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Study the performance of wedge grafting in Indian jujube under different growing conditions

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Abstract
The experiment was conducted at the experimental orchard and in the polyhouse of the Department of Horticulture, CCS HAU, Hisar during the year 2019-20 to find the effect of grafting time and growing conditions on ber cultivars Gola and Umran. Among different time of grafting operation. The minimum number of days taken to sprouting was recorded during 4th week of February which was followed by 1st week of March under polyhouse condition in cv. Gola. The graft success was recorded highest under polyhouse condition when grafting was performed during 3rd week of February which was followed by 2nd and 4th week of February and in open field during 4th week of February in cv. Umran. The growth parameters *i.e.*, shoot length, shoot diameter and number of leaves were recorded significantly higher when grafting was performed during 4th week of February under open field condition in cv. Gola. The study delves that the performance of wedge grafting in Indian jujube best resulted showed during 3rd week of February under polyhouse condition and 4th week of February under open field condition in cv. Umran and Gola cultivars.

Keywords: Wedge grafting, environmental conditions, Gola, Umran, propagation

1. Introduction
Ber or Indian jujube (*Ziziphus mauritiana* L.) also called king of arid fruits, belongs to the family Rhamnaceae, a minor fruit crop which is suitable in both arid and semi-arid conditions for successful cultivation. It is extremely drought hardy crop due to its deep root system and grown successfully in tropical and sub-tropical regions up to 1000 m above mean sea level. Due to less requirement of water in ber crop, well suited to dry land farming. In ber, propagation is done by both seeds and vegetative methods. Most commonly used method is seed, but these plants do not produce true-to-type fruits which lead to great variation in fruit yield and other characters, therefore, to obtain and maintain the genetic uniformity of clone/cultivar in fruit crops, there is great significance of vegetative propagation. Basic requirement for any fruit crop is the planting material due to its influence on ultimate yield in terms of quality and quantity (Singh *et al*., 2015) [12]. Ber has been successfully propagated by wedge grafting in Israel (Nerd and Mizrahi, 1998) [9]. In India, due to lack of information related to propagation method by using wedge grafting, there is immense need to find out a suitable method of vegetative propagation for quick multiplication of elite ber plants. Keeping the above facts under considerations, the present work was carried out to find the response of wedge grafting in ber cultivars, Gola and Umran in different growing conditions *i.e*. polyhouse and open field. *Ziziphus rotundifolia* is commonly used as rootstock for grafting which can withstand to long periods of drought, salt and water logging, therefore, can be grown on degraded or marginal land. Hence, considering the above importance the present investigation "Study the performance of wedge grafting in Indian jujube under different growing conditions" has been planned with the objective to study the performance of wedge grafting in ber under different growing conditions.

2. Materials and Methods
The experiment was carried out at the experimental farm of the Department of Horticulture, CCS Haryana Agricultural University, Hisar, situated at 215.2 m above sea level with coordinates of 29º 10' N latitude and 75 º 46' E longitudes. The experiment was conducted to study the wedge grafting in two ber cultivars Gola and Umran. One year old ber seedlings were grafted at different time *i.e.*T_1- 3rd week of January, T_2- 4th week of January, T_3- 1st week of February, T_4- 2nd week of February, T_5- 3rd week of February, T_6- 4th week of February, T_7-

1st week of March and T_8-2nd week of March under polyhouse condition (medium cost polythene with fan and pad cooling system) and open field conditions. This experiment laid out in the randomized block design with 32 treatments and 3 replications.

During the investigation following observations on grafts were recorded; number of days taken to sprouting, success percent/graft success (%), shoot length (cm) at 60 and 90 days after grafting, shoot diameter (cm) at 60 and 90 days after grafting and number of leaves at 60 and 90 days after grafting. The first axillary bud breaking of the grafts as influenced by the growing conditions and time of grafting was observed critically and data were collected every day. The days required for bud breaking from the date of grafting was taken periodically. Form them, the average time required for bud breaking was calculated. The percentage of successful grafts of individual treatment was calculated by using the following formula:

$$\text{Percentage of graft success} = \frac{\text{Number of successful grafted plants}}{\text{Total number ofplants grafted}} \times 100$$

Length and diameter of sprouted shoots were recorded in each treatment and average data was worked out for each replication after emergence of bud till 90 days and expressed in cm. The total number of leaves in each sprouted shoot and whole scion of each grafted plant under each treatment were counted periodically and mean number of leaves per graft was calculated.

3. Results

3.1 Number of days taken to sprouting

A perusal of data given in Table 1 indicates that the grafting time, growing conditions and cultivars significantly influenced the number of days taken to sprouting. The minimum number of days taken (18.93) to sprouting was recorded when plants grafted during 4th week of February which was found to be at par with 1st week of March (19.66) and significantly less as compared to other grafted time and the maximum number of days taken during 3rd week of January (31.94) irrespective of growing conditions and cultivars (Table 1b). Growing conditions differed significantly among each other in influencing days taken to sprouting. Days taken to sprouting were recorded minimum (23.38) under polyhouse condition which was significantly lower to open condition (25.45) irrespective of grafting time and cultivars (Table 1b). Days taken to sprouting were significantly lower (24.01) in cv. Gola as compared to cv. Umran (24.83) irrespective of grafting time and growing conditions (Table 1c).The interaction effect of growing conditions and grafting time was found non-significant (Table 1b). However, days taken to sprouting were minimum (17.85) under polyhouse condition when plants grafted during 4th week of February whereas, maximum days (33.26) taken under open condition when grafting was done during 3rd week of January. The interaction between cultivars and grafting time was found non-significant (Table 1c). The number of days taken to sprouting was minimum (18.50) in cv. Gola when plants grafted during 4th week of February whereas, maximum number of days (32.16) taken in cv. Umran when plants grafted during 3rd week of January. The interaction between cultivars and growing conditions was found non-significant (Table 1d). The number of days taken to sprouting was minimum (22.84) in cv. Gola under polyhouse condition whereas, maximum days (25.73) were taken in cv. Umran under open condition. The interaction effect of grafting time, growing conditions and cultivars was found non-significant (1a). However, the number of days taken to sprouting was minimum (17.22) under polyhouse condition in cv. Gola when grafting was done during 4th week of February whereas, maximum number of days taken (33.56) under open condition in cv. Umran when grafting operation was done during 3rd week of January. Plants grafted in polyhouse condition required less time to sprouting as compare to open condition in all the treatments. It might be due to the interception of light inside the polyhouse which increased the temperature and didn't lose throughout the night which leads to production and interlocking of parenchymatous cells by scion and stock results intimate contact of cambial region of both stock and scion under favourable environmental conditions *i.e.,* high temperature and relative humidity in February month under polyhouse which promotes better and early sprouting. These results are in accordance with the findings of Singh and Pandey (1998) [11] and Joshi *et al*. (2014) [6] in guava. The relative humidity is the key factor for bud sprouting and higher humidity leads to early bud sprouts in guava (Singh *et al*., 2007) [10]. Furthermore, suitable temperature and water availability enhance the rate of photosynthesis which leads to production of more food material that facilitates better growth and development of graft sprout. At the range of temperature between 24 ºC and 28 ºC, the graft union formation was favoured but failed to develop at lower temperature *i.e.,* 15 to 20 ºC and at high temperature caused tissue injury and death of callus cells (Asante and Barnett, 1998) [2]. Thus, the process of bud sprouting slows down under open condition in January due to very low temperature. The number of days taken for sprouting was less in cv. Gola as compare to cv. Umran may be due to the varietal difference that attributed with the genotypic variations.

Table 1: Effect of grafting time, growing conditions and cultivars on number of days taken to sprouting in ber plants

1a: Grafting time × Growing Conditions × Cultivars					
Grafting time	**Gola**		**Umran**		**Mean**
	Open field	**Polyhouse**	**Open field**	**Polyhouse**	
T_1 (3rd week of January)	32.96	30.47	33.56	30.75	31.94
T_2 (4th week of January)	30.99	27.85	31.08	28.64	29.64
T_3 (1st week of February)	28.62	25.74	28.67	26.87	27.48
T_4 (2nd week of February)	25.83	24.21	27.06	26.19	25.82
T_5 (3rd week of February)	21.74	20.10	23.07	21.62	21.63
T_6 (4th week of February)	19.77	17.22	20.26	18.47	18.93
T_7 (1st week of March)	20.32	18.43	20.65	19.26	19.66
T_8 (2nd week of March)	21.19	18.67	21.46	19.60	20.23
Mean	25.18	22.84	25.73	23.92	

1b: Growing Conditions × Grafting time									
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**Mean**

Open field	33.26	31.03	28.65	26.45	22.40	20.01	20.48	21.33	25.45
Polyhouse	30.61	28.24	26.31	25.20	20.86	17.85	18.85	19.13	23.38
Mean	31.94	29.64	27.48	25.82	21.63	18.93	19.66	20.23	

1c: Cultivars × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Gola	31.72	29.42	27.18	25.02	20.92	18.50	19.37	19.93	24.01
Umran	32.16	29.86	27.77	26.63	22.35	19.36	19.96	20.53	24.83
Mean	31.94	29.64	27.48	25.82	21.63	18.93	19.66	20.23	

1d: Cultivars × Growing Conditions

	Open field	Polyhouse	Mean
Gola	25.18	22.84	24.01
Umran	25.73	23.92	24.83
Mean	25.45	23.38	

CD $_{0.05}$

Grafting time	1.11
Growing Conditions	0.55
Cultivars	0.55
Growing Conditions × Grafting time	NS
Cultivars × Grafting time	NS
Cultivars × Growing Conditions	NS
Grafting time × Growing Conditions × Cultivars	NS

3.2 Success percent/Graft success (%)

The data recorded on graft success have been presented in Table 2. Graft success was significantly affected by all the treatments *i.e.* grafting time, growing conditions and cultivars. Significantly higher graft success (35.00%) was found when plants grafted during 3rd week of February which was found to be at par with 2nd week of February (30.83%) as well as 4th week of February (30.83%) and lower graft success (18.33%) was found when plants grafted during 3rd week of January irrespective of growing conditions and cultivars (Table 2b). Polyhouse condition resulted in statistically higher graft success (27.92%) over open condition (23.33%) irrespective of grafting time and cultivars (Table 2b). Likewise, statistically higher graft success (28.54%) was recorded in cv. Umran as compare to cv. Gola (22.71%) irrespective of growing conditions and grafting time (Table 2c). The interaction effect of growing conditions and grafting time was found significant (Table 2b). The highest graft success (41.67%) was found under polyhouse condition when grafted during 3rd week of February which was found to be at par with 2nd week (36.67%) and 1st week of February (30.00%) whereas, the lowest graft success (13.33%) was found under open condition when plants grafted during 3rd week of January. The interaction effect of cultivars and grafting time was found non-significant (Table 2c). The highest graft success (38.33%) was found in cv. Umran when grafting was performed during 3rd week of February whereas, lowest graft success (15.00%) was found in cv. Gola when plants grafted during 3rd week of January. The interaction effect of cultivars and growing conditions was found significant (Table 2d). The highest graft success (30.83%) was found under polyhouse condition in cv. Umran which was statistically at par with cv. Umran under open condition (26.25%) and cv. Gola under polyhouse condition (25.00%) whereas, the lowest graft success (20.42%) was found under open condition in cv. Gola. The interaction effect of grafting time, growing conditions and cultivars was found non-significant (Table 2a). The highest graft success (43.33%) was found under polyhouse condition in cv. Umran when grafting was performed during 3rd week of February whereas the lowest graft success (10.00%) was found under open condition in cv. Gola when grafting was performed during 3rd week of January. The higher rate of graft success under polyhouse condition might be due to more congenial micro-climate. Graft success is directly proportional to relative humidity and because of high relative humidity under polyhouse condition the per cent of graft success was found higher as compare to open condition. A high level of humidity in the vicinity of the cambial region of the graft union is essential for the production of parenchyma cells which leads to quick healing of graft joints and early formation of graft union. Hartmann *et al.* (1997) [4] resulted that the new callus tissue developing from the cambial region is made up of thin walled, turgid cells which are more prone to desiccation and die. Jalal *et al.* (2018) [5] obtained 100 per cent graft take under polyhouse condition. The highest rate of graft success was found in cv. Umran as compare to cv. Gola. This result is also in accordance with the finding of Naik *et al.* (2016) [8] in ber who reported that highest per cent graft success in cv. Umran over cv. Gola. This difference in per cent graft success is mainly due to the varietal response to different propagation methods under different environmental conditions observed by Erdogan (2006) [3] in walnut.

Table 2: Effect of grafting time, growing conditions and cultivars on graft success (%) in ber plants

2a: Grafting time × Growing Conditions × Cultivars

Grafting time	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T_1 (3rd week of January)	10.00	20.00	16.67	26.67	18.33
T_2 (4th week of January)	13.33	23.33	20.00	30.00	21.67
T_3 (1st week of February)	16.67	26.67	20.00	33.33	24.17
T_4 (2nd week of February)	20.00	33.33	30.00	40.00	30.83
T_5 (3rd week of February)	23.33	40.00	33.33	43.33	35.00
T_6 (4th week of February)	30.00	26.67	36.67	30.00	30.83
T_7 (1st week of March)	26.67	16.67	30.00	23.33	24.17
T_8 (2nd week of March)	23.33	13.33	23.33	20.00	20.00
Mean	20.42	25.00	26.25	30.83	

2b: Growing Conditions × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Open field	13.33	16.67	18.33	25.00	28.33	33.33	28.33	23.33	23.33

Polyhouse	23.33	26.67	30.00	36.67	41.67	28.33	20.00	16.67	27.92
Mean	18.33	21.67	24.17	30.83	35.00	30.83	24.17	20.00	

2c: Cultivars × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Gola	15.00	18.33	21.67	26.67	31.67	28.33	21.67	18.33	22.71
Umran	21.67	25.00	26.67	35.00	38.33	33.33	26.67	21.67	28.54
Mean	18.33	21.67	24.17	30.83	35.00	30.83	24.17	20.00	

2d: Cultivars × Growing Conditions

	Open field	Polyhouse	Mean
Gola	20.42	25.00	22.71
Umran	26.25	30.83	28.54
Mean	23.33	27.92	

CD $_{0.05}$

Grafting time	8.81
Growing Conditions	4.41
Cultivars	4.41
Growing Conditions × Grafting time	12.46
Cultivars × Grafting time	NS
Cultivars × Growing Conditions	6.23
Grafting time × Growing Conditions × Cultivars	NS

3.3 Shoot length (cm) at 60 days after grafting

It is evident from the data presented in Table 3 that all treatments significantly influenced the shoot length at 60 days after grafting. Plants grafted during 4th week of February showed significantly highest shoot length (23.01 cm) which was found to be at par with 1st week of March (22.67 cm) and the lowest found during 3rd week of January (15.69 cm) irrespective of growing conditions and cultivars (Table 3b). Growing conditions differed significantly among each other in influencing shoot length. However, plants grafted under open condition showed numerically more shoot length (20.68 cm) than polyhouse condition (19.54 cm) irrespective of grafting time and cultivars (Table 3b). Cultivar Gola showed significantly higher shoot length (20.50 cm) as compare to cv. Umran (19.72 cm) irrespective of grafting time and growing conditions (Table 3c). The interaction effect of growing conditions and grafting time was found significant (Table 3b). The highest shoot length (24.25 cm) was recorded when plants grafted during 4th week of February which was found to be at par with 1st week (23.99 cm) and 2nd week of March (23.08 cm) whereas, the lowest shoot length (15.03 cm) was recorded when plants grafted during 3rd week of January under open condition. The interaction between cultivars and grafting time was found non-significant (Table 3c). The highest shoot length (23.49 cm) was recorded in cv. Gola when plants grafted during 4th week of February whereas, the lowest shoot length (14.98 cm) was recorded in cv. Umran when plants grafted during 3rd week of January. The interaction between cultivars and growing conditions was found non-significant (Table 3d). The highest shoot length (21.22 cm) was recorded in cv. Gola under open condition whereas, the lowest shoot length (19.29 cm) was recorded in cv. Umran under polyhouse condition. The interaction effect of grafting time, growing conditions and cultivars was found non-significant (3a). However, the highest shoot length (24.79 cm) was recorded in cv. Gola when plants grafted during 4th week of February whereas, the lowest shoot length (14.50 cm) was recorded in cv. Umran when plant grafted during 3rd week of January under open condition.

Table 3: Effect of grafting time, growing conditions and cultivars on shoot length (cm) at 60 days after grafting in ber plants

3a: Grafting time × Growing Conditions × Cultivars

Grafting time	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T_1 (3rd week of January)	15.56	17.23	14.50	15.47	15.69
T_2 (4th week of January)	18.40	18.38	16.81	18.06	17.91
T_3 (1st week of February)	18.67	19.13	18.41	18.53	18.69
T_4 (2nd week of February)	21.90	19.46	20.26	19.39	20.25
T_5 (3rd week of February)	22.48	20.57	21.30	20.18	21.13
T_6 (4th week of February)	24.79	22.19	23.71	21.34	23.01
T_7 (1st week of March)	24.52	21.16	23.45	21.57	22.67
T_8 (2nd week of March)	23.44	20.18	22.73	19.75	21.53
Mean	21.22	19.79	20.15	19.29	

3b: Growing Conditions × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Open field	15.03	17.61	18.54	21.08	21.89	24.25	23.99	23.08	20.68
Polyhouse	16.35	18.22	18.83	19.43	20.37	21.77	21.36	19.97	19.54
Mean	15.69	17.91	18.69	20.25	21.13	23.01	22.67	21.53	

3c: Cultivars × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Gola	16.40	18.39	18.90	20.68	21.53	23.49	22.84	21.81	20.50
Umran	14.98	17.44	18.47	19.83	20.74	22.52	22.51	21.24	19.72
Mean	15.69	17.91	18.69	20.25	21.13	23.01	22.67	21.53	

3d: Cultivars × Growing Conditions

	Open field	Polyhouse	Mean
Gola	21.22	19.79	20.50
Umran	20.15	19.29	19.72

CD $_{0.05}$

Grafting time	1.43
Growing Conditions	0.72
Cultivars	0.72
Growing Conditions × Grafting time	2.02
Cultivars × Grafting time	NS

				Cultivars × Growing Conditions	NS
Mean	20.68	19.54		Grafting time × Growing Conditions × Cultivars	NS

3.4 Shoot length (cm) at 90 days after grafting

A perusal of data given in Table 4 indicates that the grafting time, growing conditions and cultivars significantly influenced the shoot length at 90 days after grafting. Plants grafted during 4th week of February showed significantly the highest shoot length (62.02 cm) and the lowest shoot length was recorded during 3rd week of January (31.06 cm) irrespective of growing conditions and cultivars (Table 4b). Grafted plants under open condition showed numerically more shoot length (47.67 cm) than polyhouse condition (46.54 cm) irrespective of grafting time and cultivars (Table 4b). Cultivar Gola showed significantly higher shoot length (47.75 cm) as compare to cv. Umran Cultivar (46.46 cm) irrespective of grafting time and growing conditions (Table 4c). The interaction effect of growing conditions and grafting time was found significant (Table 4b). The highest shoot length (65.46 cm) was recorded when plants grafted during 4th week of February which was found to be at par with 1st week of March (62.68 cm) whereas, the lowest shoot length (28.99 cm) was recorded when plants grafted during 3rd week of January under open condition. The interaction between cultivars and grafting time was found non- significant (Table 4c). The highest shoot length (62.87 cm) was recorded in cv. Gola when plants grafted during 4th week of February whereas, the lowest shoot length (30.13 cm) was recorded in cv. Umran when plants grafted during 3rd week of January.The interaction between cultivars and growing conditions was found non-significant (Table 4d). The highest shoot length (48.36 cm) was recorded in cv. Gola under open condition whereas, the lowest shoot length (45.94 cm) was recorded in cv. Umran under polyhouse condition. The interaction effect of grafting time, growing conditions and cultivars was found non-significant (4a). The highest shoot length (66.32 cm) was recorded in cv. Gola when plants grafted during 4th week of February whereas, the lowest shoot length (28.17 cm) was recorded in cv. Umran when plants grafted during 3rd week of January under open condition.

Table 4: Effect of grafting time, growing conditions and cultivars on shoot length (cm) at 90 days after grafting in ber plants

4a: Grafting time × Growing Conditions × Cultivars

Grafting time	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T1 (3rd week of January)	29.82	34.17	28.17	32.09	31.06
T2 (4th week of January)	32.93	37.23	32.52	36.56	34.81
T3 (1st week of February)	35.42	41.50	35.28	40.25	38.11
T4 (2nd week of February)	43.67	46.48	42.54	44.78	44.37
T5 (3rd week of February)	55.90	53.44	54.04	51.35	53.68
T6 (4th week of February)	66.32	59.41	64.61	57.75	62.02
T7 (1st week of March)	63.58	54.25	61.77	55.33	58.73
T8 (2nd week of March)	59.27	50.53	56.95	49.43	54.05
Mean	48.36	47.13	46.98	45.94	

4b: Growing Conditions × Grafting time

	T1	T2	T3	T4	T5	T6	T7	T8	Mean
Open field	28.99	32.73	35.35	43.11	54.97	65.46	62.68	58.11	47.67
Polyhouse	33.13	36.90	40.88	45.63	52.40	58.58	54.79	49.98	46.54
Mean	31.06	34.81	38.11	44.37	53.68	62.02	58.73	54.05	

4c: Cultivars × Grafting time

	T1	T2	T3	T4	T5	T6	T7	T8	Mean
Gola	32.00	35.08	38.46	45.08	54.67	62.87	58.92	54.90	47.75
Umran	30.13	34.54	37.77	43.66	52.70	61.18	58.55	53.19	46.46
Mean	31.06	34.81	38.11	44.37	53.68	62.02	58.73	54.05	

4d: Cultivars × Growing Conditions

	Open field	Polyhouse	Mean
Gola	48.36	47.13	47.75
Umran	46.98	45.94	46.46
Mean	47.67	46.54	

CD 0.05

Grafting time	2.15
Growing Conditions	1.07
Cultivars	1.07
Growing Conditions × Grafting time	3.04
Cultivars × Grafting time	NS
Cultivars × Growing Conditions	NS
Grafting time × Growing Conditions × Cultivars	NS

3.5 Shoot diameter (cm) at 60 days after grafting

The data on shoot diameter at 60 days after grafting was influenced significantly by grafting time and growing conditions (Table 5). Grafting time significantly differed with each other in shoot diameter at 60 days after grafting. Plants grafted during 4th week of February showed significantly the highest shoot diameter (0.27 cm) and the lowest shoot diameter showed during 3rd week of January (0.18 cm) irrespective of growing conditions and cultivars (Table 5d). Plants grafted under open condition showed more shoot diameter (0.24 cm) than polyhouse condition (0.23 cm) irrespective of grafting time and cultivars (Table 5d). The effect of cultivars on shoot diameter was found non-significant irrespective of grafting time and growing conditions (Table 5c). The interaction effect of growing conditions and grafting time was found significant (Table 5b). The highest shoot diameter (0.28 cm) was recorded when plants grafted during 4th week of February which was statistically at par with 1st week of March (0.27 cm) whereas, the lowest shoot diameter (0.18 cm) was recorded when plants grafted during 3rd week of January under open condition. The interaction between cultivars and grafting time was found

non-significant (Table 5c). The highest shoot diameter (0.28 cm) was recorded in cv. Gola when plants grafted during 4th week of February whereas, the lowest shoot diameter (0.18 cm) was recorded in cv. Umran when plants grafted during 3rd week of January. The interaction between cultivars and growing conditions was found non-significant (Table 5d). The highest shoot diameter (0.24 cm) was recorded in cv. Gola as well as in cv. Umran (0.24 cm) under open condition whereas, the lowest shoot diameter (0.22 cm) was recorded in cv. Umran under polyhouse condition. The interaction effect of grafting time, growing conditions and cultivars was found non-significant (5a). However, the highest shoot diameter (0.29 cm) was recorded in cv. Gola when plants grafted during 4th week of February whereas, the lowest shoot diameter (0.17 cm) was recorded in cv. Umran when plant grafted during 3rd week of January under open condition.

Table 5: Effect of grafting time, growing conditions and cultivars on shoot diameter (cm) at 60 days after grafting in ber plants

5a: Grafting time × Growing Conditions × Cultivars

Grafting time	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T_1 (3rd week of January)	0.18	0.19	0.17	0.19	0.18
T_2 (4th week of January)	0.19	0.20	0.19	0.20	0.19
T_3 (1st week of February)	0.20	0.21	0.22	0.21	0.21
T_4 (2nd week of February)	0.25	0.22	0.24	0.22	0.23
T_5 (3rd week of February)	0.26	0.24	0.25	0.22	0.24
T_6 (4th week of February)	0.29	0.27	0.28	0.26	0.27
T_7 (1st week of March)	0.27	0.26	0.27	0.25	0.26
T_8 (2nd week of March)	0.25	0.23	0.26	0.25	0.25
Mean	0.24	0.23	0.24	0.22	

5b: Growing Conditions × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Open field	0.18	0.19	0.21	0.25	0.26	0.28	0.27	0.26	0.24
Polyhouse	0.19	0.20	0.21	0.22	0.23	0.27	0.25	0.24	0.23
Mean	0.18	0.19	0.21	0.23	0.24	0.27	0.26	0.25	

5c: Cultivars × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Gola	0.19	0.19	0.20	0.24	0.25	0.28	0.26	0.24	0.23
Umran	0.18	0.20	0.21	0.23	0.24	0.27	0.26	0.26	0.23
Mean	0.18	0.19	0.21	0.23	0.24	0.27	0.26	0.25	

5d: Cultivars × Growing Conditions				CD 0.05	
	Open field	Polyhouse	Mean	Grafting time	0.01
				Growing Conditions	0.01
Gola	0.24	0.23	0.23	Cultivars	NS
				Growing Conditions × Grafting time	0.02
Umran	0.24	0.22	0.23	Cultivars × Grafting time	NS
				Cultivars × Growing Conditions	NS
Mean	0.24	0.23		Grafting time × Growing Conditions × Cultivars	NS

3.6 Shoot diameter (cm) at 90 days after grafting

The data pertaining to shoot diameter at 90 days after grafting has been presented in Table 6. All the treatments except cultivars were found to be significant for influencing the increase in shoot diameter at 90 days after grafting. Plants grafted during 4th week of February showed significantly the highest shoot diameter (0.35 cm) and the lowest showed during 3rd week of January (0.22 cm) irrespective of growing conditions and cultivars (Table 6b). Plants grafted under open condition showed more shoot diameter (0.29 cm) than polyhouse condition (0.28 cm) irrespective of grafting time and cultivars (Table 6b). Cultivar Gola showed more shoot diameter (0.29 cm) over cv. Umran (0.28 cm) irrespective of grafting time and growing conditions (Table 6c). The interaction effect of growing conditions and grafting time was found significant (Table 6b). The highest shoot diameter (0.36 cm) was recorded when plants grafted during 4th week of February which was found to be at par with 1st week of March (0.34 cm) whereas, the lowest shoot diameter (0.21 cm) was recorded when plants grafted during 3rd week of January under open condition. The interaction between cultivars and grafting time was found non-significant (Table 6c). The highest shoot diameter (0.35 cm) was recorded in cv. Gola when plants grafted during 4th week of February whereas, the lowest shoot diameter (0.21 cm) was recorded in cv. Umran when plants grafted during 3rd week of January. The interaction between cultivars and growing conditions was found non-significant (Table 6d). The highest shoot diameter (0.29 cm) was recorded in cv. Gola as well as in cv. Umran (0.29 cm) under open condition whereas, the lowest shoot diameter (0.27 cm) was recorded in cv. Umran under polyhouse condition. The interaction effect of grafting time, growing conditions and cultivars was found non-significant (Table 6a). However, the highest shoot diameter (0.36 cm) was recorded in cv. Gola when plants grafted during 4th week of February whereas, the lowest shoot diameter (0.20 cm) was recorded in cv. Umran when plants grafted during 3rd week of January under open condition.

About shoot parameter *viz*., shoot length and shoot diameter at 60 and 90 days. The Shoot length and shoot diameter at 60 and 90 days after grafting were significantly increased with increasing days. The higher shoot length and shoot diameter were found under open condition as compare to polyhouse condition might be due to the favourable environmental conditions *i.e.* maximum temperature (39ºC), minimum temperature (24ºC) and relative humidity (75%) in open field condition which leads to more growth of scions as compare to other growing conditions. This resulted in quick and strong

graft union formation, better compatibility of scion-stock and better uptake of nutrients and water under open condition which influenced positively shoot parameters. However, these results are not in line with the findings of Sivudu *et al*. (2014) [13] in mango, Joshi *et al*. (2014) [6] in guava, Syamal *et al*. (2012) [14] in guava and Ahmed *et al*. (2007) [1] in walnut, where they found the highest length and diameter of shoot under polyhouse condition as compare to open condition irrespective of the time of grafting. The significant difference in shoot diameter can also occur due to the growing stage of scion which encourages the highest scion diameter with respect to temperature and relative humidity presents in the atmosphere. Shoot diameter was equivalent in both growing conditions but slightly more shoot diameter was observed under open condition than polyhouse condition. The same result was obtained in aolna by Jalal *et al*. (2018) [5]. The increase in diameter might be due to higher cell activity and the synthesis of more food material through a process of photosynthesis under open condition (Kamboj *et al*., 2017) [7].

Table 6: Effect of grafting time, growing conditions and cultivars on shoot diameter (cm) at 90 days after grafting in ber plants

6a: Grafting time × Growing Conditions × Cultivars

Grafting time	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T_1 (3rd week of January)	0.22	0.23	0.20	0.21	0.22
T_2 (4th week of January)	0.25	0.24	0.24	0.23	0.24
T_3 (1st week of February)	0.26	0.26	0.25	0.27	0.26
T_4 (2nd week of February)	0.29	0.28	0.29	0.27	0.28
T_5 (3rd week of February)	0.31	0.29	0.32	0.30	0.31
T_6 (4th week of February)	0.36	0.34	0.35	0.34	0.35
T_7 (1st week of March)	0.35	0.32	0.34	0.31	0.33
T_8 (2nd week of March)	0.32	0.28	0.33	0.27	0.30
Mean	0.29	0.28	0.29	0.27	

6b: Growing Conditions × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Open field	0.21	0.25	0.25	0.29	0.31	0.36	0.34	0.32	0.29
Polyhouse	0.22	0.23	0.26	0.27	0.30	0.34	0.32	0.28	0.28
Mean	0.22	0.24	0.26	0.28	0.31	0.35	0.33	0.30	

6c: Cultivars × Grafting time

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Mean
Gola	0.23	0.25	0.26	0.28	0.30	0.35	0.34	0.30	0.29
Umran	0.21	0.23	0.26	0.28	0.31	0.34	0.33	0.30	0.28
Mean	0.22	0.24	0.26	0.28	0.31	0.35	0.33	0.30	

6d: Cultivars × Growing Conditions

	Open field	Polyhouse	Mean
Gola	0.29	0.28	0.29
Umran	0.29	0.27	0.28
Mean	0.29	0.28	

CD $_{0.05}$	
Grafting time	0.02
Growing Conditions	0.01
Cultivars	NS
Growing Conditions × Grafting time	0.03
Cultivars × Grafting time	NS
Cultivars × Growing Conditions	NS
Grafting time × Growing Conditions × Cultivars	NS

4. Conclusion

From the results of present study, it is concluded that the maximum graft success was obtained when grafting was operated during 3rd week of February under polyhouse condition and 4th week of February under open field condition in cv. Umran whereas, the growth parameters *i.e.* shoot length, shoot diameter and number of leaves were recorded higher in cv. Gola when grafting was performed during 4thweek of February under open condition. In view of the variation in the climatic conditions of Hisar where extremely low temperature prevails during winter months especially temperature as low as freezing point accompanied by frost in December and January, wedge grafting during February under both conditions could give the best results for rapid multiplication of elite, true to type and disease-free planting materials for fulfilling the requirement of planting materials to the farmers in less time.

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