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Research Article

Effect of Climate on Graft-Take, Potential Rootstocks and a Comparative Study on Grafting Techniques in Cashew (*Anacardium occidentale* L.,)

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Abstract

The Bapatla technique of soft-wood grafting on 35-45 days old root stock retained with one pair of leaves was observed with greater percentage of success during December and January for the regions of coastal Andhra Pradesh. This technique gave good graft-take with a high percentage of scion sprouting with good growth of grafts having maximum plant height, number of leaves and maximum leaf area per graft during all the months except during March when compared to normally adopted methods of vegetative propagation for multiplication of cashew in India. The vigourous rootstocks of commercial giant and dwarf cultivars as well as hybrids developed at cashew research station of Bapatla in Andhra Pradesh may be useful for identification and development of dwarfing rootstocks in cashew for high productivity, suitability to high density planting and adoptability to diverse agroclimatic conditions of India. The presented germplasm of high yielding cultivars, dwarf cultivars and hybrids are a valuable resource i) to study the reproductive biology of cashew ii) develop cultivars with high percentage of hermaphrodite flowers iii) to produce scions with prolific yields iv) to improve national income from export earnings of cashew nuts and v) to sustain the quality standards and international market. Physiological studies on the potential rootstocks of cashew is the present research need.

Keywords: Weather; Growth; Leaves; Rootstock; Scion; Dwarf

Introduction

Cashew (*Anacardium occidentale* L.), belongs to Anacardiaceae, a family that has 60-74 genera and 400 to 600 species. Cashew is commercially important for nuts, fenny and shell liquid, is a dollar earning plantation crop. Cashew is considered as goldmine of wastelands due to its adaptability to poor and marginal sandy soils, hill slopes of forest, red and laterite soils of east and west coast of India. Presently, cashew is grown in an area of 8.68 lakh ha with an annual production of 6.65 lakh tons of raw cashew nuts in India.

The demand for cashew is ever increasing for its kernels in domestic and international markets to compete with Vietnam and Brazil [1]. Important growing states of India include Andhra Pradesh, Goa, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa and Tamil Nadu. Though current production accounts to 45% of global production, the yield per hectare in India was poor (860 kg/ha) when compared to Vietnam (4,125 kg/ha) and Nigeria (2,000 kg/ha) during 2007-08 [2]. Though low productivity due to adverse climatic conditions necessiated import of raw cashew kernels in some years from other countries, India maintained its lead by exporting 446 million kg of cashew kernels in 2009 [3].

Cashewnut is a valuable nutritional source of vitamins, unsaturated fatty acids and proteins while the cashew apple is for contents of large amounts of vitamin C, sugars, fibres and minerals like calcium, phosphorous and iron. The weight by weight ratio of nut to peduncle is 1:10 and the cashew apples are in use for consumption as fresh fruit or as sweets, jams and various drinks made out of it. It is a major crop in Brazil, Vietnam, India, Nigeria, Tanzania, Indonesia, Guinea-Bissau, Cote D'Ivoire, Mozambiqu and Benin.

The Brazilian cashew trees are less popular dwarf type (CCP-76) while the most common were giant type (Vengurla-2, Sulabha, BRS274, AZA2, AC4) grown in most cashew growing countries [4]. Andhra Pradesh is the lead state from India while Vietnam (860,060 tonnes kernels) is the lead country followed by India (745,000 tonns kernels) and Brazil in cashew kernal production and export to USA, Europe, and other middle east countries (www.FAO.org; https://www.nda.agric.za).

Cashew tree produces three kinds of flowers during the season, among which bisexual flowers are the only source for production of cashew nuts due to presence of fertile female flowers along with male flowers. The other kinds of solitary male and sterile abnor-

mal flowers are useless for cashew production. Though literature says confusing statements about the production and productivity of cashew trees in comparison to high yielding clones and dwarf cultivars from Brazil and other cashew growing regions [5], the production of cashew cultivars or clones is always dependant on the abundance of hermaphrodite (bisexual) flowers in a terminal panicle and adequate pollination.

Over a period of 4 to 5 months (70-90 days) of anthesis (flowering period), only 10 percent of bisexual flowers exist out of 200 to 1600 flowers in a panicle. The male flower provides abundant fertile pollen grains (53.2-96.4% in A. occidentale; 90-94 % in wild species, A. microcarpum, A. othonarium and A. pumilum) for female part of the bisexual flowers for pollination and fruit set. Thus, reason for low fruit set is not the pollen fertility but self in comaptibility and limitations of pollinators in cashew orchards. Although cross pollination contributes 85 percent of perfect flowers fertilized, only 4 to 6 percent reach to maturity producing nuts and the remaining shed away at different stages of development [6].

The hermaphrodite flowers/panicle (155.04), nut length (3.34 cm), both nut yield/plant at 6th harvest (3.635 kg) and cumulative yield for 6 harvest (12.179 kg), apple weight (68.24 g), juice content (45.84 ml) and total sugar (10.54%) were recorded maximum in H-303. Maximum sex ratio (0.64), widest nut (2.46 cm), longest apple (5.86 cm), maximum vitamin C (266.25 mg/100 g) were associated with Dhana. The highest nut weight (9.32 g), kernel weight (2.84 g), shelling percentage (30.74%) and kernel of top grade (W180) were associated with Vengurla-7. Minimum harvesting period (30.24 days) and lowest acidity (0.32%) of apple were observed in BPP-8. Multivariate divergence analysis of cashew germplasm revealed five distinct groups, Group-1: consisting of Vengurla-3 only, Group-2: having H-105, H-303 and H-320, Group-3: consisting of H-68 and NRCC2, Group-4: having BH-85, Madakkathara-1, Vengurla-7, H-255, H-1600, NRCC-1 and Jhargram-1 and Group-5 having germplasms BH6 and Dhana. The germplasm H-303 was found most suitable for the new alluvial plains of West Bengal followed by BPP-8, Dhana and Vengurla7 [7].

Among the 40 germplasm lines of cashew evaluated at Cashew Research Station (CRS), Bapatla, the highest mean annual nut yields have been recorded with T.No 275 (26.15 kg/tree) followed by T.No. 228 (14.76 kg/tree). The cumulative nut yields were found highest with BLA 39-4 (66.48 kg/ tree) followed by T.No 5/1 (60.04 kg/tree) after 9 annual harvests. Mean nut weight was highest in Priyanka (11 g) followed by T.No 15/4 (8.90 g). Shelling percentage ranged from 25.65 to 36.17% across the lines evaluated [8].

Pruning by decapitating shoots back to 5 cm in mid-July, mid-August and mid-September months of the leader shoots, lateral shoots and leader as well as lateral shoots, BPP-4 performed better as compared to the off-season cultivar BPP-6. The vigorous cultivar BPP-4 and off-season production cultivar BPP-6 performed well during a rainy year compared to the dry year which was associated with prolonged dry spell and delayed rains in August-September months. The off-season cultivar of cashew needs essentially the pruning of the leader shoot in mid-August so as to avoid the off-season flowering and to increase productivity in the normal season. Pruning of leader shoots in mid-July was found to be beneficial to produce higher per tree yield of nuts with a percentage increase of 17.68 to 23.60 at CRS, Bapatla [9].

The dwarf PLD 57 is precocious with low setting percentage and nut yield. This dwarf was crossed with the semi tall types, Anakkayam 1 (ANK 1) and Madakkathara 1 (MDK 1) and progenies were evaluated. The seedlings with open pollinated seeds expressed the dwarf characters. The hybrids of ANK 1 × PLD 57 started flowering early from second year onwards, but failed to show the dwarf character [10]. At CRS, Bapatla, among the F1 progenies of 1997, H-36 had the highest cumulative nut yield of 68.30 kg/tree and in 1998 hybrids H-94 had the highest yield of 21.3 kg/tree. Among 48 F1s of 1999, highest yield was recorded with H-132 which had 16.65 kg/tree. In the hybrid progenies of 2000 and 2001 highest cumulative yields were recorded with H-216 and H-254 which yielded 23.7 and 22.55 kg/tree respectively [11].

Different techniques of vegetative propagation in cashew were tried with varied degrees of success at regional station of the Central Plantation Crops Research Institute (C.P.C.R.I.) in Vittal during 1977–78. The techniques tried were: (i) Veneer grafting on six month old seedlings raised in polybags, (ii) Side grafting on 3–5 year old cashew trees, (iii) Patch building on six month old seedlings raised in polybags, (iv) Patch budding in situ on one year old shoots in adult trees, (v) Air-layering. (vi) Mound layering, (vii) Cleft-grating on 8–10 month old seedlings raised in polybags, (viii) Whip-grafting on 8–10 month old seedlings raised in polybags, (ix) Stone-grafting on 40–45 days old seedlings and (x) Stem cuttings [12].

To improve the yield and to maintain the stable performance of hybrids, vegetative propagation method of recent development, soft-wood grafting is found to be the easy, economical and ideal for producing grafts in short period of time. The weather conditions play a prominent role on soft-wood grafting, influencing the graft take and growth of the grafted plant. Therefore, the best month of grafting has to be found out to get a high percentage of success. Besides time of grafting, age and number of leaves retained on root stock also play a better role on graft-take. The softwood grafting is being practiced on 35 to 45 days old rootstock retaining one pair of leaves in Bapatla of Andhra Pradesh state while on 60 days old rootstock retaining two pairs of leaves on rootstock in Puttur of Karnataka state in India. Therefore, presented research study was conducted during 1996-97 to find out the best month for grafting, age and number of leaves to be retained on rootstock during and after grafting. Presented findings were also compared with previous research results on vegetative propagation in cashew to include im-

provements required in cashew research, cultivation and production in coastal Andhra Pradesh region.

Materials and Methods

A pot culture experiment was conducted twice during 1996-97 at Cashew Research Station (CRS), Bapatla in Andhra Pradesh, India with two main factors 1) month of grafting (M) and 2) the two techniques of Bapatla and Puttur. The mean weekly meteorological data during the experimental period was presented in the figure 1. The technique of Bapatla uses 35-45 days old rootstock with one pair of leaves as proposed [13] while Puttur technique uses 60 days old rootstock with two pairs of leaves [14] to prepare soft-wood grafts in cashew. The method of softwood grafting in the present investigation included (a) retaining two leaves on 30 days old root-stock for Bapatla method and (b) retaining four leaves on 45 days old root-stock for Puttur method. The treatment combinations included seven months from September (M1) to March (M7) with varied climate and two (Bapatla and Puttur) techniques of grafting.

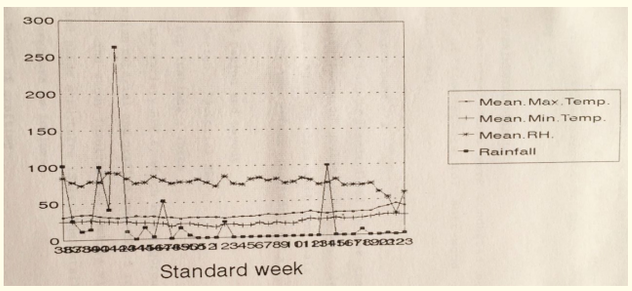

Figure 1: Mean weekly weather data during the cashew crop's experimental period (3-9-96 to 10-6-97).

The vigorously growing BPP-6 was adopted as a scion material and grafted over BPP-5 rootstock. The potted soil mix in black plastic bags has all the necessary nutrients required for the growth of rootstock seedlings of cultivar BPP-5. The three seeds of BPP-6 were planted in each bags two months before grafting to impose the assigned treatments and were triplicated in each treatment and replication. The scion sticks were collected from the mother tree selected from the orchard, a day prior to the day of grafting. Grafting was done early in the morning and the scion sticks were collected in the afternoon hours of the day before grafting and with a thorough selection of the healthy branches from the parent tree BPP-6.

The images of rootstocks, prepared rootstocks with wedge, and grafted stock-scion union covered with a plastic bag were shown in figures 2, 3 and 4 respectively for both Bapatla and Puttur techniques. Standard and recommended growth practices were adopted for raising rootstock seedlings and for soft-wood grafts prepared in cashew. The experiment was conducted in a factorial concept of Randomized Block Design (RBD) with three replications and the overall view of the cashew grafts in the experimental nursery of our research station were posted in figure 5.

Figure 2: The seedlings ready for softwood grafting using a). Bapatla technique and b). Putture technique.

Figure 3: Scion inserted into the cleft matching the cambial regions of rootstocks prepared using a). bapatla technique and b). Puttur technique.

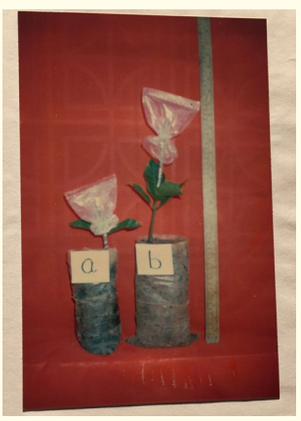

Figure 4: Scion grafted on the rootstock closely fastened and graft covered with polythene cover in a). Bapatla technique and b). Puttur technique.

Figure 5: Over all view of the experiment with cashew softwood grafts at Cashew nursery at CRS, Bapatla during 1996-97.

The data were collected on the percentage of scion sticks sprouted, percent success and growth of grafts in terms of graft height, number of leaves per graft and total leaf area of the graft. The entire data was subjected to standard statistical procedures [15] by manually calculating the means, averages and factorial analysis using modern scientific calculator (Casio) electronic type with digital display.

Result and Discussion

The sprouting of scion-sticks was considered as an important indication of successful grafting. The observations on this aspect (Table 1) indicated that the percentage of success is low during 15 days after grafting (DAG) reaching maximum during 30 DAG in all the months. The data of table 1 on percentage of scion sticks sprouted were statistically significant under both methods at all the three stages after soft- wood grafting. After 30 DAG, in all the above treatments, the percentage of scion-sticks sprouted is very limited indicating that the precured scion-sticks generally takes 15 to 30 days for complete sprouting after grafting by which time the metabolites present in the scion-sticks will be utilized by the sprouting buds. Thus, in all the months and under both techniques of grafting, maximum percentage of scion sticks sprouted was 82.49% on 45th DAG, and similar results were reported [16-18] in mango. The sprouting of scion-sticks was more in grafts prepared during December (M_4) (82.49%) followed by September (M_1) (76.38%) while the success was low in March (M_7) month. This could be attributed to favorable light, temperature and humidity occurring during September and December (M_4) months while these climatic factors were unfavorable during March (M_7).

Soft-wood graftsprepared in the month of	Scion Sticks Sprouted (%)							
	15 DAG		30 DAG		45 DAG		Total	
	B	P	B	P	B	P	B	P
September M_1	06.47	15.61	67.05	50.38	02.80	00.95	76.58	66.94
October M_2	09.33	20.57	40.19	32.95	07.00	06.66	56.57	60.18
November M_3	17.60	19.23	46.86	40.00	04.20	05.61	68.66	64.84
December M_4	06.29	12.40	72.77	58.85	03.40	01.14	82.49	72.39
January M_5	06.09	14.91	62.47	26.37	04.70	03.43	73.32	44.77
February M_6	13.14	28.95	35.42	13.52	06.10	02.09	54.66	44.56
March M_7	13.52	13.33	23.81	22.05	00.70	00.95	38.09	36.33
Column Average (Mean)	10.35	17.86	49.80	34.87	04.13	02.98	64.34	55.72
CD (P=0.05)	00.05	00.07	00.08	00.09	00.03	00.05	-	-
CV (%)	28.18	30.65	16.62	23.70	29.41	48.25	-	-

Table 1: Percentage of scion sticks sprouted in Bapatla (B) and Puttur (P) techniques of rootstock preparation on 15, 30 and 45 days after grafting (DAG) during seven different months (M_1 to M_7).

Note: Each cell of respective data row from M_1 to M_7 represents an average of the replicated data collected from three individual grafts in each replication of each treatment combination.

It was clearly observed (Table 2) in both the techniques after 90 days, the grafts prepared during December (M4) recorded the highest percentage of success (59.24%) while the lowest success percentage was observed in the grafts prepared during March (M7) (20.20%). The reason for this low success in graft-take in March (M7) might be due to rising temperatures along with the high relative humidity from February to June months in agro-climatic region of CRS in Bapatla. These results were in line with the previous observations [16,19]. It was also observed that in all the treatments, the maximum percentage of success was observed during first 30 days period of grafting, a slight decline in next 30 days and maintained constant after 60 days of grafting. From this study, it is revealed that scion sticks sprouted earlier could sustain well due to favorable environmental conditions. The scion sticks sprouted after 30 days of grafting could not able to sustain for longer periods as they are weak by the time they sprout due to exhaus-

tion of available assimilates and rootstock mortality. These results are supported by previous findings [20]. The reasons for failure or low success rate of grafts prepared during months from February to June could also be attributed to high temperatures and greater variations in diurnal temperatures which retard the formation of the cambial cells and their healing. The failure to produce callus results in gap between scion and rootstock [21-23].

The data pertaining to growth of grafts in terms of graft height (Table 3) and the number of leaves per graft (Table 4), indicated significance in growth differences due to the effect of climate on grafts prepared during seven different months. The graft height was maximum in grafts prepared during January (M5) and December (M4) in both the techniques indicating that early sprouting of grafts gave a rapid spurt in growth as explained in mango [24]. It

Soft-wood grafts prepared in the month of	Success Percentage of Softwood grafts [Days After Grafting (DAG)]					
	30 DAG		60 DAG		90 DAG	
	B	P	B	P	B	P
September M_1	64.95	59.90	54.10	50.01	52.76	50.01
October M_2	53.71	62.29	46.47	50.29	43.80	50.29
November M_3	58.57	64.76	53.81	51.81	50.90	51.43
December M_4	74.10	70.29	62.67	57.42	59.24	56.19
January M_5	69.43	29.33	57.62	23.05	56.10	22.20
February M_6	60.76	59.62	52.38	17.33	52.20	47.29
March M_7	40.76	47.85	22.43	42.29	20.20	42.29
Column Average (Mean)	60.33	56.29	49.93	41.74	47.89	45.67
CD (P=0.05)	0.08	0.09	0.08	0.11	0.08	0.11
C V (%)	14.06	17.55	17.13	24.13	17.87	24.16

Table 2: Success percentage of soft-wood grafts of Bapatla (B) and Puttur (P) techniques of rootstock preparation on 30, 60 and 90 days after grafting (DAG) during seven different months (M_1 to M_7).

Note: Each cell of respective data row from M_1 to M_7 represents an average of the replicated data collected from three individual grafts in each replication of each treatment combination.

Soft-wood grafts prepared in the month of	Height of grafts (cm)					
	30 DAG		60 DAG		90 DAG	
	B	P	B	P	B	P
September M_1	18.37	20.47	20.00	22.27	21.82	25.56
October M_2	18. 20	18.89	19.55	22.03	21.32	24.53
November M_3	18.88	24.43	20.35	25.37	21.02	28.41
December M_4	18.20	24.43	20.47	25.71	23.00	28.66
January M_5	19.57	24.39	21.20	26.03	24.78	28.41
February M_6	17.35	21.57	18.58	24.19	21.15	25.57
March M_7	17.68	20.16	19.20	20.97	21.30	22.21
Column Average (Mean)	18.32	22.05	19.91	23.80	22.06	26.19
CD (P=0.05)	00.78	01.05	00.84	00.94	01.13	01.34
C V (%)	07.06	07.82	07.07	06.52	08.47	08.46

Table 3: Height of the graft (cm) in Bapatla (B) and Puttur (P) techniques of rootstock preparation on 30, 60 and 90 days after grafting (DAG) during seven different months (M_1 to M_7).

Note: Each cell of respective data row from M_1 to M_7 represents an average of the replicated data collected from three individual grafts in each replication of each treatment combination.

could also be attributed that the rapid scion growth in accordance with the rise in temperature that follow in the months of February (M6) and March (M7) as explained [25] in mango. The lowest graft height in the month of March (M7) could be ascribed to lower temperature in December hampering the bud sprout and their growth rate in similarity to those revealed earlier in mango grafts [26].

Soft-wood grafts prepared in the month of	Total number of leaves per graft					
	30 DAG		60 DAG		90 DAG	
	B	P	B	P	B	P
September M_1	05.00	04.08	07.00	06.66	10.60	08.56
October M_2	04.60	03.29	06.60	06.43	08.53	09.91
November M_3	05.40	05.10	06.20	05.79	08.10	08.80
December M_4	05.08	05.39	05.60	06.83	10.80	12.84
January M_5	05.08	03.37	07.90	06.49	13.90	10.10
February M_6	04.18	02.84	07.40	07.13	09.53	10.00
March M_7	04.00	02.45	06.13	05.41	08.27	08.60
Column Averages (Mean)	04.76	03.79	06.69	06.39	09.96	09.83
CD (P=0.05)	00.49	00.64	00.85	00.88	01.36	01.35
C V (%)	17.11	27.05	28.93	22.65	22.22	22.63

Table 4: Number of leaves per graft observed in Bapatla (B) and Puttur (P) techniques of rootstock preparation on 30, 60 and 90 days after grafting (DAG) during seven different months (M_1 to M_7).

Note: Each cell of respective data row from M_1 to M_7 represents an average of the replicated data collected from three individual grafts in each replication of each treatment combination.

The total number of leaves per graft (Table 4) were also observed significantly different among treatments and showed the similar distinctive variability for the traits studied above. The rapid spurt in the scion sprouts and their growth might have resulted in the production of larger number of leaves in the grafts prepared in the month of January (M5). The stored food from photosynthesis by two leaves and four leaves of respective roots stocks was helpful in providing boost in the intial growth of scion and for success of the graft union.

Similarly, leaf area per graft (Table 5) is also an important trait reflecting the efficiency of photosynthesis and amount of carbohydrates prepared by the new leaves produced on the scion and number of leaves retained on the rootstock to initiate the new sprouts on scion for production of new leaves. The grafts prepared in the month of September (M1) produced maximum total leaf area per graft (277.9 cm2). This was attributed to the larger size of leaves produced on these grafts and the efficiency of endogenous hormonal biosynthesis.

Soft-wood grafts prepared in the month of	Leaf area per graft (cm^2)					
	30 DAG		60 DAG		90 DAG	
	B	P	B	P	B	P
September M_1	113.11	93.10	176.71	150.59	277.88	233.74
October M_2	93.32	88.28	131.54	125.34	167.42	170.57
November M_3	103.16	105.87	102.70	109.77	107.45	115.00
December M_4	155.55	130.37	180.00	181.20	196.81	194.88
January M_5	124.64	61.16	148.67	85.30	180.71	151.18
February M_6	94.15	60.70	121.77	81.80	171.84	143.91
March M_7	59.11	30.50	162.64	94.90	173.88	142.95
Column Average (Mean)	106.15	81.43	146.29	118.41	182.28	164.60
CD (P=0.05)	16.70	15.00	20.10	15.80	22.50	25.30
C V (%)	26.02	30.47	22.74	22.08	19.84	25.39

Table 5: Leaf area per graft (cm^2) in Bapatla (B) and Puttur (P) techniques of rootstock preparation on 30, 60 and 90 days after grafting (DAG) during seven different months (M_1 to M_7).

Note: Each cell of respective data row from M_1 to M_7 represents an average of the replicated data collected from three individual grafts in each replication of each treatment combination.

Comparison of Bapatla and Puttur techniques of softwood grafting in cashew

The age of the rootstock is one among the various factors responsible for success in soft-wood grafting technique in cashew. It was found that 90-100 days rootstock was more suitable for Konkan region of Maharashtra while 30 days old seedlings were the best for Dakshina Kanara district of Karnataka [27]. In Andhra Pradesh, the lower two leaves that were intact to the rootstock seedlings during grafting increased the percentage of success with better union and vigor considerably reducing the rootstock mortality [28]. Contrarily, retention of four leaves on the stock of the graft induced quicker sprouting and increased the success of grafting in cashew [24,29]. As such it was felt necessary to ascertain the appropriate stage of the rootstock under local agro-climatic conditions of tropical coastal humid climate of Bapatla.

The results of various parameters recorded were compared between the two techniques of Bapatla and Puttur, indicated a pair of leaf on the root stock during grafting was the best and sufficient to provide equally competitive growth and potential success in graft-take when compared to older method of retaining four leaves. The success due to retention of two leaves could be attributed to prevailing congenial and salubrious climate during the experimental period from the month of September 1996 to June 1997 (Figure 1). The warm climate coupled with high relative humidity in Bapatla were favorable for early sprouting of scion sticks and rapid growth of sprouts when rootstock with limited leaves (only two) were intact.

Although the results of Puttur technique of retaining two pairs of leaves on rootstock were in tune with the Bapatla technique, numerically less values were recorded under Puttur technique. It could be attributed to more loss of moisture from the rootstock through increased transpiring area (four leaves per rootstock). In a warm climate of Bapatla, increased radiation might have increased the transpiration rate and utilization of available photosynthesis in the metabolic process, respiration. This might have resulted in less availability of carbohydrates for the union of the graft. These results are in conformity with the previous findings in cashew [13] and Mango [30], who reported that as the age of the rootstock advances, the grafting success was reported to be reduced.

Thus, from the foregoing results and discussions it can be concluded that grafting during December to January with Bapatla technique of retaining a pair of leaves on rootstock during grafting period is beneficial under local agro-climatic conditions of Bapatla region in Andhra Pradesh. Further with Bapatla technique, more than 50 per cent graft success was observed in all the months except in march (M7) consistently during 30, 60 and 90 DAG (Table 1) and this success was most economical and viable for maintaining a commercial nursery in cashew [31]. The reason for superiority of Bapatla technique of retaining two leaves and 35-45 days old rootstock for preparation of softwood grafts might be because of the successful and early graft union between chosen young, actively growing, vigorous rootstock of BPP-5 and a prolific apical bud scions of BPP-6 as well as by transfer of food materials properly and timely by the cambial regions of the rootstock and scion at the initial stages of the grafting and receipt of the endogenous hormonal signals from source (rootstock) to sink (scion).

Comparison of softwood grafting with other methods of grafting in Cashew

There were more than ten standard techniques of vegetative propagation in practice at various geographical locations of cashew growing regions in India. The technique of air-layering during March to May was significantly superior over other seven techniques with a 94 percent success in field establishment. The techniques, side grafting (June, July and October) and patch budding in situ (April, May and June) were at par. Mound layering with 74 per cent success in shooting, veneer grafting and patch budding with 92 and 80 per cent establishment in the field respectively were observed. The percentage take in cleft grafting was high in September (58%) followed by 54 per cent in August while the success in whip grafting being 44 and 40 per cent in August and September months respectively [12].

The present research findings on softwood grafting revealed more success in production of successful grafts within 60days of grafting with maximum leaf area, graft hight, with high percentage of sprouted scions after grafting as well as excellent field establishment without mortality when compared to the above stated techniques. These rootstocks of Bapatla cashew cultivars were proven to be highly vigorous having the highest total conductance during graft union. The graft union or the ability of the root system to take up ions and export them to scions in sufficient quantities might have not played a crucial role in success but the hormones that were produced in association with the anatomical changes in scion for graft growth due to signals received from the rootstock (source) region were the key factors for unexpected extremity in success of softwood grafts in cashew. These results were in line with the findings observed in shoot and root growth of apple grafts [32].

The same authors also explained that the anatomical changes associated with the graft union between the scion and rootstock played a role in the rootstock effect by transporting physiologically active substances. Their direct measurements of stem tissue hydraulics (water flow per unit time) on young fruiting apple trees, scion sap flow as determined by leaf area proved direct influences of the type of rootstock on which scions were grafted. Their comparison of invigorating rootstocks with dwarfing rootstocks in apple revealed that the graft union between a dwarfing rootstock and a scion offered considerably higher resistance to water flow than that evident with an invigorating rootstock. The water flow per unit of stem tissue was lower for the dwarfing rootstock compared to

the invigorating rootstock. The hormones such as the auxins, cytokinins and gibberellins, along with abscissic acid, might have played major roles in determining shoot and root growth and development [32].

Over all, the hybrids developed at CRS, Bapatla can be improved through this new and improved softwood grafting on 45 days old rootstocks retaining two leaves i) to realise stable yields of cashew nut, ii) mass multiplications of productive cultivars during December and January and iii) for identification and development of dwarfing rootstocks for cashew to adapt high density planting.

Conclusion

The research results revealed that use of vigorous rootstocks of 45 days old, retaining two leaves, for softwood grafting was highly successful in graft take with more leaf area within two months. These grafts were well established in the field with less or no mortality after transplanting in coastal regions of Andhra Pradesh in India. The reasons for this success may lead paths for future research on roots of these roots stocks along with those of the available dwarf cashew cultivars (*Anacardium occidentale* L Var. *Nanum*) of Brazil and hybrids of PLD 57 in India to identify the most valuable source-sink relationships of hormonal regulations involved in transport of biosynthates from rootstock to scion. This might also lead to the invention of dwarfing rootstocks with precosity, longevity, high productivity in cashew and with high adaptibility to diverse soil and climatic conditions. Production of small or dwarf trees is one of the great interests in fruit crop production or industry level, especially for their suitability to high density planting and technology driven pre-and post-harvest management and processing steps. The production of dwarf rootstocks was successful in few fruit crops like guava, mango, anonaceae, loquat, citrus, apple and peach and has facilitated fruit production in both protected and open field conditions. Hope, cashew will join one among them in upcoming future.

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