is around 20,000 MT (FAOSTAT, 2018) and half of the produce is exported. Almost the entire produce comes from seedling trees covering roughly 35,000 hectares in temperate region of the North Western Himalayas 1200 rn to 3500 rn above mean sea level. Besides a few hundred thousand trees in Jammu & Kashmir province, thousands of walnut trees with nuts of good quality also occur further South-East in the interior of Himachal Pradesh. The major walnut growing countries are China, USA, Iran, Ukrain, Turkey and Mexico (Upadaya 2017). In India, the important walnut producing states are Jammu and Kashmir, Himachal Pradesh and Uttarakhand. In Jammu and Kashmir the total area under walnut cultivation is 84,777 ha with a production of 2, 79,422 MT (Anonymous, 2019) 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 (Gandev, 2007) as it is very nutritious fruit, containing 64.5 per cent fats, 15.6 per cent protein, 10.6 per cent carbohydrates and 687 calories of energy per 100g (Singh *et al.,* 1967). It also contains good amount of Vitamin B_6 among all the other nuts. Both immature fruits and green hulls of walnut are very rich sources of ascorbic acid containing about 2- 2.5% and 0.4-0.8% on fresh basis respectively. Walnuts contain important phytochemicals as well as high amounts of polyunsaturated fats which do offer potential benefits for both brain health and brain function. It has Omega-3 which plays a part by helping

to reduce oxidative stress in the brain. Walnut also a potential multipurpose nut crop helps in reclaiming deteriorated lands and environment. Because of urban development and changing land-usage, most lands have been deteriorated by human. In addition, natural disasters have exacerbated this problem. Vahdati *et al.*, (2018) reported that walnut trees with their strong root system have a key role in maintaining lands against destructive factors such as erosion and human activity. It can be cultivated in deteriorated lands not only to prevent soil erosion but also as a productive and lucrative product. Even if walnut trees yield in deteriorated lands is just 1 t ha^{-1}, its revenues will be five times higher than many annual crops.

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, vigour, kernel size, shape and quality that ultimately hamper the grading of nuts for export (Sharma *et al*., 2003). Among various causes of low productivity undescripted type of seedling plants population is most important one and also due to lack of standard propagation techniques and absence of regular orchard of known cultivar (Bhat and Ahmed, 2003). 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 by different methods of propagation like wedge grafting and patch budding are well known in case of walnut (Mir and Kumar, 2011) but none of these methods became popular for mass multiplication due to in consistency in their success. It has been reported that most economical and practical vegetative method for walnut propagation is grafting and budding (Bhat *et al.*, 2003; Thapar and Rana 1961). Time of rootstock planting, type of scionwood, age of rootstock and hormonal content are also known to influence the grafting success. Van't Westeinde (1990) and Erdogan (2006) preferred scion material obtained from middle and basal parts of vigorous shoots from the previous season's growth. Jindal and Gautam (2001) reported that scion wood that have short piece of 2 year old wood with or without least pith result in better graft success.

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. 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 known to be influenced by the method, time and environment conditions to which the plants are subjected to grow before and after propagation. 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. Since, no systematic work has been carried out to see the combined influence of the rootstock planting time, scion type and time of grafting. Therefore, the present investigation entitled, "Exploring combinations of rootstock planting time, scion type and time of grafting on grafting success of walnut plants" was conducted at the Research Farm of Division of Fruit Science SKUAST-K-Shalimar

MATERIALS AND METHODS

Seedling rootstock of uniform size and vigor were selected for experiment. The 2-year old rootstocks were planted at month's interval (2^{nd} fortnight of November, 2^{nd} fortnight of December and 2^{nd} fortnight of January) in the polyhouse at a spacing of 20 × 30 centimeter leaving a space of 45 centimeter after every third row for grafting, however other cultural operations were similar in all the treatments.

A. Scion wood collection

The scion material used were taken from Sulaiman variety of walnut released by SKUAST-Kashmir. The bud sticks used for grafting were, collected during dormant period and stored in pit under natural condition. Two types of scion wood was collected one stick having middle portion of current season growth with 3-5 buds and other having middle portion of current season growth (3-5buds) with small piece (3cm) of 2- year old-wood.

B. Time and methodology of grafting

Grafting were performed in the third week of February and first week of March 2018. For this purpose about 12 cm long scion wood of walnut cv. Sulaiman, having 3-5 buds from the previous season growth was collected. A piece of scion wood containing three to five buds was used for grafting. Grafting operation was carried out at fifteen days interval using wedge method of grafting in poly-house. The grafted plants were tied with polythene in order to avoid desiccation of the graft union. Regular pinching was done to control the unwanted growth of shoots from the seedlings, below graft union. Various cultural operations were followed in nursery bed like weeding, hoeing, control of insect-pest and diseases from time to time. Observations of grafted walnut plants were recorded as per standard procedures.

RESULTS AND DISCUSSION

A. Days taken to bud swelling

Days taken to bud swelling were significantly influenced by time of rootstock planting, scion type and time of grafting. Among three rootstock planting timings, the minimum days taken for bud swelling (24.80 days) was recorded in November planting. This may be due to the reason that plants escaped transplanting shock due to in situ grafting, provided

stored food material for callus formation and maximized cambial contact between stock and scion. That's why earlier formation of cambial tissue between stock and scion took minimum days for bud swelling. These results are in conformity with Kumar (2011) and Ladon *et al*., (2020).

Scion type also influenced the days taken to bud swelling. Minimum days for bud swelling (26.68days) was recorded by grafting with scion type having middle portion of current season growth with 3-5 buds. This may be due to the presence of more reserve food in young scions and actively growing tissues that enhance bud swelling. These results are in conformity with Tanuja (2017) in Sapota.

Time of grafting also exhibited the significant influence on days taken to bud swelling. The minimum days for bud swelling (26.68 days) was recorded when grafting was performed during 3rd week of February. This may be due to the prevailing optimum and maximum temperature, coupled with good humidity which favour early contact and minimizes number of days for bud swelling. These results are in conformity with Kumar and Mir (2011) in walnut.

Interaction between time of rootstock plantings, scion type and time of grafting had significant influence on days taken to bud swelling. Minimum days taken to bud swelling (22.69 days) was recorded when rootstock was planted during 2nd fortnight of November with scion type having middle portion of current season growth and grafted during 3rd week of February (Table 1).

B. Days taken to bud bursting

Days taken to bud bursting was significantly influenced by time of rootstock planting, scion type and time of grafting. Among three rootstock planting timings, the minimum days taken for bud bursting (27.21days) was recorded in November planting. This may be due to the presence of auxins and prevailing favourable conditions which helped in early bud bursting through intercalary meristem at nodal region. These results are in conformity with Bhavya *et al*. (2018).

Scion type also significantly influenced the days taken to bud bursting. The minimum days for bud bursting (30.4days) was recorded by grafting with scion type having middle portion of current season growth with 3-5 buds. This may be due to regenerating ability of plant which is found higher in younger scion and this could be due to higher meristimatic activity of cells in younger scion resulting in faster callus formation and quick healing of graft union that enhance bud bursting. These results are in conformity with Tanuja (2017) who observed the similar results in sapota.

Time of grafting also exhibited the significant influence on days taken to bud bursting. The minimum days for bud bursting (29.24 days) was obtained when grafting was performed during 3rd week of February. This may be due to early and good contact of cambial layers of stock and scion and favourable environmental conditions during February, which resulted in early callus formation and thus took minimum days for bud bursting. The reason for late bud bursting in plants grafted during 1st week of March (33.48days) might be due to lower temperature and humidity which delayed the callus formation and took more days for bud bursting. These result are in congruence with Kumar (2011) and Upadhaya (2017) who observed similar results in walnut.

The interaction between time of rootstock planting and scion type and time of rootstock planting, scion type and time of grafting revealed that rootstock planted during 2nd fortnight of November and grafted with scion type having middle portion of current season growth during 3rd week of February took minimum days for bud bursting (24.42 days). These results are in conformity with Kumar (2011), Upadhaya (2017) and Tanuja (2017) (Table 1).

C. Initial graft success (%)

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 (75.28%) was recorded in November planting. Minimum initial graft success was recorded when rootstock was planted in January (47.19%). 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.

Scion type also significantly influenced the initial graft success per cent Maximum initial graft success per cent (63.66%) was obtained with scion type having middle portion of current season growth with 3-5buds. 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 (2017) who obtained similar results in sapota.

Time of grafting also exhibited the significant influence on initial graft success per cent. Maximum initial graft success (65.64%) was recorded when the grafting was performed during 3rd week of February. This may be due to the prevailing favourable environmental conditions during February and rapid sap flow which favour the healing process, and thus established the continuity of cambial and vascular tissue for the graft success .The reason for minimum initial graft success in 1st week of March (58.94%) might be due to lower temperature and humidity which delayed the callus formation. These result are in conformity with Kumar (2011) and Upadhaya (2017) 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 (Table 2).

D. Final graft success (%)

Final graft success per cent was significantly influenced by time of rootstock planting, scion type and time of grafting. Among three rootstock planting time, the maximum final graft success (69.05%) 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. Minimum final graft success (40.91%) was recorded when rootstock was planted in January. This may be due to the reason that the plants were in stage of transplanting shock and whole of energy of plants was diverted for overcoming transplanting shock and little amount of energy might have diverted towards the formation of callus.

Scion type also influenced the initial graft success per cent. The maximum final graft success (58.00%) 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 (2017) 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 (63.54%) was obtained when the grafting was performed during 3rd week of February. This may be due to early and good contact of cambial layers of stock and scion and favourable environmental conditions during February and rapid sap flow which favour the healing process and established the continuity of cambial and vascular tissue for the graft success . The reason for minimum final graft success in 1st week of March (56.89%) might be due to lower temperature and humidity which delayed the callus formation. These results are in congruence with Kumar (2011) and Upadhaya (2017) who reported similar results in walnut.

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 (71.45%) 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 (72.61%) 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 (75.23%) was found when rootstock was planted during 2nd fortnight of November and grafting was performed during 3rdweek of February with scion type having middle portion of current season growth with 3-5buds. These results are in line with Upadhyay *et al.* (2017) and Vanaja *et al.* (2017) in walnut and guava, respectively (Table 2).

E. Number of leaves per plant

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 (11.34) 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. This results are in conformity with the findings of Hassan (2019) who reported the 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 (10.55) 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 meristematic activity and better healing of grafts during this period resulted in more number of leaves per plant. These results are in congruence with Upadhaya (2017) and Hassan (2019) in walnut.

Scion type also had significant influence on number of leaves per plant. Maximum number of leaves per plant (12.89) 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 might have caused better plant growth and more number of leaves per plant with more leaf area index. The results are in conformity with Chovatia and Singh (2000) and Vahadati and Aalifar, (2016).

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 (12.96) was observed in November planting when grafting was performed during 3rd week of February. These results are in conformity with Srivastava (2012) and Zenginbal (2007). The interactions between scion type and 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 (13.29) 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 Muzafar and Kumar (2011), Ghosh *et al.* (2011), Ladon *et al.,* (2020) and Zenginbal (2007) (Table 3).

F. Leaf area (cm^2)

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 (350.02cm^2) was obtained when rootstock was planted during second fortnight of November. It might be due to vigorous growth of plant as it was capable of absorbing more nutrients and prepares more photosynthates thus resulted in maximum leaf area. Scion type also had significant influence on leaf area. Maximum leaf area (309.05cm^2) was obtained with scion type having middle portion of current season growth. This may be due to more accumulation of stored carbohydrates causing more leaf area expansion. These results are in congruence with Chovatia and Singh (2000). Time of grafting had significant influence on leaf area. Maximum leaf area (340.06 cm^2) was obtained when grafting was performed during 3rd week of February (Table 4).

Table 1: Effect of rootstock planting time, scion type and grafting period on Days taken to bud swelling and bud bursting (Days) in walnut.

Scion type	S_1			S_2			Factor mean			S_1			S_2			Factor mean		
Rootstock planting time / Time of grafting	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean
2nd fortnight of November	22.69	25.09	23.89	23.37	28.08	26.22	23.03	26.58	**24.80**	24.42	28.13	26.27	25.14	31.17	28.15	24.78	29.65	**27.21**
2nd fortnight of December	23.43	27.42	25.42	25.44	30.44	27.94	24.43	28.93	**26.68**	26.41	31.17	28.79	28.24	33.04	30.64	27.32	32.10	**29.71**
2nd fortnight of January	31.08	36.10	33.59	34.08	38.12	36.01	32.58	37.11	**34.84**	34.09	38.20	36.14	37.15	39.20	38.17	35.62	38.70	**37.15**
Mean	**25.73**	**29.63**	**27.63**	**27.63**	**32.21**	**29.89**	**26.68**	**30.82**		**28.30**	**32.5**	**30.4**	**30.17**	**34.47**	**32.32**	**29.24**	**33.48**	

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= 3rd week of February, t_2 = 1st week of March
Main effects and interaction effects

C.D(P≤0.05)				
Time of Rootstock planting(R.P)	:	0.51		0.26
Scion type(S)	:	0.41		0.21
Time of grafting(t)	:	0.41		0.21
Time of rootstock planting× Scion type	:	NS		NS
Time of rootstock planting ×Time of grafting	:	NS		0.37
Scion type× Time of grafting	:	0.59		NS
Time of rootstock planting× Scion type× Time of grafting	:	1.02		0.52

Table 2: Effect of rootstock planting time, scion type and grafting period on initial and final graft success (%) in walnut.

Scion type	S_1		Sub mean	S_2		Sub mean	Factor mean		Sub mean	S_1		Sub mean	S_2		Sub mean	Factor mean		Sub mean
Rootstock planting time / Time of grafting	t_1	t_2		t_1	t_2		t_1	t_2		t_1	t_2		t_1	t_2		t_1	t_2	
2nd fortnight of November	80.55	72.12	76.33	77.88	70.57	74.22	75.28	79.21	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	58.94	60.36	55.44	58.00	58.00	51.67	54.83		63.54	56.89

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= 3rd week of February, t_2 = 1st week of March
Main effects and interaction effects

C.D($P \leq 0.05$)				
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 3: Effect of rootstock planting time, scion type and grafting period on number of leaves per plant and final height of grafted plants in walnut.

Scion type	S_1			S_2			Factor mean			S_1			S_2			Factor mean		
Rootstock planting time / Time of grafting	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean
2nd fortnight of November	13.29	10.42	**11.85**	12.64	9.03	**10.83**	11.34	12.96	**9.72**	138.03	130.30	**134.17**	135.25	128.33	**131.79**	132.98	135.14	129.31
2nd fortnight of December	11.29	8.45	**9.87**	9.10	7.71	**8.40**	9.13	10.19	**8.08**	125.27	118.13	**121.70**	120.12	110.08	**115.10**	118.40	122.69	114.10
2nd fortnight of January	9.74	7.00	**8.37**	7.31	6.52	**6.91**	7.64	8.52	**6.76**	105.27	101.66	**103.47**	100.30	95.00	**97.62**	100.56	102.78	98.33
Mean	**17.16**	**8.62**	**12.89**	**9.68**	**7.75**	**8.71**		**10.55**	**8.18**	122.85	116.69	**119.78**	118.55	111.13	**114.85**		120.20	113.92

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= 3rd week of February, t_2 = 1st week of March
Main effects and interaction effects

C.D($P \leq 0.05$)				
Time of Rootstock planting(R.P)	:	0.41		0.33
Scion type(S)	:	0.33		0.27
Time of grafting(t)	:	0.33		0.27
Time of rootstock planting× Scion type	:	NS		0.46
Time of rootstock planting ×Time of grafting	:	0.58		0.46
Scion type× Time of grafting	:	0.47		0.38
Time of rootstock planting× Scion type× Time of grafting	:	0.82		0.66

The favorable conditions prevailing inside the structure stimulated rapid callusing and early contact of cambial layers, which enabled the graft to heal quickly and made a strong union ultimately leading to better strength and faster growth. The results are in line with Kumar and Mir (2011) and Ladon *et al.,* (2020).

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 (386.64cm^2) was obtained when rootstock was planted during 2nd fortnight of November and grafted during 3rd week of February. These result are in conformity with the findings of Upadhaya (2017) in walnut.

G. Scion girth (cm)

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 (4.8cm) 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 (4.31cm) 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 (Tanuja, 2017). 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. The results are in line with Chovatia and Singh (2000).

Time of grafting had significant influence on scion girth. Maximum scion girth (4.61cm) 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 Kumar and Mir (2011).

Interaction between time of rootstock planting, scion type and time of grafting had significant influence on scion girth. Maximum scion girth (5.58cm) 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 result are in conformity with Upadhaya (2017) (Table 4).

H. Final height of grafted plant

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 (132.98cm) 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 (100.56cm) was obtained when rootstock was planted during 2nd fortnight of January. These result are in conformity with Srivastava (2012).

Scion type had significant influence on final plant height. Maximum final plant height (119.78cm) 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 (120.20cm) 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 Porebsiki *et al*. (2002) and Srivastava (2012).

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 favourable temperature and relative humidity available for a comparatively longer period which was responsible for the increase in the final plant height. Similar findings has been described by Srivastava (2012) and Vahdati and Aalifar (2016).

I. Temperature and Relative humidity

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 parenchyme cells of callus have soft walls and they lose their moisture in dry places (Vahadati, 2012).

CONCLUSION

The present investigation entitled "Vegetative propagation of walnuts under polyhouse conditions" 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.

Table 4: Effect of rootstock planting time, scion type and grafting period on leaf area (cm^2) and scion girth (cm) in walnut.

Scion type	S_1			S_2			Factor mean			S_1			S_2			Factor mean		
Rootstock planting time / Time of grafting	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean	t_1	t_2	Sub mean
2nd fortnight of November	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
2nd fortnight of December	380.15	301.47	340.81	378.59	298.08	338.33	339.57	379.37	299.77	5.17	4.06	4.61	4.99	3.65	4.32	4.46	5.08	3.85
2nd fortnight of January	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
Mean	343.03	276.88	309.95	337.10	271.43	304.26		340.06	274.16	4.78	3.84	4.31	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= 3rd week of February, t_2 = 1st week of March
Main effects and interaction effects

C.D(P≤0.05)				
Time of Rootstock planting(R.P)	:	1.57		0.09
Scion type(S)	:	1.28		0.07
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

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