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VEGETATIVE PROPAGATION OF SOME IMPORATANT TREE SPECIES BY ROOTING CUTTINGS

T.Surendran
K.K.Seethalakshmi

KERALA FOREST RESEARCH INSTITUTE
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ABSTRACT

Vegetative propagation by rooting stem cuttings is a simple and comparatively less expensive method for clonal multiplication of genetically superior trees. In the present investigation branch cuttings of important timber species, viz., *Tectona grandis, Gmelina arborea, Haldina cordifolia, Hopea parviflora*, *Melia dubia* and *Swietenia macrophylla* were tried for root induction. The - study was extended to *Leucaena ieucocephala, Acacia mangium* and *Casuarina equisetifolia* in view of their potential for afforestation programmes in the state. Treatments with five growth regulating substances (GRS) (indole acetic acid, IAA; indole butyric acid, IBA; naphthyl acetic acid, NAA; Coumarin, Cou and boric acid, BA) at two concentrations each (10 and 100 ppm) were given separately to find out the most effective treatment. The influence of season on rooting was studied by repeating the treatments at monthly intervals. Results indicate that all the three factors, i. e., GRS, their concentration and season, have considerable effect on induction of rooting in cuttings. Of the ten species, rooting could be obtained only in *T. grandis, G. arborea, L. leucocephala, C. equisetifolia* and *A. mangium.* A treatment of IBA 100 ppm in May was most effective for *T, grandis* while NAA 100 ppm in April gave best results for *G. arborea. L. leucocephaia* was comparatively easy to root and a treatment of BA 10 ppm in September gave profuse rooting and sprouting. For root induction in sprigs of C. *equisetifolia,* treatment with a GRS was essential. Maximum percentage of rooting was in November with a treatment of IBA 10 or 50 ppm; in control only callus formation was observed. In a preliminary trial with A. *mangium* in June, treatment of IAA 1000 ppm (quick dip) appeared promising. The possible reasons for variation in rooting potential between species and within species are discussed.

INTRODUCTION

Regeneration from vegetative parts such as stem, root, rhizome or leaves in addition to the normal reproduction by seeds, is observed in many plants. Propagules raised by vegetative means retain the genetic constitution of parent plants without segregation as noticed in sexual reproduction. Due to this advantage, vegetative propagation has been practised for a long time in forestry and horticulture to produce planting stock of desired genetic constitution in tree/crop improvement programmes. Another advantage is that, large scale multiplication of selected individuals can be easily achieved for the commercial exploitation of improved varieties. Besides, vegetative propagation can be used for regeneration of tree species having problems of irregular seeding habits, long flowering and fruiting intervals, poor seed setting, low percentage of germination and undesirable short or long period of seed dormancy.

Genetic improvement of *T. grandis* and *G. arborea* deserves special attention since they are important plantation species. Vegetative propagation by grafting has already been standardised for the former and seed orchards are raised in various parts of the country (Kedharnath and Venkatesh, 1963; Ven. katesh *et al.*, 1986). But recently indications of stock–scion incompatability and ecotype variations affecting percentage of success were pointed out (Emmanuel and Bagchi, 1984). Mass propagation by tissue culture has been reported for tree species and with teak multiple shoot and root induction was possible from terminal buds of trees about 100 years old (Gupta et al., 1980). However, besides some practical problems, the sophistications resulting in the higher cost of propagules compared to seedlings, increase the initial expenses for establishment of large scale plantations using this technique. If propagation by rooting cuttings can be perfected for tree species, it will have definite advantages over other methods in raising plantations of genetically superior individuals with desired characters besides being simple and less expensive. However, before this is achieved a number of factors affecting rooting in cuttings have to be studied.

Many tree species like eucalypts (Campinhos and Ikemori, 1980) *Triplochiton scleroxylon* (Leakey *et al.*, 1982), Dipterocarps (Srivastava and Maggil, 1981) and *Gmelina* arborea (Florido, 1978) have been successfully propagated in large scale by cuttings. A large number of tree species have also been screened for their rooting potential (Nanda, 1970; Lohani *el al.*, 1980; Amatya, 1982). The results indicate that optimum conditions for rooting vary with species and also depend on the age and nature of cuttings used for rooting experiments. Hence standardisation of effective growth regulating substances, dosage, and best season for induction of rooting is required for each species. The present investigation was taken up to develop methods for rooting stem cuttings of important timber species of Kerala. *Gmelina arborea* Roxb., *Haldina cordifolia* (Roxb.) Ridsal, *Hopea parviflora* Bedd., *Melia dubia*, Cav., *Sweitenia macrophylla* (L) Jacq., *Tectona grandis* L. f. and *Xylia xylocarpa* (Roxb.) Taub. were selected for the study. Of these, propagation of *H. cordifolia*, *H. parviflora*, and *M. dubia* through seeds is not promising. Seeds of *H. cordifolia* are very minute. 1 g containing about 11,000 seeds (Troup, 1921) making it difficult to collect in right time. In *H. parviflora* seeds germinate without any dormancy and viability is completely lost within 40 days (Joshi, 1980). Although good natural regeneration is observed for *M. dubia*, seed germination in the nursery beds has been found to be very poor (ca. 2%) and also the seeds take a long time to germinate. G. *arborea*, *T. grandis*, *S. macrophylla* and *X. xylocarpa* are important timber yielding trees. Propagation of plus trees with superior phenotypic characters, quality of wood with higher wood production will help to increase the yield from plantations. The study was also extended to *Acacia mangium* Willd. *Casuarina equisetifolia*, J.R. & G. Forst. and *Leucaena leucocephala* (Lam.) de Wit which are grown under afforestation and Social Forestry programmes in the state due to their faster growth and capacity for nitrogen fixation.

MATERIALS AND METHODS

Tree Species

Branch cuttings of the following ten tree species were used in rooting experiments. The age of the parent trees in years and locality of collection are given in parentheses : 1. *Acacia mangium* (2, Peechi), *Casuarina equisetifolia* (6, Peechi), *Gmelina arborea* (5, Nilambur), *Haldina cordifolia* (20. Peechi), *Hopea parvijlora* (40, Nilambur), *Leucaena leucocephala* (I, Nilambur), *Melia dubia* (30, Nilambur), *Swietenia macrophylla* (20, Nilambur), *Tectona grandis* (33, Nilambur) and *Xylia xylocarpa* (35, Nilambur).

Preparation of cuttings

The branches of appropriate size were collected from the lower part of the crown of trees and brought to laboratory as soon as possible. Leaves were removed carefully and cuttings of about 20 cm in length and 1.5 to 2 cm diameter were made using a sharp knife, The basal end of the cutting was dipped in water immediately to prevent air bubbles entering the vascular system which may later interfere with the absorption of growth regulating substances. For *A. mangium,* cuttings having three pairs of leaves and terminal bud intact were used whereas for *C. equisetifolia* the sprigs (a lateral shoot with a few “needles” and a portion of bark) were utilized.

Preparation of Solutions

Five growth regulating substances (GRS) viz. indole acetic acid (IAA), indole butyric acid (TBA), napthyl acetic acid (NAA), coumarin (Cou) and boric acid (BA) were selected for treating the cuttings. The aqueous solutions of GRS were prepared by dissolving weighed quantities in 3-5 ml of ethyl alcohol and making up to 1000 ml with water. For quick dip, alcoholic solutions were prepared by dissolving the required quantities in 50% ethyl alcohol.

Treatment and Planting

Except for *A. mangium,* *C. equisetifolia* and *H. cordifolia* branch cuttings of all tree species were given the following 11 treatments separately. T_1, - Control (filtered water only); T_2,. - IAA 10 ppm; T_3 IAA - 100 ppm; T_4 - IBA 10 ppm; T_5 - IBA 100 ppm; T_6 - NAA 10 ppm; T_7, - NAA 100 ppm; T_8 - coumarin 10 ppm; T_9 - coumarin 100 ppm; T_{10} - boric acid 10 ppm; T_{11}, - boric acid 100 ppm.

Cuttings of each species were separated into 11 groups of 10 each assuring that every group contained cuttings of various diameter range in equal numbers. Treatments were given by dipping the basal portion (2-3 cm) in aqueous solution of GRS for 24 h. The treated cuttings were planted In sunken nursery beds filled with sand. For *A. mangium* and *H. cordifolia* a quick dip for 30 s. in alcoholic solutions of IAA and IBA at 1000 ppm was used. In the case of *C. equisetifolia* three concentrations of IBA(10. 50 and 100 ppm) with 30 sprigs (3 replicates of 10 each) were used in each treatment. Cuttings of these three species were planted in polybag containers (10x 15 cm) and kept in a humidity chamber at 95% RH. Nursery beds and polybag containers were watered twice a day in the morning and evening during summer and care was taken to avoid water logging during monsoon. Cuttings were provided with partial shade of woven coconut leaf thatches during summer to avoid sun scorch.

Seasonal effect

To study the effect of season on rooting, material was collected at monthly intervals and all the treatments were repeated. For *C. equisetifolia* treatments were carried out at bimonthly intervals. The effect of season was not studied for *A. mangium* and *H. cordifolia.* The data on rainfall and temperature during the experimental period (January to December 1983) were gathered from weather stations at Nilambur and Peechi (Fig.

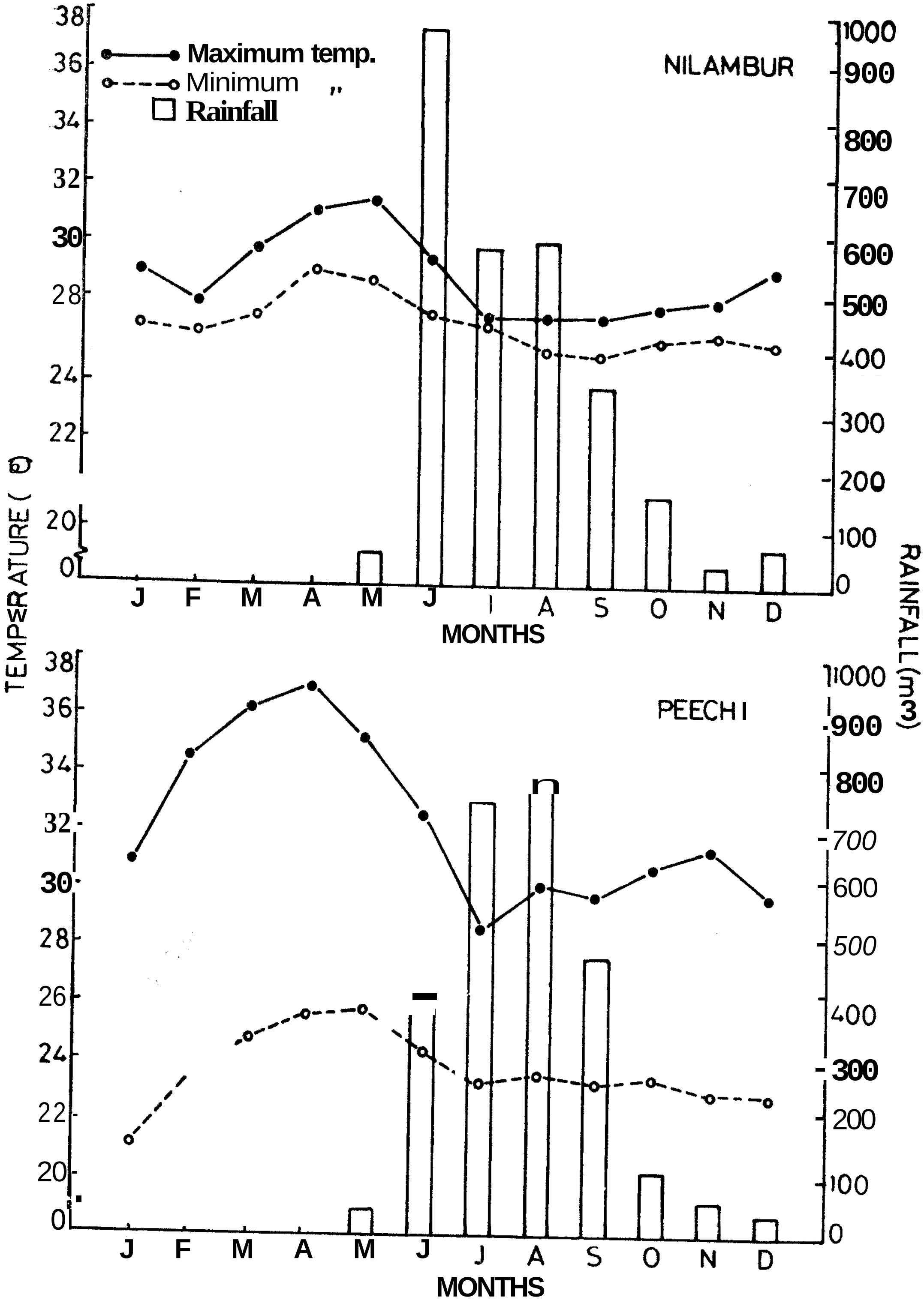

Fig. 1. Variation in temperature and rainfall at Nilambur and Peechi during the experimental period (January to December 1983).

Observations

The cuttings were uprooted from nursery beds six months after planting and observations recorded on percentage of rooting; number and length of roots as well as number and height of sprouts per rooted cutting. For 4. *mangium* and *C. equisetifolia* observations were taken after three months. Statistical analyses were carried out using Analysis of variance and Duncan’s new multiple range test (Keppel, 1973) after applying appropriate transformations. Since there was fairly large variation in the sub class number, unweighted analysis of cell means were carried out only as a quick test for detecting the presence of interactions. Ranking of treatments was done with respect to each character and the common treatments picked out from the best group for each character.

RESULTS

Rooting and sprouting responses varied with species, growth regulating substances, their concentration and also the season of treatment. Of the ten species tried, rooting was obtained only in five, viz, *Tectona grandis, Gmelina arborea, Leucaena leucocephala, Casuarina equisetifolia* and *Acacia mangium.* Although good sprouting was observed in cuttings of *Melia dubia* and *Swietenia macrophylla*, most of the sprouted cuttings dried in the absence of root formation. Neither rooting nor sprouting could be induced in cuttings of *Haldina cordifolia. Hopea parviflora* and *Xylia xylocarpa* by any of the treatments attempted. Data pertaining to maximum response obtained with different treatments of GRS as compared to control and the treatments which gave best response in each month are only presented. Since there are only single replicate values the mean squares for different factorial effects in the analysis of variance could not be tested for their significance with regard to percentage of rooting. The values of mean squares show that the higher order interaction (month x GRS x concentration) cannot be assumed nonsignificant. Hence the treatments which gave maximum percentage of rooting have to be considered as the best. The results are presented only for those species which gave positive response Each species is dealt with separately below.

Tectona grandis

Induction of rooting in branch cuttings of *T. grandis* was not very promising as the maximum rooting obtained with GRS was only 40%.

Percentage of rooting: Of the three auxins, NAA 100 ppm during March and IBA 100 ppm (Plate I a) in May gave maximum rooting. In control, rooting occurred only during March and the percentage was very low (10%). Rooting was observed from January to June and October to December with GRS treatment. Season had considerable effect on rooting: no rooting was observed during July, August and September (Table 1).

Number of sprouts: The best treatments were IBA 100 ppm and IAA 100 ppm in March and May respectively both giving 4 sprouts. In control maximum number was 3. Number of sprouts was influenced by all the three factors, i. e,, month, GRS and concentration as their interaction was highly significant (Table 2.)

Height of sprouts: The height growth of sprouts was facilitated by auxin and boric acid. Treatment with suitable GRS gave a six-fold increase (Table 1) in the height of sprouts (15 cm) as compared to that of control (2. 5 cm). Although the three factor interaction was not significant, the interactions month x GRS, and GRS x concentration were highly significant (Table 2). The best treatments were NAA 10 ppm in October followed by NAA 10 ppm in March and IBA 10 ppm in May. The variation between control vs treated remained constant over various months since the interaction is not significant.

Number of roots: Number of roots was enhanced by NAA, IBA and coumarin. Four treatments (IBA 100 ppm in January, NAA 100 pprn in October, cournarin 100 ppm in November, and NAA 10 ppm in December) were equally effective having 4 roots per cutting while in control there was only one root per cutting (Table 1). The effect of month was not significant when analysed separately but all the two factor interactions (month x GRS, GRS x concentration and month x concentration) were significant. Best treatments selected by DMRT are given in Table 2. The difference between control vs rest remained constant over months.

Length of roots: A three-fold increase in the length of roots over control was obtained in promising treatments (Table I). Maximum root length was obtained with coumarin 100 pprn in November (16 cm) followed by IBA 100 ppm in January (15.8 cm) and NAA 10 ppm in October (13.5 cm). Only GRS had significant effect on length of roots when considered independantly (Table 2) but the interactions, month x GRS and GRS x concentration were significant at p=0.01. The variation between control vs rest remained constant over months.

Gmelina arborea

The response of *G. arborea* was better compared to *T. grandis* with a maximum of 60% rooting.

Table 1. Sprouting and rooting response of branch cuttings of *T. grandis* during various months.

Month of treatment*	Percentage of rooting + a	b	++ c	No. of sprouts a	b	c	Height of sprouts a	b	c	No. of roots a	b	c	length of roots a	b	c
JAN	0	30	NAA 1	0	2	IBA 1	0	9.5	IBA 2	0	4	IBA 2	0	15.8	IBA 2
FEB	0	30	NAA 1	0	2	IAA 2	0	3.5	IBA 2 IAA 2	0	3	NAA 1	0	9.2	NAA 1
MAR	10	40	NAA 2	3	4	IBA 2	2.5	13.0	NAA1	1	2	IAA 2	5	12.8	NAA 1
APR	0	30	NAA 1	0	2	IBA 2 NAA 2	0	11.0	NAA 2	0	3	IAA 2	0	12.8	IAA 2
MAY	0	40	IBA 2	0	4	IAA 2	0	13.0	IBA 1	0	3	NAA 1	0	10.3	IBA 2
JUN	0	20	IBA 2	0	2	IBA 2	0	6.0	BA 1	0	2	IBA 2 Cou. 2	0	12.8	IBA 2
OCT	0	10	NAA 1	0	2	IAA 2	0	15.0	NAA 1	0	4	NAA 2	0	13.5	NAA 1
NOV	0	20	Cou. 1	0	2	BA 1	0	11.0	BA 1	0	4	cou.2	0	16.0	cou. 2
DEC	0	10	NAA 1	0	2	NAA 1	0	5.0	NAA 1	0	4	NAA 1	0	12.0	NAA 1

* No rooting in July, August and September

+a Values obtained for control, b - maximum response obtained with treatment of GRS, c - treatment (s) which gave maximum response.

++ Numerical after GRS is the concentration: 1-10 ppm; 2-100 ppm.

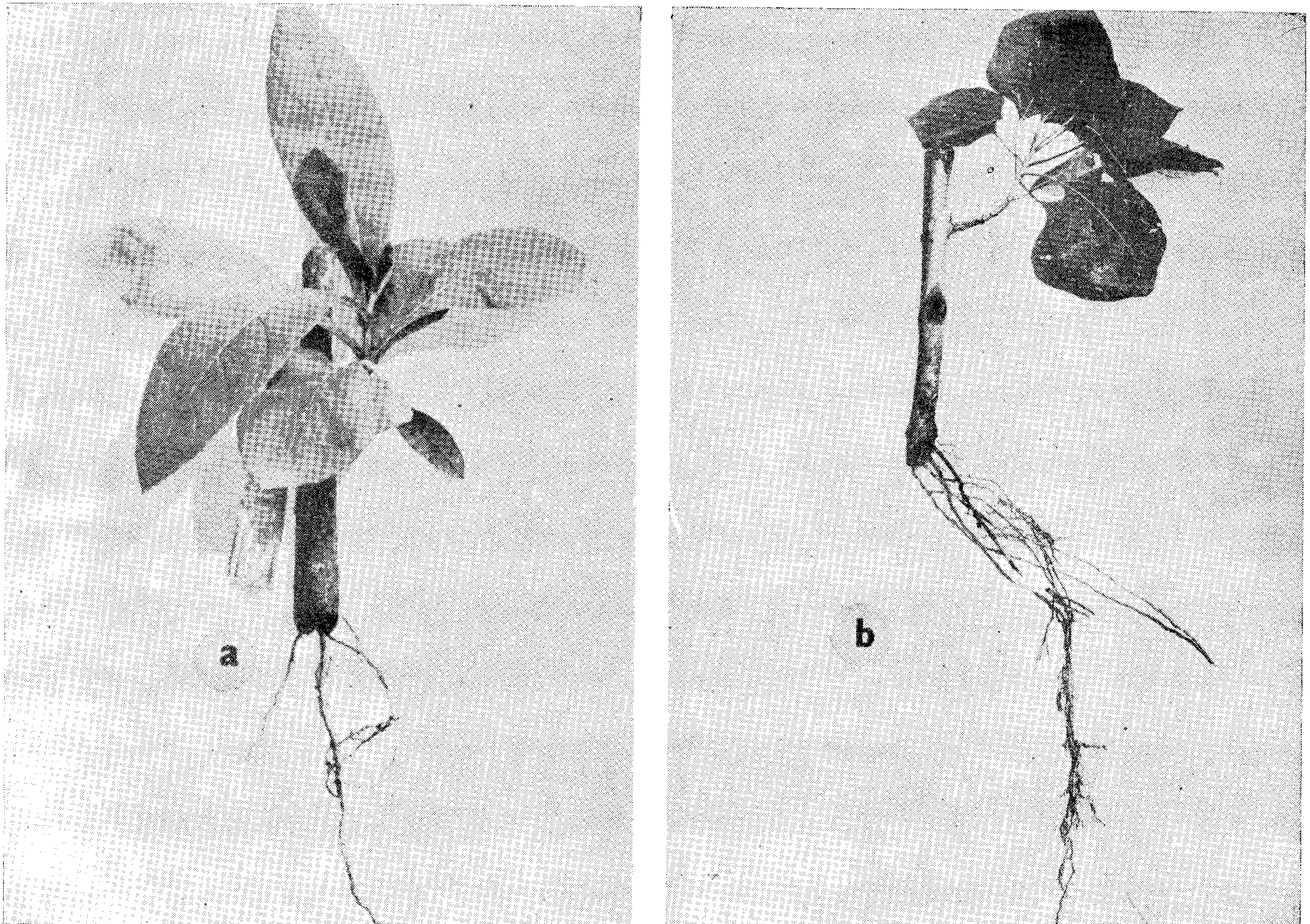

Plate I Branch cuttings of (a) *T. grandis* and (b) *G. arborea* treated with IBA and NAA 100 ppm respectively (six months after treatment)

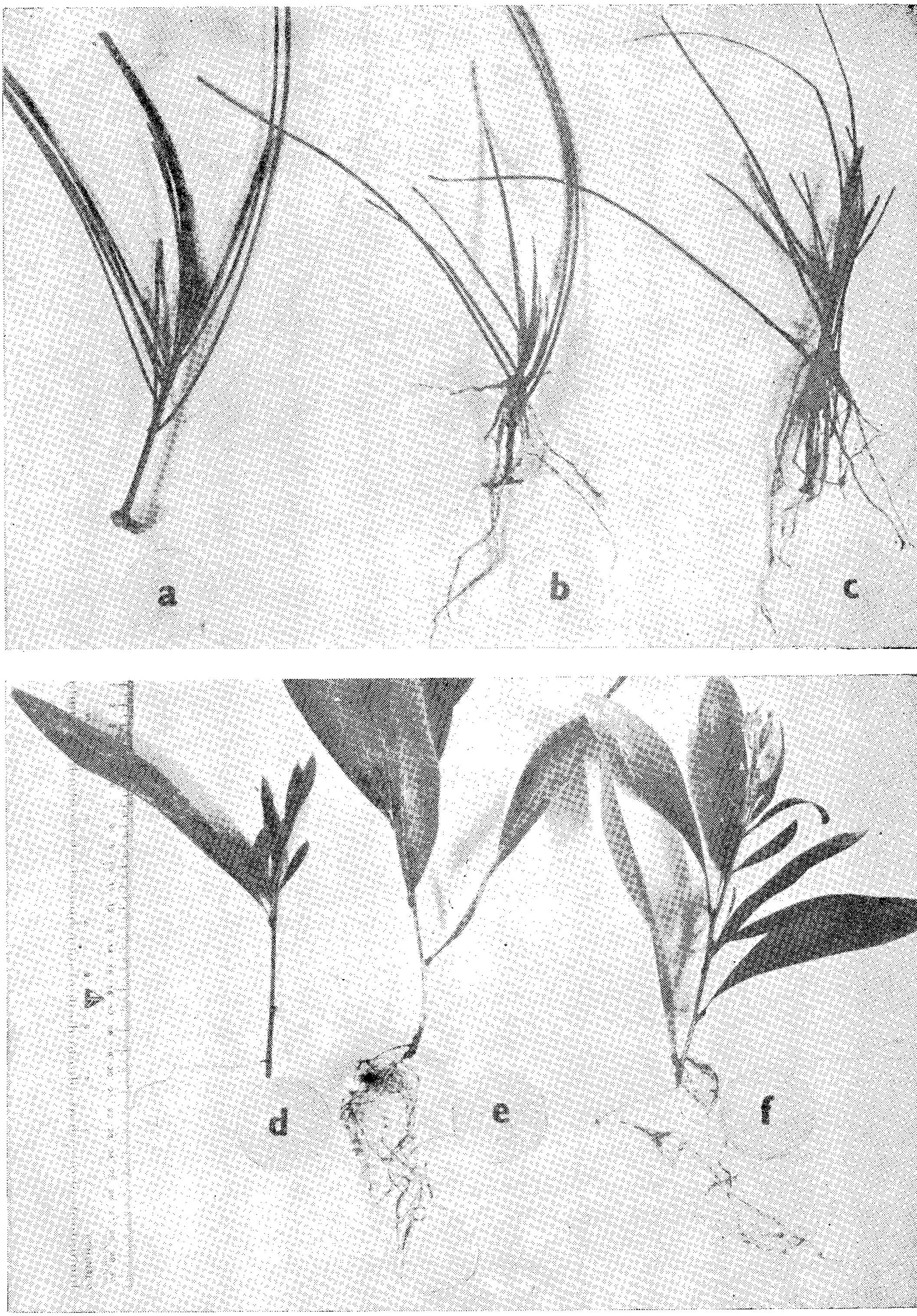

Plate II a, b, c, Sprigs of *C. equisetifolia:* a. control; b. IBA 50 ppm; c. IBA 100 ppm (three months after treatment)

d, e, f, branch cuttings of *A. mangium*: d. control; e. IBA 1000 ppm; f. IAA 1000ppm. (three months after treatment).

Table 2 *Tectona grandis*. Anlaysis of variance of rooting and sprouting responses

sources	Percentage of rooting Mss	F-values			
		No. of sprouts	Height of sprouts	No. of roots	L.ength of roots
Month	108.63	10.51**	3.46**	1.85ns	2.19ns
GRS	192.55	17.97**	8.44**	25.23**	13.17**
Concn	69.39	13.22**	2.72ns	4.97*	1.01ns
Month x GRS	57.26	7.19**	3.03**	5.59**	5.17**
Month X Concn	39.81	7.36**	2.17ns	2.80*	1.92ns
GRS X Concn	137.83	22.30**	7.45**	16.60**	12.98**
Month X GRS X Concn	24.37	5.19**	1.61ns	1.90ns	1.89ns
Control Vs Rest	97.81	7.27**	6.08**	10.06**	7.93**
Control Vs Rest x Month	7.27	7.29**	0.57ns	0.73ns	1.30ns
Best group of treatments by DMRT (Except for % rooting)	NAA100 March IBA 100 May	TBA100 March IAA 100 May	NAA 10 Oct and March IBA 10 May	IBA 100 Jan NAA100 Oct COU 100 Nov NAA10 Dec	Cou 100 Nov IBA 100 Jan NAA 10 Oct

** Significant at P = 0.01; * significant at P = 0.05; ns not significant.

Percentage of rooting: Season had a pronounced effect on rooting of stem cuttings of *G. arborea.* In control, rooting was observed only in cuttings collected during January and March with a maximum response of 20% (Table 3). With treatment of various GRS the rooting occurred in cuttings treated during seven months, i e. from January to July. NAA and IAA were effective in most of the months with maximum rooting in NAA 100 ppm during April (600%) (Plate I, b) followed by IAA 100 ppm in March *(50%).*

Number of sprouts: Maximum number of (7) sprouts were recorded in cuttings treated with coumarin 10 ppm during April. As compared to the maximum obtained in control (6) the increase was only marginal (Table 3). The F–values obtained (Table 4) for different factorial effects reveal that three factor interactions (month x GRS x concentration) are significant. The best treatments selected by DMRT are given in Table 4.

Height of sprouts: Treatment with GRS enhanced the growth of shoots (Table 3). A treatment with IAA 10 ppm in July gave the maximum height of 21.5 cm which is more than three times when compared to the maximum of 6cm in control during January. The height of sprouts was influenced by all the three factors, i.e. GRS, concentration and month of treatment (Table 4). The best treatments selected by DMRT were IAA 10 ppm and NAA 100 ppm in July

Number of roots: More number of roots was observed in cuttings treated with auxin and boric acid as compared to that of control (Table 3). Maximum number of 7 roots developed with a treatment of IAA 10 ppm in July followed by 5 in IBA ppm during March. The observed F–values for factorial effects show that the three factor interaction is significant (Table 4) indicating that these factors have a cumulative effect on rooting.

Length of roots: There was considerable increase in length of roots in some of the treatments (Table 3). The best treatment was IBA 100 ppm in June which gave a four-fold increase in root length as compared to control. The F-values for various factors, their interaction and best treatments selected by DMRT are given in Table 4,

Leucaena leucocephala

Of the ten species tried for rooting, *L. Ieucocephala* gave most promising results. Although there was a seasonal effect, cuttings could be rooted throughout the year. The maximum rooting and sprouting response obtained in each month with and without treatment of GRS are given in Table 5.

Percentage of rooting: Treatment with GRS improved the rooting response of cuttings. Percentage of rooting in control varied from 10 to 60 while it was

Table 3 Sprouting and rooting responses of branch cuttings of *G. arborea* during various months

Month of treatment*	Percentage of rooting a[+]	b	c[++]	No of sprouts a	b	c	Height of sprouts (cm) a	b	c	No. of roots a	b	c	Length of roots (cm) a	b	c
JAN	10	40	IAA 1	6.0	6.0	IBA 2	6.0	8.0	IBA 2 cou 2	2.0	3.5	IAA 1	6.5	11.5	Cou 2
FEB	0	20	IAA 1,2 BA 2	0.0	6.0	Cou 1	0.0	7.0	IAA 1	0.0	3.5	IAA 2	0.0	9.3	BA 2
MAR	20	50	IAA 2	4.5	6.0	IBA 2	4.5	8.8	IAA 1	3.5	5.0	IBA 2	3.9	12.3	IAA 2
APR	0	60	NAA 2	0.0	7.0	COU 1	0.0	15.0	IAA 1	0.0	4.5	BA 1	0.0	14.3	Cou 1
MAY	0	40	Cou 1	0.0	4.0	IBA 2 BA 2	0.0	7.0	IAA 2 cou 2	0.0	4.0	NAA 1	0.0	12.0	IBA 2
JUN	0	30	NAA 1	0.0	4.0	IBA 1	0.0	13.0	IBA 1	0.0	2.5	IBA 1	0.0	26.3	IAA 1
JUL	0	20	IAA 1	0.0	4.0	NAA 1	0.0	21.5	IAA 1	0.0	7.0	IAA 1	0.0	12.5	NAA 2

[+] a — values obtained for control, b—maximum response obtained with treatment of GRS, c—treatment which gave maximum response.

[++] Numerical after GRS is the concentration 1-10 ppm, 2-100ppm

* No rooting was observed from August to December

Table 4. ***Gmelina arborea:*** Analysis of variance of rooting and sprouting responses

Sources	MSS	F-values			
	Percentage of rooting	No. of sprouts	Height of sprouts	No. of roots	Length of roots
Month	432.51	29.05**	30.37**	46.80**	21.16**
GRS	161.83	11.90**	18.86**	22.51**	11.23**
Concentration	6.81	24.53**	0.35ns	2.18ns	13.46**
Month x GRS	74.02	6.38**	7.85**	10.38**	7.10**
Month x Concentration	41.85	7.83**	38.19**	10.81**	2.35*
GRS x Concentration	15.47	3.80**	3.55**	8.50**	0.91ns
Month x GRS x Concn.	44.31	10.35**	14.82**	18.22**	14.97**
Control Vs Rest	148.87	11.20**	29.06**	32.92**	28.03**
Control Vs Rest x Month	30.20	11.77**	9.26**	13.76**	6.79**
Best group of treatments by DMRT	NAA 100 April	Cou 10 April	IAA 10 July	IAA 10 July	IBA 10 June
Except for % rooting	IAA 100 March	IAA 100 April	NAA 100 July	IBA 100 March	Cou 10 April

** Significant at P=0.01; * Significant at P=0.05; ns=not significant.

20 to 80 in GRS treated cuttings. In control, rooting occurred for a period of 8 months, whereas, with GRS treatment, cuttings showed some response throughout the year. Treatments which gave maximum rooting (80%) were IAA 100 ppm in January, IBA 100 ppm in February and BA 10 ppm in September.

Number of sprouts: There was no considerable increase in number of sprouts by treatment of GRS. Of the five GRS, boric acid was most effective than auxins (Table 5). While control had a maximum of 5 sprouts by treatment maximum number obtained was 6 (BA 10 ppm in February and April). Analysis of variance shows significant interaction between month, GRS and concentration (Table 6). The variance due to control vs treated did not turn out significant because their difference did not remain constant over months as shown by significant interaction.

Heightof sprouts: Both GRS and season appeared to have considerable effect on height of shoots. Maximum shoot growth was recorded during September. There was two fold increase over control in IAA 100 ppm during this month (Table 5). The selected treatment by DMRT are given in Table 6.

Number of roots: More roots developed in cuttings treated with GRS in comparison with control. Maximum number of roots recorded in control was about 7 while the best treatment (BA 100 ppm in September) gave about 9 roots per cutting (Table 5). Rooting was influenced by all the three factors month, GRS and concentration as the interaction among them was highly significant (Table 6).

Length of roots: Maximum root length of 49.7 cm was observed in control during September (Table 5). Length of roots in cuttings during various months showed considerable difference. In general GRS treatments were not effective in enhancing root length over control although the variation between treatments and the interactions were found significant, the difference between control vs treated was not significant (Table 6).

Casuarina equisetifolia

Sprigs of *C. equisetifolia* treated with IBA developed roots while only callus formation was observed in control (Plate I1 a, b, c) Unlike other tree species rooting in *C. equisetifolia* was obtained only during July to January.

Percentage of rooting: Maximum percentage of rooting (70%) was recorded in sprigs treated with IBA 10 ppm during November followed by (66. 7%) IBA 50 ppm in the same month (Table 7). Analysis of variance indicates that difference between the three concentrations of IBA is not significant with regard to percentage of rooting (Table 8).

Number of roots: Maximum number (8) of roots was obtained in sprigs treated with IBA 100 ppm followed by IBA 10 ppm (7) (Table 7). Analysis of

Table 5. Rooting and sprouting responses of branch cuttings of *L. leucocephaia* during various months

Month of treatment	Percentage of rooting			No. of sprouts			Height of tallest sprout (cm)			No. of roots			Length of roots (cm)		
	a[+]	b	c[++]	a	b	c	a	b	c	a	b	c	a	b	c
JAN	50	80	IAA 2	3.4	5.0	cou 1	13.6	20.8	IBA 2	6.8	8.4	IBA 2	10.1	18.0	IAA 2
FEB	30	80	IBA 2	5.0	5.5	BA 1	26.7	33.0	IAA 1	4.0	5.1	IBA 2	9.6	9.8	BA 2
MAR	60		NI	1.3	1.6	IAA 1	93.8	184.2	IAA 1	2.5	7.3	BA 1.	44.9	46.1	IAA 1
APR	20	70	IBA 2	4.0	6.0	BA 1	18.0	24.2	IAA 2	4.0		NI	8.0	13.0	NAA 1
MAY	30	60	NAA 2	2.7	5.0	IAA 1	21.0	32.2	IAA 1	3.3	4.5	IBA 1	7.4	15.1	IBA 2
JUN	0	30	IBA 2	0.0	3.0	IAA 1,2 NAA 2	0.0	24.0	IAA 1	0.0	6.0	IAA 1	0.0	11.6	NAA 2-
JUL	0	20	AA	0.0	3.0	IAA 1,2 NAA 2	0.0	26.5	IBA 1	0.0	4.0	NAA 2 Cou 1	0.0	13.1	IBA 1
AUG	30	60	IAA 1	1.7	3.0	NAA 1	33.0		NI	4.0		NAA 2	17.7		NI
SEP	30	80	BA 1	1.0	1.5	IAA 2	136.7	252.5	IAA 2	1.7	9.1	BA 2	49.7		M
OCT	10	40	IBA 2	1.0	3.0	NAA 1	17.0	27.0	NAA 1	2.0	4.0	IAA 2	8.5	19.5	IBA 1
NOV	20		NI	5.0		NI	14.0		N1	1.0	7.0	IBA 2	3.0	13.8	IAA 2
DEC	0	30	IBA 2	0.0	2.0	IBA 2	0.0	18.0	1BA 1	0.0	6.0	NAA2	0.0	12.6	IBA 2

+ a. Values obtained for control b. Maximum response obtained with treatment of GRS
c. Treatment (s) which gave maximum response

++ Numerical after GRS is concentration 1 - 10 ppm, 2 - 100 ppm
NI-no increase over control, AA all auxins

Table 6. *Leucaena leucocephala*. Analysis of variance of roofing and sprouting responses

Sources	MSS	F-values			
	Percentage of rooting	No. of sprouts	Height of sprouts	No. of roots	Length of roots
Month	1246.02	24.57**	155.31**	20.61**	26.28**
GRS	1486.42	31.83**	111.10**	59.09**	46.31**
Concn	168.25	1.08ns	2.10ns	3.43ns	0.94ns
Month X GRS	138.66	5.25**	9.18**	6.37**	3.19**
Month X Concn	79.73	4.57**	6.14**	2.40**	2.74**
GRS X Cancn	91.99	3.87**	2.62*	3.09**	2.12*
Month X GRS X Concn	54.80	3.30**	6.46**	2.57**	1.80*
Control vs Rest	34.88	2.15ns	12.41**	5.89**	0.01ns
Control VS Rest X Month	188.88	11.19**	13.12**	7.38**	8.19**
Best group of Treatment by DMRT (Except for % rooting)	IAA 100 Jan IBA 100 Feb BA 10 Sept	BA 10 April BA 10 Feb	IAA 100 sept BA 10Sept cou10sept	BA 100 Sept IBA 100 Jan	Control Sept IAA 10 March

** Significant at P=0.01; *significant at P=0.05; ns=not significant.

Table 7. Rooting response *of C. equisetifolia* in various months

Treatment	Percentage of rooting				No. of roots				Length of roots (cm)			
Month*	Jul	Sep	Nov	Jan	Jul	Sep	Nov	Jan	Jul	Sep	Nov	Jan
Control	0	0	0	0	0	0	0	0	0	0	0	0
IBA 10	20.0	0	70.0	16.7	4.2	0	2.5	7.3	4.3	0	1.9	2.0
IBA 50	50.0	56.7	66.7	20.0	6.3	4.6	4.6	4.5	4.0	1.0	2.2	1.7
IBA 100	40.0	20.0	20.0	10.0	8.3	4.8	5.2	4.6	2.9	1.7	1.8	2.9

* No rooting was observed in March and May

Table 8. *C. equisetifolia:* Analysis of variance of rooting response

	F-values		
Sources	% rooting	No. of roots	Length of roots
Month	0.07^{ns}	1.39^{ns}	48.38**
GRS	0.24^{ns}	12.97**	155.10**
Replication	0.008^{ns}	0.44^{ns}	2.02^{ns}
Month x GRS	0.04^{ns}	1.05^{ns}	13.24**
Best treatment	IBA 10 Nov	IBA	IBA 10 July

Variance showed that the effect of GRS was significant while season and the interaction between GRS x season was not significant (Table 8).

Length of roots. Both GRS and month affected length of roots. Maximum length of 4.3 cm was recorded in July on cuttings with a treatment of IBA 10 ppm. Sprigs treated with all the three concentrations of IBA in July showed better root growth (Table 7). Effect of month and GRS was highly significant with regard to length of roots (Table 8).

Acacia mangium

Preliminary trial with *A. mangium* in June indicated the possibility of rooting cuttings. Of the three treatments (control, IAA 1000 ppm and IBA 1000 ppm quick dip) maximum percentage of rooting was obtained in cutting treated with IAA 1000 ppm, (43%) while it was only 14% in control. Number and height of sprouts were also enhanced by IAA (Plate II d,e,f). However, IBA was better for growth of roots. The longest root (16.7 cm) developed on cuttings treated with IBA while in control root length was only 6 cm.

DISCUSSION

Considerable variation is observed in rooting potential of cuttings of different species and within species. Depending on the rooting potential, plants are classifed into three categories: (i) easy-to-root, they root without any GRS application (ii) shy-to-root, they can be induced to root with exogenous applications of proper GRS and (iii) difficult-to-root, they do not root even with the application of GRS. Of the ten species tried in the present study *L. leucocephala* was easy-to-root. Percentage of rooting was enhanced in cuttings of *T. grandis*, *G. arborea* and *A, mangium* treated with GRS. However, in *C. equisetifolia* only GRS treated cuttings developed roots (shy-to-root). But the GRS and their different concentrations were not effective in inducing rooting in cuttings of remaining five species (difficult-to-root), In addition to auxins known to induce root formation (Thimann and Behnke-Rogers, 1950, Komissarov, 1964), a non-auxinic chemical, boric acid was also found effective for *L. leucocephala.*

One of the reasons for failure to induce rooting in cuttings of tree species such as *H. cordifolia*, *H. parviflora*, *X. xylocarpa*, *M. dubia* and *S. macrophylla* tried in this study may possibly be the effect of age; branch cuttings were collected from mature trees (20 years old.). Reduced rooting potential due to aging is attributed to the production of rooting inhibitors as in eucalypts *(Paton et al.,* 1970) or reduction in rooting cofactors such as phenols in *Hedera helix* (Rigouard, 1969). Anatomical characters of the cuttings have also some bearing on rooting ability. Increase in sclerenchymatous tissue becomes a mechanical barrier for the emergence of roots. Stem cuttings taken from young seedlings root much more easily than those taken from older plants (Gardner, 1929. Hitchcock and Zimmerman, 1932. Sax, 1962. Libby *et al.,* 1972). Rejuvenation can be induced in difficult - to - root species by cutting back the stock plants (hedging) or by induction of coppice growth. Rooting of coppice cuttings was highly successful with eucalypts (Hartney, 1980, Campinhos and Ikemori, 1980. Heth *et al.,* 1986) while cuttings from mature trees failed to root. High rooting percentage (about 100%) is reported for *T. grandis* with sprouting buds nipped off from stumps and planted in polythene containers kept in a glass house (Hussain *et al.,* 1976). Further, high relative humidity with mist is known to promote rooting in a number of species (Grange and Loach, 1984). Low rooting in teak in the present study could be related to age and absence of mist during experimentation. In addition to maintenance of sufficient water potential in cuttings, mist probably help to leach out some of the antimetabolites and growth retardants which are inhibitory for rooting. It will be worthwhile to study the effect of age, relative humidity and higher concentration of GRS with regard to the tree species which have not responded to any of the treatments attempted.

For species giving positive response, rooting varied with season and GRS treatment. Except for *C. equisetifolia* where maximum rooting occurred during monsoon it was during summer months (January to May). Development of adventitious roots on trunks of the parent tree of *C. equisetifolia* during July supports our results, For *L. leucocephala* good rooting response was obtained in September in addition to summer months. In general, rooting response was enhanced and the period for which rooting obtained was extended by treatment with GRS. Various external factors like humidity, light, temperature, rooting medium and internal factors such as endogenous growth regulating substances, level of nutrients, growth retardants and antimetabolites are known to affect rooting in cuttings (Komissarov, 1964; Nanda, 1970; Hartman and Kestler, 1976). The seasonal variation observed in rooting potential of cuttings from the same species may be either due to physiological nature of the cuttings, variation in external factors or interaction of both. Depending on the endogenous level of GRS, application of exogenous GRS may be promotive, ineffective or even inhibitory for rooting of cuttings (Nanda, 1970).

Although treatment of GRS enhanced sprouting and rooting in cuttings of some species, single treatment does not give all the positive responses of sprouting and rooting in.a particular season. Hence, selection of the best treatment for large scale propagation of a species was done by giving more importance to percentage of tooting and compared its performance to control with regard to other parameters. If there were more than one treatment giving maximum percentage of rooting, the performance with regard to height of sprouts and length of roots was taken into account. Number of sprouts was not considered since development of many sprouts on cuttings will lead to numerous branches consequently affecting the height growth of plants. The selected GRS, concentration and month of treatment for tree species are given in Table 9. Results obtained for *T. grandis* conform to the earlier observations of Nanda (1970), and Bhatnagar and Joshi (1978). Maximum rooting was obtained with treatment of IBA 100 ppm during summer months (Florido, 1978). Somasundaram and Jagadees (1977) have propagated the springs of *C. equisetifolia* using a commercial hormone powder Seradix-2, in July.

Table 9. Best treatments for rooting in stem cuttings of various tree species

Tree species	Growth regulating substance	Concentration	Month of treatment	Maximum % rooting obtained
T. grandis	IBA	100	May	40
G. arborea	NAA	100	April	60
L. leucocephala	BA	10	September	80
C. equisetifolia	IBA	10	November	70
A. mangium	IAA	1000	June	43

The present investigation only indicates the possibility of rooting cuttings of few timber species. The success obtained was limited except for *L. leucocephala* and *C. equisetifolia*, Further investigations on various factors which influence rooting such as effect of age, relative humidity, rooting medium, effect of growth regulating substances and concentration and clonal variations are necessary to obtain maximum favourable responses for each species.

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