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Influence of methods of budding of Khasi Mandarin (*Citrus reticulata* Blanco.) performed on different types of rootstock

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Abstract

Khasi Mandarin (*Citrus reticulata* Blanco.) is a commercially important mandarin fruit of Northeast India, known for its unique flavour, juiciness, and high market demand. The present study was conducted to assess the performance of Khasi Mandarin on different rootstocks under foothills areas of Arunachal Pradesh. T-budding and Modified Chip budding were performed, and key growth parameters were monitored up to 90 days after budding. Maximum bud take success of 73.33% and budding success of 68.89% were recorded in Modified Chip budding on Rough lemon. The results showed a notable increase in sprout length (10.27 cm), girth (1.76 mm), number of leaves on sprout (7.43), leaf area (14.97 cm^2), total chlorophyll content (0.82 mg/g) and total carotenoid content (0.17 mg/100 g). The success of budding was attributed to rapid vascular connection, efficient nutrient translocation, and favourable environmental conditions. The findings suggested that Rough Lemon served as a suitable rootstock for the propagation of Khasi Mandarin with Modified Chip budding, supporting large-scale multiplication and improved orchard establishment in the region.

Keywords: Khasi mandarin, budding, rootstocks, multiplication, budding success

Introduction

Khasi Mandarin, *Citrus reticulata* Blanco. is a unique and highly valued mandarin grown predominantly in the Northeastern regions of India, particularly in the state of Meghalaya. It is renowned for its vibrant colour, juicy pulp, and rich citrus flavour, thus, holds a significant place in the region's agricultural economy and is recognized with a Geographical Indication (GI) tag of Meghalaya. Meghalaya, with its favourable climatic conditions, especially in the Khasi and Jaintia Hills, provides the ideal environment for the cultivation of this fruit. Its cultivation covers thousands of hectares, and districts like East Khasi Hills and Ri-Bhoi are among the leading producers. The fruit is not just economically valuable but also plays a crucial role in local culture, festivals, and trade. The Khasi Mandarin has also gained recognition for its potential in exports, as its organic and chemical-free cultivation methods attract both domestic and international buyers. The government has been taking initiatives to boost its production through modern farming techniques, better irrigation facilities, and farmer training programs. Moreover, Khasi Mandarin's high Vitamin C content makes it an important fruit for nutrition and health. In December 2023, Meghalaya exported 20 metric tons of Khasi Mandarin to Dubai. Mandarin occupies an area of 477 thousand Hectares with production of 6219 thousand MT in the country (Anonymous, 2021) [1].

In Northeast the crop occupies an area of 117.89 thousand ha and production of 672.78 thousand metric tons (Anonymous, 2017) [2]. Despite its immense potential the productivity of mandarin in the northeast is only about 5.86 MT/ha than the national productivity of 11.08 MT/ha (Barbora *et al.*, 2019) [4]. Challenges such as local farmers being dependent on old orchards which are of seedling origin, climate change, pest infestations, and the need for better market linkages remain. Efficient propagation methods ensure the production of true-to-type, disease-free, and vigorous planting material, which is essential for establishing healthy orchards and enhancing fruit yield.

Therefore with this view, a study was conducted with objectives to find out the suitable budding methods and evaluate a suitable rootstock for Khasi Mandarin.

Materials and Methods

The study was conducted at College of Horticulture and Forestry, CAU (Imphal), Pasighat, Arunachal Pradesh in 2022. Budsticks from healthy mother plant were collected and two methods of budding: T'-budding (B1) and Modified Chip budding (B2) were performed on various locally available rootstocks of age one-and-a-half-year, viz., Khasi Mandarin (R1), Rough Lemon (R2), Rangpur Lime (R3), Volkamer Lemon (R4) and Pummelo (R5).

Bud take percentage refer to the successful union of scion and stock within a period of 30 days after budding operation and calculated by counting numbers of sprouted scion over a particular rootstock. Budding success (%) was counted on the basis of continued survival of sprouted scion after three months of budding.

$$\text{Budding success (\%)} = \frac{\text{number of sprouted bud}}{\text{total bud inserted}} \times 100$$

Days required for sprouting of the bud in each treatment were recorded by observing the scion regularly in the nursery. Vegetative parameters such as sprout length, girth of sprout, number of leaves, leaf area, total chlorophyll and carotenoid contents were recorded after 3 months of budding. Leaf area was measured using leaf area meter (Biovis Leaf area meter; Model number J371A). Estimation of total chlorophyll content was done as per Arnon's method (Arnon, 1949) [3] and Carotenoid estimation as per Lichtenthaler and Buschmann (2001) [1].

Results and Discussion

1. Budding Performance

Bud take and Budding success (%): Maximum bud take percentage (Table 1) was observed in Modified Chip budding performed on Rough Lemon (73.33%) which was at par with Modified Chip budding done on Khasi Mandarin (71.11%) and Rangpur Lime (71.11%), whereas the lowest was observed in 'T' budding done on Rangpur Lime and Volkamer Lemon with bud take percentage of 48.89%. This may be due to good sap flow of the stock and ease of budding operation. Findings of Bhullar *et al.,* 1980 [5] recorded a bud take percentage of 85-95% in Kinnow Mandarin budded on Rough Lemon.

Maximum budding success was recorded when Modified Chip budding was done on Rough Lemon (68.89%) which was at par with Modified Chip budding done on Rangpur Lime (64.44%) (Table 2). Similar result was reported by Deshmukh *et al.,* (2017) [6] with budding success of 68.33% when Khasi Mandarin was budded on Rough Lemon. Singh and Chahal (2021) [12] also reported budding success of 77.5% on Rangpur Lime when Kinnow Mandarin was used as scion. Budding success is due to the union of vascular tissues of scion and stocks that result in rapid movement of nutrients to the growing sprouts. Budding success depends on favourable environmental conditions such as temperature, humidity, and moisture. Rapid callus formation, efficient vascular connection, and healthy plant material further enhance the chances of a strong and lasting union.

Number of days taken to sprout

Methods of budding had significant effect on number of days taken by scion bud to sprout on different rootstock (Table 3). Modified Chip budding done on Khasi Mandarin took less time to sprout (34.47 days), followed by Modified Chip budding done on Rangpur Lime (38.14 days) and maximum time was taken by Pummelo with 'T' budding (47.57 days). Gurung *et al.,* (2020) [7] justified the present result. They reported that Darjeeling Mandarin budded on Rangpur Lime required about 33.33 days to sprout and 34.33 days when budded on Rough Lemon

Table 1: Influence of method of budding and type of rootstock on bud take percentage of Khasi Mandarin (%).

Method of budding	Type of rootstock				
	R1	R2	R3	R4	R5
B1	51.11	57.78	48.89	48.89	51.11
B2	71.11	73.33	71.11	55.56	53.33
$CD_{0.05}$	11.54				
SEm±	4.16				

Table 2: Influence of method of budding and type of rootstock on budding success of Khasi Mandarin (%).

Method of budding	Type of rootstock				
	R1	R2	R3	R4	R5
B1	51.11	55.56	48.89	46.67	51.11
B2	62.22	68.89	64.44	46.67	51.11
$CD_{0.05}$	10.45				
SEm±	3.65				

Table 3: Influence of method of budding and type of rootstock on number of days taken to sprout.

Method of budding	Type of rootstock				
	R1	R2	R3	R4	R5
B1	44.98	42.87	44.78	41.33	47.57
B2	34.47	42.84	38.14	39.30	40.19
$CD_{0.05}$	2.59				
SEm±	0.92				

B1 ('T' Budding) and B2 (Modified Chip budding), R1 (Khasi Mandarin), R2 (Rough Lemon), R3 (Rangpur Lime), R4 (Volkamer Lemon) and R5 (Pummelo)

2. Sprout growth parameters

Sprout length: Modified Chip budding performed on Rough Lemon showed maximum sprout length (10.27cm), followed by Modified Chip budding done on Khasi Mandarin and the lowest sprout length was seen on Pummelo with Modified Chip budding (2.38cm) (Table 4). Randhawa and Kaur (2019) [12] reported buddling length of 16.49 cm when Sweet Orange budded on Carrizo, 120 days after budding**.** Maximum girth was observed when 'T' budding was done on Rough Lemon (1.76 mm) which was at par with Modified Chip budding done on the same rootstock (1.68 mm) (Table 5).

Growth of sprout after budding is influenced by how well the graft union establishes and how efficiently nutrients and water are transported through the newly formed vascular tissues. If the cambial layers align well and the connection heals quickly, the scion receives adequate nutrients and hormones, promoting healthy and elongated sprout growth. However, if the union is weak or vascular connection is delayed, the sprout may grow slowly due to limited nutrient flow. Environmental factors like temperature, moisture, and light, as well as the vigour of the rootstock and scion, also significantly impact sprout development.

Table 4: Influence of method of budding and type of rootstock on length of sprout (cm).

Method of budding	Type of rootstock				
	R1	R2	R3	R4	R5
B1	6.23	6.96	6.77	6.03	2.41
B2	7.61	10.27	6.71	6.48	2.38
$CD_{0.05}$	0.86				
SEm±	0.31				

Table 5: Influence of method of budding and type of rootstock on girth of sprout (mm).

Method of budding	Type of rootstock				
	R1	R2	R3	R4	R5
B1	1.37	1.76	1.39	1.56	0.96
B2	1.26	1.68	1.58	1.51	0.84
$CD_{0.05}$	0.16				
SEm±	0.06				

B1 ('T' Budding) and B2 (Modified Chip budding), R1 (Khasi Mandarin), R2 (Rough Lemon), R3 (Rangpur Lime), R4 (Volkamer Lemon) and R5 (Pummelo)

Number of leaves

Interactions showed maximum number of leaves (Table 6) when Modified Chip budding was done Rough Lemon (7.43) whereas 'T' budding on Pummelo showed minimum number of leaves (2.40) and was at par when Modified Chip budding was done on the same (2.45). Similar finding was reported by Singh *et al.*, (2012) [11] when Nagpur mandarin was budded on Rough Lemon (6.46).

Leaf area

Interaction effect of method of budding performed in different rootstocks on leaf area (Table 7) showed maximum leaf area in Rangpur Lime with 'T' budding (14.97cm^2) and the minimum leaf area was noticed in Pummelo with 'T' budding (3.28cm^2). Deshmukh *et al.*, (2017) [6] recorded 26.00 cm2 after 180 days of budding Khasi Mandarin on Rough Lemon. Maximum leaf area after budding or grafting is usually the result of improved nutrient and water uptake through a well-established graft union. Once the vascular connection between scion and rootstock is successfully formed, the scion receives a steady supply of essential nutrients and growth hormones, especially Cytokinins and Auxins, which promote cell division and expansion. It is again influenced by environmental, nutrient factors as well as the nature of stock and scion.

Total chlorophyll and Carotenoid content

Significantly maximum content of total chlorophyll was recorded when Modified Chip budding was done on Rough Lemon (0.82 mg/g), followed by 'T' budding performed on Rough Lemon (0.79 mg/g) and the minimum was recorded in T-budded Volkamer Lemon (0.31 mg/g) as shown in Fig 1. Deshmukh *et al.*, (2017) [6] in Khasi Mandarin budded on Rough Lemon. They reported a total chlorophyll content of 0.86 mg/g. Higher carotenoid content (Fig 2) was observed when 'T' budding and Modified Chip budding were performed on Rough Lemon (0.17 mg/100 g).

Higher chlorophyll and carotenoid content after budding or grafting is often a sign of improved physiological activity and successful union formation.

Table 6: Influence of method of budding and type of rootstock on number of leaves on the sprout.

Method of budding	Type of rootstock				
	R1	R2	R3	R4	R5
B1	6.15	6.12	4.89	6.02	2.40
B2	5.99	7.43	5.68	6.52	2.45
$CD_{0.05}$	0.76				
SEm±	0.17				

Table 7: Influence of method of budding andtype of rootstock on leaf area(cm^2).

Method of budding	Type of rootstock				
	R1	R2	R3	R4	R5
B1	14.93	8.97	14.97	11.75	3.28
B2	11.76	9.14	9.42	11.26	3.47
$CD_{0.05}$	0.43				
SEm±	0.15				

B1 ('T' Budding) and B2 (Modified Chip budding), R1 (Khasi Mandarin), R2 (Rough Lemon), R3 (Rangpur Lime), R4 (Volkamer Lemon) and R5 (Pummelo)

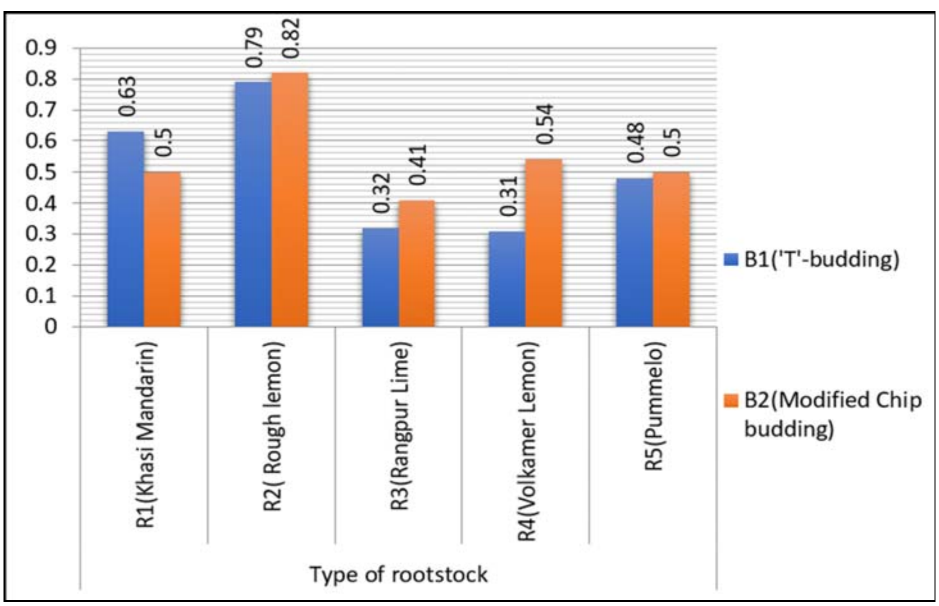

Fig 1: Influence of method of budding and type of rootstock on total chlorophyll content of the leaf (mg/g).

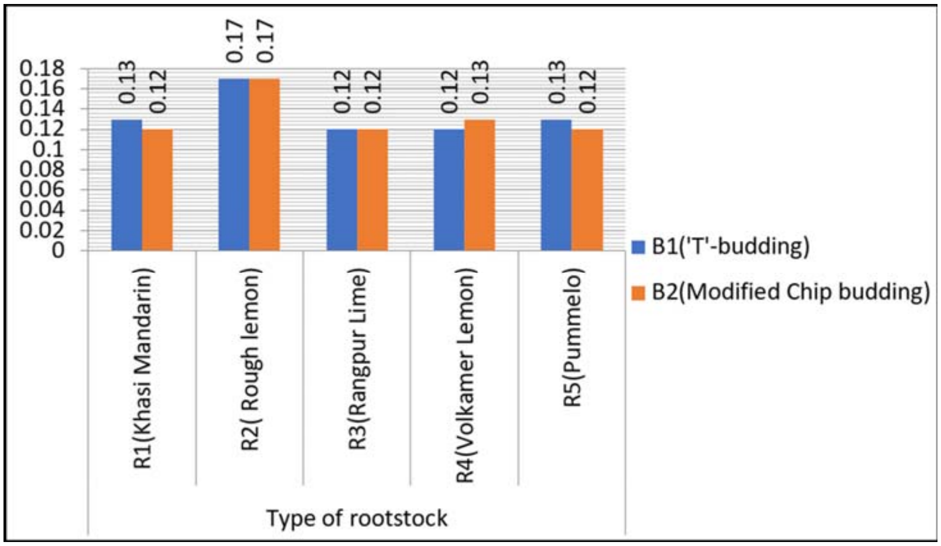

Fig 2: Influence of method of budding and type of rootstock on carotenoid content of the leaf (mg/100 g).

Conclusion

From the present investigation it was found that Modified Chip budding was a better method of budding for Khasi Mandarin and Rough Lemon found to be the most promising rootstock among other rootstocks for the region in terms of graft success, sprout growth, leaf development, and overall plant vigour. With growing awareness and government support, Khasi Mandarin continues to flourish as a key agricultural product of Northeast India, contributing to both the economy and the cultural heritage of the region. The propagation and multiplication of Khasi Mandarin play a vital role in conserving this valuable indigenous citrus variety and meeting the growing demand in both local and national markets. Promoting scientific propagation practices is therefore a key to sustaining the commercial cultivation and genetic purity of Khasi Mandarin in the years to come.

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