Softwood grafting in tamarind (*Tamarindus indica* L.)

ABSTRACT: An investigation was carried out to "Softwood grafting in tamarind (*Tamarindus indica* L.)". The experiment was carried out at the department of Plantation, Spices, Medicinal and Aromatic crops, Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka during 2022. The experiment was carried out with the main objective of studies on softwood grafting techniques using low-cost poly tunnel, shade net and poly house condition facilities. The results revealed that among different treatment combinations, C_3M_2 (poly house + March) had significant influence on tamarind grafts and recorded minimum number of days taken to first sprouting (9.8), highest graft success percentage (90%) at 90 DAG and graft survival Percentage (85%), maximum sprout length (48.90 cm), sprout diameter (0.78 mm), graft height (67.26 cm), graft girth (8.52 mm), number primary branches per graft (7.63), number of leaves (60.06), incremental height (9.30 cm), graft vigour index (6095.56) and net returns (₹1944.86) at 150 DAG. Whereas, longer period for sprouting (24.27 days), minimum graft success (28.33%) at 90 DAG and survival (40.00%), lowest sprout length (24.90 cm), sprout diameter (0.38 mm), graft height (38.16 cm), graft girth (3.98 mm), number primary branches per graft (3.40), number of leaves (29.76), incremental height (1.90 cm), graft vigour index (1045.34) and net returns (₹405.86) was noticed in the treatment C_2M_4 (Shade net + May) at 150 DAG.

INTRODUCTION

Tamarind (*Tamarindus indica* L.) is a monotypic tree spice, popularly known as "Indian date". The name tamarind was derived from the Arabic word "Tamur -ul Hind" meaning 'date of India'. This belongs to the family Caesalpinaceae and sub family Caesalpinioideae with a somatic chromosome number of 2n= 24. It is a resilient tree that thrives in the warm, tropical and subtropical climates. It is tolerant to drought and grows well in sandy soils. Additionally, it works well in deep soils and is tolerant of difficult or rocky terrain. It has an ability to withstand heavy winds. This tree roots exudates potent allelo chemicals that helps to prevent weed growth around tamarind tree (Purseglove, 1981). Tamarind has an alternative bearing tendency, which is one of the limitations because it makes tamarind cultivation less profitable for growers. Cropping does not follow a systematic pattern, as implied by the term irregular bearing. Alternative bearing is a genetic factor that can be identified in tamarind trees from the first years of fruiting (Singh *et al.* 2019). Tamarind trees are mainly raised from seeds. Tree seedlings typically exhibit a lengthy juvenile phase. The technique of vegetative propagation was developed primarily to preserve elite seedling clones, and the practise of growing trees from seed has been abandoned. Whereas, grafted plants are precocious and start to bear pods within 4-5 years. A fully grown-up trees produces nearly 200 kg of fruits per year. It is reported that, PKM-1 yields about 260 kg ripe fruits against 165 kg/tree in local cultivar (Kumar *et al*., 1993) while high yielding, elite types DTS-1 (500 kg/plant) and DTS-2 (450 kg/plant) from University of Agricultural Sciences, Dharwad, India was reported (Patil *et al*., 1997). Varieties of tamarind consists of brown sour types, local types like Bangalore tamarind, Tumkur tamarind, Hosur tamarind, Krishnagiri tamarind, Natham tamarind, Nagarkoil tamarind, Villupuram tamarind, Ranchi tamarind. Other few improved varieties *viz*., Urigam, Pratisthan, DTS-2, GKVK-6 and GKVK-33, red type and sweet type. Although air layering is thought to be the most affordable way of vegetative multiplication, it did not show to be very successful in the instance of tamarind due to the formation of poor-quality roots and hence, poor field survival. (Shashi Kumar *et al.*, 2012). Softwood grafting provides a good response to these issues by increasing the graft success and survival percentage of high-quality grafts with the least chance of failure, assisting in the better and more uniform development of orchards (Ram and Pathak, 2006).

MATERIAL AND METHODS

The experiment was conducted at the department of Plantation, Spices, Medicinal and Aromatic crops (PMA), Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka. It is situated at an elevation of 612 m above the mean sea level at 16 º15' North latitude and 74º 45' East longitude. Arabhavi lies in Zone-3, Region- 2 of agro climatic zones of Karnataka. The experiment was carried out with the main objective of studies on softwood grafting technique using low-cost poly tunnel, shade net and poly house condition facilities.

DTS-1, a variety released by UAS, Dharwad was used as scion material for softwood grafting. The terminal shoots of the previous season growth of this variety with 15 cm length having size of pencil thickness and free from pest and diseases were selected from the mother block of Department of PMA, KRCCH, Arabhavi, Karnataka. The curing is done one week prior to the selection of scion material. The scion which are pre cured before are collected in the morning on the day of grafting from the mother plant. The scions are transported to the place of grafting immediately after separating from mother plant by wrapping it in the moist cloth. On the same day, these pre-cured scions were used for softwood grafting. The grafting was performed on every forth night of the months February, March, April and May. Later the grafted plants were placed under three growing conditions *Viz*. Low-cost poly tunnel, shade net (50%) and poly house.

Treatment details

T_1	–	C_1M_1: Low-cost poly tunnel + February
T_2	–	C_1M_2: Low-cost poly tunnel + March
T_3	–	C_1M_3: Low-cost poly tunnel + April
T_4	–	C_1M_4: Low-cost poly tunnel + May
T_5	–	C_2M_1: Shade net (50%) + February
T_6		C_2M_2: Shade net (50%) + March
T_7	–	C_2M_3: Shade net (50%) + April
T_9	–	C_3M_1: Polyhouse + February
T_{10}	–	C_3M_2: Polyhouse + March
T_{11}	–	C_3M_3: Polyhouse + April
T_{12}	–	C_3M_4: Polyhouse + May

RESULTS AND DISCUSSION

Days to first sprout

The least number of days for first sprouting (13.54) was taken when the grafting was conducted under the poly house (C_3) while, the highest number of days needed for first sprouting (17.92) was recorded in the shade net condition (C_2). But the more time for first sprouting (20.36) was observed in the grafts made during the fort night of May (M_4). In the treatment interactions, the least number of days (9.80) taken for sprouting was noted when the grafting was performed under poly house on the fort night of March (C_3M_2) presented in Table 1. However, the number of days taken for first sprouting (24.27 days) were maximum under shade net during the month of May (C_2M_4). The key factor could be the favourable climatic conditions, which might have caused early vascular tissue contact and cambium layer development, which led to early sprouting. The finding was closely in agreement with Raghavendra *et al*. (2011) in wood apple and Chander *et al*. (2016) in jamun.

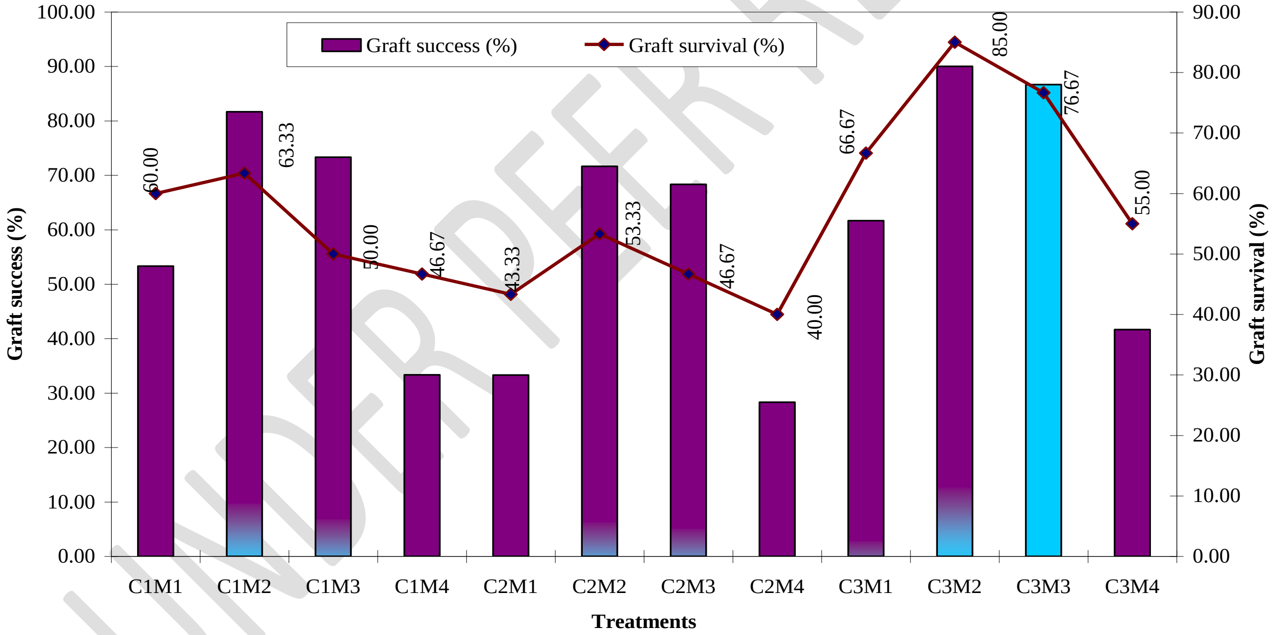
Graft success (%) at 90 DAG

The influence of growing conditions and different months on graft success (%) is presented in Fig.1. The maximum (70.00%) graft success was noted under poly house conditions, while the least graft success (50.40%) was recorded in shade net (50% shade) condition (C_3) at 90 DAG. The graft success (81.11%) was maximum when grafting was done in the month of March (M_2) at 90 DAG. Whereas, the minimum graft success (34.4%) was observed when the grafting was done in the month of May (M_4) at 90 DAG (Fig 1). In the treatment combination the graft success (90.00%) was highest when grafting was performed during the month of March under poly house (C_3M_2), while minimum (28.33%) graft success (%) was recorded under shade net conditions during the month of May (C_2M_4) at 90 DAG. This might be caused by later fruit harvesting, tamarind's usual leaf fall, and the plant's dormant state between December and February. At this period there will be storage of sufficient food material in the scion which helps to better success (Pawar *et al.,* 2003). Due to ideal humidity levels, temperate temperatures, and healthy biochemical conditions, February and March saw the highest success rates (Dhutraj *et al.,* 2018).

Graft survival (%) at 150 DAG

The influence of different growing conditions and different months on graft survival (%) is presented in Fig 1. The graft survival per cent was highest (70.83), when grafting was performed under poly house (C_3) at 150 DAG. Whereas, the minimum graft survival per cent (45.83%) was noted under shade net conditions (C_2) at 150 DAG. The tamarind grafts prepared during the month of March recorded the maximum graft survival percentage (67.22%) and the minimum (47.22%) was recorded in the May grafted plants at 150 DAG (Fig. 1). Among various treatment combinations the grafts kept under poly house grafted during the month of March (C_3M_2) recorded the highest graft survival percentage (85.00%). At 150 DAG, lowest graft survival was seen in shade net during the month of May (C_2M_4). The higher success rate could be attributed to optimal conditions (higher temperature and relative humidity) inside the poly house for a longer period of time, which prevented desiccation of the scion and formed a better union of grafted scion and stocks, resulting in better graft survival. The mentioned result is in accordance with Singh *et al.* (2007) in guava and Raghavendra *et al.* (2011) in wood apple.

Fig. 1: Influence of different months of grafting and growing conditions on graft success (%) and graft survival (%)



Propagating Condition (C) C_1: Low-cost poly tunnel C_2: Shade net C_3: Poly house

Months of grafting (M) M_1: February M_2: March M_3: April M_4: May

Sprout length (cm) at 150 DAG

The length of sprout was maximum (30.06 cm) under poly house (C_3) condition at 150 DAG. The length of the sprout was lowest (30.06 cm) under shade net (50%) condition (C_2) at 150 DAG. The length of sprout was highest (41.40 cm) when grafting was done in the month of March (M_2) at 150 DAG. Whereas, the minimum sprout length (27.53 cm) was observed in grafts done during the month of May (M_4) at 150 DAG. Among various treatment combinations the maximum length of the sprout (48.90 cm) was recorded when the grafting was performed under poly house in the month of March (C_3M_2) at 150 DAG. However, the minimum length of sprout (24.90 cm) was noted when the grafting was performed under shade net (shade 50%) condition in the month of May (C_2M_4) at 150 DAG. The effect of growing conditions and different months on sprout length (cm) is presented in Table 1. The controlled humidity and temperature may be to blame for this. The growth of more sprouts, which results in increased meristematic activity and improved graft healing, may be the other factor. The present result is in accordance with the results of Pujari and Magdum (1991) in sapota. The maximum sprout length of grafts in March may be due to optimal temperature, which promotes higher cell activity and early sprouting, resulting in a greater number of leaves. Studies in custard apple conducted by Kulkarni (1990) and Pawar *et al*. (2003) provide support for the findings.

Sprout diameter (mm) at 120 DAG

The influence of growing conditions and different months on sprout diameter (mm) is presented in Table 1. The sprout diameter was significantly higher (0.60 mm) when the grafting was performed under the poly house (C_3) conditions while, it was minimum (0.46 mm,) when the grafting was done under the shade net (50% shade) at 120 DAG. At 120 DAG, grafting done in the month of May produced the smallest sprout diameter (0.41 mm), whereas grafting done in the month of March produced the considerably largest sprout diameter (0.64 mm). The interaction effect of different growing conditions and month of grafting resulted in significantly maximum (0.78 mm) thickness of the sprouts when grafting was performed and maintained under poly house during month of March (C_3M_2) followed by April under poly house (C_3M_3) at 120 DAG. However, when the grafting was carried out in May (C_2M_4) under a shade net (50 % shade), the lowest sprout diameter (0.37 mm) was noted. This could be due to the excellent sap flow and continuous food supply from stored food, which improved the graft union process and resulted in greater scion diameter growth (Hartmann *et al.*, 2007).

Incremental height (cm) of the graft at 150 DAG

The influence of growing conditions and different months on incremental height (cm) of the graft is presented in Table 1. The incremental height was higher (9.30 cm) when the grafting was done and maintained under the poly house (C_3M_2) while it was minimum (2 3.36 cm) when the grafting was done under the shade net (50% shade) at 150 DAG. The grafting which was performed in the month of March (M_2) resulted in the significantly, highest (5.91 cm) incremental height at 150 DAG. Grafting performed in the month of February (M_1) showed lowest incremental height (3.63 cm) at 150 DAG in grafted plants. The treatment combination of different growing conditions and month of grafting resulted in a significantly, maximum (9.30 cm) increment in the height when grafting performed and maintained under poly house during the March (C_3M_2) at 150 DAG. Whereas, at 150 DAG, minimum (3.16 cm) incremental height was observed when it was grafted and maintained under low-cost poly tunnel during the month of February (C_1M_1). This result might be ascribed to its ability to build up more of the photosynthates and its subsequent partitioning thereby resulting into development of greater framework of grafted plant (Thockchom *et al*., 2019).

Height (cm) of the graft at 150 DAG

The graft height was highest (52.73 cm) in the grafts under poly house condition (C_3) at 150 DAG. Although, the graft height was minimum (40.40 cm) in shade net (shade 50%) condition (C_2) at 150 DAG. The graft height was maximum (52.73 cm) when grafting was performed in March (M_2) at 150 DAG. Whereas, the height of the graft was minimum (39.21 cm) at 150 DAG. As a result, when the grafting was done under a poly house in the month of March (C_3M_2) at 150 DAG, the height of the graft (67.26 cm) was maximum among the different treatment combinations. However, the minimum graft height (38.16 cm) was obtained when grafting was performed under shade net conditions during the month of May (C_2M_4) at 150 DAG which is represented in Table 2. The results obtained was similar with the findings of Naik and Kumar (2018) in jack fruit. The numerous growth factors such as the number of sprouts, leaf and leaf area which are sources of photosynthesis and photosynthates accumulate and are necessary for graft growth. Graft height is typically greater in the protected controlled situation. Similarly, according to Khopade *et al*. (2013), the height of grafts is maximum in red poly houses was noticeably higher than that in open circumstances in jamun. Sivudu *et al*. (2014) noticed that grafting under naturally ventilated polyhouse resulted in the maximum graft height, followed by partial shade under coconut and 50% shade net in mango graft.

Girth of the graft (mm) at 150 DAG

The influence of growing conditions and different months on graft thickness (mm) is represented in Table 2. The highest (6.86 mm) graft girth was under the grafts under poly house (C_3), while the smallest (5.14 mm) graft thickness was recorded in the grafts kept under shade net (shade 50 %) at 150 DAG. The grafting which was performed at different months had a significant increase in graft diameter. The highest graft diameter (7.32 mm) was noted when grafting was done in the month of March (M_2) at 150 DAG. Whereas, the lowest graft diameter (4.68 mm) was noticed in the grafts prepared during month of May (M_4) at 150 DAG. The greatest (8.52 mm) graft thickness was detected in grafts grafted under poly house in March (C_3M_2), while the least (3.98 mm) graft diameter was reported in grafts grafted under shade net in May (C_2M_4). This is due to the more moisture and nutrient availability in scion stick. These findings one presented are in agreement with the finding observed by Jha and Brahmachari (2002).

Number of primary branches per graft at 150 DAG

Significantly, maximum number of branches per graft (5.69) followed by low-cost poly tunnel (C_2). At 150 DAG, the shade net condition (C_3) had the fewest branches per graft (4.44). Among the different months of grafting, the highest number of branches per graft (6.53) was observed when grafting was performed on March (M_2) at 150 DAG. However, when grafting was done on May (C_4) at 150 DAG, the bare minimum number of branches per graft (3.57) was noted. The grafting was done under poly house on the first forth night of March (C_3M_2), which considerably increased the number of branches per graft to a maximum of 7.63. Whereas, the lowest number of branches per graft (3.40) was observed in grafting performed on May under shade net (C_2M_4) at 150 DAG. The effect of growing conditions and different months on number of primary branches is presented in Table 2. Climate-related elements like favourable temperature and relative humidity, which promote greater cell activity and early sprouting and result in more count of leaves and branches per graft which might be the cause of the creation of a higher number of branches per graft. Similar findings have also been found by Uchoi (2010) in jamun and Thejashwani (2018) in tamarind.

Number of leaves per graft at 150 DAG

The grafting performed at various different months had a significant impact in increasing the count of leaves per graft (Table 2). The grafts under the poly house (C_3) showed the maximum number of leaves (44.63) while, the lowest number of leaves (35.35) was recorded in the grafts kept under shade net conditions (C_2) at 150 DAG. The grafts grafted during the month of March (M_2) showed the highest (48.75) number of leaves, while the grafts prepared during the month of May (M_4) showed the lowest (33.20) number of leaves per graft at 150 DAG. The interaction effect of different growing conditions and month of grafting resulted in a significantly, the higher number of leaves (60.06) was noted in the grafts kept under poly house grafted in the month of March (C_3M_2). However, the number of leaves (29.76) were minimum when grafting was performed in the month of May under shade net (shade 50%) condition (C_2M_4) at 150 DAG. The higher number of leaves were visible when the combined effects of the several months of grafting and growing conditions were used. This might be the result of the polyhouse being at its ideal temperature during this time as opposed to other conditions, which encourages more cell activity and early sprouting, which result in the most leaves. The findings are supported by studies in jamun by Chander *et al.* (2016) and guava by Nanditha *et al.* (2017).

Graft vigour index

The study revealed that, different growth conditions along with months of grafting and their combination resulted significant impact on graft vigour index during the experiment (Table 2). Among different growing conditions, at 150 DAG highest vigour index (6068.19) was recorded under poly house (C_3). Grafting performed at different months had significant impact on graft vigour index. The highest vigour index (3068.56) was noticed when grafting was done in the month of March (M_2), followed by April (M_3) at 150 DAG. Whereas, the lowest vigour index (1045.34) was observed grafts done during the month of May (M_4) at 150 DAG, respectively. Among various treatment combinations the highest vigour index (6094.56) was recorded when the grafting was performed under poly house in the month of March (C_3M_2) 60, 90, 120 and 150 DAG. However, the least vigour index (1045.34) was noted when the grafting was performed under shade net (shade 50%) condition in the month of May (C_2M_3) at 150 DAG. This could be because the activation of apical and auxiliary buds was attributable to the better success in grafts due to earlier defoliation. (Deulin, 1981).

Economics

Total production cost was maximum (₹1115.14) for the grafts prepared under poly house (C_3) while it was lowest (₹965.14) for the grafts prepared under the low-cost poly tunnel (C_1). The cost of cultivation is same for different months of grafting but differ with respect to the growing conditions (Table 3).

Highest gross return (₹3060) was seen under poly house grafted during month of March (C_3M_2) and lowest (₹1440) in the grafts prepared and maintained under shade net during month of May (C_2M_4). Highest net returns (₹1944.86) were observed in the grafts under poly house performed during the month of March (C_3M_2) and lowest (₹405.86) was seen in the grafts under shade net prepared during month of May (C_2M_4**)**. Maximum unit cost (₹48.08) was seen in the grafts under shade net during month of May (C_2M_4) and lowest (₹21.86) was seen under poly house in the month of March (C_3M_2).

Highest returns per rupee of expenditure (₹2.74) was seen under poly house in the month of March (C_3M_2) and lowest (₹1.39) was seen in the grafts under shade net during month of May (C_2M_4. It was due to high percentage of graft success and survivability of the grafts kept under poly house grafted in the month of March, while graft success and survivability was very less in the grafts kept under shade net done in the month of May (C_2M_4).

Table 1. Influence of different months of grafting and growing conditions on days to first sprout, Sprout diameter (mm) at 120 DAG, Sprout length (cm), incremental height (cm), Number of leaves, Number of primary branches, Graft vigour index at 150 DAG.

Treatments	Days taken for first sprout	Sprout diameter (mm)	Sprout length (cm)	Incremental height (cm)

Conditions (C)				
Low-cost poly tunnel (C_1)	15.68	0.51	34.26	4.06
Shade net (C_2)	17.92	0.46	30.06	3.36
Poly house (C_3)	13.54	0.60	37.95	5.32
S. Em±	0.15	0.003	0.19	0.40
CD@ 1%	0.81	0.03	1.26	2.61
CV (%)	3.15	2.64	1.96	32.76
Months (M)				
February (C_1)	16.82	0.47	30.25	3.63
March (M_2)	12.42	0.64	41.40	5.91
April (M_3)	13.25	0.58	37.18	3.76
May (M_4)	20.36	0.41	27.53	3.70
S. Em±	0.81	0.02	0.59	0.52
CD @ 1%	3.29	0.09	2.41	2.15
CV (%)	3.56	3.09	5.21	37.25
Interaction (C×M)				
C_1M_1	16.87	0.49	31.28	4.03
C_1M_2	13.00	0.58	39.61	4.86
C_1M_3	13.33	0.56	37.45	3.69
C_1M_4	19.53	0.43	28.72	3.66
C_2M_1	16.8	0.41	27.86	3.16

C_2M_2	14.47	0.55	35.69	3.56
C_2M_3	16.13	0.55	31.79	3.40
C_2M_4	24.27	0.38	24.9	3.33
C_3M_1	16.8	0.52	31.61	3.70
C_3M_2	9.80	0.78	48.90	9.30
C_3M_3	10.30	0.63	42.32	4.20
C_4M_4	17.27	0.46	28.98	4.10
Mean	15.71	0.528	34.09	4.24
S.Em±	0.33	0.01	1.02	0.91
CD @ 1%	1.34	0.04	4.17	3.72

Table 2. Influence of different months of grafting and growing conditions on Graft height (cm), Graft girth (mm), Number of leaves, Number of primary branches, Graft vigour index at 150 DAG

Treatments	Graft height (cm)	Graft girth (mm)	Number of primary branches	Number of leaves	Graft vigour index
Conditions (C)					
Low-cost poly tunnel (C_1)	43.16	6.14	5.20	39.50	2676.70
Shade net (C_2)	40.40	5.14	4.44	35.35	2083.70
Poly house (C_3)	49.76	6.86	5.69	44.63	3660.70
S. Em±	0.20	0.06	0.016	0.59	85.68
CD@ 1%	1.35	0.37	0.11	3.85	557.88
CV (%)	1.61	3.29	1.14	5.14	10.57
Months (M)					
February (C_1)	40.71	5.29	4.48	35.16	2039.90
March (M_2)	52.73	7.32	6.53	48.75	4358.40
April (M_3)	45.13	6.89	5.85	42.20	3469.00
May (M_4)	39.21	4.68	3.57	33.20	13.60.70
S. Em±	0.40	0.34	0.06	0.37	64.34
CD @ 1%	1.63	1.37	0.26	1.52	261.92
CV (%)	2.70	3.94	3.86	2.82	6.87
Interaction (C×M)					
C_1M_1	41.73	5.54	4.83	35.96	2229.9
C_1M_2	48.1	7.4	6.3	45.33	3937.2

C_1M_3	44.06	6.82	6.06	42.43	3241.8
C_1M_4	38.76	4.81	3.6	34.3	1297.7
C_2M_1	38.23	4.63	3.56	32.53	1278.8
C_2M_2	42.83	6.04	5.66	40.86	3069.8
C_2M_3	42.4	5.91	5.13	38.23	2902.7
C_2M_4	38.16	3.98	3.4	29.76	1083.4
C_3M_1	42.16	5.72	5.06	37.00	2610.9
C_3M_2	67.26	8.52	7.63	60.06	6068.2
C_3M_3	48.93	7.94	6.35	45.93	4262.5
C_4M_4	40.7	5.27	3.73	35.53	1701.2
S.Em±	0.69	0.14	0.11	0.64	111.44
CD @ 1%	2.82	0.56	0.46	2.64	453.66

Table 3. Economics of tamarind grafts for different month of grafting grown under different growing conditions

Treatments	**Total cost (₹)**	**No. of grafts survived**	**Gross returns (₹)**	**Net returns (₹)**	**Unit cost (₹)**	**Returns per rupee of expenditure (₹)**
C_1M_1	965.14	36	2160	1194.86	26.80	2.24
C_1M_2	965.14	38	2280	1314.86	25.40	2.36
C_1M_3	965.14	30	1800	834.86	32.17	1.87
C_1M_4	965.14	28	1680	714.86	34.46	1.74
C_2M_1	1034.14	26	1560	525.86	39.77	1.51
C_2M_2	1034.14	32	1920	885.86	32.31	1.86
C_2M_3	1034.14	28	1680	645.86	36.93	1.62
C_2M_4	1034.14	24	1440	405.86	43.08	1.39
C_3M_1	1115.14	40	2400	1284.86	26.55	2.15
C_3M_2	1115.14	51	3060	1944.86	21.86	2.74
C_3M_3	1115.14	46	2760	1644.86	24.24	2.48
C_3M_4	1115.14	33	2016	900.86	33.14	1.78

Conclusion

The treatment combination C_3M_2 (Poly house + March) was found to be superior in terms of growth parameters such as sprouting time, graft success (%), graft survival (%), sprout length, sprout diameter, incremental height, graft height, girth of the graft, number of primary branches, number of leaves, graft vigour index and net returns.

As a result, the treatment combination C_3M_2 (Poly house + March) was discovered to be the most suitable for tamarind grafting and it may be recommended for the production of high-quality tamarind planting material.

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