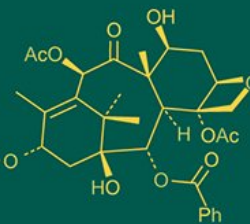
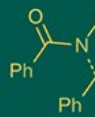


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Propagation studies in Bael

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Abstract

The present investigation entitled “Propagation studies in bael” was conducted during 2025-26 at Fruit Nursery, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in a Factorial Randomised Block Design (FRBD) with twelve treatment combinations replicated three time to find out suitable method and time of propagation in bael. It involved two factors, Factor A - Method of propagation with two levels i.e., M₁ - Chip budding, M₂ - Softwood grafting and Factor B - Time of propagation (T₁ - 3rd week of July, T₂ - 1st week of August, T₃ - 3rd week of August, T₄ - 1st week of September, T₅ - 3rd week of September, T₆ - 1st week of October). Softwood grafting has found more suitable and successful method of propagation in bael compared to chip budding. The plants grafted on 1st week of August resulted in earlier bud sprouting, longer sprout shoot length and maximum final survival.

Keywords: Bael, Chip budding, Softwood grafting

Introduction

Bael (*Aegle marmelos* L. Corrêa) is an important hardy fruit crop belonging to the Rutaceae family, prevalent in India and various regions of tropical and subtropical South and Southeast Asia. In English, it is widely referred to as Bengal quince, Indian quince, holy fruit and Golden apple, whereas in Hindi, it is known as bael or bilva (Sharma *et al.*, 2013) [14]. This tree has been linked to traditional Indian medicine for centuries as its fruits, leaves, bark, roots and seeds being employed in Ayurvedic and other medicinal applications (Baliga *et al.*, 2011) [1]. Bael is found growing in countries including India, Sri Lanka, Pakistan, Bangladesh, Myanmar, Thailand and most nations in South-East Asia Mortan. Bael is predominantly found flourishing at the foothills of the Himalayas, particularly in areas like Uttranchal, Jharkhand, Madhya Pradesh, the Deccan Plateau and the eastern coastline (Singh *et al.*, 2023) [16]. As per the 2024-25 First Advance estimates, India recorded about 9.27 thousand hectares area under bael cultivation, yielding an annual production of 64.74 thousand tonnes. Odisha emerged as the leading state in bael production, with 7.30 thousand hectares area and a production of 46.36 thousand tonnes. In Chhattisgarh, bael was grown on 0.08 thousand hectares, resulting in an estimated production of 0.53 thousand tonnes. (Department of agriculture and farmers welfare, GOI, 2025). Traditionally, bael has been propagated via seeds. However, there is a notable limitation associated with the progenies from seeds, as they generally do not remain true to type, has a lengthy juvenile phase and inadequate production, productivity and quality of fruits. To obtain true-to-type planting materials, vegetative propagation methods are essential. Among these techniques, budding, grafting, layering, and the use of root suckers are prevalent for the multiplication of bael. Currently, patch budding and softwood grafting are increasingly being utilized in commercial settings for bael propagation (Singh *et al.* 2018) [17].

Materials and Methods

The present investigation entitled “Propagation studies in bael” was conducted during 2025-26 at Fruit Nursery, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola with the objectives to study the effect of chip budding and softwood grafting success in bael, to find out suitable method and time of propagation in bael. The experiment was laid out in Factorial Randomised Block Design (FRBD) with twelve treatment combinations replicated three times considering method of propagation as first factor with two levels M₁ (Chip budding),

M₂ (Softwood grafting) and time of propagation as second factor with six levels T₁ (3rd week of July), T₂ (1st week of August), T₃ (3rd week of August), T₄ (1st week of September), T₅ (3rd week of September), T₆ (1st week of October). 1 year old rootstock was selected for propagation. The budding and grafting operations were performed for six times starting from 3rd week of July to 1st week of October with the interval of 15 days. The observation was recorded after 180 days of budding and grafting.

Results and Discussions

Number of days to sprouting

The days to sprouting were significantly influenced by different method of propagation, time of propagation and their interaction in bael as represented in table 1. Significantly, the least number of days to sprouting (20.00 days) was recorded in M₂ (softwood grafting), whereas the longest duration (24.50 days) was recorded in M₁ (chip budding). Similar results have been reported by Maurya *et al.* (2025) [6] in bael. For different time of propagation, significantly, minimum days to sprouting were observed in T₂ i.e., 1st week of August (17.51 days), which was at par

with T₁ i.e., 3rd week of July (18.97 days). While maximum days were taken to sprout in T₆ i.e., 1st week of October (26.94 days). It might be due to good sap flow in the bark and also because of the weather conditions such as optimum temperature and high humidity during that period, because of which early sprouting occurs. Among different treatment combinations, Minimum days to sprouting were observed in M₂T₂ i.e., softwood grafting performed during 1st week of Aug (16.28 days), which was at par with M₂T₁ i.e., softwood grafting on 3rd week of July (17.86 days) and M₂T₃ i.e., softwood grafting on 3rd week of Aug (18.25 days). Whereas, maximum days to sprouting were recorded in M₁T₆ i.e., chip budding on 1st week of October (29.78 days), which was statistically at par with M₁T₅ i.e., chip budding on 3rd week of Sept (28.42 days). The results following the pattern of Muniyappan *et al.* (2019) [9] in jamun. The earlier sprouting was recorded in softwood grafting, particularly during 1st week of August may be because of favourable conditions prevailing during that period, which promote better cambial activity, rapid callus formation and better graft union.

Table 1: Effect of different method and time of propagation on number of days taken to sprout

Treatments	Number of days taken to sprout (180 DAG)						
	Time of propagation						
Method of propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M1 (Chip budding)	20.08	18.74	23.72	26.28	28.42	29.78	24.50
M2 (Softwood grafting)	17.86	16.28	18.25	19.76	23.75	24.10	20.00
Mean	18.97	17.51	20.98	23.02	26.08	26.94	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		Sig.		
SE m (±)	0.29		0.50		0.71		
CD at 5%	0.86		1.48		2.10		

Bud sprouting (%)

The data presented in table 2 represents significant difference in bud sprouting. Significantly, maximum bud sprouting (70.00%) was recorded in M₂ (softwood grafting) and minimum bud sprouting (40.00%) was recorded in M₁ (chip budding). Among different time of propagation, maximum bud sprouting (76.67%) was recorded in T₂ i.e., 1st week of August, which was followed T₃ i.e., 3rd week of August (66.67%). Whereas, the minimum bud sprouting (20.00%) was recorded in T₆ i.e., 1st week of October. A similar pattern was noted by Rani *et al.* (2015) [10] in guava. The interaction effect was also significant. Significantly, the highest rate of bud sprouting was observed in M₂T₂ which involved softwood grafting performed during the first week

of August (86.67%), followed closely by M₂T₃ representing softwood grafting performed during the third week of August (80.00%). These two treatments are statistically at par with each other. Conversely, the lowest bud sprouting was noted in M₁T₆ corresponding to chip budding performed during the first week of October (20.00%), which was similar to M₁T₁ indicating chip budding in the third week of June (26.67%). The increased sprouting percentage recorded for softwood grafting in the first week of August can be attributed to the favorable conditions of temperature, humidity, and moisture prevalent during that period. These results align with the findings of Sharma (2019) [13] in the same species.

Table 2: Effect of different method and time of propagation on bud sprouting (%)

Treatments	Bud Sprouting (%) (180 DAG)						
	Time of propagation						
Method of propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M1 (Chip budding)	26.67	66.67	53.33	40.00	33.33	20.00	40.00
M2 (Softwood grafting)	73.33	86.67	80.00	66.67	60.00	53.33	70.00
Mean	50.00	76.67	66.67	53.33	46.67	36.67	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		Sig.		
SE m (±)	1.60		2.77		3.92		
CD at 5%	4.73		8.18		11.58		

Sprout shoot length

The sprout shoot length was significantly influenced by different method, time and their interaction as shown in table 3. Significantly, maximum sprout shoot length was observed in M₂ i.e. softwood grafting (25.97 cm), while, minimum sprout shoot length was observed in M₁ i.e. chip budding (23.77 cm). Among different time of propagation, significantly, maximum sprout shoot length (31.31 cm) was observed in T₂ i.e., 1st week of August which was followed by T₁ i.e., 3rd week of July (29.48 cm). These two treatments were statistically at par with each other. While, minimum was recorded in T₆ i.e., 1st week of October (18.09 cm). The observed increase in sprout shoot length can be ascribed to favourable atmospheric conditions, particularly elevated temperature and humidity. Similar results have been reported by Sonawane *et al.* (2012) [18] also found longer

sprout shoot length in the month of July. The interaction effect also showed significant difference, Maximum sprout shoot length was observed in M₂T₂ i.e., softwood grafting performed during 1st week of August (32.14 cm) which is statistically at par with M₂T₁ i.e., softwood grafting performed during 3rd week of July (31.75 cm) and M₁T₂ i.e., chip budding performed during 1st week of August (30.48 cm). While, minimum sprout shoot length was observed in M₂T₆ i.e., softwood grafting performed during 1st week of October (16.84 cm). Favourable temperature and humidity during the early August may have promoted better graft union formation and active growth of the scion, resulting in longer sprouts, particularly under softwood grafting. The present results are in conformity with the findings of Jamoh *et al.* (2021) [15] in pomegranate.

Table 3: Effect of different method and time of propagation on sprout shoot length

Treatments	Sprout shoot length (cm) (180 DAG)						
	Time of propagation						
Method of propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M1 (Chip budding)	27.22	30.48	23.90	21.42	20.24	19.35	23.77
M2 (Softwood grafting)	31.75	32.14	28.27	25.42	21.39	16.84	25.97
Mean	29.48	31.31	26.09	23.42	20.82	18.09	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		Sig.		
SE m (±)	0.48		0.83		1.18		
CD at 5%	1.42		2.46		3.47		

Scion diameter (mm)

The scion diameter was significantly influenced by different method and time of propagation. Significantly maximum scion diameter was observed in M₂ softwood grafting (5.47 mm) which was statistically at par with M₁ chip budding (5.18 mm). This could be attributed to inadequate bud union during the chip budding process. For different time of propagation, Significantly, maximum scion diameter was

observed in T₁ i.e., 3rd week of July (6.45 mm), followed by T₂ i.e., 1st week of August (6.02 mm). These two treatments were statistically at par with each other. While, the minimum scion diameter was recorded in T₆ i.e., 1st week of October (3.99 mm). The findings are consistent with those of Tripathi (2001) [19] in bael. The interaction between method and time of propagation did not show a significant effect on scion diameter.

Table 4: Effect of different method and time of propagation on scion diameter

Treatments	Scion diameter (mm) (180 DAG)						
	Time of propagation						
Method of propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M1 (Chip budding)	6.38	5.89	5.36	5.08	4.56	3.82	5.18
M2 (Softwood grafting)	6.52	6.15	5.78	5.24	4.98	4.16	5.47
Mean B	6.45	6.02	5.57	5.16	4.77	3.99	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig		Sig		NS		
SE m (±)	0.10		0.17		0.24		
CD at 5%	0.29		0.50		-		

Number of leaves graft⁻¹

The number of leaves graft⁻¹ was significantly influenced by different method and time of propagation. Significantly maximum number of leaves per graft were observed in M₂ i.e., Softwood grafting (21.75). While, minimum number of leaves per graft were observed in M₁ i.e., Chip budding (19.99). Similar findings have been reported by Muniyappan *et al.* (2019) [9] in jamun. Among different time of propagation, significantly, maximum leaves per graft (27.13) was observed in T₂ i.e., 1st week of August, which

was followed by T₁ i.e., 3rd week of July (24.84), while minimum was observed in T₆ i.e., 1st week of Oct (14.28). This may result from the increased height of plants, leading to a greater number of leaves, an extended growing season, and a more vigorous growth phase. Similar results were recorded by Misra *et al.* (2001) [7] in bael, Ghosh *et al.* (2012) [3] in bael. The interaction effect between method and time of propagation was non-significant for number of leaves graft⁻¹.

Table 5: Effect of different method and time of propagation on number of leaves graft⁻¹

Treatments	Number of leaves graft ⁻¹ (180 DAG)						
	Time of propagation						
Method of propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M1 (Chip budding)	23.16	25.42	22.84	19.45	15.76	13.32	19.99
M2 (Softwood grafting)	26.53	28.84	22.33	20.16	17.43	15.24	21.75
Mean	24.84	27.13	22.58	19.80	16.59	14.28	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		NS		
SE m (±)	0.39		0.68		0.96		
CD at 5%	1.16		2.02		-		

Leaf area (cm²)

Leaf area was significantly influenced by different method and time of propagation. Significantly, maximum leaf area was observed in M₂ softwood grafting (39.28 cm²). Whereas, the minimum leaf area was observed in M₁ chip budding (36.94 cm²). It might be due to fact that the softwood grafted plants were earlier in sprouting and leaf emergence and faster in further vegetative growth as compared to chip budding. Among different time of propagation, Significantly, maximum leaf area was observed

in T₂ i.e., 1st week of Aug (43.55 cm²), followed by T₁ i.e., 3rd week of July (39.98 cm²). While, the minimum leaf area was recorded in T₆ i.e., 1st week of Oct (33.82 cm²) which was closely followed by T₅ i.e., 3rd week of September (35.55 cm²) and T₄ i.e., 1st week of September (36.85 cm²). These treatments were statistically at par with each other. The present results are in support with the findings of Sharma (2019) [13] in bael. No significant interaction was observed between the method and time of propagation for the leaf area.

Table 6: Effect of different method and time of propagation on leaf area

Treatments	Leaf area (cm ²) (180 DAG)						
	Time of propagation						
Method of propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M1 (Chip budding)	38.17	42.60	37.17	36.40	34.53	32.80	36.94
M2 (Softwood grafting)	41.80	44.50	40.67	37.30	36.57	34.83	39.28
Mean B	39.98	43.55	38.92	36.85	35.55	33.82	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		NS		
SE m (±)	0.61		1.06		1.50		
CD at 5%	1.81		3.13		-		

Branch graft⁻¹

The data regarding the branch graft⁻¹ influenced by different method of propagation and time of propagation was recorded and presented in Table 7. Significantly maximum branch graft⁻¹ was observed in M₂ softwood grafting (4.91). Whereas, the minimum branches per graft was observed in M₁ chip budding (3.99). Differences in branch number may be due to variation in graft/bud establishment and efficiency of water and nutrient translocation, resulting in differences in shoot development. Among time of propagation, significantly, maximum branches per graft was observed in T₃ i.e., 3rd week of Aug (5.20), which was statistically at par with T₂ i.e., 1st week of Aug (4.97). While, the minimum

branch per graft was recorded in T₆ i.e., 1st week of October (3.57). The similar trend has been recorded by Rawat *et al.* (2023) [11] in Jamun. The interaction effect between method and time of propagation also show significant difference, significantly, maximum branch graft⁻¹ was observed in M₂T₃ i.e., softwood grafting performed during 3rd week of Aug (5.52) which was statistically at par with M₂T₂ i.e., softwood grafting performed during 1st week of Aug (5.42) and M₂T₄ i.e., softwood grafting performed during 1st week of Sept (5.31). While, minimum branches per graft was observed in M₁T₅ i.e., chip budding performed during 3rd week of Sept (2.95) which is statistically at par with M₁T₆ i.e., chip budding performed during 1st week of October (3.25).

Table 7: Effect of different method and time of propagation on branch graft⁻¹

Treatments	Branch graft-1 (180 DAG)						
	Time of propagation						
Method of propagation	T ₁ 3rd week of July	T ₂ 1st week of August	T ₃ 3rd week of August	T ₄ 1st week of September	T ₅ 3rd week of September	T ₆ 1st week of October	Mean
M1 (Chip budding)	4.35	4.51	4.89	4.02	2.95	3.25	3.99
M2 (Softwood grafting)	4.90	5.42	5.52	5.31	4.25	3.90	4.91
Mean	4.62	4.97	5.20	4.67	3.69	3.57	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		Sig.		
SE m (±)	0.06		0.11		0.16		
CD at 5%	0.19		0.34		0.48		

Fresh weight of roots (g)

The data regarding fresh weight of roots influenced by different method of propagation and time of propagation was recorded and presented in Table 8. Notably, the highest fresh weight of roots was recorded in M₂, which corresponds to softwood grafting (33.18 g), whereas the lowest fresh weight of roots was noted in M₁, or chip budding (31.26 g). Among different time of propagation, Significantly, maximum fresh weight of roots (38.93 g) was observed in T₃ i.e., 3rd week of August which was

statistically at par with T₄ i.e., 1st week of September (37.33 g), while, minimum was recorded in T₆ i.e., 1st week of October (27.13 gm). It might be due to the prevalence of favorable atmospheric conditions like temperature and humidity which are favorable for the vegetative growth. Such conditions are beneficial for promoting plant growth (Sarfaraz *et al.* 2023). The variation in the fresh weight of roots due to the interaction of propagation method and time was statistically non-significant.

Table 8: Effect of different method and time of propagation on fresh weight of roots

Treatments	Fresh weight of roots (g) (180 DAG)						
	Time of propagation						
Method of Propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M1 (Chip budding)	31.13	28.76	38.08	36.42	27.72	25.43	31.26
M2 (Softwood grafting)	32.67	29.48	39.79	38.25	30.07	28.83	33.18
Mean	31.90	29.12	38.93	37.33	28.89	27.13	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		NS		
SE m (±)	0.62		1.07		1.51		
CD at 5%	1.82		3.16		-		

Dry weight of roots (g)

Dry weight of roots varied significantly by the influence of propagation method, propagation time and their interaction. Significantly, maximum dry weight of roots was observed in M₂ i.e. softwood grafting (11.60 g), while, minimum fresh weight of roots was observed in M₁ i.e. chip budding (10.21 g). Among time of propagation, Significantly, maximum dry weight of roots (13.66 g) was observed in T₃ i.e., 3rd week of August which was followed by T₄ i.e., 1st week of September (12.15 g), while, minimum was recorded in T₆ i.e., 1st week of October (9.14 g). Among different treatment combinations, Maximum dry weight of roots was observed

in M₂T₃ i.e., softwood grafting performed during 3rd week of August (15.25 g) which was followed by in M₁T₄ i.e., chip budding performed during 1st week of September (12.84 g) and minimum fresh weight of roots was observed in M₁T₆ i.e. chip budding performed during 1st week of October (8.23 g). The variation in dry root weight across method and time combinations can be attributed to differences in root development and nutrient uptake. Favorable treatment combinations lead to better root development, enhancing nutrient absorption and supporting improved plant growth, resulting in greater accumulation of photosynthates and dry matter. (Sharma *et al.* 2020) ^[15].

Table 9: Effect of different method and time of propagation on dry weight of roots

Treatments	Dry weight of roots (g) (180 DAG)						
	Time of propagation						
Method of Propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M1 (Chip budding)	10.28	9.08	12.08	12.84	8.74	8.23	10.21
M2 (Softwood grafting)	11.85	10.46	15.25	11.46	10.52	10.06	11.60
Mean	11.06	9.77	13.66	12.15	9.63	9.14	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		Sig.		
SE m (±)	0.22		0.38		0.53		
CD at 5%	0.64		1.11		1.57		

Final survival (%)

The data regarding final survival of grafts influenced by different method of propagation and time of propagation was recorded and presented in Table 10. Significantly, maximum survival of grafts was observed in M₂ viz softwood grafting (59.99%), while, minimum final survival of grafts was observed in M₁ viz chip budding (33.33%). The results are in agreement with those recorded by Hariharan *et al.* (2021) ^[4] in wood apple and Maurya *et al.*, (2025) ^[6] in bael. Among time of propagation, Significantly, maximum final survival of grafts (71.11%) was observed in T₂ i.e., 1st week of August which was followed by T₃ i.e., 3rd week of August (61.11%). While, minimum was recorded in T₆ i.e., 1st week of October (25.55%). The interaction effect was also significant, Maximum final survival of grafts was

observed in M₂T₂ i.e., softwood grafting performed during 1st week of August (80.00%) which is statistically at par with M₂T₃ i.e., softwood grafting performed during 3rd week of August (73.33%) and M₂T₁ i.e., softwood grafting performed during 1st week of July (73.33%). While, minimum final survival of grafts was observed in M₁T₆ i.e. chip budding performed during 1st week of October (15.55%). The highest final survival rate observed under the interaction M₂T₂ can be ascribed to the beneficial combination of softwood grafting techniques and the favorable climatic conditions experienced in the first week of August. Similar results reported Muniyappan *et al.* (2019) ^[9] in jamun. Similar trend has been observed by Hariharan *et al.* (2021) ^[4] in wood apple.

Table 10: Effect of different method and time of propagation on final survival of grafts

Treatments	Final survival (%) (180 DAG)						
	Time of propagation						
Method of Propagation	T ₁ 3 rd week of July	T ₂ 1 st week of August	T ₃ 3 rd week of August	T ₄ 1 st week of September	T ₅ 3 rd week of September	T ₆ 1 st week of October	Mean
M ₁ (Chip budding)	15.55	62.22	48.89	31.11	26.67	15.55	33.33
M ₂ (Softwood grafting)	73.33	80.00	73.33	51.11	46.67	35.55	59.99
Mean	44.44	71.11	61.11	41.11	36.66	25.55	
INTERACTION (M X T)							
	M		T		M X T		
'F' Test	Sig.		Sig.		Sig.		
SE m (±)	1.59		2.75		3.89		
CD at 5%	4.69		8.12		11.49		

Conclusion

The present investigation entitled “Propagation studies in bael” revealed that the method and time of propagation significantly influenced the success of chip budding and softwood grafting in bael. Softwood grafting found to be more suitable method of propagation in bael outperforming chip budding in various growth parameters. Among the different times of propagation, 1st week of August found to be the most suitable time for propagation in bael recording earlier sprouting, highest sprouting percentage, sprout shoot length, number of leaves per graft, leaf area and final survival of grafts. Overall, the treatment combination, softwood grafting on 1st week of August found to be more effective for propagation in bael.

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