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Propagation Studies in Sapodilla [*Manilkara zapota* (L.) P. Royen]: A Review

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ABSTRACT

Sapota [*Manilkara zapota* (L.) P. Royen] is an important commercial fruit crop of *Sapotaceae* family grown for fresh fruits and chicle production. Sapota when propagated by vegetative means, produce true to type plant material and reduces juvenile period and result in early commercial production. Various propagation techniques on different rootstocks were tried for the purpose. Among different rootstocks, khirni (*Manilkara hexandra*) was found most successful and is used for commercial plant propagation as it possesses high graft compatibility with sapota and plants produce fruits of excellent quality with high yield. Various vegetative propagation techniques have been standardized and used on large scale depending upon season and region. The general techniques used for sapota propagation are softwood grafting, veneer grafting, side grafting, inarching and air layering. Softwood grafting is employed in regions with moderate temperature and high relative humidity which prevent desiccation of scion stick. Veneer and side grafting using mature scion stick is also found effective in regions with variable climates. Inarching technique possess high graft survival rate and is practiced by private nurseries. Propagation through cuttings is not successful in sapota even when treated with rooting hormones. Micro-propagation in sapota by tissue culture techniques have been tried but application remains limited to academics only. This may be due to high phenolic contents and sap exudation in explant. Special protocols for successful root and shoot regeneration are required to be standardized for commercial scale plant propagation.

Key words: Inarching, Khirni, *Manilkara zapota*, Propagation, Side, Softwood grafting, Veneer.

Sapota [*Manilkara zapota* (L.) P. Royen] is one of the important commercial fruit crops of tropical regions of India which belongs to family *Sapotaceae* and native to South Mexico and Central America (Singh, 1991). It is also known by different names in different regions like Sapoti in Brazil, chicopote in Mexico and chicku or sapota in India (Mortan, 1987). In India major proportion is consumed as fresh fruit whereas in Mexico, Guatemala and British Honduras it is commercially cultivated for chickle production. Now a day's cultivation of sapodilla is in trend due to its low cost of production and long commercial life of the trees. Sapota fruit is very sweet and tasty and rich source of various nutrients and total soluble solids (20-25°Brix) with considerable amount of proteins (Selvaraj and Pal, 1984), fat, fibres and minerals like calcium (28 mg), iron (2 mg), phosphorus (27 mg) and vitamins such as thiamine (20 µg), riboflavin (30 µg), niacin (0.2 mg), vitamin A (48 µg), vitamin C (6 mg) per 100 gram of fruit pulp (Mortan, 1987).

Sapota is such a crop that has adaptation to a wide range of soil and climatic conditions. India ranks first in sapota production in the world with a production of 1.28 million tonnes from an area of 1.07 lakh hectares. Karnataka is the leading state with an area of 29.99 thousand hectares having an annual production of 350.33 thousand MT. Gujarat ranks second in area 29.56 thousand hectares having production of 325.15 thousand MT. The productivity of sapota vary from 0.1 to 31.56 MT/ha and Tamil Nadu having maximum productivity *i.e.* 31.56 MT per ha (Anonymous, 2018).

Sapodilla plants are very hardy which thrives well under harsh weather conditions. The area under sapodilla cultivation in the country is increasing day by day due to its wider adaptability, high nutritive value and low maintenance cost. The cultivation of sapota is a profitable venture as it requires minimal plant protection measures due to less incidence of pest and diseases. For the establishment of new orchard there is continuous demand for true to type good quality planting material, but the rate of increase in the area is limited due to the non-availability of quality planting material. In general, sapota plant is propagated by both seeds and vegetative means. Sapota fruit produces viable seeds recalcitrant in nature. Seedlings possess higher heterozygosity and juvenility having slow growth rate. It takes about 8-10 years to bear fruit, but grafted plants flower within 4-5 years (Richards, 1943). So seedling plants can't be used for commercial plantation. The propagation by seed is limited to crop improvement programmes only.

Rootstock and seed germination

Sapota is propagated by various vegetative means as it

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reduces juvenility and maintains uniformity and genetic stability in the planting material. Several vegetative methods used are whip grafting, side grafting, tongue grafting, cleft grafting, inarching, wedge grafting, veneer grafting and air layering, although sapota cannot be propagated by cuttings even with the help of plant growth regulators (Chadha, 1992). Air layering and side grafting are commonly used in Maharashtra and Karnataka. The air layering is very easy and quicker method of propagation but the plants propagated by this technique are shallow rooted and prone to uprooting due to high wind velocity. Multiplication of sapota by micro-propagation has been tried but without much success (Bapat and Narayanaswami, 1977; Purohit *et al.* 2004).

The rootstock has a great influence on grafted plants in term of size, canopy and fruit characteristic *i.e*. size, shape and quality (Mukherjee and Litz, 2009). Different rootstocks can be used for sapota propagation such as mahua (*Madhuca latifolia*), rayan or khirni (*Manilkara hexandra*), mee tree (*Madhuca longifolia*) and sapota (*Manilkara zapota*) *etc*. Plants propagated on mahua rootstock produce vigorous trees, of poor quality fruits whereas mee trees shows graft incompatibility. *Manilkara hexandra* is found to be the best rootstock having better stock-scion compatibility and produces fruits of excellent quality and high yield (Sayed, 1962). *Chrysophyllum lanceolatum* showed potential as a new rootstock for sapota and grafted plants grown in different agro-climatic conditions of the Kerala state produced fruits of good quality and yield. *C. lanceolatum* proved one of the best rootstocks for sapota Kalesh *et al.* (2005).

The seed priming with different chemicals significantly improved germination potential in khirni Bhanuprakash *et al.* (2008). Similarly, Reddy and Khan, (2002) have also reported significant effect of chemicals on seed germination of khirni. The seeds soaked in GA_3 at 100 ppm resulted in highest germination percentage (85.8) followed by those soaked in GA_3 at 200 ppm both of which were superior to other treatments. However, lowest germination (41.7 %) was recorded for untreated control. Positive effect of gibberellic acid on germination have been reported by Wankhede *et al.* (2008). The enhancement of germination by GA_3 can be attributed to the fact that it antagonizes the ill effect of inhibitors and induces the *de novo* synthesis of proteolytic enzymes like alpha amylase and ribonuclease. These enzymes hydrolyze starch in the endosperm providing the essential sugars for the initiation of growth processes in the developing embryo (Copeland and Mc Donald, 1995). In khirni seeds, germination started 13 days after sowing and continued up to 39 days. Different treatments significantly affected the germination period. The earliest germination, *i.e.*, least imbibition period (13 days) with minimum germination period (7 days) was observed in seeds soaked in KNO_3@ 2% while delayed germination, *i.e*., longest imbibition period (25.8 days) with maximum germination period (13.2 days) was observed in untreated seeds. The mean daily germination (MDG) varied significantly in different treatments for *M. hexandra* and was found to be highest (3.48) in seeds soaked in 200 ppm GA_3 and statistically least value (1.07) was counted for untreated seeds. The highest germination index (4.39), peak value (3.78) and germination value (12.25) were obtained in seeds soaked in 100 ppm GA_3. Overall, treatment with gibberellic acid (GA_3) resulted in maximum seed germination. In majority of the cases, seedling vigour was found to be better in the seeds treated with 100 ppm GA_3 followed by those treated with 200 ppm GA_3 as compared to other treatments.

Bajaniya *et al.* (2018) also reported that seed treatment of khirni with gibberellic acid @ 200 ppm for 24 hrs soaking found most effective for seedling height, number of leaves, number of branches, leaf area, stem diameter, fresh weight of stem, dry weight of stem and other parameters. Vachhani *et al.* (2014) studied the influence of chemicals and cow-dung slurry as seed treatment on germiability, growth and development of *Manilkara hexandra* under controlled condition. The investigation was carried out with different growing soil media like soil + FYM + vermicompost + paddy husk in the composition of (6:2:1:1) The results of experiment revealed that the treatment of GA_3 200 ppm recorded the higher percentage of germination and maximum seedling length, root length, number of leaves and number of branches**.**

According to Ratna *et al.* (2018), khirni seeds possess poor germination due to hard seed coat and continuously increasing pressure on the natural wild population is gradually eroding its genetic variability. To enhance germination and seedling growth in khirni, seeds were subjected to soaking in distilled water, GA_3 (100 and 200 ppm), Thiourea (1 and 2%) and KNO_3 (1 and 2%). Growth parameters of khirni seedlings were recorded at 75 and 150 days after sowing (DAS). Significant variations in growth attributes of khirni seedlings were observed. The highest germination percentage, shoot length, number of leaves, shoot fresh weight, shoot dry weight, seedling vigor index - I and seedling vigour index II were obtained in the seeds treated with 100 ppm GA_3 while root length, stem diameter, tap root diameter, root fresh weight, root dry weight and root: shoot ratio 75DAS were higher in the seeds treated with 200 ppm GA_3. Seeds treated with 1% thiourea had higher root: shoot ratio 150DAS. The findings suggest that treatment of seeds with 200 ppm GA_3 showed efficacy in improving seed germination, growth characteristics and vigour of khirni seedlings.

The increase in seed germination by optimum concentration of gibberellic acid might be due to enhancement of hydrolase enzyme (particularly alpha-amylase) synthesis (Prasad and Prasad, 2009).GA_3 controls mobilization of starch which acts as a respiratory substrate leading to immediate enhancement in cell elongation (Shah, 2007).Gibberellins also help in enhancing the availability of reserved mineral elements which promote the germination process (Salisbury and Ross, 1995). Increased seedling vigor by GA_3 application has also been reported in many tree species to produce elite seedlings (Ballantyne, 1991). Therefore, on the basis of results of the experiment it

may be recommended that maximum number of vigorous seedlings can be produced by treatment with GA_3@ 100 ppm followed by GA_3 @ 200 ppm for 36 hours. However, the seeds treated with 2% KNO_3 took minimum days to complete germination and hence the imbibition and germination period were reduced but the germination percentage in the GA_3 treated seeds. Therefore, it can be concluded that pre-soaking khirni seeds in these chemicals had significant effect on germination percentage.

The seedlings of the khirni collected from forest area that are germinated naturally are mostly utilized for nursery production. These seedlings are collected in rainy reason and utilized for grafting in Jan-Feb. depending on the time of grafting. These seedlings are collected from forest area of West Bengal and Andhra Pradesh and marketed to various parts of the country for sapodilla propagation. Various grafting methods have been attempted in different regions of the country but inarching continues to be the most popular method of propagation for most of the private nurseries although various other techniques were also standardized.

Effect of various techniques on grafting success

Survival percentage

The survival percentage varied with the technique and season of grafting. While studying the effect of various propagation techniques in sapodilla on survival rate, Hussain and Bukhari, (1977) reported maximum survival percentage *i.e*. 60.00 per cent in veneer grafting followed by inarching and side grafting. The minimum success rate was recorded in the plants propagated through tongue grafting followed by whip grafting *i.e*. 25.00 and 37.50 per cent, respectively.

Kulwal *et al.* (1985) reported that sapota when propagated by softwood grafting there was 80 per cent survival in the month of July-August followed by September to October and reported high rate of mortality in the month of May-June. Bhuva *et al.* (1990) found that sapota propagated by inarching on rootstock *Mimusops hexandra* had maximum survival percentage *i.e*. 90 per cent in the month of February followed by January.

Waghmare (1990) studied the influence of age of rootstocks of khirni on softwood grafting in sapota and reported maximum graft survival *i.e.* 59 per cent in plants grafted on 15 months old khirni rootstock followed by 12 months old rootstock. Sandhu (1991) worked on the standardization of various vegetative propagation techniques in sapodilla at University College of Agriculture, Calcutta University and reported that plants propagated by veneer grafting had maximum survival percentage *i.e*. 82.5 per cent followed by splice grafting. The minimum survival percentage was recorded in the plants propagated by cleft grafting. While comparing different months of grafting, he further revealed that the plants grafted in the month of October had maximum average survival percentage *i.e*. 90 per cent and minimum in the month of December *i.e*. 25 per cent followed by January and February *i.e*. 30 per cent in each month. It was reported by Sengupta, (1999) that among four vegetative propagation techniques *i.e*. veneer, cleft, side and whip grafting, sapota plants propagated with veneer grafting had maximum survival per cent.

Pampanna *et al.* (2000) worked on standardization the softwood grafting on Khirni rootstock in sapodilla. The maximum survival percentage was recorded in the month of May *i.e*. 60 per cent followed by April grafts. The minimum graft success was recorded in the month of January followed by February (6.67 and 10.00 per cent, respectively). The plants grafted in the month of October, November and December were recorded with 100 per cent graft mortality. The maximum graft success in the month of April might be due to congenial temperature and humidity during the period under study *i.e*. temperature range of minimum and maximum 20.90 to 36.90°C with optimum relative humidity *i.e*. 65 per cent and also stated that the unsuccessful grafts were re-grafted in the upcoming year *i.e*. in the month of May with 60 per cent graft success. In an another experiment Pampanna and Sulikeri (2001) studied the effect of pre-curing of scion stick for the success of softwood grafting in sapota cv. Kalipatti at UAS, Dharwad and reported that plants grafted using precured scion wood for 10 days and stored in moist sphagnum moss for 3 days before grafting had maximum survival *i.e*. 80 per cent. Islam *et al.* (2004) reported that average maximum graft survival for the plants grafted through cleft, modified cleft and veneer grafting was 89.12, 94.09 and 78.36 per cent, respectively when grafted in June whereas minimum graft survival was recorded in the month of September irrespective of propagation techniques.

Shirol *et al.* (2005) experimented on different methods of propagation and season of grafting in khirni and reported that plants grafted through inarching had maximum graft success. The success rate was higher in the month of June-July irrespective of technique of propagation. He also observed that the higher success rate in the month of June-July might be due to high relative humidity *i.e*. 76-80 per cent and minimum fluctuation in the mean of maximum and minimum temperature. Nache *et al.* (2006) studied on the propagation of khirni plant by air layering at HRS, UAS, Bangalore. The shoots treated with 5000 ppm IBA recorded maximum rooting percentage *i.e*. 76 per cent whereas minimum rooting (36%) was observed in case of control. Plant shoots treated with IBA only gave better rooting as compared to combination of IBA and NAA. Wazarkar *et al.* (2009) reported that plants propagated by softwood grafting in the month of July had maximum survival percent one month after grafting whereas plants grafted in August had minimum survival percent.

Ghosh *et al.* (2010) worked on standardization of propagation of different cultivars and season by softwood grafting of sapota and reported maximum survival percentage in the plants grafted in July whereas minimum survival percentage was recorded in the plants grafted during September. The plants grafted in October recorded zero per cent survival. Maske *et al.* (2010) conducted an

experiment on success of softwood grafting in sapota at Rahuri in Maharashtra. The sapota plants were propagated by using wedge grafting at fortnight of January to December and recorded that maximum survival percentage in the August *i.e*. 100 per cent followed by May. Minimum graft survival was recorded in the month of October. The plants grafted in the month of November to April were recorded with very poor survival percentage. Patil *et al.* (2012) conducted an experiment to study effect of age of scion on softwood grafting in sapota cv. Cricket Ball at Regional Fruit Research Station, Katol and observed that 3 months old scion shoot grafted on khirni rootstock by wedge grafting had maximum survival per cent *i.e*. 77.49 per cent recorded 150 days after grafting. Kalalbandi *et al.* (2014) worked on standardization of softwood grafting of sapodilla cv. Kalipatti propagated on rootstock Khirni under 50 per cent shade net. The maximum graft survival percentage was recorded in the month of August, whereas minimum graft survival percentage was recorded in the month of May after 60 days of grafting. Sanjay and Singh, (2015) reported the effect of time on softwood grafting on Mahua and khirni under semi-arid western Indian conditions. Mahua and Khirni plants propagated in the month of March were recorded with maximum graft survival percentage *i.e*. 76.66 and 70.00 per cent, respectively. Minimum survival rate was noticed in the month of September and November in Mahua and Khirni, respectively. The study was conducted by Tanjua and Thippesha, (2016) on effect of scion stick of different diameters *i.e*. 5.02, 4.63, 4.38 and 4.02 mm on success rate of softwood grafting in sapota. Among different diameters of scion shoot, the scion with diameter of 5.02 mm recorded with maximum graft success *i.e*. 58.00 per cent and minimum in the plants grafted with 4.02 mm diameter scion *i.e*. 49.40 per cent.

Effect of various propagation techniques on days and duration of bud sprouts

Days to bud sprout

Hussain and Bukhari, (1977) reported least number of days to bud sprout *i.e*. 22.89 days in veneer grafting and recorded delayed sprouting in the plants propagated through tongue and splice grafting (26.00 and 25.80 days, respectively). The study was conducted by Kalalbandi *et al.* (2014) on standardization of softwood grafting in sapota under 50 per cent shade net. The minimum number of days to bud sprout was recorded in the plants propagated on 15th September *i.e*. 14.33 days which were at par with 15th August and 15th July for this parameter (14.42 and 14.64 days, respectively). The maximum numbers of days to bud sprout were recorded in the plants grafted on 15th January *i.e*. 18.50 days followed by 15th February *i.e*. 17.86 days. Tanjua and Thippesha, (2016) studied the effect of variable scion stick diameter on success rate of softwood grafting in sapota. The plants were grafted by using scion stick of four different diameters *i.e*. 5.02, 4.63, 4.38 and 4.02 mm. Out of these, the plants grafted with relatively thick scion stick of diameter 5.02 mm took minimum number of days to bud sprout. Nitish *et al.* (2019) experimented on effect of time on success of softwood grafting in sapodilla on invigorated rayan rootstock. The plants grafted in the month of July took minimum number of days to bud sprout *i.e*. 19.14 days whereas maximum number of days taken by August grafts.

Duration of bud sprout

The duration of bud sprouting varies with respect to temperature, humidity, type of scion stick used, season and technique of grafting. Singh and Bons, (2016) observed that duration of bud sprouting ranged from 10.4 to 11.2 days among different propagation techniques and minimum number of days taken for the completion of bud sprouting was recorded in wedge grafting followed by veneer and side grafting which were at par with each other. While comparing season of grafting they found shortest duration of bud sprouting in plants grafted in the month of March whereas longest duration was recorded in the month of February. While studying the effect of both season and method of grafting and reported that plants grafted through veneer grafting in the month of March took minimum number of days for completion of bud sprouting and maximum (12.5 days) in the side grafting done in the month of February. The study was conducted by Tanjua and Thippesha, (2016) on effect of variable scion stick diameter on success rate of softwood grafting in sapota. The plants were grafted by using scion stick of four different diameters, out of these scion sticks, the relatively thick scion shoot took minimum days for the completion of bud sprout *i.e*. 24.80 days and maximum for the plants grafted with thin scion stick.

Effect of various vegetative propagation techniques on plant growth

Plant height

The growth of the graft varies with the propagation techniques, time, temperature and humidity. Sandhu, (1992) worked on the standardization of various vegetative propagation techniques in sapota. The plants propagated with veneer grafting had maximum graft height followed by splice grafting. Pampanna and Sulikeri, (2000) worked on standardization of softwood grafting in sapodilla by invigorating Khirni rootstock and observed that average maximum plant height was recorded in plants grafted in the month of April followed by March. The minimum plant height was recorded for the January and February grafts and was at par with each other after 120 days of grafting. The plant height recorded after 180 days of grafting was observed maximum in the month of April and minimum in January, respectively. Patil *et al.* (2012) conducted an experiment on softwood grafting in sapota cv. Cricket Ball and observed that 90 days old scion shoot grafted on khirni rootstock by wedge grafting had maximum plant height *i.e*. 14.38 cm as compared to plants grafted using six-month old scion stick *i.e*. 12.13 cm.

Singh and Bons, (2016) reported significant variation in graft height with time and methods of propagation. The maximum average plant height was recorded in side grafting

i.e. 57.6 cm whereas minimum in wedge grafting (46.9 cm) which was at par with veneer grafting 90 days after grafting. While comparing different seasons of grafting, the plant height ranged from 43.33 to 56.1 cm in August and March, respectively. The study was conducted by Tanjua and Thippesha, (2016) on effect of scion stick diameter on success rate of softwood grafting in sapota and observed maximum plant height *i.e*. 37.60 cm in plants grafted by thick scion shoot of diameter 5.02 mm whereas minimum in plants propagated by thin scion shoot *i.e*. 35.20 cm after 90 days of grafting. The study was carried out by Nitish *et al.* (2019) on effect of time on success of softwood grafting in sapota on invigorated rayan rootstock reported that the plants grafted in the month of July recorded maximum graft height whereas minimum graft height having for August grafts. Niranjan, (2011) reported that the sapota cv. Kalipatti grafted on khirni rootstock by modified approach grafting on 15th July had maximum plant height *i.e*. 35.33 cm whereas minimum in the August grafts under Orissa conditions.

Scion and rootstock girth

The scion and rootstock girth are the important parameters governing success rate and further growth and development of the plants. The study was carried out by Sandhu, (1991) on the standardization of various propagation techniques in sapota under Calcutta conditions and reported that plants propagated by veneer grafting had maximum average scion diameter *i.e*. 13.4 mm followed by splice grafting and cleft grafting, respectively. Tanjua and Thippesha, (2016) studied the effect of scion stick diameter on success rate of softwood grafting in sapota. The plants propagated with relatively thick scion shoot of diameter 5.02 mm were recorded with maximum scion girth whereas minimum in the plants grafted with thin scion stick after 45 days of grafting.

The study on effect of season on growth of graft in softwood grafting in sapota was carried out by Ghritlahare and Ashutosh, (2018) at Orissa University of Agriculture and Technology, Bhubaneswar. The plants propagated on 20th July had maximum increase in scion diameter *i.e*. 2.00 mm followed by 20th August (1.90 mm). Whereas minimum incremental scion diameter was recorded in the month of September (20th) *i.e*. 1.70 mm followed by 20th June *i.e*. 1.87 mm four month after grafting.

Number of shoots and Shoot length

The number of shoots per plant may vary with the food material stored in the scion stick *i.e*. diameter of the scion. It was opined by Wazarkar *et al.* (2009) that plants propagated by softwood grafting in the month of July had maximum increment in length of scion (11.43%) after 30 days of grafting. The plants grafted in August had minimum increase in scion length (8.34%) after 30 days of grafting. The study was conducted by Kalalbandi *et al.* (2014) at Marathwada Agricultural University, Parbhani on standardization of softwood grafting in sapodilla under 50 per cent shade net. It was reported that plants propagated in the mid of August had maximum shoot length *i.e*. 9.48 cm followed by mid-September *i.e*. 8.80 cm after six months of grafting. The minimum sprout length was recorded in the plants grafted on 15th March *i.e*. 7.05 cm and 15th April *i.e*. 7.07 cm. Tanjua and Thippesha, (2016) studied the effect of scion diameter on success rate of softwood grafting in sapota. The plants grafted with relatively thick scion stick of diameter 5.02 mm had maximum number of sprouts 2.10 and minimum (1.06) in the plants grafted with thin scion stick after 90 days of grafting. The plants grafted with scion shoot of diameter 5.02 mm recorded with maximum sprout length 4.02 cm and minimum for the plants grafted with thin scion shoot *i.e*. 2.33 cm after 45 days of grafting. The study on effect of season on the growth of grafts in softwood grafting in sapota was carried out by Ghritlahare and Ashutosh, (2018). The plants propagated on 20th July recorded maximum shoot length *i.e*. 4.73 cm followed by 20th June *i.e*. 4.62 cm. whereas minimum shoot length was recorded in the month of September (20th) *i.e*. 4.57 cm followed by 20th August *i.e*. 4.57 cm after 120 days of grafting.

Number of leaves, leaf size and area

Leaves are the site where various photosynthetic activities take place and plant health is judged by number of leaves and leaf size *i.e*. leaf area which is dependent upon the graft union. An experiment was conducted by Pampanna and Sulikeri, (2000) on standardizing the time of grafting in sapodilla on invigorated Khirni rootstock and reported maximum number of leaves per plant in the month of May *i.e*. 9.67 followed by April. The minimum number of leaves were recorded in the month of January *i.e*. 4.50 and February *i.e*. 4.75 and were at par with each other after 120 days of grafting.

Ghosh *et al.* (2010) reported maximum number of leaves in softwood grafting in the month of July followed by June and minimum number of leaves were recorded in the plants grafted in September. Patil *et al.* (2012) conducted an investigation on softwood grafting in sapota cv. Cricket Ball and observed that plants grafted with three months old scion stick had maximum number of leaves *i.e*. 16.99 as compared to plants grafted through six-month old scion stick *i.e*. 12.63 after 150 days of grafting. The study was conducted by Kalalbandi *et al.* (2014) on standardization of softwood grafting in sapota and found maximum number of leaves in the plants grafted on 15th September followed by 15th August with values of 14.44 and 14.10, respectively. The minimum number of leaves were recorded in the plants grafted on 15th April *i.e*. 10.33.

While studying the effect of scion diameter on success rate of softwood grafting in sapota, Tanjua and Thippesha, (2016) reported that scion shoot of diameter 5.02 mm recorded with maximum number of leaves per plant (7.10) and minimum (4.86) in the plants grafted with scion shoot of 4.02 mm diameter after 90 days of grafting. The plants grafted by using scion stick of diameter 5.02 mm recorded with maximum leaf length and breadth *i.e*. 7.20 and 4.10 cm, respectively whereas minimum with thin scion shoot *i.e*. 4.98 and 3.46 cm, respectively after 90 days of grafting.

The study on effect of season on the growth of grafts in softwood grafting in sapota was carried out by Ghritlahare and Ashutosh, (2018). The plants propagated on 20th July were recorded with maximum number of leaves per plant *i.e*. 15.40 followed by 20th August *i.e*. 13.57. Whereas minimum number of leaves per plant was recorded in the month of September. The plants propagated on 20th July were recorded maximum leaf area *i.e*. 17.87 cm^2 followed by 20th August *i.e*.14.45 cm^2. Whereas minimum leaf area was recorded in the month of September (20th) *i.e.* 9.01 cm^2 followed by 20th June *i.e*. 12.10 cm^2 after 120 days of grafting.

Micropropagation in sapota

Micropropagation of the fruit plants generally offer many advantages over other techniques as more number of true to type plantlets can be produced from a single plant, this also offers multiplication of disease free propagules under controlled and aseptic conditions that are independent of environmental constraints. This also requires less space and time and proves more economical after standardization of the protocol. For successful propagation, standard protocols are prerequisite and with regard to woody perennials such as fruit crops, very few protocols have been standardized and micro-propagation in most of fruit crops is not successful owing to high phenolic contents and contaminations.

Very little work with respect to successful *in vitro* multiplication of sapota using tissue culture techniques have been reported owing to contamination, high phenolic content in explants taken from mature growing plants and latex exudation. Purohit and Singhvi (1998) developed protocol for sapota micropropagation using cotyledonary node segments and were able to induce multiple shoots from nodal segments by forced axillary branching and rooting in shoots and successfully transferred the plants in soil. Later on Purohit *et al.* (2004) used leaf segments for shoot bud differentiation in sapota. They reported high shoot bud regeneration in explants from middle portion of leaves taken from middle part of shoots.

Yuniastuti *et al.* (2016) studied effect of type of explant and different concentrations of 6-Benzyl Adenine (BAP) cytokinin supplemented in Woody plant Medium (WPM) on *in vitro* multiplication. They observed shoot and leaf regeneration in all the combinations but root induction was observed in few treatments. Among type of explant, lateral meristem showed encouraging results when cultured in media supplemented with 2 ppm BAP.

Further investigations are required to standardize culture media, hormonal concentrations and type of explant for callus induction and successful shoot and root regeneration. The major hindrance in *in vitro* propagation of sapota such as phenol leaching and sap exudation need to addressed using different absorbent compounds.

CONCLUSION

Sapodilla is commercially propagated through asexual means, but seed propagation is limited to crop improvement owing to high heterozygosity. Moreover, plants of seedling origin possess long juvenile phase. For true to type multiplication and commercial production of sapota, it becomes mandatory to propagate sapota through vegetative means. Successful vegetative propagation is dependent upon various factors such as rootstock, season and technique of propagation, type of scion stick *etc*.

Various techniques used for clonal multiplication include veneer grafting, side grafting, inarching, wedge grafting, tongue, whip grafting and air layering, yet propagation through cuttings is unsuccessful. The success of technique of grafting varies according to region and season of grafting. Generally, conditions such as high temperature around 25-35°C coupled with high relative humidity of 70-80% are reported to be conducive for sapota propagation. Softwood grafting using wedge grafting technique is successfully practiced in regions with mild temperature and high relative humidity, especially coastal regions.

Various rootstocks are used for grafting of sapodilla, but most widely used rootstock for commercial production is khirni as it possesses high graft compatibility and plants grafted on khirni rootstock produce fruits of excellent quality with increased production. Khirni seeds are recalcitrant and have poor germination. Several studies proved that germination and seedling vigour can be improved with help of seed priming with chemicals such as GA, KNO_3 and thiourea *etc*.

Type of scion wood also influence success of grafting in sapota, thick scion sticks have shown to increase graft survival and vegetative growth in grafts. Pre-curing of scion stick 10 days prior to grafting is also found beneficial for successful grafting. Propagation of sapota using biotechnological approaches such as micro-propagation under *in vitro* conditions is found unsuccessful due to high phenolic contents and latex exudation and limited to academic publications only. So practical commercial multiplication of the sapodilla by tissue culture need to be standardized.

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