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Effect of potting media, time of collection of planting material, type of cuttings and auxin in bud sprouting and rooting of *A. malaccensis* Lamk: The most economically important tree species of north eastern region

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Abstract
Present investigation was carried out to determine the successful vegetative propagation of *Aquilaria malaccensis* to study the effect of best potting media, time of planting material collection, effect of different hormonal concentration and type of cuttings for bud sprouting and rooting. In potting media selection where, best budding (25.75±0.83) recorded in 500ppm IBA followed by (18.25±0.83) in 500ppm NAA from hard cuttings in coarse sand. Cuttings in potting media coarse sand treated with different hormones *viz.* IBA, IAA and NAA solution in six different combinations showed distinct variations in bud sprouting and rooting of the cuttings. Cuttings collected from Titabar area of Jorhat district were showed best results in bud sprouting from hard cuttings (7.75±0.83) of 500 ppm NAA followed by (3.75±0.43) in 500 ppm IBA. The potential of propagation of the species through hard cuttings showed best rooting (40%) 200ppm IBA and (33%) in 200ppm NAA respectively. Highest number of rooting and survivality was recorded in the hard branch cuttings collected from Titabar area of Jorhat district under nursery condition. However, the highest survival percentage (75-80%) was observed in the rooted cuttings transplanted in soil: sand: FYM with IBA and NAA respectively.

Keywords: Bud sprouting, rooting, hard cutting, nursery, incubation condition

Introduction

Aquilaria malaccensis Lam. locally known as *'Sasi'* is a most commercially essential non timber tree species of Southeast Asian tropical forests. Its height grows up to 15–25 m. The species is very valuable for its production of resinous heart wood for luxury perfume, fragrance and soap manufactures etc. and largely for perfume industries (Anonymous, 1948) [4]. It is found growing naturally in the forests of north east India, mainly in lowland and on hillsides between altitudes of 100 m up to 500 under high humid, sub-tropical climate with rainfall 1800-3500 mm per annum. Among the fifteen species of the genus found, eight are known to produce agar wood (Ng *et al.* 1997) [56]. The most valuable species namely *A. malaccansis* are available in the north eastern states of India (Giri, 2003) [24]. The distribution was reported in Bangladesh, Bhutan, India, Indonesia, Iran, Malaysia, Myanmar, Philippines, Singapore and Thailand (Oldfield *et al.*, 1998) [59]. In India, it is confined to the north east region and mostly in the foot hills of Arunachal Pradesh and rocky terrain forests of Changlang, Lower Dibang Valley, Lohit and Papum Pare district (Tabin, 2012) [77] and also found in Manipur, Meghalaya, Mizoram, Nagaland, Tripura and West Bengal (Palit, 1996) [61]. In Assam, the tree is cultivated in the district of Sibsagarh, Golaghat, Nowgong, Darrang, Sadiya, Goalpara and in Garo Hills and Cachar. Comparing in the wild source natural population is decreasing rapidly and becoming endangered through uncontrolled harvesting against the demand for agar wood. As a result, it is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1994). The species is vulnerable according to the IUCN red list, and has been incorporated in the world list of threatened trees (Oldfield *et al.*, 1998) [59]. This species is also measured critically endangered in India (IUCN, 2009) and almost extinct in the wild in Assam (Anonymous, 2003) [5].

The tree is cultivated in the home gardens of upper Assam and contributes appreciably up to 20% of the total annual income of the family by selling the cut log with agar wood. Several researchers have reported on propagation of the species through seeds, that they are generally germinate readily after maturity (Kundu and Sett, 2005) [45] however, recalcitrant in nature and their rate of germination decreases with the increase in the period of storage (Kundu and Kachari, 2000) [44]. Viability period is only 15 days after this time which is gradually decreases (Saikia 2011 [68], Shankar 2012 [70], Ahmad and Gogoi, 2000) [1]. Hence, recalcitrant nature of seeds along with short term viability of the species is determined for propagation is through vegetative means.

As reported, the rooting of cuttings through vegetative means is one of the most expanded and efficient method of propagation (Awan *et al.* 2012) [7]. Adventitious root development is the key step, which contains root induction, root initiation and projection related to the emergence of root primordial (Berthon *et al.*, 1990; Heloir *et al.*, 1996) [8, 36]. In forestry species, vegetative plant parts selected from natural populations are widely used in breeding programs for multiplication to obtain elite plants (Hartmann *et al.* 1990) [31, 32]. When media contains proper environment like good aeration, proper water and sufficient nutrient availability then it helps to develop excessive roots system and results in excellent plant growth (Neelam and Ishtiaq 2001) [53]. Davies and Hartman, 1988 [16] stated that propagation through cutting is the most economical method of vegetative propagation. The basic initial planting material is also considered an essential necessity of a crop for both its development of quality and quantity, is reported by Singh *et al.* 2005 [71]. Geiss *et al.* 2009 [23], Li *et al.* 2009 [48], da Costa *et al.* 2013 [14] in his studies reported that, besides auxin, light, temperature and mineral nutrition are the most important factor. Cuttings can also develop adventitious roots spontaneously without exogenous auxin supply i.e. without hormone as for example in *Pisum sativum* and *Populus* spp (Nordström and Eliasson 1991, Rigal *et al.* 2012) [57, 65]. However, auxins have emerged as a central player in stimulating roots formation of cuttings in different species and there are the most convincing evidences that auxins are essential for root development (Hartmann and Kester 1982) [35].

Keeping in view of these above findings, present study was targeted with various experiments to standardize the best potting media, concentration of different rooting hormones, type of cuttings as well as best season for collection of planting materials for maximum bud sprouting and rooting ability under different environmental conditions. Hence, the present study was considered for the propagation, though rooting of cuttings as a fast, practically applicable and economic method of multiplication for this most economically important species *A. malaccensis*.

Materials and Methods

Experimental study was carried out during the period from January-September for two consecutive years in the nursery area located at the Rain Forest Research Institute, Jorhat Assam (26.7817° N and 94.2917° E). The study area has Tropical Monsoon Rainforest climate experiencing four distinct seasons: winter (December to February), spring (March to May), a mild summer (June to August) and a pleasant autumn (September to November). The summer temperature is around 30 °C but varies between 30 and 35 °C. Summer starts in mid May accompanied by high humidity and heavy rainfall and frequent rain sometimes reduces the temperature. The peak of the monsoons is during June.

In order to work out the experimental trials for sprouting and rooting of various types of cuttings of the species, branches were collected from 6-8 years old trees from three different places namely Titabor (Jorhat district), Namti (Sibsagarh district) and Nahoroni (Golaghat district). As they were collected in the dry season, prepared cuttings were leafless. Collection was done in the morning time to avoid high sunlight, heat and carried to the experimental area i.e. the nursery field of RFRI, Jorhat, Assam on the same day for preparation of cuttings. Before that each branch was waxed up at the basal and proximal ends at the collection time. Cuttings are kept in moist gunny bags after collection in order to keep them turgid and kept them in shaded fresh conditions. The nursery area was covered with agro shed to check full sunlight. Before starting of preparation of all were thoroughly washed with tap water and quickly dipped in Bavestine with 1g per liter of water solution to avoid any fungal infection for 2 min and kept in open air for 5 min. After this, cuttings were prepared for length and girth as per the requirement for the different experiments and waxing was done on the upper part of all cuttings. Hence, exogenously applied auxins have a predictable and consistent effect across plant species in inducing adventitious rooting so different hormones solutions were prepared and treated with the cuttings. Plant growth regulators were prepared in liquid form using absolute ethyl alcohol which was diluted to 50% with distilled water. These solutions were prepared by using solvent and volume make up was completed by adding distilled water for IBA (Indole 3-butyric acid), NAA (Napthalene - acetic acid) and IAA (Indole 3- acetic acid) and without hormone i.e. untreated set of cuttings (control) dipped in tap water. Different types of cuttings namely hard and semi hard cuttings were planted in poly bags (7x9 inch) whereas the tender cuttings were planted directly in the nursery beds and in poly tunnel filled up with coarse sand and all are kept under nursery condition provided with agro shed net.

Standardization of potting media

Initial experiment was conducted for selection of potting media for conducting the different experiments for sprouting and rooting of *A. malaccensis*. Where, three different potting media such as coarse sand, vermiculite and soil: sand: FYM (1:1:1) were used.

Branch cuttings

Semi-hard and hardwood cuttings were collected from the trees planted heavily in home stead garden in big plot from Titabar (Jorhat), Namti (Sibsagarh) and Naharoni (Golaghat district) of upper Assam (Fig. 1). After collection, branches were prepared in different size and length considering the experiments. Branch cuttings of length 18-20 cm and diameter 10-12mm, leaf less, each having 2-4 nodes were used during the trials. A total of seven treatments including control were considered for branch cutting trials as stated below.

- 200 ppm IBA, 200 ppm NAA, 200 ppm IAA,
- 500 ppm IBA, 500 ppm NAA, 500 ppm IAA,
- 1000 ppm IBA, 1000 ppm NAA, 1000 ppm IAA,
- 100 ppm IBA +100 ppm NAA
- 100 ppm NAA +100 ppm IAA
- 100 ppm IAA +100 ppm IBA
- Control (Without hormone)

For this trial, cuttings were planted in three different potting media such as a) coarse sand, b) sand: soil: FYM 1:1:1, c) vermiculite and observed for bud sprouting, percent of rooting, number of roots, root length etc. After 4 months cuttings were removed from the media and observation were recorded. All rooted cuttings were transplanted in poly bags filled with the prepared media Soil: Sand: FYM (1:1:1)) and kept under nursery condition.

Statistical methods

The design of all the experiments is conducted with three replications and 25 numbers of cuttings for each treatment were planted in CRD (Completely Randomized Design) with 3 blocks.

Results

Effect of potting media on sprouting in different treatments and type of cuttings

The experiment of potting media selection for bud sprouting, the results inferred in coarse sand for hard cuttings in IBA 500 ppm (25.75±0.83) showed best followed by 500 ppm NAA with (18.25±0.83**)** in the same potting media. Sand: Soil: FYM also possesses better results than the cuttings planted in vermiculite. In case of semi hard cuttings, results possess best in 500 ppm IBA (14±1.58) followed by 500 ppm of NAA (12.75±0.43).

Table 1: Effect of potting media on sprouting in different treatments and type of cuttings of *A. mallaccensis*

Hormone	Treatment (in ppm)	CS		S:S:FYM		vermiculite	
		Hard	Semi hard	Hard	Semi hard	Hard	Semi hard
IBA	0	15.25±0.83	5.25±0.43	0±0	3.25±0.43	0±0	0±0
	200	11±0.71	9±0.71	0±0	0±0	0±0	0±0
	500	25.75±0.83	14±1.58	11.5±1.12	0±0	0±0	0±0
	1000	17.5±0.5	11.5±0.5	1.5±0.5	6.25±0.43	0±0	0±0
	100IBA+100NAA	22.5±0.5	12.5±0.5	0±0	0±0	0±0	0±0
NAA	0	12.5±0.5	0±0	3.25±0.43	0±0	1.25±0.43	0±0
	200	7.5±0.5	3.75±0.43	5.5±0.5	0±0	0±0	0±0
	500	18.25±0.83	12.75±0.43	11.25±0.83	5.25±1.6	7.25±0.83	6.75±0.43
	1000	5.75±0.83	2.0±0.71	7.5±0.5	6.0±0.71	8.0±0.71	1.5±0.50
	100NAA+100IAA	6.25±0.83	3.5±0.5	7.0±0.71	5.75±0.83	0±0	0±0
IAA	0	11.5±1.12	9.5±0.5	4.5±0.5	0±0	0±0	0±0
	200	9.25±0.43	6±0.71	0±0	6.25±0.43	0±0	0±0
	500	7.25±0.43	5±0.83	3.75±1.25	1.75±0.43	0±0	0±0
	1000	13.5±0.5	11±0.71	1.25±0.83	0±0	0±0	0±0
	100IAA+100IBA	6.5±0.5	5.5±0.50	0±0	5.0±0.71	0±0	0±0

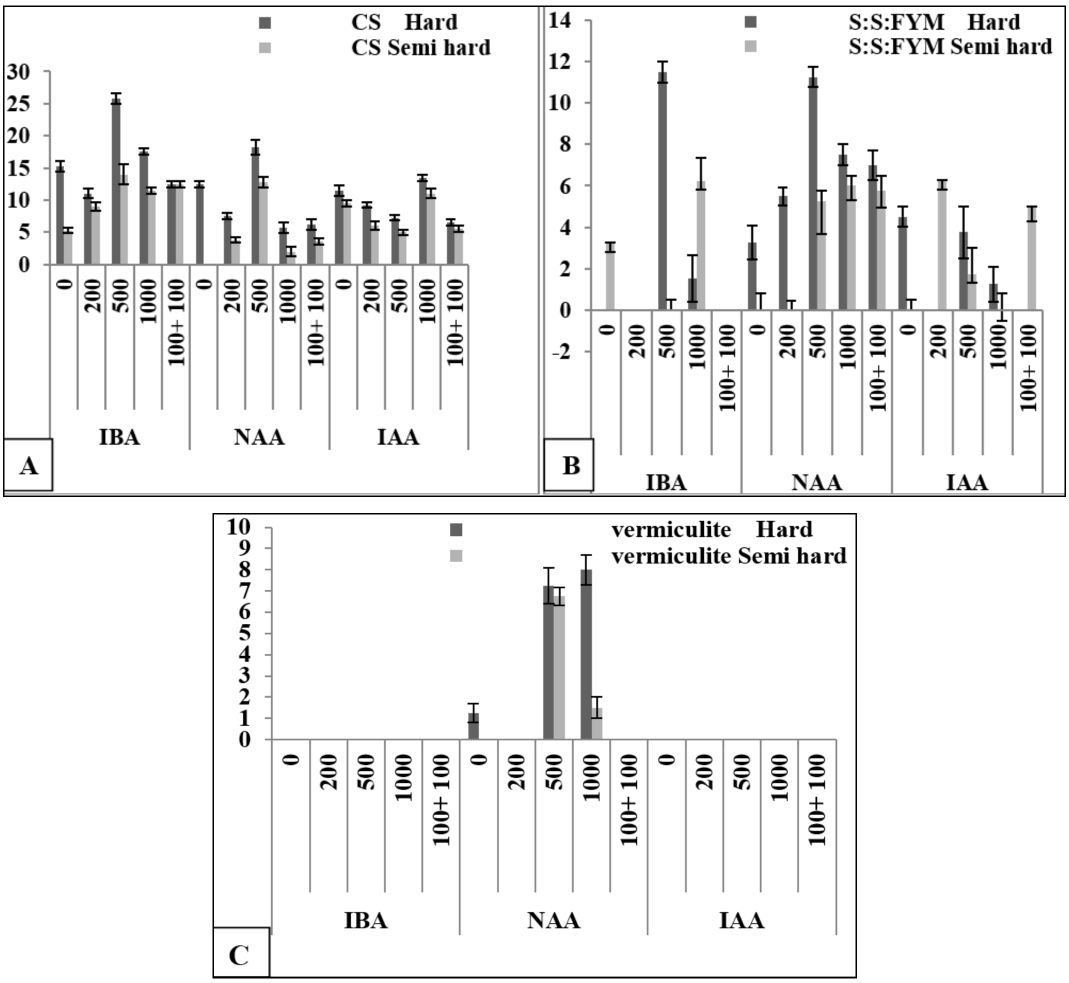

Fig 1: A, B, C. Effect of potting media on sprouting in different treatments and type of cuttings of *A. mallaccensis*

Initiation of bud sprouting was recorded after two weeks of planting of the cutting and data recorded for three month. Very healthy leaves were observed from hard cuttings in coarse sand media (Fig. 2). Vermiculite shows very poor results. Hence, for the future course of study coarse sand was selected as best potting media.

Effect on bud sprouting in respect to the place of collection and type of cuttings

Cuttings collected from three different places treated with different hormonal concentration on bud sprouting are presented in the (Table.2). Average percentage of bud sprouting from semi hard cuttings was recorded less.

Table 2: Effect on budding with respect to the place of collection and type of cuttings of *A. mallaccensis*

Hormone	conc. (ppm)	Jorhat,	Titabar	Golaghat, Nahoroni		Sibsagarh,	Namti
		Hard	Semi hard	Hard	Semi hard	Hard	Semi hard
IBA	0	2.5±0.5	0±0	1.5±0.5	0±0	1.25±0.43	0±0
	200	2.75±0.43	0±0	1.2±0.5	1.5±0.5	0±0	0±0
	500	3.75±0.43	1.75±0.4	1.75±0.4	0±0	0±0	3.25±0.8
	1000	2.5±0.5	1.5±0.5	1.1±0.8	1.25±0.8	2.25±0.8	2.25±0.8
	100IBA+100NAA	1.5±0.5	0±0	0±0	0±0	0±0	0±0
NAA	0	3.5±0.5	0±0	0±0	0±0	1.53±0.4	0±0
	200	3.5±0.5	0±0	1.5±0.5	0±0	0±0	0±0
	500	7.75±0.83	0±0	3.25±1.3	0±0	0±0	0±0
	1000	2.25±0.83	0±0	1.25±0.8	0±0	0±0	0±0
	100NAA+100IAA	1.5±0.5	0±0	0±0	0±0	0±0	0±0
IAA	0	1.25±0.43	0±0	0±0	0±0	0±0	0±0
	200	2.5±0.5	0±0	0±0	0±0	0±0	0±0
	500	1.0±0.71	0±0	1.25±0.8	0±0	0±0	0±0
	1000	1.75±0.43	0±0	0±0	0±0	0±0	0±0
	100IAA+100IBA	0±0	0±0	1.5±0.5	0±0	0±0	0±0

Cuttings collected from Titabar area of Jorhat district were showed best results in bud sprouting from hard cuttings (7.75±0.83) of 500 ppm NAA followed by (3.75±0.43) in 500 ppm IBA and in some of the experiments also in untreated cuttings. Semi hard cutting shows poor results almost in all the treatments. In view of places collected the planting materials, better results also observed Sibsagarh district and followed by Golaghat district. Bud regeneration was recorded usually after 14 days after planting. In the dry season February, it has been observed approximately 3-4 weeks later. Sprouting percentage may be affected by the place of collection, treatments and type of cuttings. While, in response of semi hard cuttings is very low in most of the treatments.

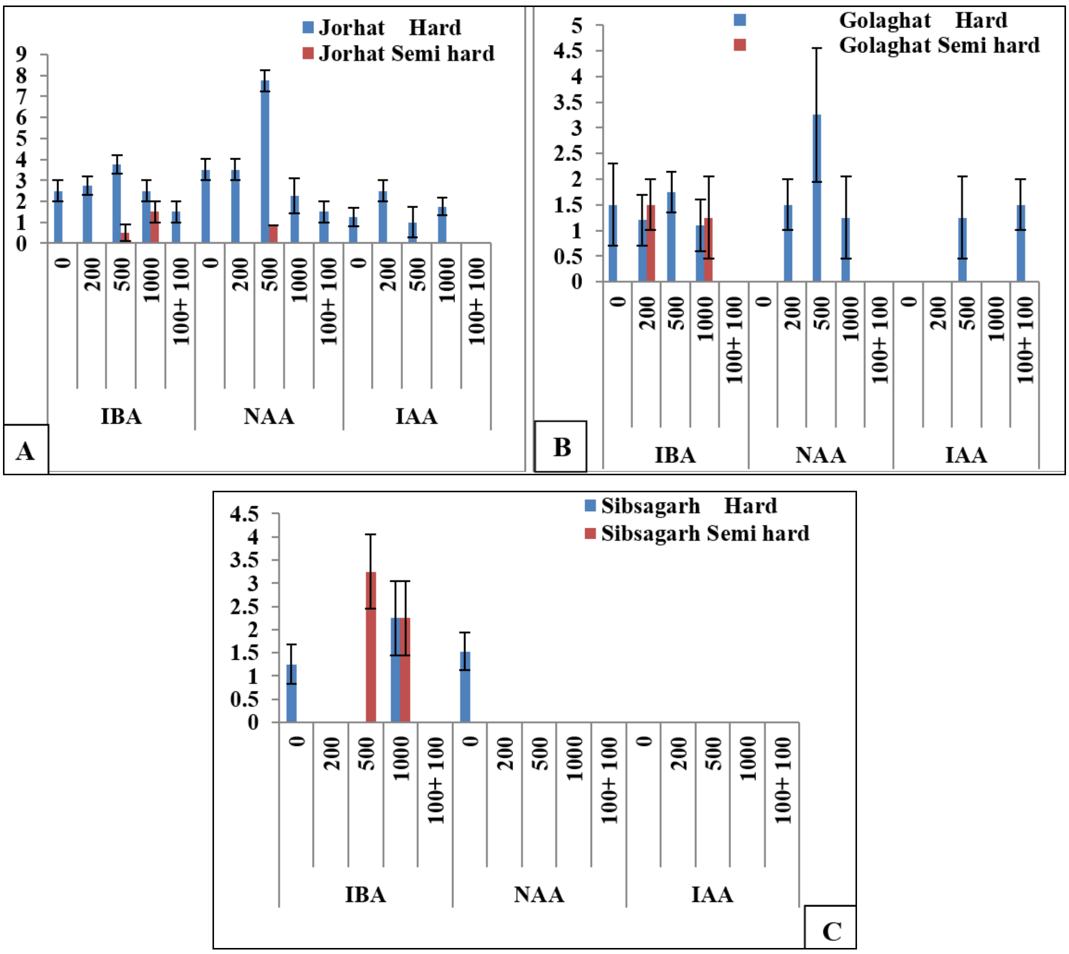

Fig 2: A, B, C. Effect on budding with respect to the place of collection and type cuttings of *A. mallaccensis*

Propagation through branch cuttings

The results of the experiments for the effects of time of collection, source of cuttings, auxin and their concentrations on number of roots per rooted cutting were presents in (Table 3). Percentage of rooted cuttings and number of roots per cutting differed among the type of cuttings. The species showed increased rooting when IBA was applied compared to the control, but sensitivity to applied IBA varied relative to the type of cutting. Cuttings attained higher rooting percentages from hard cuttings where semi hard cuttings were less responsive.

Table 3: Rooting of branch cuttings in different time of collection and type of cuttings of *A. malaccensis*

Treatment (in ppm)	January				February				March			
	Hard		Semi-hard		Hard		Semi-hard		Hard		Semi-hard	
	(%) of rooting	Root length in cm (no. of roots)	(%) of rooting	Root length in cm (no. of roots)	(%) of rooting	Root length in cm (no. of roots)	(%) of rooting	Root Length in cm (no. of roots)	(%) of rooting	Root length in cm (no. of roots)	(%) of rooting	Root length in cm (no. of roots)
IBA 200	0	0	0	0	14	3.1±1.4	0	0	40	3.6±1.3 (numerous)	10	2.4±0.67
NAA200	0	0	0	0	12	5.4±0.84	0	0	33	9.7±1.2 (07)	11	5.7±1.3
100 IBA + 100 NAA	0	0	0	0	5	3.1±0.61	0	0	10	2.5±.83 (numerous)	0	0
Control	0	0	0	0	0	0	0	0	5	0	0	0

Each value is a mean of 5 replicates

Overall, rooting percentages was recorded when sources of cuttings in coarse sand in the treatment 200ppm IBA was highest (40%0 followed by 200ppm NAA (33%) respectively. Rooting results also observed in 100 IBA + 100 NAA in compared to control. Cuttings collected in the month of March shows more effective than the other time of collection. In the month of January results recorded poor than February, shows better results of sprouting. Other auxin treatment shows very low response hence, the results not tabulated.

The results showed that numerous roots have been recorded from the cuttings treated with auxin IBA and long roots are from the NAA incorporating growth hormones. Cuttings collected during March and hardwood cuttings. No application of auxin (control) cause that cuttings had minimum rooting while collecting semi-hardwood cutting response is very less. Cuttings collected during the month of January data recorded of rooting showed very less. Root length was affected by the different type of auxin used. Variations being observed between the different types of auxin, where, IBA had more effective. Root length is long in hardwood cuttings treated with NAA and IBA showed lump of numerous roots with only 1-2 long roots. Bud sprouting developed per cutting was affected by rooting media. Best sprouting was observed in coarse sand and lowest roots in the vermiculite. Among IBA treatments, the highest roots per cutting were observed in the cuttings treated with 200 ppm and 200 ppm NAA and the lowest is without treatment. After 3-4 months cuttings had initiated roots and later months recorded did not increase. Majority of rooted cuttings developed bud sprouting and roots at the time of the first evaluation two weeks after planting. Maximum survival percentage (75-80%) was recorded in soil: sand: FYM.

Discussion

In vegetative propagation, sprouting and adventitious root development is the key step which contains root induction, root initiation and projection, related to the emergence of root primordial (Berthon *et al.*, 1990; Heloir *et al.*, 1996) [8, 36]. Hartmann *et al.*1990 [31, 32] reported that the physiological status of the mother plant is an important prerequisite in achieving a homogeneous rooting of cutting. He also reported (Hartmann *et al.* 2002) [34] the observation of seasonal changes strongly which affected the physiological status of mother plant that and it is an important pre requisite in achieving for budding and rooting of cutting. In the present study also exhibit the time of collection of cuttings in response to budding and rooting. In case of hormonal treatment, among the available auxins IBA is generally the most commonly used rooting hormone because of its higher root-inducing capacity compared with indole 3-acetic acid (IAA). Dharmasiri *et al.* 2005 and Kepinski and Leyser 2005 [18, 39] also reported that NAA showed the strongest rooting activity compared to the natural auxin IAA. Similar to our study (Oinam *et al.* 2011) [60] stated that depending on the species, the type of explants and the growth conditions IBA can be used alone or in combination with other auxins such as NAA for rooting of cuttings. In the current investigation effect hormonal concentrations of combination of NAA, IBA and combination of both shows sprouting and rooting success of cuttings. As, Stewart and Bannister 1973 [73], Taulavuori *et al.* 1997 [79] stated that the effect of temperature and precipitation changes during a year affect photosynthesis and carbohydrate content in all biochemical reactions of photosynthesis. Tolvanen A and Taulavuori K. (1998) [82] also reported that unless the temperature increase triggers growth to start many months earlier than normal. A wide variation in temperature between winter and summer is resulted in our study site and best response observed cuttings collected during the dry season. Taiz and Zeiger, 2010 [78] reported that when temperatures exceed on June and September photosynthetic rates decrease. Respiration rates also increase as a function of temperature and interaction between photorespiration and photosynthesis becomes apparent in temperature responses. In our present investigation, temperature and water which may also play an important role in capacity of rooting and survival rate of plants during hot summer. Rooting ability of cuttings has often been affected by the temperature of the plant environment prior to taking cuttings (Dykeman 1976, Worrall 1976, Hansen 1990) [21, 85, 30]. These results were further supported in studies that indicate time of collection as one of the major factors affecting in propagation of plant species (Klein and Hebbe 2000, Swamy *et al.* 2002, Bhardwaj and Mishra 2005, Haile *et al.* 2011) [43, 75, 76, 9, 27, 28]. In our results we also achieved good results in bud sprouting and rooting in the cuttings collected during dry season i.e. March. In case of root development some studies also indicate the larger diameter or older cuttings resulting in root development, growth stem and better survival (Dickmann *et al.*, Rossi 1999, Camp *et al.* 2011) [20, 12]. Rossi (1999) [66] showed affected both above ground biomass production and survival rate in *Salix*. Hartmann and Kester (1983) [33] stated that IBA could be used in a wide range of concentrations without giving toxic effect to the cuttings by inducing basipetal transport of assimilates with sink strength successively enhanced by increases in IBA concentration which increases in number of roots per rooted cutting which is consistent with the response of other tropical tree species such as *Triplochiton scleroxylon* (Leakey *et al.*1982), *Nauclea diderrichii* (Leakey 1990) *Cordia alliodora* and *Albizia guachepele* (Mesen 1993) [52]. IBA and NAA are commercially widely used to induce adventitious root in cuttings of many plant species and they were found to be more stable and effective in most cases (Ludwig-Muller *et al.* 2005, Rout 2006, Wei *et al.* 2013) [49, 67, 84]. This result incorporates with several studies that indicate high auxin application can produce toxicity and NAA are more toxic than IBA, so lower NAA concentrations than IBA concentrations should be selected (Zeng 1988) [86]. As similar to our result, Aminah *et al.*, 1995 [2]; Mesén *et al.*, 1997 [51]; Eganathan *et al.*, 2000 [22]; Negash, 2002, 2003 [54, 55]; Tchoundjeu *et al.*, 2002 [81]; Husen and Pal, 2007a [38] also reported on the positive response of rooting to IBA application and was observed where this auxin induced root development. Similar to our study higher root development found in cuttings from young rather than from mature trees has been reported in other species, such as *Prosopis cineara* (Arya *et al.*, 1994) [6], *Inga feuillei* (Brennan and Mudge, 1998), *Juniperus procera* (Negash, 2002) [55], *Argania spinosa* (Nouaim *et al.*, 2002) [58], *Robinia pseudoacacia* and *Grewia optiva* (Swamy *et al.*, 2002) [75, 76], *Backhousia citriodora* (Kibbler *et al.*, 2004a) [41] and *Ulmus villosa* (Bhardwaj and Mishra, 2005) [9]. The species growing in highly seasonal environments such as tropical forest, increased in temperature during spring when bud dormancy ends and favoring root development in leafless hardwood cuttings (Puri and Verma, 1996; Bhardwaj and Mishra, 2005; Kibbler *et al.*, 2004b, Haile *et al.*, 2011) [63, 9, 42, 27, 28]. Considering the collection time, Velazquez-Herrera 2011 reported that good results is generally obtained when leafless cuttings were completely dormant, prior to the beginning of bud swelling and development of flowers and leaves before the onset of the rainy season. Our rooting trial is also on set of rainy season and same leafless cuttings results rooting. Again, an increase in rooting potential has also been found when cuttings are collected towards the end of the dry season but before bud breaking (Danthu *et al.*, 2002) [15]. Goel and Behl (2004) [25] reported that physiologically mature tissues generally take more time to initiate roots and develop fewer roots than those physiologically juvenile materials. Puri and Swamy (2000) [62] mentioned that most of earlier workers used 20-22 cm size as the optimum size for root induction in woody plants. We have accomplished a propagation procedure through which 18-21 cm long this is due to carbohydrates stored in the cuttings and supply food for bud sprouting. Similar results were also examined by other researchers (Khattak *et al.*, 1983; Debnath and Maiti, 1990) [40, 17]. In case of rooting media, best performing results is in coarse sand, which is porous and helps in the formation and expansion of roots. Sardeoi (2014) [69] noted maximum number of roots in loamy soil media among eight different rooting media. It may be due to more porosity and aeration that enhances roots penetration more deeply in sand media and attains more length. Ramtin *et al.* (2010) [64] reported that longer roots are produced in beds with lower capacity of water retention.

Application of rooting hormone to enhance the rooting capability of cutting has been suggested by many authors. A positive effect of IBA on rooting percentage and on root number has been observed of vegetative propagation by Amri *et al.*, 2010 [3] and its positive effect. Shoot growth a positive relationship between the developments of both types of tissues is common in leafless hardwood cuttings and has been considered an indicator of metabolic activity (Tchigio and Duguma, 1998, Dick *et al.* 1998) [80, 19]. IBA is a root promoting hormone that stimulates the activity of cambium to initiate roots (Rahman *et al.*, 1991). In present study, rooting was significantly affected by auxin concentration, highest number of root per cutting was achieved at 200 ppm IBA solution. Similar studies were reported by (Struve and Moser 1984) [74] in Scarlet Oak seedlings where they found a huge increase in adventitious root regeneration by auxin treatments as compared to control seedlings. Similarly (Houle and Babeux 1998) [37] shared similar results in *Salix planifolia*. It is also reported that the application of IBA may have an indirect influence by enhancing the speed of translocation and movement of sugar to the base of cuttings and consequently stimulate rooting to increase the number and quality of root produced per cutting (Haissing 1974) [29]. Further it has been reported that IBA 300 ppm is the best growth regulator to be used for vegetative propagation of Hackberry with enhanced rooting percentage (Singh, R. 2006) [72]. Maximum rooting percentage is reported per plant was recorded by on application of IBA (Gopich and Meena 2015) [26]. The similar result was reported on stem cuttings of *Ginkgo biloba* L. on effect of IBA in different concentrations and cuttings were collected during February- March. Results revealed that NAA have shown maximum sprouting and survival and rooting in IBA. Results of the present investigation hard cuttings performed better than the semi hard cuttings.

Fig 3: *Aqilaria malaccensis* at homestead garden

Fig 4: Sprouting of branch cuttings

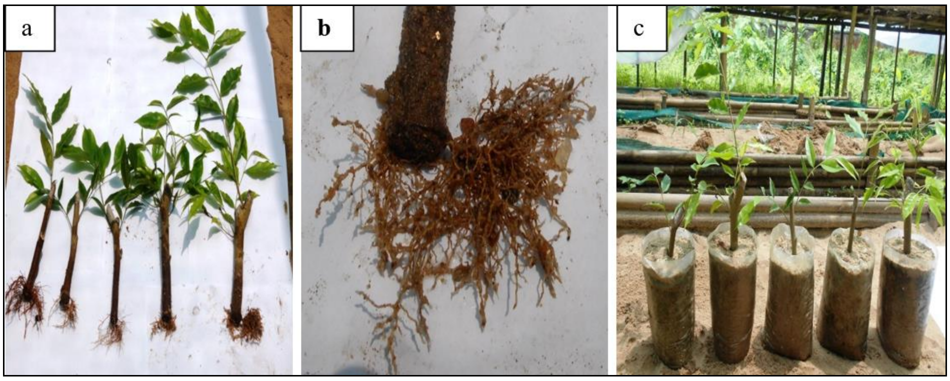

Fig 5: Rooted cuttings of *A. malaccensis* treated with 200 ppm IBA, a & b c. planted in polybags consisting of Soil: sand: FYM (1:1:1)

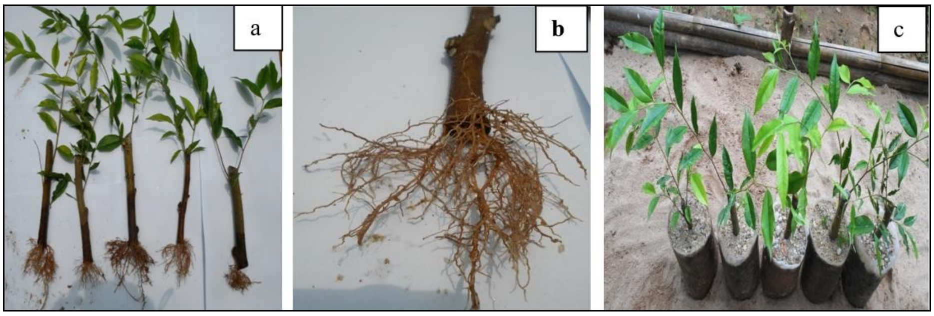

Fig 6: Rooted cuttings of *A. malaccensis* treated with 200 ppm NAA, a & b c. rooted cuttings planted in polybags consisting of Soil: sand: FYM (1:1:1)

Conclusion

Based on the results of this study, it could be concluded that rooting of cuttings is a complex phenomenon which involves very different events and successful rooting is determined by the number of roots formed, root elongation and shoot growth. However, the present study indicates that cutting collection from young trees of 6-8years old during the dry seasons before monsoon showed the best under nursery condition. Sprouting was observed in case of both type of cuttings but better rooting was observed only in hard cuttings followed by semi hard cuttings. Total three potting media were used during experimental trials the coarse sand was standardized as the best media for buds sprouting and rooting in different type of cuttings of the species. After transplanting of rooted cuttings to the poly bags filled up with Soil: Sand: FYM (1:1:1) survivality was recorded (75-80%) for the cuttings treated with IBA and NAA. All auxin concentrations responded more or less in sprouting as well as in rooting of the cuttings as compared to control. Hormonal treatment with 200 ppm IBA followed by 200 NAA was proven as the best for rooting of hard branch cuttings of *A. malaccensis*. The lowest rooting ability was found in the cuttings collected during late spring onwards. It also can be concluded that rooting ability of cuttings is strongly influenced by collection time, type of auxin, hormonal concentrations, type of cutting etc.

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