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Clonal Variation in Rooting Eucalypt Cuttings With Different Levels of IBA Concentrations

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ABSTRACT

The present study involves combined effect of genotypes and IBA concentrations on rooting and related parameters in eucalypts cuttings. The study was conducted in the propagation chamber installed in Wimco Seedlings which is used for commercial production of clonal eucalypts. It involves 13 commercially grown clones viz., BCM 288, BCM 2023, BCM 413, BCM 411, BCM 2135, BCM 316, BCM 2070, BCM 2045, BCM 2306, BCM 526, Wimco 12 and, K 23 and K 25 and 5 concentrations of IBA viz., 0 ppm, 2500 ppm, 5000 ppm, 7500 ppm and 10000 ppm. Results indicate improvement in rooting percent, number of 1st and 2nd order roots, length of main lateral root, number of roots emerged out of bottom hole of root trainer cavity, shoot length and sprouting percent of the cuttings. There was significant clonal variation in rooting and related parameters. Five clones viz., BCM 413, Wimco 12, BCM 411, BCM 316 and BCM 2045 gave over 90% rooting even without application of IBA. Clone BCM 288 was designated as difficult to root as it gave less than 60% rooting even with maximum level of IBA concentration. Grouping of clones in different rooting ability categories with application of different levels of IBA concentrations indicate moving of many clones from difficult to root category to easy to root category with application of higher concentrations of IBA.

Key Words:

clone, *Eucalyptus*, IBA, rooting, variation

INTRODUCTION

In India, the eucalypts culture has a history of over two centuries during which the tree has been planted in different locations and debated for its silvicultural and environmental values (Dhiman and Gandhi 2014). It is one of the main planted forest trees (FSI 2015) which is helping in meeting the domestic and industrial wood requirement in the country. Tree growers prefer its culture under different plantation programs both integrated on farms in agroforestry and also as pure plantations to realize its biological potential. Of recent, its clonal culture is picking up in many countries including India. Eucalypts clonal culture is a huge success in Brazil (Dehon et al. 2013), India (Dhiman and Gandhi 2014; Kulkarni 2014), China

(Xu et al. 2008) and a few other countries (Griffin 2014). In India, its clonal culture has fast picked up during the last two decades. It is estimated that around 40-50 million clonal eucalypts plants were produced in the country during the beginning of this decade (Piare Lal 2011; Dhyani et al. 2013; Dhiman and Gandhi 2014) and the number is constantly increasing. India is reported to have around 500 eucalypts clones out of which around 2 dozens are commercially grown (Dhiman and Gandhi 2014). These clones have been developed by different organizations i.e. ITC-PSPD (BCM series), Wimco Seedlings (Wimco Series), Kerala Forest Research Institute (K series), Forest Research Institutes and a few others.

Each clone is genetically different material which needs matching packages and practices at each level of their culture for harnessing its potential in production forestry. Clonal eucalypts is reproduced through nodal softwood cuttings in routine propagation under controlled environment conditions. Eucalypts improvement programs screen out even good performing clones due to their poor rooting ability which restricts harnessing their production potential. There is always a scope of including even difficult to root clones in propagation system by increasing their rooting success with management interventions including application of rooting hormones. Besides physiological conditions of the cuttings their rooting success also depends on the hormonal treatment (Hitchcock and Zimmerman 1939; Wendling et al. 2000; Brondani et al. 2010a). IBA is the most frequently and commonly used rooting hormone in forest tree species since long (Hitchcock and Zimmerman 1939; Griffith 1940, Hare 1974; Hartmann et al. 2002). Weaver (1972) suggested that IBA persists near the site of application to effectively induce root initiation in cuttings. Optimum concentration varies with clones among many other factors. The paper gives an account of the application of different concentrations of IBA for increasing rooting in different clones

MATERIALS AND METHODS

The present study was conducted in the mist chamber installed at the production facility of ITC -PSPD (Unit Wimco Seedlins) at Bagwala, Rudrapur, Uttarakhand. The experiment was conducted in a split plot design in which 13 clones were randomized in main plots and five concentrations of root promoting hormone-IBA viz., 0 ppm, 2500 ppm, 5000 ppm, 7500 ppm and 10000 ppm were randomized in sub plots. Thirteen commercially grown clones included in the study were: BCM 288, BCM 2023. BCM 413, BCM 411, BCM 2135, BCM 316, BCM 2070, BCM 2045, BCM 2306, BCM 526 all of ITC PSPD (Badhrachalam); Wimco 12 of Wimco Seedlings and; K 23 and K 25 of Kerala Forest Research Institute. There were three replications, each having 30 cuttings. The nodal cuttings of 10 cm length were prepared from 45 days old shoots collected from three years old hedges especially managed for cutting production at R&D Centre of Wimco Seedlings, Rudrapur, Uttarakhand. The pair of leaves of each cutting was half cut as suggested by Dhiman and Gandhi (2014). The lower one cm stem of the cuttings was rubbed with powder formulations of IBA at the time of insertion of cuttings in rooting media. The powder formulation of IBA hormone was prepared in chalk powder and well mixed before application. Half of the cuttings were inserted in the vermiculite (horticulture grade) filled in block type root trainer cavities of 50 cc volume having 60 cells per tray. Root trainers containing cuttings were kept inside mist chamber which was maintained at around 80% humidity and 35-40°C temperature. The cuttings were planted in root trainers during middle of October and the data for rooting percent, number of 1st and 2nd order roots/cutting, length of main lateral root, number of roots emerged out of bottom hole of root trainer cavity, sprouting percent, number of shoots/cutting and length of the longest shoot/cutting were recorded on the 28th day of setting the cuttings. The final survival of cuttings was recorded on the 90th day of setting the cuttings. The data was subject to statistical analysis and results were compared at 0.05 level of confidence.

RESULTS AND DISCUSSION

The data on average rooting percent due to different concentrations of IBA in all the tested clones is given in table 1 which clearly indicate that the increase in IBA concentration had significant effect on mean values of all the studied parameters viz., rooting (%), 1st order and 2nd order roots (No.)/cutting, length of longest root and shoot/cutting, roots (No.) emerged out of bottom of root trainer cavity and length of fresh (new) shoot/cutting. Application of 10000 ppm powder formulation resulted in significantly higher values in all the studied parameters when compared with control and with any other concentration of IBA applied on the base of cuttings. Control (0 ppm) gave significantly lower mean values for all the studied parameters when compared with mean values of all other concentrations of IBA. There was a gradual increase in the mean values of all the studied parameters with gradual increase in the IBA concentration from 0 ppm to 10000 ppm. IBA has been used in different formulations and concentrations for promoting rooting in eucalypts softwood cuttings (Weaver 1972; Chandra and Yadav 1986; Day et al. 1988; Almeida et al. 2007; Brodani et al. 2010a, b, and 2012).The results of this study also draw support from a number of publications which reported increase in rooting and related parameters with increase in IBA concentration (Almeida et al. 2007; Brondani et al. 2008; 2010a and b; Day et al. 1998).

Table 1. Effect of IBA concentration (main plot) on rooting and sprouting parameters

IBA (ppm)	Rooting (%)	1st order roots/ cutting (No.)	Length of longest root (cm)	2nd order roots/ cutting (No.)	Roots emerged out of bottom hole of cavity (No.)	Sprouting (%)	sprouts/ cutting (No.)	Fresh shoot length/ cutting (cm)
0	63.0	1.2	2.3	1.3	3.9	40.1	1.6	0.8
2500	71.7	2.2	3.4	1.8	7.0	46.4	2.7	1.7
5000	75.9	3.2	4.4	3.1	10.1	50.3	3.4	2.3
7500	81.4	4.3	5.0	5.9	12.5	53.0	3.7	2.8
10000	86.6	6.6	7.0	10.1	17.2	59.4	4.2	3.3
SEdiff	0.85	0.9	0.9	1.49	0.43	0.72	0.34	0.3
CD.05	1.66	1.76	1.76	2.92	0.84	1.4	0.67	0.59

The clonal variation on rooting and sprouting parameters based on overall effect of IBA concentrations is given in table 2. The results indicate significant clonal variation in the entire studied root and shoot parameters. Clones BCM 411, BCM 316, Wimco 12, BCM 413 and BCM 2045 gave over 90 percent rooting. Nine clones gave above average and 4 below average rooting percent of 75.7% under the combined effect of IBA treatments. BCM 411 gave maximum rooting of 92.8% which was statistically at par with that of BCM 413, Wimco 12, BCM 316, and BCM 2045 but was significantly higher than that of all other clones. Minimum rooting of 17.2% was obtained in BCM 288 which was significantly lower than all other clones. Average number of 1st and 2nd order roots was 1.11 per cutting and 3.11 per cutting respectively. Number of 1st and 2nd order roots/cutting were higher than their average number in K 23, BCM 411, K 25, BCM 316, BCM 2070, and BCM 2045 clones and below average in the remaining clones. Clone K 23 produced the longest root of 8.3 cm which was statistically at par with that of K25, BCM 316, BCM 2070, and BCM 2045 but significantly higher than that in the remaining clones. Six clones viz., BCM 2023, K 23, BCM 411, BCM 2135, BCM 316 and BCM 2070 produced more roots (those emerged out of bottom hole) than average number of 10.2 per cutting, while the remaining clones produced less number of such roots. Clone 2045 gave significantly higher sprouting of 92% compared to any other clone. There were 7 clones over and 6 clones below average sprouting percent of 49.8%. Number of sprouts/cutting and length of the longest shoot per cutting were maximum in clone BCM 413 and these values were significantly higher than all other clones. In case of number of sprouts per cutting there were 6 clones above and 7 clones below the average number of sprouts per cutting, whereas in case of length of the longest shoot per cutting, 7 clones were above and 6 clones were below the average length of 2.2 cm. The study is in line with findings of Hunt (2011) who reported similar findings in case of *Pinus* hybrid.

Table 2. Effect of Clones (sub plots) on rooting percent

Clone (main plot)	Rooting (%)	1st order root (No.)	Length of main root (cm)	2nd order roots /cutting (No.)	Roots emerged out of bottom hole (No.)	Sprouting (%)	Sprouts /cutting (No.)	Length of fresh sprout (cm)
BCM 2023	84.3	2.2	2.8	2.4	11.3	42.1	2.6	1.4
BCM 413	91.4	3.0	2.1	1.9	6.0	59.5	6.1	4.1
Wimco 12	91.6	1.0	0.7	0.6	1.2	45.2	3.9	2.5
K 23	85.4	5.1	8.3	13.7	22.1	78.4	4.1	3.1
BCM 411	92.8	3.5	6.4	9.8	15.5	60.0	4.2	3.2
BCM 2135	85.8	3.4	4.3	4.4	12.2	50.8	2.6	1.8
K 25	67.0	3.6	5.8	4.9	8.3	56.5	1.7	1.8
BCM 288	17.2	0.9	1.3	0.1	4.2	11.8	1.4	0.8
BCM 316	92.2	9.3	7.9	8.6	14.6	46.1	1.6	1.5
BCM 2070	47.2	3.7	7.9	4.9	19.8	53.2	1.8	1.0
BCM 2045	91.3	4.2	7.0	5.7	8.9	92.9	3.5	2.4
BCM 2306	84.9	2.1	1.3	0.1	2.4	39.7	4.4	2.4
BCM 526	53.1	3.5	1.8	1.0	5.6	11.6	2.7	2.3
Mean	75.7	3.5	4.4	4.5	10.2	49.8	3.1	2.2
SEdiff	1.16	1.11	1.11	3.11	0.72	1.25	0.61	0.57
CD0.05	2.40	2.29	2.89	6.42	1.49	2.59	1.26	1.17

Interaction effect of main plot (clones) and subplot treatments (IBA concentrations) on rooting parameters as given in table 3 and table 4 show significant variation for rooting percent and for number of roots emerged from the bottom hole of root cavity among different combinations of treatments. A minimum rooting of just 7.0% was recorded in clone BCM 288 without IBA treatment to almost complete rooting (100%) with 10000 ppm treatment in clone Wimco 12. There was over 80% rooting success in BCM 2023, BCM 413, Wimco 12, BCM 411, BCM 316, BCM 2045 clones with or without hormonal treatments. Emergence of roots from the base of root cavities kept elevated on root stands in chambers is an indicator of fast and quick development of roots. The data present in Table 4 indicate that clone BCM 288 produced significantly less number of roots those emerged out of the bottom hole of root trainer cavities with all IBA treatments compared to other clones indicating its delayed and slow development of roots in this clone. Maximum root number of 45.7/cutting emerged out of root cavity bottom hole were in clone BCM 2070 with 10000 ppm IBA concentration and this value was significantly higher than all other values recorded for this parameters in the study. There were non-significant differences for 1st order, 2nd order roots/cutting and for length of main lateral root in cuttings indicting that within 28 days of setting the cuttings, the tested clones and IBA concentrations could not produce significant variation within this period of data recording. Almeid et al. (2007) while studying the rooting of different *Eucalyptus cloeziana* clones treated with different concentrations of IBA reported differential response in clones to IBA applications. Clonal variation in rooting success and speed in eucalypts were also reported by some other authors (Hartmann et al. 2002; Ferreira et al. 2004; Brondani et al. 2012; Dhiman and Gandhi 2014).

Table 3. Interaction effect of clones and IBA concentrations on rooting and root parameters

Clone/IBA(ppm)	Rooting (%)					**1st** order roots/cutting(No.)					**2nd** order roots/cutting (No.)				
	0	2500	5000	7500	10000	0	2500	5000	7500	10000	0	2500	5000	7500	10000
BCM 2023	80.0	81.0	82.3	85.0	93.3	0.4	1.0	1.7	2.4	5.7	0.1	0.1	0.1	0.1	11.4
BCM 413	90.0	90.3	90.7	91.7	94.3	1.1	2.7	3.0	3.4	4.7	0.1	0.1	0.1	4.3	4.7
Wimco 12	87.3	87.7	90.0	93.0	100.0	0.1	0.1	0.7	1.7	2.4	0.1	0.1	0.1	0.1	2.7
K 23	63.7	87.7	90.3	92.7	92.7	2.0	4.3	5.3	5.7	8.0	7.9	8.7	11.5	19.9	20.4
BCM 411	89.7	92.0	93.0	93.0	96.3	1.0	2.0	3.3	5.3	5.7	0.1	0.1	4.5	11.5	32.7
BCM 2135	67.7	81.3	91.3	93.0	95.7	2.0	2.3	2.7	4.7	5.4	0.1	0.7	5.7	7.7	7.8
K 25	41.0	51.7	63.0	87.3	92.0	1.7	2.4	3.3	5.3	5.3	0.1	0.5	0.8	7.4	15.5
BCM 288	7.0	9.7	13.0	18.7	37.7	0.1	0.4	0.7	0.7	2.4	0.1	0.1	0.1	0.1	0.1
BCM 316	91.7	92.0	92.3	92.3	92.7	2.0	6.7	9.3	10.0	18.3	5.0	6.0	8.8	10.0	13.4
BCM 2070	6.3	40.7	51.0	67.7	70.3	3.0	3.3	3.7	4.0	4.3	1.8	3.2	4.9	6.4	8.2
BCM 2045	87.0	90.3	91.0	94.0	94.3	1.7	2.7	4.0	6.0	6.7	1.7	3.3	4.1	8.3	10.9
BCM 2306	74.3	81.0	84.3	90.7	94.0	0.1	0.4	1.1	1.4	7.4	0.1	0.1	0.1	0.1	0.2
BCM 526	33.0	46.3	54.7	58.7	72.7	0.1	0.1	2.4	5.0	10.0	0.1	0.1	0.1	1.1	3.4
Mean	63.0	71.7	75.9	81.4	86.6	1.2	2.2	3.2	4.3	6.6	1.3	1.8	3.1	5.9	10.1
SEdiff			3.06					NS					NS		
CD.05			6.00												

Table 4. Interaction effect of clones and IBA concentration on some other root parameters

Clone/ IBA (ppm)	Length of main lateral root(cm)					Roots emerged from cavity hole No.)				
	0	2500	5000	7500	10000	0	2500	5000	7500	10000
BCM 2023	1.1	2.5	3.0	3.5	3.7	1.7	10.0	14.0	15.0	16.0
BCM 413	0.9	1.7	2.2	2.5	3.0	1.3	2.7	3.0	10.0	13.0
Wimco 12	0.1	0.1	0.2	0.3	2.9	0.1	0.1	1.3	1.3	3.3
K 23	5.1	8.4	9.2	9.2	9.5	10.0	14.7	24.3	26.3	35.0
BCM 411	0.8	3.4	5.6	6.6	15.7	5.0	15.3	16.7	17.3	23.0
BCM 2135	1.1	4.2	5.0	5.6	5.6	5.0	6.3	12.7	18.0	19.0
K 25	1.7	2.6	6.6	7.4	10.5	1.7	5.0	6.3	11.0	17.3
BCM 288	0.1	0.4	1.4	1.4	3.1	0.1	5.0	5.0	5.0	6.0
BCM 316	6.6	6.7	7.9	8.6	9.5	11.3	13.3	16.0	16.0	16.3
BCM 2070	6.7	7.4	7.9	8.4	9.2	8.3	10.0	17.3	17.7	45.7
BCM 2045	5.1	5.5	5.7	7.0	11.6	6.3	7.3	9.0	10.0	12.0
BCM 2306	0.1	0.4	1.7	2.1	2.4	0.1	0.1	3.3	3.7	5.0
BCM 526	0.1	0.4	1.4	2.1	4.9	0.1	1.7	2.3	11.7	12.3
Mean	2.3	3.4	4.4	5.0	7.0	3.9	7.0	10.1	12.5	17.2
SEdiff			NS					1.55		
CD.05								3.04		

Data given in table 5 indicate significant differences for sprouting (%) whereas, number of shoots/cutting and length of longest shoot produced non-significant differences. Significantly higher values were recorded for clone BCM 2045 within each treatment of IBA application. Clone BCM 288 on the other hand produced significantly lower values for sprouting (%) within each level of IBA application. The combined effect of clones and IBA treatment could not produce significant differences for number of sprouts per cutting and length of longest shoot. Fast and speedy rooting and sprouting in cuttings are good indicators in the success of propagation system. Clones giving early rooting and sprouting would be cost effective and is an advantage in propagation systems. This study finds support from the findings of Wendling and Xavier (2005).

Table 5. Interaction effect of clones and IBA concentration on sprouting of eucalypts cuttings

Clone/ IBA (ppm)	Sprouting (%)					Sprots/cutting(No.)					Length of main sprout (cm)				
	0	2500	5000	7500	10000	0	2500	5000	7500	10000	0	2500	5000	7500	10000
BCM 2023	33.7	35.7	42.3	44.3	54.3	1.4	2.0	2.7	3.0	4.0	0.4	0.9	1.4	1.7	2.7
BCM 413	42.7	56.3	60.3	62.7	75.3	6.0	6.0	6.0	6.0	6.7	3.0	4.0	4.2	4.7	4.7
Wimco 12	40.3	42.0	45.7	48.7	49.3	2.7	3.3	4.0	4.3	5.3	2.0	2.3	2.7	2.8	2.8
K 23	60.0	77.3	81.0	83.3	90.3	2.0	2.7	4.7	5.3	6.0	0.7	1.0	3.5	4.8	5.3
BCM 411	55.0	55.7	59.7	64.7	65.0	0.1	4.7	4.7	5.3	6.0	0.1	3.0	3.7	4.5	4.8
BCM 2135	47.3	49.3	50.3	50.3	57.0	0.7	2.0	2.7	3.4	4.0	0.4	1.5	1.5	2.7	2.7
K 25	51.3	52.0	53.0	56.3	69.7	0.1	1.0	2.0	2.7	2.7	0.1	0.6	2.0	2.0	4.2
BCM 288	0.1	9.7	10.0	13.0	26.0	0.1	1.4	1.4	2.0	2.0	0.1	0.5	0.9	1.2	1.4
BCM 316	40.7	41.7	46.3	50.0	52.0	0.1	1.7	2.0	2.0	2.4	0.1	1.4	1.8	2.0	2.4
BCM 2070	33.3	46.7	59.0	59.3	67.7	1.4	1.4	1.7	2.0	2.7	0.2	0.4	1.0	1.2	2.0
BCM 2045	88.0	90.0	92.7	94.0	100.0	3.0	3.0	3.3	4.0	4.0	1.3	2.5	2.6	2.6	3.2
BCM 2306	23.7	36.3	42.7	47.0	49.0	3.4	4.0	4.7	4.7	5.0	1.4	1.8	2.0	2.8	4.0
BCM 526	5.0	10.0	10.3	16.0	16.7	0.1	1.4	4.0	4.0	4.0	0.1	2.5	2.5	2.9	3.3
Mean	40.1	46.4	50.3	53.0	59.4	1.6	2.7	3.4	3.7	4.2	0.8	1.7	2.3	2.8	3.3
SEdiff			2.58					NS					NS		
CD.05			5.06												

Table 6. Categorization of clones on the basis of their rooting ability with and without IBA application

Rooting category	0 ppm	2500 ppm	5000 ppm	7500 ppm	10000 ppm
Very easy to root (>90%)	BCM 413, BCM 316	BCM 413, BCM 411, BCM 316, BCM 2045	BCM 413, WIMCO 12, K 23, BCM 411, BCM 2135, BCM 316, BCM 2070, BCM 2045	BCM 413, WIMCO 12, K 23, BCM 411, BCM 2135, BCM 316, BCM 2045, BCM 2306	BCM 413, BCM 2023, WIMCO 12, K 23, BCM 411, BCM 2135, K 25, BCM 316, BCM 2045, BCM 2306
Easy to root (80-90%)	BCM 2023, WIMCO 12, BCM 411, BCM 2045	BCM 2023, WIMCO 12, K 23, BCM 2135	BCM 2023, BCM 2306	BCM 2023, K 25	
Moderate to root(60-80%)	BCM 2135, K 23, BCM 2306	BCM 2306	K 25	BCM 2070,	BCM 2070, BCM 526
Difficult to root (<60%)	BCM 288, K 25, BCM 2070, BCM 526	K 25, BCM 288, BCM 2070, BCM 526	BCM 288, BCM 526	BCM 288, BCM 526	BCM 288

Clones divided in different rooting categories (Table 6) indicate shifting most of them from hard to root status to easy to root status with increase in IBA concentration. There were only 3 clones giving over 90% rooting without IBA treatment which increased to 5 numbers with 2500 ppm, 9 with 5000 ppm, 10 with both 7500 ppm and 10000 ppm treatments. Some clones like K 25 shifted its status from hard to root without application of IBA to easy to root (>90%) with 10000 ppm IBA treatment. There have been some attempts of grouping clones according to rooting ability (Dhiman and Gandhi 2014). This list contains some additional clones which have been included in the commercial production. Some clones like BCM 288, BCM 526 and BCM 2070 demand interventions during cutting propagating system or hormonal treatment which may include other rooting hormones and or their combinations with IBA to achieve desirable rooting success. Further studies in improving the rooting by drenching the cutting production hedges with 0.2% solution of NPK solution at monthly interval and collection of cuttings from young shoots at around 30-35 days age with application of 5000 ppm IBA treatment of cuttings have led to acceptable rooting of over 80% in BCM 288 (unpublished)

Eucalypts were once considered hard to root. Management interventions in using juvenile cuttings produced under specific cultural inputs and treatment of cuttings with clone specific concentrations of root promoting hormones in specialized chambers with controlled conditions have helped a great deal in achieving desirable success. Rooting varies widely among different Eucalypts species and clones. Five clones viz., BCM 413, Wimco 12, BCM 411, BCM 316 and BCM 2045 gave over 90% rooting even without application of IBA and these clones are now easily propagated without IBA treatment in the propagation facility, whereas, difficult to root clone like BCM 288 are propagated by integrating cultural and hormonal treatments.

REFERENCES

Almeida FD, Xavier A, Dias JMM, Paiva HN 2007 Auxin (IBA and NAA) effects on minicuttings rooting of *Eucalyptus cloeziana* F. Muell. clones. Revista Árvore, 31(3): 455-463.

Brondani GE, Baccarin FJB, Ondas HW, Stape JL, Gonçalves AN, and Almeida M 2012 Low temperature, IBA concentrations and optimal time for adventitious rooting of Eucalyptus benthamii mini-cuttings. Journal of Forestry Research, 23(4):583-592.

Brondani GE, Grossi F, Wendling I, Dutra LF, and Araujo MA 2010a IBA application for rooting of *Eucalyptus benthamii* Maiden &Cambage x *Eucalyptus dunnii* Maiden minicuttings. Acta Scientiarum Agronomy, 32(4): 667-674.

Brondani GE, Wendling I, Grossi F, Dutra LF, and Araujo MA 2010b *Eucalyptus benthamii* x *Eucalyptus dunnii* minicutting technique: (ii) minicutting survival and rooting in relation to collection and seasons. Ciência Florestal, 20(3):453-465.

Brondani GE, Wendling I, Araujo MA, and Pires PP 2008 Indolbutyric acid in gel for minicuttings rooting of *Eucalyptus benthamii* Maiden & Cambage x *Eucalyptus dunnii* Maiden. Scientia Agraria, 9 (2):153-158.

Chandra JP and Yadav MPS 1986 Clonal propagation of Mysore gum (*Eucalyptus* hybrid), Ind. For., 112(9):783.

Day JS, Gould KS, Jameson, and Ameson PE 1998 Adventitious root initiation, plasticity, and response to plant growth regulator treatments of seedling, juvenile, and adult *Elaeocarpus hookerianus* plants. New Zealand Journal of Botany, 36(3): 477-484.

Dehon G, Rezende SP, De Resende MDV and De Assis TF 2013 *Eucalyptus* breeding for clonal forestry. In: Challenges and Opportunities for the World's Forests in the 21st Century. Ed. Fenning TM. Forestry Sciences, 81: 393–424.

Dhiman RC and Gandhi JN 2014 Status of eucalypt clonal culture in India. In: Eucalypts in India. Eds. Padam Prakash Bhojveid, Shalendra Kaushik, Yash Pal Singh, Dinesh Kumar, Manisha Thapliyal and Santan Barthwal. ENVIS Centre on Forestry, National Forest Library and Information Centre, FRI, Dehradun. pp. 60-116.

Dhyani SK, Handa AK and Uma 2013 Area under agroforestry in India. An assessment for present status and future perspective. Indian J. of Agorforestry, 15(1):1-11.

Ferreira EM, Alfenas AC, Mafia RG, Leite HG, Sartorio RC, Penchel FRM 2004 Determination of the optimum time for rooting of mini-cuttings of *Eucalyptus* spp. clones. Revista Árvore, 8(2):183-187,

FSI 2015. India state of forest report 2011. Forest Survey of India, Dehradun, MoE&F.

Griffin AR 2014 Clones or improved seedlings of eucalyptus? Not a simple choice. International Forestry Review, 16(2):216-224.

Griffith BC 1940. Effect of indolebuteric acid, indoleacetic acid and alpha naphthalene acetic acid on rooting of douglas fir and sitka spruce. J. For., 38:496-501.

Hare RC 1974 Chemical and environmental treatments promoting rooting of pine cuttings. Can. J. For. Res., 4:101-106.

Hartmann HT, Kester DE, Davies JFT and Geneve RL 2002 Plant propagation: Principles and Practices. 7th ed. New Jersey: Prentice-Hall,

Hitchcock AE and Zimmerman PW 1939 Comparative activity of root inducing substances and methods for treating cuttings. Contr. Boyce Thomp. Inst. 10:461-480.

Hunt MA, Trueman SJ, Rasmussen A 2011 Indole-3-butyric acid accelerates adventitious root formation and impedes shoot growth of *Pinus elliottii* var. *elliottii* x *P. caribaea* var. *hondurensis* cuttings. New Forests, 41(3) 349-360.

Kulkarni HD 2014 Eucalypt Improvement at ITC. In: Eucalypts in India. Eds. Padam Prakash Bhojveid, Shalendra Kaushik, Yash Pal Singh, Dinesh Kumar, Manisha Thapliyal and Santan Barthwal. ENVIS Centre on Forestry, National Forest Library and Information Centre, FRI, Dehradun. pp. 149-180.

Piare Lal 2011 Clonal agroforestry plantations in India. In: IUFRO Symposium on short rotation forestry: synergies for wood production and environmental amelioration Feb. 10-12, 2011, PAU Ludhiana, pp. 69-70.

Weaver RJ 1972 Plant growth substances in agriculture, W.H. Freeman and Co. San Fransisco.

Wendling I, and Xavier A 2005 Indolbutiric acid and serial minicutting technique on rooting and vigor of *Eucalyptus grandis* clone minicuttings. Revista Árvore, 29(6): 921-930.

Wendling I, Xavier A, Gomes JM, Pires IE, and Rade HB 2000 Minicuttings and microcuttings rooting of *Eucalyptus grandis* W. Hill ex maiden clones as affected by IBA. Revista Arvore, 24(2): 187–192.

Xu JM, Li GY, Lu, Z, Xiang DG, Zeng B, Zhang N and Guo H 2008 Investigation on eucalypt forest plantations subjected to the freezing catastrophe in southern China. Scientia Silvae Sinicae,