Influence of grafting season and environment on leaf emergence dynamics and biomass accumulation in ber (*Ziziphus mauritiana* Lamk) cultivars

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 Received: 05.03.2026/Accepted: 03.05.2026

ABSTRACT

The present study investigated the influence of grafting season and growing environment on leaf emergence dynamics and biomass accumulation in ber (*Ziziphus mauritiana* Lam) cultivars Gola and Umran. The experiment was conducted at CCS Haryana Agricultural University, Hisar, Haryana using wedge grafting at eight different time intervals from the third week of January to the second week of March under polyhouse and open field conditions. Results revealed that grafting time, growing conditions and cultivars significantly affected leaf emergence and vegetative growth parameters. Grafting during the fourth week of February proved most effective, resulting in the earliest leaf emergence (22.14 days), highest leaf number at 60 days (21.94) and 90 days (69.90) as well as maximum fresh (39.83 g) and dry (19.07 g) shoot weight. Open field conditions generally promoted better vegetative growth, including higher leaf production and shoot biomass, compared to polyhouse conditions. Among cultivars, Gola exhibited slightly superior performance in terms of early leaf emergence and leaf number compared to Umran. Interaction effects were mostly non-significant, indicating independent influence of the main factors. The findings suggest that late February grafting under open field conditions is optimal for improving graft establishment and early growth in ber.

Keywords: Ber; *Ziziphus mauritiana*; Biomass accumulation; Grafting time; Polyhouse; open field; Leaf emergence; Vegetative growth; Wedge grafting

INTRODUCTION

Ber or Indian jujube (*Ziziphus mauritiana* Lam), belongs to the family Rhamnaceae. India is regarded as its center of origin and the species has a chromosome number of 2n = 4x = 48. Renowned as the King of Arid Fruits or Desert Apple, ber is highly valued for its exceptional tolerance to draught, heat, salinity and poor soils along with its regular bearing habit and economic viability under low input dryland conditions. The genus *Ziziphus* includes approximately 135-170 species, of which nearly 17 are indigenous to India (Islam and Simmons 2006). Among cultivated varieties, Umran and Gola are commercially important in north India due to their superior fruit quality and yield potential (Singh et al 2015). As of 2020-2021, the total area under jujube cultivation in India was 52,000 ha, with a production of approximately 579,000 MT (Sawant et al 2023).

The ber fruits are full of sugar, vitamin C and a good number of mineral components. It is richer in protein, phosphorus, calcium, carotene and vitamin C than an apple and it outperforms oranges in these nutrients as well as in carbs, calcium, iron and vitamin C (Kapse et al 2025). Consequently, the crop plays a significant role in food security and livelihood enhancement in resource-constrained regions.

Propagation of ber through seeds often results in substantial genetic variability because of its cross pollinated nature. Seedlings frequently exhibit differences in growth habit, fruit quality, yield potential and maturity period, which limit their suitability for commercial orcharding. To ensure genetic uniformity and maintain desirable cultivar traits, vegetative propagation is, therefore, preferred. Although budding (T or I budding) is widely practiced, wedge grafting has emerged as a promising alternative for rapid

multiplication of elite, true to type planting material. Successful graft union formation in wedge grafting depends largely on precise cambial alignment, which facilitates callus development and vascular continuity between scion and rootstock. The success of grafting is influenced by multiple factors, including grafting time, physiological status of scion and rootstock, environmental conditions and post-grafting management. Temperature and relative humidity are particularly critical, with 24-26°C and 70-80 per cent relative humidity reported as favourable for graft establishment (Visen et al 2010). Despite the growing demand for quality planting material, systematic evaluation of wedge grafting under different growing environments remains limited. In this context, the present investigations were undertaken to assess the performance of wedge grafting in ber cultivars Gola and Umran under polyhouse and open field conditions, with the objective of identifying the most suitable grafting time and growing environment for enhancing graft success and early vegetative growth.

MATERIAL and METHODS

The experiment was conducted at the experimental farm of the Department of Horticulture, CCS Haryana Agricultural University, Hisar,Haryana (29°102 N, 75°462 E; 215.2 m amsl). The study evaluated the influence of grafting time and growing conditions on the success of wedge grafting in ber (*Z mauritiana*) cultivars Gola and Umran. One year old ber seedlings were grafted at eight different time intervals viz 3rd week of January (T_1), 4th week of January (T_2), 1st week of February (T_3), 2nd week of February (T_4), 3rd week of February (T_5), 4th week of February (T_6), 1st week of March (T_7) and 2nd week of March (T_8), under polyhouse conditions (medium cost polythene structure equipped with fan and pad cooling system) and open field conditions.

The experiment was laid out in a randomized block design comprising 32 treatment combinations with three replications. Observations recorded included number of days to first leaf emergence, number of leaves at 60 and 90 days after grafting, fresh shoot weight and dry shoot weight. Fresh weight of the sprouted shoot and entire scion was measured for each treatment at 60 and 90 days after grafting using an electronic weighing balance and mean values were computed for each replication. Dry weight was determined by oven-drying the samples at 55°C until constant weight was attained, followed by recording the average weight for each replication.

The data were analysed following the procedure for randomized block design. Treatment means were compared using the critical difference at the 5 per cent level of significance (Panse and Sukatme 1985). Statistical analysis was performed using the OPSTAT software package (Sheoran et al 1998).

RESULTS and DISCUSSION

Days taken to first leaf emergence

Grafting time, growing conditions and cultivars significantly influenced the days taken to first leaf emergence (Table 1). T_6 (4th week of February), T_7 (1st week of March) and T_8 (2nd week of March) resulted in the minimum duration (22.14, 22.53 and 23.45 days respectively) for leaf emergence and the maximum duration (35.89 days) was recorded under T_1 (3rd week of January), irrespective of growing conditions and cultivars. In the plants under polyhouse there was early leaf emergence (26.70 days) compared to open field (28.68 days). Between cvs, Gola required fewer days (27.24) for 1st leaf emergence than Umran (28.14). All interactions were found to be non-significant indicating that the observed variations were not statistically meaningful. Comparable varietal differences were documented by Singh et al (2007) in guava. Syamal et al (2012) reported improved graft performance under favourable environmental conditions.

Number of leaves at 60 days after grafting

The data presented in Table 2 reveal that the number of leaves at 60 days after grafting was significantly influenced by grafting time, growing conditions and cultivars. The maximum number of leaves (21.94) was recorded in A_6, whereas, the minimum was observed in T_1 (10.63), irrespective of growing conditions and cultivars. Open field conditions lead to higher number of leaves (16.89) compared to polyhouse conditions (16.20). Similar seasonal effects on vegetative growth were reported by Ghojage et al (2011) in jamun. Cultivar Gola produced more leaves (16.93) than cv Umran (16.16), irrespective of grafting time and growing conditions. Under the interaction effect, T_1 (9.47) and T_2 (4th week of January) (11.11) in open field resulted in lowest and T_6 (23.01) and T_7 (21.51) in open field the highest number of leaves. The effect of interactions: cultivars and grafting time,

Table 1. Effect of grafting time, growing conditions and cultivars on the number of days taken for first leaf emergence in ber (Grafting time × Growing conditions × Cultivars)

Grafting time	Number of days				
	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T_1	36.91	34.69	37.11	34.85	35.89
T_2	34.22	31.74	34.55	32.28	33.20
T_3	32.53	28.55	32.16	29.54	30.69
T_4	28.76	27.46	30.45	29.26	28.98
T_5	24.89	23.15	26.31	24.17	24.63
T_6	22.40	20.85	23.38	21.93	22.14
T_7	22.74	21.27	23.72	22.37	22.53
T_8	24.07	21.62	24.59	23.50	23.45
Mean	28.32	26.17	29.03	27.24	

Table 1. Contd….. (Growing conditions × Grafting time)

Growing condition	Number of days								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Open field	37.01	34.39	32.34	29.61	25.60	22.89	23.23	24.33	28.68
Polyhouse	34.77	32.01	29.04	28.36	23.66	21.39	21.82	22.56	26.70
Mean	35.89	33.20	30.69	28.98	24.63	22.14	22.53	23.45	

Table 1. Contd….. (Cultivars × Grafting time)

Cultivar	Number of days								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Gola	35.80	32.98	30.54	28.11	24.02	21.63	22.01	22.85	27.24
Umran	35.98	33.42	30.85	29.86	25.24	22.65	23.05	24.05	28.14
Mean	35.89	33.20	30.69	28.98	24.63	22.14	22.53	23.45	

Table 1. Contd….. (Cultivars × Growing conditions)

Cultivar	Number of days		
	Growing condition		Mean
	Open field	Polyhouse	
Gola	28.32	26.17	27.24
Umran	29.03	27.24	28.14
Mean	28.68	26.70	

$CD_{0.05}$

Grafting time: 1.35, Growing conditions: 0.67, Cultivars: 0.67, Growing conditions × Grafting time: NS, Cultivars × Grafting time: NS, Cultivars × Growing conditions: NS, Grafting time × Growing conditions × Cultivars: NS

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, T_8: 2nd week of March, NS: Non-significant

Table 2. Effect of grafting time, growing conditions and cultivars on total number of leaves on sprouted shoots at 60 days after grafting in ber (Grafting time × Growing conditions × Cultivars)

Grafting time	Number of leaves at 60 days				
	Gola		Umran	Mean	
	Open field	Polyhouse	Open field	Polyhouse	
T_1	9.82	12.08	9.11	11.52	10.63
T_2	11.29	13.24	10.93	13.18	12.16
T_3	12.98	14.04	12.40	13.60	13.26
T_4	17.86	15.42	17.20	15.14	16.41
T_5	19.28	18.55	18.61	17.48	18.48
T_6	23.95	21.68	22.06	20.07	21.94
T_7	22.40	19.18	20.74	18.48	20.20
T_8	21.13	17.95	20.48	17.50	19.27
Mean	17.34	16.52	16.44	15.87	

Table 2. Contd….. (Growing conditions × Grafting time)

Growing condition	Number of leaves at 60 days								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Open field	9.47	11.11	12.69	17.53	18.95	23.01	21.57	20.81	16.89
Polyhouse	11.80	13.21	13.82	15.28	18.02	20.88	18.83	17.73	16.20
Mean	10.63	12.16	13.26	16.41	18.48	21.94	20.20	19.27	

Table 2. Contd….. (Cultivars × Grafting time)

Cultivar	Number of leaves at 60 days								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Gola	10.95	12.27	13.51	16.64	18.92	22.82	20.79	19.54	16.93
Umran	10.31	12.06	13.00	16.17	18.05	21.07	19.61	18.99	16.16
Mean	10.63	12.16	13.26	16.41	18.48	21.94	20.20	19.27	

Table 2. Contd….. (Cultivars × Growing conditions)

Cultivar	Number of leaves at 60 days		
	Growing condition		Mean
	Open field	Polyhouse	
Gola	17.34	16.52	16.93
Umran	16.44	15.87	16.16
Mean	16.89	16.20	

$CD_{0.05}$

Grafting time: 1.21, Growing conditions: 0.61, Cultivars: 0.61, Growing conditions × Grafting time: 1.71, Cultivars × Grafting time: NS, Cultivars × Growing conditions: NS, Grafting time × Growing conditions × Cultivars: NS

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, T_8: 2nd week of March, NS: Non-significant

cultivars and growing conditions and grafting time, growing conditions and cultivars was non-significant.

These findings are in agreement with those of Jalal et al (2018), who reported significant environmental effects on vegetative growth in aonla. Comparable results were also reported by Raghavendra (2008) in wood apple.

Number of leaves at 90 days after grafting

Data on the number of leaves at 90 days after grafting are presented in Table 3. The grafting time, growing conditions and cultivars significantly influenced leaf production. Irrespective of growing environment and cultivars, T_6 produced the highest number of leaves (69.90), whereas, the lowest (25.64) was recorded in T_1. Similar effects of grafting time on vegetative growth are reported by Ghojage et al (2011) in jamun. Plants grown under open conditions developed significantly more leaves (48.41) than those under polyhouse (47.23) conditions. Comparable findings are reported by Rani et al (2013) in guava. Among cultivars, cv Gola recorded a higher leaf number (48.55) than Umran (47.09). Under the interaction between grafting time and growing conditions, maximum number of leaves were recorded in open field and T_6 (72.41) and minimum in open field and T_1 (23.50). Rest of the interactions were non-significant. These findings are in agreement with those of Rani et al (2015) in guava.

Fresh shoot weight

Analysis of Table 4 showed that grafting time and growing conditions significantly influenced fresh shoot weight, whereas, the effect of cultivars was non-significant. Across cultivars and environments, A_6 recorded the highest fresh shoot weight (39.83 g), while the lowest (29.47 g) occurred in T_1, supporting earlier findings that optimal grafting period enhance vegetative growth (Aziz 2024). Growing conditions also had a significant effect, with open field grown plants producing greater fresh shoot weight (35.12 g) than those under polyhouse conditions (34.57 g), irrespective of grafting time and cultivar. Similar findings were reported by Bhat et al (2014), who emphasized the importance of grafting time in regulating shoot growth, leaf production and scion development. The positive influence of favourable environmental conditions on graft performance and plant vigour has been reported by Ahmed et al (2012). The effect of cultivars and interactions was non-significant.

Dry shoot weight

Data in Table 5 indicate that grafting time was the only factor significantly affecting shoot dry weight, whereas, the effect of growing conditions and cultivars was non-significant. Similar findings were reported by Kurre et al (2024), who emphasized the decisive role of grafting time in regulating bud emergence, leaf formation and plant vigour. Across cultivars and environments, T_6 resulted in highest dry shoot weight (19.07 g), while the lowest occurred in T_1 (14.54 g), supporting earlier reports identifying February as optimal for improving graft success and plant performance (Matsushita 2025). The effect of growing conditions, cultivars and all interactions was non-significant. Environmental factors such as temperature, humidity and light play a supportive role in graft survival and growth (Wang et al 2024).

CONCLUSION

The study clearly demonstrates that grafting season plays a decisive role in determining the success and early growth of ber grafts. Grafting performed during the fourth week of February consistently resulted in faster leaf emergence, greater leaf production and higher biomass accumulation, indicating that this period provides the most favourable physiological and environmental conditions for graft union establishment and subsequent growth. Although polyhouse conditions slightly hastened leaf emergence, open field conditions proved more conducive for overall vegetative development and biomass production. Among the cultivars tested, Gola showed a marginal advantage over Umran in terms of growth performance. The largely non-significant interaction effects suggest that grafting time is the dominant factor influencing graft success, irrespective of cultivar or growing environment. Therefore, for practical nursery management and large-scale propagation, wedge grafting of ber should ideally be carried out in late February under open field conditions to achieve better growth and efficient production of quality planting material.

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Table 3. Effect of grafting time, growing conditions and cultivars on total number of leaves on sprouted shoots at 90 days after grafting in ber (Grafting time × Growing conditions × Cultivars)

Grafting time	Number of leaves at 90 days				
	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T_1	24.57	28.36	22.42	27.19	25.64
T_2	28.86	33.54	27.18	31.54	30.28
T_3	35.18	39.27	35.67	38.17	37.07
T_4	46.39	42.11	45.70	42.02	44.05
T_5	58.61	54.67	55.46	53.35	55.52
T_6	73.28	68.22	71.55	66.57	69.90
T_7	65.47	62.51	64.39	60.29	63.17
T_8	61.39	54.34	58.45	53.46	56.91
Mean	49.22	47.88	47.60	46.57	

Table 3. Contd….. (Growing conditions × Grafting time)

Growing condition	Number of leaves at 90 days								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Open field	23.50	28.02	35.43	46.04	57.03	72.41	64.93	59.92	48.41
Polyhouse	27.78	32.54	38.72	42.07	54.01	67.40	61.40	53.90	47.23
Mean	25.64	30.28	37.07	44.05	55.52	69.90	63.17	56.91	

Table 3. Contd….. (Cultivars × Grafting time)

Cultivar	Number of leaves at 90 days								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Gola	26.47	31.20	37.22	44.25	56.64	70.75	63.99	57.86	48.55
Umran	24.81	29.36	36.92	43.86	54.41	69.06	62.34	55.96	47.09
Mean	25.64	30.28	37.07	44.05	55.52	69.90	63.17	56.91	

Table 3. Contd….. (Cultivars × Growing conditions)

Cultivar	Number of leaves at 90 days		
	Growing condition		Mean
	Open field	Polyhouse	
Gola	49.22	47.88	48.55
Umran	47.60	46.57	47.09
Mean	48.41	47.23	

$CD_{0.05}$

Grafting time: 2.06, Growing conditions: 1.03, Cultivars: 1.03, Growing conditions × Grafting time: 2.91, Cultivars × Grafting time: NS, Cultivars × Growing conditions: NS, Grafting time × Growing conditions × Cultivars: NS

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, T_8: 2nd week of March, NS: Non-significant

Table 4. Effect of grafting time, growing conditions and cultivars on fresh shoot weight of ber plants (Grafting time × Growing conditions × Cultivars)

Grafting time	Fresh shoot weight/plant (g)				
	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T_1	28.42	31.20	27.78	30.47	29.47
T_2	29.27	32.52	29.52	31.49	30.70
T_3	33.42	33.29	32.55	32.42	32.92
T_4	35.48	34.20	36.46	33.14	34.82
T_5	37.42	35.18	36.67	35.42	36.17
T_6	41.23	39.23	40.63	38.22	39.83
T_7	39.36	37.63	39.54	37.06	38.40
T_8	37.61	36.29	36.51	35.37	36.45
Mean	35.27	34.94	34.96	34.20	

Table 4. Contd….. (Growing conditions × Grafting time)

Growing condition	Fresh shoot weight/plant (g)								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Open field	28.10	29.39	32.99	35.97	37.04	40.93	39.45	37.06	35.12
Polyhouse	30.84	32.01	32.86	33.67	35.30	38.72	37.35	35.83	34.57
Mean	29.47	30.70	32.92	34.82	36.17	39.83	38.40	36.45	

Table 4. Contd….. (Cultivars × Grafting time)

Cultivar	Fresh shoot weight/plant (g)								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Gola	29.81	30.89	33.36	34.84	36.30	40.23	38.50	36.95	35.11
Umran	29.13	30.51	32.49	34.80	36.04	39.43	38.30	35.94	34.58
Mean	29.47	30.70	32.92	34.82	36.17	39.83	38.40	36.45	

Table 4. Contd….. (Cultivars × Growing conditions)

Cultivar	Fresh shoot weight/plant (g)		
	Growing condition		Mean
	Open field	Polyhouse	
Gola	35.27	34.94	35.11
Umran	34.96	34.20	34.58
Mean	35.12	34.57	

$CD_{0.05}$

Grafting time: 1.08, Growing conditions: 0.54, Cultivars: NS, Growing conditions × Grafting time: NS, Cultivars × Grafting time: NS, Cultivars × Growing conditions: NS, Grafting time × Growing conditions × Cultivars: NS

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, T_8: 2nd week of March, NS: Non-significant

Table 5. Effect of grafting time, growing conditions and cultivars on dry shoot weight of ber (Grafting time × Growing conditions × Cultivars)

Grafting time	Dry shoot weight/plant (g)				
	Gola		Umran		Mean
	Open field	Polyhouse	Open field	Polyhouse	
T_1	14.90	14.57	14.28	14.41	14.54
T_2	14.87	15.09	15.03	15.24	15.06
T_3	15.46	15.69	15.00	15.22	15.34
T_4	15.21	16.00	15.53	16.08	15.70
T_5	17.23	16.97	16.53	16.38	16.78
T_6	19.67	19.00	19.39	18.20	19.07
T_7	18.64	17.25	17.83	18.22	17.98
T_8	17.20	17.20	17.89	16.73	17.26
Mean	16.65	16.47	16.44	16.31	

Table 5. Contd….. (Growing conditions × Grafting time)

Growing Condition	Dry shoot weight/plant (g)								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Open field	14.59	14.95	15.23	15.37	16.88	19.53	18.23	17.55	16.54
Polyhouse	14.49	15.16	15.45	16.04	16.68	18.60	17.74	16.96	16.39
Mean	14.54	15.06	15.34	15.70	16.78	19.07	17.98	17.26	

Table 5. Contd….. (Cultivars × Grafting time)

Cultivar	Dry shoot weight/plant (g)								
	Grafting time								Mean
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
Gola	14.73	14.98	15.58	15.61	17.10	19.34	17.94	17.20	16.56
Umran	14.35	15.14	15.11	15.80	16.46	18.80	18.03	17.31	16.37
Mean	14.54	15.06	15.34	15.70	16.78	19.07	17.98	17.26	

Table 5. Contd….. (Cultivars × Growing conditions)

Cultivar	Fresh shoot weight/plant (g)		
	Growing condition		Mean
	Open field	Polyhouse	
Gola	16.65	16.47	16.56
Umran	16.44	16.31	16.37

$CD_{0.05}$

Grafting time: 0.47, Growing conditions: NS, Cultivars: NS, Growing conditions × Grafting time: NS, Cultivars × Grafting time: NS, Cultivars × Growing conditions: NS, Grafting time × Growing conditions × Cultivars: NS

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, T_8: 2nd week of March, NS: Non-significant

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***How to cite this article*:** Sonia, Baloda S, Sahil and Sharma VK 2026. Influence of grafting season and environment on leaf emergence dynamics and biomass accumulation in ber (*Ziziphus mauritiana* Lamk) cultivars. Int J Farm Sci 16(2-3): 1-9; doi: 10.5958/2250-0499.2026.00012.5.