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Effect of cutting dimensions, rooting media and incubation on vegetative propagation of *Prunus armeniaca*

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ABSTRACT

Propagation through cuttings of *Prunus armeniaca* – a tree borne oilseed of mid hills and dry temperate regions in India was tested by using three treatments. Vegetative propagation provides the opportunity in multiplication by cuttings by providing true-to-its-type plant and producing superior individuals. Effect of length and diameter, type and concentration of auxin and incubation method and duration on rooting of cuttings in wild apricot was studied. The study concluded that the optimal condition for rooting percentage in *P. armeniaca* is maximum using the incubator for 18 days on cutting length of 15 cm and cutting diameter of 1.0-1.5 cm after the application of IBA @ 5000 ppm. The survival percentage was also enhanced from 50.00 % to 53.33 % when cutting length of 15 cm and cutting diameter of 1.0-1.5 cm with IBA @ 5000 ppm incubated for 18 days at 30^{o}C.

INTRODUCTION

Wild apricot was cultivated in China from about 3000 BC and Central Asia is its center of origin and also includes other wild and cultivated apricots (Vavilov, 1951). Distribution of wild forms and allied species is between 33 and 70^{o}E longitude and 53 and 30^{o}N latitude which cover the temperate zone of Asia (Kostina, 1936). In India, it is an important fruit and tree borne oilseed in dry temperate regions of North-Western Himalayas.

On a usual basis, it acts as a pioneer species in the course of community succession in deforested area (Zhibin *et al*., 2001) and also an important multipurpose tree in the region under existing system of agroforestry (Singh and Chaudhary, 1993).

The oil extracted from seeds has number of utilizations in cosmetics, pharmaceutical agent for various diseases, tumors and ulcers (Rieger, 2006). The seed yields 27 per cent of kernels and the kernels yield about 44.3 per cent oil. Oil contains around 94 per cent of unsaturated fatty acids (Gandhi *et al*. 1997) and 75 per cent oleic acid (Aggarwal *et al*.1974) and linoleic acids. It is also utilized for cooking, body massage and as a raw material for cosmetic and pharmaceutical industry (Hegde *et al*. 2012). Moreover, the amygdalin or vitamin B17 are reported in this fruit and was isolated in the year 1830 and used in 1845 to treat cancer in Russia. It is also helpful for preventing and treating asthma, cough, constipation, migraine, hypertension, chronic inflammation, and other reaction source diseases and for the treatment of cancer, to improve

cerebral function (Milazzo *et al*. 2006). The delicious fruit can be consumed fresh and can also be processed to juice, jam, and dried fruit in smaller amount (Schmitzer *et al*. 2011).

It is mainly propagated by seeds and rarely by vegetative means. The yield varies from year to year due to its inadequate fruit set and /or excessive fruitlet abscission. Extreme temperatures, wet or windy weather at or around blooming time can, by impeding pollen germination, tube growth and bee activity (Vasiliakis and Porlingis, 1984) are responsible for its reduce fruit set. This brings the significance of multiplication of trees through cuttings. Vegetative propagation is widely used to improve yield and quality and circumvent some of the biological problems hindering reforestation (Leakey, 2014).This technique is being increasingly applied in tree improvement programmes. Webster (2010) gave three principal considerations for successful propagation. First, the propagule must be healthy and in the appropriate physiological condition, second the cutting may need physical or chemical treatment to aid its rooting and, finally, the cutting must be placed in an environment conducive to survival, root induction, and/or root development. For root biology, cellular characteristics of root require long standing observations for the hidden half of the plant body (Waisal *et al*. 2002). The success of vegetative propagation depends upon proper environment, the genetic components and the physiological status of cuttings, etc. (Kristiansen *et al*. 2005; Cunningham, 2001).

2.MATERIAL AND METHODS

2.1 Propagation method and cutting establishment

The location as a cutting source for wild apricot was identified before cutting collection and initiation of experiments in *Chakrata* (Uttarakhand). At the same time according to the model described by Leakey, 1990, four non-mist propagating units were constructed having dimensions of 2.5×1.25× 0.5 m. The racks were filled with stones, coarse and fine grained gravel and sand. Fine grained sand acted as the rooting medium which remained saturated with water all the time through capillary action. Before filling the racks with materials and substrates, the racks were cleaned. UV-stabilised plastic sheet that covered the chambers from sides and top, conserved water vapours, thereby maintaining high humidity condition inside the chamber. A green agro-shade net (25 per cent light permeability) was stretched over the non-mist propagation chambers at 3 meter height during April to July in order to reduce the rise in temperature inside the chambers. To minimize the fungal attacks, Bavistin solution at 0.025 percent concentration was sprayed on the branch cuttings and shoot sprouts every alternate week throughout the experiment. A separate experiment was conducted to evaluate the rooting percentage performance with the change in the propagation environment. Three propagation environments were considered namely: nursery bed, non-mist propagation chamber and polyhouse. The best performance in terms of rooting ability was observed in non-mist propagation chamber and that is why the rest of the experiments were conducted in same environment in order to get best results in rooting response in *Prunus armeniaca*.

The period of collection of branch cuttings were Mid-February. A gap of 6-7 cm was kept between adjacent cuttings. Moreover, the technique used for insertion vertically is that the cuttings were gently pressed into sand so that the one-third part of the cutting protruded out of sand. The cuttings were regularly watered as and when required to moisten the sand. The experiments were conducted for eight weeks in the non-mist propagation chambers. All the cuttings where callus formation and rooting was observed on the day of observation were removed with the help of bamboo stick. Removal of rooted cuttings was carried out repeatedly

at weekly intervals and this operation continued up to the end of ten weeks. The temperature and relative humidity were monitored inside the non-mist propagation chamber by hygrometer and themometer. Values for these two parameters ranged from 15ºC (night) to 39ºC (day) and relative humidity ranged from 96-98%. Pilot experiment was conducted to observe the combined effect of diameter and length of branch cutting with the type and concentration of the auxin. The success was observed with 5000ppm IBA and the full fledged study was also taken in a reverse manner for the cross verification of the results.

2.2 Experimental Design

2.2.1 Effect of length and diameter on rooting of cuttings in wild apricot

Four trees were selected on the basis of phenotype and fruit yield from each site were used in this experiments. Branch cuttings of three levels of length (10cm, 15cm and 20cm) and diameter classes (0.5 - 1.0 cm, 1.0 - 1.5 cm and 1.5 - 2.0 cm) were selected. The donor plants from Chakrata were approximately 22 years old plants. Factorial completely randomised design was followed in ten cuttings for each replication on February 10, 2014. Three replicates for each treatment were selected to investigate the rooting ability of combination made from length and diameter of branch cuttings made a total of 270 cuttings.The cuttings were firstly treated with Bavistin by dipping them in 1% solution for 30 minute. Thereafter, IBA growth regulator was applied in powdered formulation to the basal one centimetre portion of cuttings. Growth regulator namely IBA having concentration of 5000 ppm was used for treatment of cuttings as it was found best rooting hormone in the other experimental trials on *Prunus armeniaca*. Excessive hormone was removed by gently tapping the basal portion of cuttings.

The cuttings were observed on weekly basis for the sprouting. Once the cuttings had sprouted, the length of sprouts, number of sprouts, and number of leaves was recorded at weekly intervals.

2.2.2 Effect of type and concentration of auxin on rooting of cuttings in wild apricot

Investigation was further verified when type and concentration of auxin was treated with the most responded length and diameter dimension resulted from the first experiment when inserted vertically in non-mist propagation chamber. Indole-3-acectic acid (IAA) and Indole-3-butyric acid (IBA) were used in this experiment. Split plot design was used in where main plot was attributed to type of auxin and concentration (0 ppm, 2500ppm, 5000ppm and 7500ppm) were allocated to sub-plots and replicated 3 times. The treatments were prepared in dry formulation by mixing the IBA and IAA in talc powder and in 0 ppm was used as control where simple talc was used as a control. Each replication consisted of 10 cuttings giving a total of 240 cuttings. Allocating concentration of auxin to subplots was aimed for obtaining higher precision for this factor than the main effect (Jones and Nachtsheim 2009). The cuttings were first treated with Bavistin by dipping them in 1% solution for 30 minutes. Further same observations were taken as in the above experiment.

2.2.3 Effect of incubation method and duration on rooting of cuttings in wild apricot

The best results achieved from both the above experiments were treated with incubation environments (incubator and outdoor pit) and duration (0, 3, 6, 9, 12, 15, 18 and 21 days) at 8 levels. Randomised complete block design was applied and replicated three times and each replication consists of 5 cuttings making a total of 480 cuttings.

For incubation in incubator, colourless polythene bags of size 60 cm x 35 cm and river sand were taken. Sand was moistened with tap water (sand 8: water 1 v/v) and filled in polythene bags to 20

cm height. Ten branch cuttings, loosely tied in two bundles of five cuttings each, were placed vertically in the middle of each polythene bag. More sand was filled inside the polythene bag so that sand was there all around the branch cuttings as well as on top of the cuttings to approximately 5 cm height. The polythene bag was tied with *sutli* at the top to close it making a dome-shaped space of about 10 cm height for air. Twenty holes were made with a pointed rod of 5 mm diameter in the dome shaped area to allow exchange of air between cuttings and outside. Ten polythene bags, prepared with this procedure, were kept in incubators. The temperature in the incubators was set at 30^{o}C having 55 per cent humidity. On alternate days, the polythene bags were opened, 50 ml water was sprinkled over sand inside each polythene bag to keep the incubation medium moist and the bags were closed immediately.

For incubation in outdoor pit, a pit was dug in the nursery area during last week of January 2015. The ground layer was filled with sand up to 15 cm. Ten branch cuttings, loosely tied in two bundles of five cuttings each were placed vertically in the middle of sand. Sand was moistened with tap water (sand 8: water 1 v/v) and filled in polythene bags to 20 cm height. A polythene sheet was used to seal the pit. Watering was done every week up to 21days of incubation.

After the cuttings had been incubated for scheduled days mentioned above and maximum of 21 days, they were removed and planted in the non-mist propagation chambers. Appropriate type and concentration of auxin (resulted from above experiment). Further the above observations were made as in the above experiments.

2.3 ***Data Collection and Analyses***

After rooting, data was collected following 8 weeks in the non-mist propagation chamber which included sprouting and rooting percentage, percent survival, number of roots, root length. Root length was measured with a scale. It was referred to be rooted by the presence of minimum >1mm in length. Thereafter, the rooted branch cutting was removed and planted in polythene bag of size 22 cm x 13 cm having sand 2: soil 1: FYM 1(v/v) for hardening. In addition to the rooting, percent survival was also taken for all the cuttings.

Before the data is subjected to analysis of variance in Statistica 5.0 software, normalization of data was checked. The data was compounded in counts and then the square root transformation and arcsine transformation were employed accordingly. Nonparametric tests (the Kruskal-Wallis one-way analysis of variance by rank and the Mann-Whitney *U* test) were used for comparing mean length of roots (Siegel, 1956). This was performed as the data did not fulfil the assumptions of parametric tests. Kruskal-Wallis one way analysis of variance by ranks was used to determine if there are statistically significant differences between 2 or more groups of independent variables. Mann-Whitney test was done to compare the differences between two independent groups.

Under multivariate test, means of different parameters were compared if exhibited significantly at 5 per cent level. They are further compared using Tukey's multiple comparison tests. Tukey's post hoc test was performed by the procedure described by and Zar (2007).

$$T = q.\sqrt{\frac{MSE}{n}}$$

q= constant (Studentized range q table)
MSE= mean square within
N= number in each category (n for one condition)

3. Results and Discussion

3.1 *Effect of length and diameter on rooting of cuttings in wild apricot*

Different sprouting rates were obtained for the cuttings treated with different length and diameter classes in Table 1 and with different type and concentration of auxin in Table 2. From table 1 the interaction between length and diameter when treated with 5000 ppm IBA revealed the significant differences in sprouting percentage. Maximum (60.00%) sprouting was showed by 15 cm length (L2 class) and 1.0-1.5 cm diameter (D2 class) followed by 15 cm length (L2) having diameter 1.5-2.0 cm (D3 class) with 53.33 per cent after 29 days of planting. The minimum sprouting percentage (16.70%) was found in 10 cm length (L1) and 0.5-1.0 cm diameter (D1) class. Similarly on rooting percentage, significant effect ($p<0.05$ level) of cutting diameter and length after 64 days of planting on the branch cuttings was observed. The maximum was observed (45.00%) in 1.0-1.5 cm diameter and length of 15 cm. Minimum per cent rooting was recorded in 0.5-1.0 cm diameter and 10 cm length (13.33%). The higher number of roots and length of rooting was recorded on thicker branch cuttings. Thus, maximum number of roots (1.80) and root length (4.21 cm) was found significantly higher in branch cuttings of length 15 cm (L2) and 1.0-1.5 cm diameter class (D2) and minimum number (0.20) and root length (0.21 cm) was found in 10 cm length (L1) and 0.5-1.0 cm diameter (D1) class. Two way interaction effect on survival percentage of branch cuttings after 70 days of planting showed significant effect. The maximum survival percentage was found in length 15 cm (L2) and 1.0-1.5 cm diameter (D2) class (50.00%) followed by 15 cm length (L2) and 1.5-2.0 cm diameter (D3) class (40.00%). Both were on par with each other. The minimum (10.00%) was observed in length 10 cm (L1) and 0.5-1.0 cm (D1). Moreover, length 10 cm (L1) and diameter class 1.0-1.5 cm (D2) showed on par values (30.00%) with length (L3) 20 cm and diameter 1.5-2.0 cm (D3) class having 33.33 per cent.

Table 1. Effect of length and diameter classes on stem cuttings of *P.armeniaca*.

Length	Diameter	Percent Sprouting	Per cent rooting	Number of roots /cutting	Root length/ cutting (cm)	Per cent survival
L1 (10 cm)	0.5-1.0 cm (D1)	16.70 (14.70)^{a}	13.33 (11.73)^{a}	0.20 (1.55)^{a}	0.21 (3092.0)^{c}	10.00 (8.80)^{a}
	1.0-1.5 cm (D2)	40.00 (35.30)^{abc}	33.66 (29.62)^{ab}	0.50 (2.28)^{ab}	2.00 (3859.0)^{c}	30.00 (26.44)^{ab}
	1.5-2.0 cm (D3)	24.10 (20.60)^{ab}	23.33 (20.53)^{ab}	0.23(1.67)^{a}	0.44 (3338.0)^{c}	13.33 (11.73)^{a}
L2 (15 cm)	0.5-1.0 cm (D1)	20.00 (17.60)^{ab}	20.00 (17.60)^{ab}	0.36 (2.01)^{a}	0.67 (3428.0)^{c}	16.66 (14.66)^{a}
	1.0-1.5 cm (D2)	60.00 (52.80)^{c}	53.33 (46.93)^{d}	1.80 (4.27)^{c}	4.21 (5871.0)^{a}	50.00 (44.00)^{b}
	1.5-2.0 cm (D3)	53.33 (47.00)^{bc}	45.00 (39.63)^{cd}	1.26 (3.59)^{bc}	3.11 (5292.5)^{b}	40.00 (38.10)^{b}
L3 (20 cm)	0.5-1.0 cm (D1)	33.30 (29.40)^{abc}	33.33 (29.33)^{ab}	0.66 (2.61)^{ab}	0.89 (3778.5)^{c}	16.66 (14.66)^{a}
	1.0-1.5 cm (D2)	36.70 (32.30)^{abc}	36.66 (32.26)^{ab}	0.63 (2.59)^{ab}	1.92 (3850.0)^{c}	26.66 (23.46)^{a}
	1.5-2.0 cm (D3)	40.00 (35.30)^{abc}	40.00 (35.20)^{bc}	0.70 (2.70)^{ab}	2.19 (4076.0)^{c}	33.33 (29.33)^{ab}
F/Z-value		4.02	4.63	9.51	49.72	5.29

p-value	<0.05(S)	<0.05 (S)	<0.05 (S)	<0.05 (S)	<0.05 (S)

Means followed by same letter(s) in the same column are not significantly different at p<0.05. Values within parentheses are the square root and arc sine transformed values.

3.2 *Effect of type and concentration of auxin on rooting of cuttings in wild apricot*

The cuttings treated with IBA @ 5000 ppm (60.00%) showed significant higher sprouting percentage followed by 7500 ppm (43.00%) influence at p<0.0.5 level on sprouting percentage up to 29 days of planting. Rooting behaviour of branch cuttings when treated with IBA generally found greater than IAA and control treatment. The interaction of different type of auxin and concentration showed significant effect and maximum rooting percentage was observed in IBA 5000 ppm (54.00%) followed by IBA 2500 ppm (46.70%) and then by 7500 ppm of IBA and IAA (40.00%). The maximum number of roots was observed by IBA 5000 ppm (3.20), followed by IBA 7500 ppm (1.60) and decreased to 0.43 in untreated (control) branch cuttings. Similar results were also observed on root length where maximum was recorded in IBA 5000 ppm with 4.32 cm length followed by 7500 ppm IBA (3.03) cm) and control (untreated) cuttings recorded the least (1.27 cm). The survival varied and ranged from maximum of 45.00% per cent in IBA 5000 ppm followed 2500 IBA (36.70%) and decreased to 10.00 per cent in untreated cuttings.

Table 2. Effect of auxin type and concentrations on stem cuttings of *P.armeniaca*

Types of auxin	**Concentration**	**Sprouting percentage**	**Percent rooting**	**Number of roots/cutting**	**Length of longest root (cm)**	**Per cent survival (%)**
IAA	0 ppm (C1)	30.00 (26.40)[b]	25.33 (22.58)[c]	0.43 (0.96)[b]	1.27 (1.33)[b]	13.33 (14.66)[b]
	2500 ppm (C2)	36.70 (35.20)[a]	36.70 (32.30)[b]	0.60 (1.04)[b]	2.33 (1.68)[b]	30.00 (26.40)[b]
	5000 ppm (C3)	36.00 (32.30)[b]	33.66 (32.26)[b]	0.60 (1.04)[b]	3.00 (1.87)[b]	26.70 (23.50)[b]
	7500 ppm (C4)	40.00 (35.20)[b]	30.00 (26.40)[b]	0.57 (1.03)[b]	3.00 (1.87)[b]	30.00 (26.40)[b]
IBA	0 ppm (C1)	25.03 (22.04)[b]	23.10 (20.00)[b]	0.40 (0.96)[b]	1.27 (1.33)[b]	10.00 (8.80)[b]
	2500 ppm (C2)	46.70 (41.10)[a]	40.00 (35.20)[a]	0.63 (1.06)[b]	2.45 (1.71)[b]	36.70 (32.30)[b]
	5000 ppm (C3)	60.00 (52.80)[a]	54.00 (52.07)[a]	3.20 (1.92)[a]	4.32 (1.29)[a]	45.00 (39.63)[a]
	7500 ppm (C4)	43.00 (38.10)[a]	40.00 (35.20)[a]	1.60 (1.44)[b]	3.03 (1.87)[a]	23.33 (20.50)[b]
F-value		4.24	3.51	4.15	6.46	3.46
p-value		<0.05 (S)	<0.05 (S)	<0.05 (S)	<0.05 (S)	0.05 (S)

Means followed by same letter(s) in the same column are not significantly different at p<0.05. Values within parentheses are the square root and arc sine transformed values.

3.3 ***Effect of incubation method and duration on rooting of cuttings in wild apricot***

Interaction of incubation environment and duration exhibited significant results with sprouting percentage ranged from 60.00 per cent in 18-day incubation in incubator to 20.00 per cent in 3-

day incubation duration. Similarly, in outdoor pit, maximum sprouting percentage was observed to be 50.00 per cent in 6-day incubation and minimum was 0.00 per cent from 12 to 21 days and was found to be even less than control treatment (23.33%).

The rooting percentage of branch cuttings with respect to incubation duration and environment showed significant effect. Rooting percentage at 18 days ranged from maximum 60.00 per cent rooting in incubator to minimum 0.00 per cent in branch cuttings incubated in the outdoor pit for 21 days. The number of roots produced from each cutting revealed maximum (1.36) in incubator on 18- day and minimum (0.26) on 3-day. On the contrary, the number of roots decreased in outdoor pit as the number of incubation days increased. The maximum (0.90) was found on 3- day and minimum was observed from 12-21 days to 0.00 during incubation process. Interesting to note that number of roots in control treatment was found between 0.68-0.70 and was more than cuttings when incubated in outdoor pit for longer time and vice versa in incubator. The highest root length was observed in 18 days (5.21 cm) and lowest in 3 days (1.97 cm) in incubator. Whereas in outdoor pit the highest (4.02 cm) was recorded in 6 days and lowest (0.00 cm) from 12 to 21 days. The survival percentage was found maximum in 18 days (53.33 per cent) and minimum in 3 days (13.33%). Whereas, in outdoor pit, the maximum per cent survival was found in 6 days (36.66 %) and minimum (0.00%) was from 12-21 days.

Table 3. Effect of incubation environment and duration on stem cuttings of *P.armeniaca*

Incubation environment	Incubation duration	Sprouting percentage	Percent rooting	Number of roots/cutting	Length of longest root (cm)	Per cent survival (%)
Outdoor pit	0 days	30.00 (26.40) abc	23.33 (20.53) ab	0.70 (1.09) bcd	3.45 (7668.0) c	23.33 (20.53) ab
	3 days	26.66 (14.66) abc	26.66 (23.46) ab	0.90 (1.18) cd	2.38 (6196.0) c	13.33 (14.66) a
	6 days	50.00 (44.00) cd	46.66 (41.06) ab	0.43 (0.96) bc	4.02 (8096.0) b	36.66 (32.26) ab
	9 days	46.66 (41.06) bcd	46.66 (41.06) ab	0.26 (0.87) ab	3.26 (7606.0) c	33.33 (29.33) ab
	12 days	0.00 (0.00) a	0.00 (0.70) a	0.00 (0.70) a	0.00 (6302.0) c	0.00 (0.70) a
	15 days	0.00 (0.00) a	0.00 (0.70) a	0.00 (0.70) a	0.00 (6302.0) c	0.00 (0.70) a
	18 days	0.00 (0.00) a	0.00 (0.70) a	0.00 (0.70) a	0.00 (6302.0) c	0.00 (0.70) a
	21 days	0.00 (0.00) a	0.00 (0.70) a	0.00 (0.70) a	0.00 (6302.0) c	0.00 (0.70) a
Incubator (IN)	0 days	25.00 (21.99) abc	23.33 (20.53) ab	0.68 (1.08) bcd	3.04 (7559.0) c	15.00 (12.14) ab
	3 days	20.00 (17.60) abc	20.00 (17.60) ab	0.26 (0.87) ab	1.97 (5866.0) c	13.33 (11.73) a
	6 days	36.66 (32.26) abc	33.33 (29.33) ab	0.56 (1.02) bc	2.89 (7010.0) c	26.66 (23.46) ab
	9 days	36.66 (32.26) abc	36.66 (32.26) ab	0.50 (1.00) bc	2.96 (7159.0) c	26.66 (23.46) ab
	12 days	36.66 (32.26)	30.00	0.40 (0.94) bc	2.77 (6215.0) c	23.33

		[abc]	(26.40) [ab]			(20.53)[ab]
	15 days	36.00 (32.20) [ab]	30.00 (26.4) [ab]	0.63 (1.06)[bcd]	3.10 (7323.5) [c]	33.33 (29.33) [ab]
	18 days	60.00 (52.80)[d]	60.00 (52.80)[b]	1.36 (1.36)[d]	5.21 (9300.0)[a]	53.33 (46.93)[b]
	21 days	30.00 (26.40) [abc]	30.00 (26.40) [ab]	0.43 (0.96)[bc]	2.36 (6191.0) [c]	16.66 (14.66) [ab]
F-value		6.78	5.89	27.65	49.37	3.89
p-value		<0.05 (S)	<0.05 (S)	<0.05 (S)	<0.05 (S)	<0.05 (S)

Means followed by same letter(s) in the same column are not significantly different at p<0.05. Values within parentheses are the square root and arc sine transformed values. Values within parentheses are mean root length.

Discussion

Our study proved that incubation for 18 days with IBA @ 5000 ppm having length of 15 cm and diameter of 1.0-1.5 cm cutting is an optimal condition for rooting of *P.armeniaca*. The interaction effect has brought a significant effect on the rooting performance and survival on the growth of the cuttings. Root formation is a complex process involving a series of anatomical, physiological and biochemical events (Hartmann *et al*. 2010). A similar result was reported by Chalapathi *et al*. (2001); Bagoury *et al*. (2006); Ullah *et al*., 2012; Divakara *et al*. (2010) and Meunier *et al*. (2008). The findings also agree with the work of Keeley *et al*. (2004) worked on *Vitis aestivalis* and Chandregowda *et al*. (2006) on *Thymus vulgaris*. This was possibly because of early root initiation in longer cuttings which provided greater time for their growth and development. The higher food reserve in longer cuttings could be another reason for their better growth and development of the cuttings. Further evidence showed that a cutting's storage capacity of carbohydrates is an important determinant of rooting in stem cuttings of *Eucalyptus grandis* (Hoad and Leakey 1996).

Exogenous auxin helps in intensifying the root formation process. The ability of IBA to promote adventitious root development in branch cuttings is well known, and has been associated with enhanced transport of carbohydrates to the base of the cutting (Hartmann *et al*., 2010). Auxin influences polysaccharide hydrolysis resulting in increased content of physiologically active sugar needed to provide energy for meristematic tissues; this is followed by root primordia and root formation as reported in *Tectona grandis* (Husen and Pal 2007) and *Dalbergia sissoo* (Husen 2003). IBA which is a synthesized auxin that increases rooting and is even more effective than IAA (Kovar and Kuchenbuch, 1994). It may be attributed to IBA activity which might have caused hydrolysis and translocation of carbohydrate and nitrogenous substances at the base of cuttings and accelerated cell elongation and cell division in suitable environment (Singh and Negi, 2014) Leopold (1964) concluded that auxin played a role in physiological processes and development, requiring other substances as rooting co-factors that would stimulate rooting, a fact also observed by Weaver (1982). Auxin endogenous concentration varies over the course of rooting phases, and is needed at higher concentration during the induction phase for proper rooting (Keever *et al*., 1997) which can be supplied exogenously. IBA is involved in other auxin-mediated developmental processes, such as leaf epinasty, cell division, stem bending (Zimmerman and Wilcoxon, 1935), root hair elongation (Strader and Bartel, 2009), and cell expansion in cotyledons (Strader *et al*., 2010).

Incubation of branch cuttings at 35^{o}C has been reported by various workers to be suitable for root induction in plant species (Joeright *et al*., 2001 and Enfield, 2002). This is in harmony with the results of the present study where the incubation environment played a role due to

temperature and greater survival was found in incubator (higher temperature) than in outdoor pit. Zhu *et al*. (1986) and Zhu (1996) have recommended 'healing' (*i.e.* callusing) of stem cutting in sun-heated beds before planting so as to accelerate growth and formation of root and bud primodia.

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