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Standardization of Macro-Propagation Protocol of *Toona ciliata* M. Roem under Punjab Conditions

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Abstract: *Toona* species are amongst the most valuable timbers of tropics and the backbone of forest based industries in many countries throughout the world. The study was conducted during 2018 to standardize the macropropagation protocol of *Toona ciliata* under Punjab conditions. Two types of cuttings (stem and coppiced) were grown under two different growing media *viz*., vermiculite and Soil: Sand: FYM (1:1:1) treated with 4 treatments (500, 1000, 1500 and 2000 ppm each of IBA and NAA including control and were evaluated for 6 characters under two different planting conditions *viz*., mist chamber and greenhouse. The experiment was conducted in three different growing seasons viz., mid-March, mid-July and mid-November. Season mid-March provide better performance followed by season mid-July whereas season mid-November was poorest. Vermiculite media gave better results than Soil: Sand: FYM media, IBA than NAA, mist chamber conditions than greenhouse conditions and stem cuttings gave better results than coppiced cuttings. Stem cuttings planted in mid-March season, treated with IBA 500 ppm, planted in vermiculite media and grown under mist chamber conditions came out to be the best combination to get significant and fruitful results.

Keywords: IBA, Macropropagation, NAA, *Toona ciliata*

Vegetative propagation in forest trees is emerging as a strong alternative to the seed propagation method and now employed for operational planting in many forest species. It aims to reproduce 'true to type' progeny identical to the parent source while maintaining selected elite trees indefinitely without pre-developing true-breeding stock through inbreeding and hence enables the tree breeder to shorten a breeding program considerably. It speeds up the reproductive cycle for accelerated breeding and testing while producing more stable improved material. Vegetative propagation has the potential to capture more genetic gain to obtain greater uniformity of the tree crops than through seed regeneration as both additive and non-additive traits are readily accessible and can be exploited as compared to sexual propagation where only additive traits are accessible. Moreover, it is a good method to evaluate the genotypes and their GxE interactions. *T. ciliata* is a fast growing large deciduous tree attaining a height of upto 20-30 m with a clean bole of up to 9-12 m height. It is native to Australia and has been distributed naturally in India, Burma, Laos, Pakistan, Thailand, Malaysia, Indonesia, and China (Haines et al 2016). This is a least concerned species found majorly in hills of Tamil Nadu, Andhra Pradesh and Odisha upto an elevation of 900 m (Rao 2016). In the western sub-Himalayan tract recorded in moist localities, in sheltered ravines, along streams and even in swamp forest, while in the Western Ghats, mostly in wet evergreen forests; with scattered occurrences in moist deciduous forests (Khare 2007). It is also a characteristic tree of Eastern alluvial secondary semi-evergreen forests in Assam and in Punjab *T. ciliata* is distributed in Kandi region which mainly comprises of dry deciduous scrub forest. *T. ciliata* is moderate light demander, however, the young plants require some side protection from direct sun (Orwa et al 2009). Although it favours moist localities, if tended and worked in the early stages, it can be cultivated under dry localities receiving as low as 750 mm rainfall with 2-6 dry months with a maximum temperature as high as 49°C.

Toona species are amongst the most valuable timbers of tropics and in fact the backbone of forest-based industries in many countries throughout the world owing to its high quality timber and for the ease with which they can be grown in plantations (Bufalino 2012). Toon possesses important economic characteristics including a relatively short 15-year cycle; straight clean bole, good yields, and high value in the internal and external markets (Murakami 2008). The colour of the heartwood ranges from pinkish to dark reddish brown with a good natural texture whereas sapwood is pale yellow to brown by which it is easily demarcated from heartwood. The timber is rated as moderately durable i.e. it is moderately resistant to shoot borer attack with moderate weight, strength and hardness. The versatile timber is used for building

houses and ships, furniture, musical instruments, carvings, and numerous other uses. *T. ciliata* is also planted avenue tree and firebreaks along roadsides in north India and are often looped for fodder. The technique of propagation through vegetative means have been standardized for many species, yet limited work on *T. ciliata* under Punjab conditions has been undertaken. In this experiment, macropropagation technique has been standardized through scientific improvement for large scale production of planting materials using low-cost conventional methods.

MATERIAL AND METHODS

This experiment was conducted during 2019 at College of Horticulture and Forestry, Punjab Agricultural University, Ludhiana, Punjab, India to standardize the macropropagation protocol of *T. ciliata* under Punjab conditions. Best planting season, best planting conditions, best type of planting material for cuttings (Fig. 1), best growing media and best growth regulator for significant macropropagation of *T. ciliata* were assessed under this study.

Methodology: Mid-March (season 1), mid-July (season 2) and mid-November (season 3) were chosen as the three planting to assess the best planting season for macropropagation. Two types of cutting *viz.*, juvenile stem cuttings from one year old plants along with one year old coppicing shoots from coppiced tree were used in the study. The cuttings having dimension of 8-10 cm length and 0.4-0.8 cm diameter having single node were selected. These cuttings were pre-treated with Bavistin (3g l^{-1} water) for 10 minutes and washed thrice with running water for protection against fungal diseases. Two media *viz.*, vermiculite and Soil: Sand: FYM (1:1:1) along with two auxins *viz.* IBA and NAA with 500, 1000, 1500 and 2000 ppm concentrations each along with a control each were used for planting cuttings.

The experiment was conducted in hyco-trays in two planting conditions *viz*., mist chamber and greenhouse. The temperature and humidity range of the mist chamber ranged from 29-32°C and 65-70%, respectively. In greenhouse, the temperature and humidity ranged from 17-30°C and 45-50% in mid-March, 27-36°C and 55-60% in Mid-July and 17-31°C and 30-35% in mid-November, respectively. The water sprinkler timings were set for 30 seconds at an interval of five minutes in mist chamber whereas, in greenhouse, water sprinkling was carried out manually by rose can at an interval of an hour from 0800 hrs to 1700 hrs. Hyco-trays were also washed with Bavistin (3g l^{-1}) to reduce the further chances of fungal attack. These trays were tagged and respective growing media were filled in these trays. A horizontal cut at basal end and slanting cut at apical end of the cuttings were made and the basal end of each cutting was dipped in respective auxin concentrations for a quick dip of 1 minute. Twenty cuttings each of one year old seedling as well as coppiced shoots were used per growth regulator per growing media per planting location and were replicated thrice. These cuttings were inserted 6-7 cm deep in the trays keeping in view that the buds are outside the media.

Observations were recorded for sprouting per cent (%), survival per cent (%), rooting per cent (%), average root length (cm), collar diameter (cm) and time taken for sprouting (days) at an interval of one month. Mean data of the observations were estimated and their respected critical differences (CD) and coefficient of variation (CV 0.05%) were calculated using (SPSS 2006).

RESULTS AND DISCUSSION

Both the growing media, vermiculite (under mist chamber conditions than greenhouse conditions) gave better results for all the characters observed as compared to Soil: Sand: FYM media with similar planting conditions for both stem cuttings and coppicing shoots in season 1 (mid-march) (Table 1, 2). The overall maximum sprouting percentage of 71.67 from stem cuttings and 23.33 from coppicing shoots was observed in cuttings treated with IBA 500 ppm (Fig. 2 & 3). Similarly, maximum rooting and survival of 66.67 and 25% was observed from stem cuttings whereas it was 11.67% each for cuttings from coppicing shoots. Moreover, maximum root length and collar diameter of 16.83 and 27 mm was observed from stem cuttings whereas it was 14.23 and 23 mm for cuttings from coppicing shoots. Additionally minimum days taken to sprout were 9 in case of stem cuttings whereas cuttings from coppicing shoots took 12 days to sprout. The season 1 (mid-March), both the growing media, vermiculite (under mist chamber conditions than greenhouse conditions) again gave better results for all the characters observed as compared to Soil: Sand: FYM media with similar planting conditions for both stem cuttings and coppicing shoots for season 2 (mid-July). The overall maximum sprouting of 36.67% from stem cuttings and 23.33% from coppicing shoots was observed in cuttings treated with IBA 500 ppm. Similarly, maximum rooting and survival percentage of 23.33 and 10% was observed from stem cuttings and coppicing shoots. Moreover, maximum root length and collar diameter of 10.32 cm and 23mm was observed from stem cuttings, whereas, it was 6.37 cm and 17 mm for cuttings from coppicing shoots. Additionally minimum days taken to sprout were 10 in case of stem cuttings whereas cuttings from coppicing shoots took 12 days to sprout (Table 3, 4). The season 3 was poorest among all the seasons but similar fashion for all the growth parameters. The stem cuttings from

Table 1. Effect of stem cuttings planted in mid-March season on various parameters

Stem cuttings	Sprouting per cent				Rooting per cent				Survival per cent				Root length				Collar diameter				Days taken to sprout			
	Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2	
	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G
Control	58.33	51.67	30.00	33.33	55.00	45.00	43.33	30.00	53.33	36.67	38.33	18.33	10.03	7.49	6.42	4.67	23.00	21.00	23.00	17.00	10.00	12.00	12.00	14.00
IBA 500 ppm	71.67	56.67	48.33	43.33	66.67	48.33	51.67	38.33	63.33	43.33	48.33	36.67	16.83	10.93	9.40	6.31	27.00	26.00	30.00	24.00	9.00	10.00	12.00	13.00
IBA 1000 ppm	55.00	45.00	25.00	35.00	51.67	38.33	30.00	35.00	50.00	30.00	28.33	25.00	10.00	8.48	3.96	3.74	13.00	17.00	23.00	22.00	10.00	12.00	12.00	14.00
IBA 1500 ppm	51.67	33.33	26.67	23.33	45.00	31.67	30.00	23.33	41.67	28.33	28.33	11.67	11.22	6.25	3.42	3.42	20.00	18.00	20.00	18.00	10.00	12.00	13.00	15.00
IBA 2000 ppm	50.00	21.67	23.33	23.33	41.67	18.33	21.67	21.67	38.33	18.33	18.33	8.33	7.77	4.13	6.75	2.73	23.00	15.00	17.00	16.00	10.00	13.00	12.00	15.00
NAA 500 ppm	55.00	20.00	36.67	20.00	48.33	16.67	31.67	11.67	43.33	8.33	28.33	5.00	12.15	3.74	7.71	2.10	10.00	16.00	33.00	17.00	9.00	13.00	13.00	15.00
NAA 1000 ppm	31.67	18.33	28.33	11.67	25.00	16.67	25.00	8.33	21.67	3.33	23.33	0.00	9.75	3.22	3.86	0.00	27.00	14.00	23.00	0.00	10.00	13.00	13.00	16.00
NAA 1500 ppm	26.67	15.00	18.33	10.00	21.67	8.33	13.33	0.00	16.67	0.00	10.00	0.00	14.33	0.00	5.67	0.00	17.00	0.00	20.00	0.00	10.00	13.00	14.00	16.00
NAA 2000 ppm	28.33	11.67	10.00	3.33	23.33	1.67	6.67	0.00	18.33	0.00	6.67	0.00	10.79	0.00	3.10	0.00	20.00	0.00	17.00	0.00	10.00	14.00	15.00	16.00
SEM	4.99	1.63	1.39	1.27	1.69	1.58	1.43	1.27	1.58	1.26	1.63	0.94	0.16	0.07	0.09	0.04	0.38	0.22	0.28	0.21	0.14	0.23	0.19	1.00
CD (0.5%)	14.96	4.88	4.16	3.82	5.07	4.75	4.29	3.82	4.75	3.77	4.89	2.82	0.47	0.22	0.27	0.12	1.14	0.67	0.83	0.63	0.41	0.68	0.57	3.01
CV%	18.95	9.11	8.78	9.68	6.78	10.89	8.80	11.67	7.12	11.65	11.06	13.77	2.35	2.57	2.83	2.69	3.31	2.76	2.09	2.88	2.43	3.17	2.56	24.02

Media 1: Vermiculite, Media 2: Soil: Sand: FYM (1:1:1), M: Mist chamber conditions, G: Greenhouse conditions

Table 2. Effect of coppiced shoot cuttings planted in mid-March season on various parameters

Coppiced shoots	Sprouting per cent				Rooting per cent				Survival per cent				Root length				Collar diameter				Days taken to sprout			
	Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2	
	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G
Control	11.67	3.33	10.00	1.67	13.33	1.67	8.33	0.00	11.67	1.67	6.67	0.00	10.82	7.62	7.62	2.37	20.00	14.00	16.00	13.00	13.00	14.00	14.00	15.00
IBA 500 ppm	23.33	11.67	16.67	8.33	25.00	11.67	20.00	10.00	23.33	11.67	18.33	8.33	14.23	9.15	12.47	5.41	23.00	17.00	20.00	18.00	12.00	12.00	13.00	13.00
IBA 1000 ppm	20.00	8.33	3.33	5.00	13.33	5.00	3.33	3.33	15.00	3.33	3.33	5.00	7.42	6.11	6.62	4.33	10.00	11.00	19.00	13.00	14.00	14.00	14.00	15.00
IBA 1500 ppm	6.67	0.00	0.00	0.00	8.33	0.00	0.00	0.00	8.33	0.00	0.00	0.00	6.61	0.00	4.83	0.00	17.00	0.00	19.00	0.00	14.00	0.00	15.00	0.00
IBA 2000 ppm	5.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	3.33	0.00	0.00	0.00	4.72	0.00	4.44	0.00	15.00	0.00	14.00	0.00	15.00	0.00	16.00	0.00
NAA 500 ppm	18.33	6.67	5.00	3.33	5.00	1.67	8.33	3.33	10.00	3.33	8.33	3.33	7.33	3.16	3.15	1.82	16.00	13.00	16.00	12.00	15.00	16.00	17.00	18.00
NAA 1000 ppm	11.67	0.00	1.67	0.00	3.33	0.00	3.33	0.00	5.00	0.00	5.00	0.00	4.17	0.00	2.93	0.00	14.00	0.00	15.00	0.00	16.00	0.00	17.00	0.00
NAA 1500 ppm	5.00	0.00	0.00	0.00	1.67	0.00	0.00	0.00	3.33	0.00	0.00	0.00	2.59	0.00	0.00	0.00	13.00	0.00	0.00	0.00	17.00	0.00	0.00	0.00
NAA 2000 ppm	3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEM	1.43	1.16	1.00	0.88	1.40	1.00	1.16	0.81	1.30	1.00	1.06	0.81	0.16	0.04	0.09	0.06	0.21	0.16	0.20	0.15	0.19	0.14	0.15	0.18
CD (0.5%)	4.29	3.48	3.00	2.63	4.20	3.00	3.48	2.43	3.91	3.00	3.17	2.43	0.48	0.12	0.26	0.17	0.64	0.47	0.61	0.45	0.57	0.43	0.45	0.55
CV%	20.58	57.21	42.58	74.69	29.15	72.06	41.80	75.75	24.87	66.91	39.57	75.75	4.33	2.33	3.20	6.16	2.59	4.47	2.67	4.14	2.58	4.04	2.21	4.72

Media 1: Vermiculite, Media 2: Soil: Sand: FYM (1:1:1), M: Mist chamber conditions, G: Greenhouse conditions

Table 3. Effect of stem cuttings planted in mid-July season on various parameters

Stem cuttings	Sprouting per cent				Rooting per cent				Survival per cent				Root length				Collar diameter				Days taken to sprout			
	Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2	
	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G
Control	16.67	13.33	11.67	8.33	8.33	3.33	11.67	0.00	8.33	3.33	11.67	0.00	6.73	3.41	4.39	0.00	20.00	13.00	16.00	0.00	11.00	12.00	13.00	0.00
IBA 500 ppm	36.67	21.67	25.00	15.00	23.33	18.33	20.00	10.00	23.33	18.33	20.00	8.33	10.32	7.63	9.28	9.28	23.00	16.00	20.00	20.00	10.00	10.00	12.00	12.00
IBA 1000 ppm	16.67	18.33	8.33	8.33	13.33	8.33	8.33	3.33	13.33	8.33	25.00	3.33	7.64	4.28	4.53	4.53	10.00	11.00	19.00	19.00	11.00	12.00	13.00	13.00
IBA 1500 ppm	11.67	3.33	0.00	0.00	11.67	5.00	0.00	0.00	11.67	3.33	0.00	0.00	6.23	2.19	0.00	0.00	17.00	10.00	19.00	0.00	0.00	0.00	0.00	0.00
IBA 2000 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.17	0.00	0.00	0.00	15.00	0.00	14.00	0.00	0.00	0.00	0.00	0.00
NAA 500 ppm	11.67	13.33	11.67	3.33	8.33	3.33	8.33	0.00	8.33	1.67	6.67	0.00	3.36	3.13	6.15	0.00	16.00	13.00	16.00	0.00	11.00	13.00	13.00	0.00
NAA 1000 ppm	10.00	3.33	5.00	0.00	3.33	0.00	1.67	0.00	3.33	0.00	1.67	0.00	2.62	0.00	3.97	0.00	14.00	0.00	15.00	0.00	11.00	0.00	14.00	0.00
NAA 1500 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00
NAA 2000 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00
SEM	1.32	1.55	1.00	1.02	1.43	1.06	1.13	0.56	1.39	1.13	1.18	0.81	0.11	0.02	0.01	0.03	0.30	0.136	0.24	0.12	0.11	0.13	0.13	0.13
CD (0.5%)	3.95	4.64	3.00	3.06	4.29	3.17	3.38	1.67	4.16	3.38	3.53	2.43	0.34	0.07	0.04	0.08	0.90	0.41	0.73	0.34	0.32	0.39	0.39	0.38
CV%	19.56	32.88	24.65	45.46	32.62	43.01	35.18	64.95	31.68	50.25	36.74	108.21	4.31	1.72	0.71	2.86	3.64	3.35	3.20	4.62	2.25	4.29	3.14	7.99

Media 1: Vermiculite, Media 2: Soil: Sand: FYM (1:1:1), M: Mist chamber conditions, G: Greenhouse conditions

Table 4. Effect of coppiced shoot cuttings planted in mid-July season on various parameters

Coppiced shoots	Sprouting per cent				Rooting per cent				Survival per cent				Root length				Collar diameter				Days taken to sprout			
	Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2	
	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G
Control	11.67	3.33	8.33	0.00	3.33	3.33	3.33	0.00	5.00	1.67	1.67	0.00	3.11	0.00	2.83	0.00	15.00	0.00	11.00	13.00	14.00	0.00	14.00	0.00
IBA 500 ppm	23.33	15.00	13.33	10.00	10.00	10.00	10.00	5.00	1.00	8.33	8.33	5.00	6.37	9.15	5.14	5.41	17.00	17.00	14.00	18.00	12.00	12.00	13.00	13.00
IBA 1000 ppm	8.33	5.00	3.33	5.00	3.33	3.33	3.33	3.33	3.33	3.33	3.33	1.67	4.38	6.11	4.16	4.33	13.00	11.00	12.00	13.00	13.00	14.00	15.00	15.00
IBA 1500 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IBA 2000 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAA 500 ppm	3.33	3.33	1.67	3.33	3.33	0.00	0.00	0.00	3.33	0.00	0.00	0.00	4.41	0.00	0.00	0.00	14.00	0.00	0.00	0.00	15.00	0.00	0.00	0.00
NAA 1000 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAA 1500 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAA 2000 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEM	1.06	1.02	1.16	0.56	0.96	0.73	1.27	0.56	0.81	1.00	1.00	0.56	0.04	0.07	0.04	0.02	0.12	0.04	0.13	0.09	0.09	0.05	0.18	0.04
CD (0.5%)	3.17	3.06	3.48	1.67	2.88	2.20	3.82	1.67	2.43	3.00	3.00	1.67	0.13	0.22	0.11	0.07	0.37	0.12	0.39	0.28	0.27	0.17	0.56	0.14
CV%	34.11	53.03	67.92	47.23	75.00	68.74	99.22	103.9	58.27	117.0	117.0	129.9	3.72	7.56	4.79	3.67	3.28	2.28	5.53	3.31	2.62	3.46	6.91	2.51

Media 1: Vermiculite, Media 2: Soil: Sand: FYM (1:1:1), M: Mist chamber conditions: Greenhouse conditions

one year old seedlings poorly sprouted whereas cuttings from coppicing shoots completely failed to sprout (Table 5). Cuttings planted in greenhouse failed to sprout regardless of the cutting type and growing media. The maximum sprouting percentage, rooting percent, survival per cent, root length and collar diameter observed was 11.67, 4.67, 3.33, 4.35 and 16mm, respectively. After one month interval, all of the survived cuttings from each season were transferred to polybag (5 cm x 7 cm) containing Soil: Sand: FYM (1:1:1). These cuttings were then placed under observation in greenhouse conditions for one month. 100% survival of cuttings was observed.

In forest trees, a large number of chemicals have been tested and reported to positively influence the rooting ability of tree species. The success of enhanced root proliferation may be attributed to transformation of chemical or a physiological response of the cuttings to the applied chemical or induced hydrolysis and mobilization of nutritional factors to the site of application thereby promoting root initiation in the cuttings. Among chemicals, auxin is essential for the propagation of cuttings in many plant species used in horticultural and in forestry industries. Usually, Indole-3-butyric acid (IBA) is found to be the most effective root promoting auxin and least toxic for plant tissues (Mazzini-guedes et al 2017). It is considered to be the best and most effective root promoting substance owing to its ability to produce a strong fibrous root system, non-toxic nature over a wide range of concentration, chemical stability and high degree of effectiveness in various plant species.

Mid-January season gave the best result among all three seasons whereas mid-November gave the worst results. This was because trees have great capability to grow in spring season and they retard their growth due to dormancy induction during autumn season. Season mid-July gave the intermediate results for all the parameters among all the seasons. Vegetative propagation of *Swietenia macrophylla* through branch cuttings treated with 0.4% IBA gave highest rooting per cent, sprouting per cent and survival per cent with 0.4% IBA treatment (Azad and Matin 2015). Vegetative propagation of *T. ciliata* revealed that maximum sprouting percent (52.22%) and rooting percent (36.61%) was in cuttings treated with 8000 ppm IBA. All the concentrations of IBA gave better results than the respective NAA concentrations (Thakur 2014). Rooting success in IBA 6000 ppm was (5.72% and was higher compared to control and IBA 4000 ppm. The survival in air layering was 11%, whereas, in root suckers (27.78% in *Tecomella undulata*. The coppice shoots emerged well on stumps of one year old seedlings during March. (Kaur et al 2019). IBA (250 mg L^{-1}) showed best results with sand in terms of rooting percent (80%), number of roots (70.63), root length (11.13) and number of leaves (5.25) per rooted mini-cuttings of *Azadirachta indica* under mist chamber conditions (Gehlot et al 2014).

Fig. 1. Sprouted cuttings

Fig. 2. One month old stem cuttings treated with IBA 500 and planted in vermiculite media under mist chamber conditions

Fig. 3. One month old stem cuttings treated with IBA 500 and planted in vermiculite media under mist chamber conditions

Table 5. Effect of stem cuttings planted in mid-November season on various parameters

Coppiced shoots	Sprouting per cent				Rooting per cent				Survival per cent				Root length				Collar diameter				Days taken to sprout			
	Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2		Media 1		Media 2	
	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G	M	G
Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IBA 500 ppm	11.67	8.33	5.00	3.33	4.67	0.00	0.00	0.00	3.33	0.00	0.00	0.00	4.35	0.00	0.00	0.00	16.00	0.00	0.00	0.00	18.00	0.00	0.00	0.00
IBA 1000 ppm	3.33	3.33	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IBA 1500 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IBA 2000 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAA 500 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAA 1000 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAA 1500 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NAA 2000 ppm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEM	0.81	0.73	0.56	0.56	0.11	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.04	0.00	0.00	0.00
CD (0.5%)	2.43	2.20	1.67	1.67	0.33	0.00	0.00	0.00	1.67	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.13	0.00	0.00	0.00
CV%	75.75	98.20	129.9	259.8	37.12	0.00	0.00	0.00	259.8	0.00	0.00	0.00	6.05	0.00	0.00	0.00	0.54	0.00	0.00	0.00	3.79	0.00	0.00	0.00

Where, Media 1: Vermiculite, Media 2: Soil: Sand: FYM (1:1:1), M: Mist chamber conditions, G: Greenhouse conditions

CONCLUSION

T. ciliata respond well to macropropagation and could be a great option to propagate this species. Mid-march came out to be the best planting season for vegetative propagation of *T. ciliata*. Stem cuttings had better survival rate and longer roots than cuttings obtained from coppiced shoots. Vermiculite gave better results than Soil: Sand: FYM irrespective of the planting season or planting conditions. Similarly, IBA gave better results than NAA with respective concentration irrespective of the planting season, planting conditions or growth media. Overall, stem cuttings planted in mid-March season, treated with IBA 500 ppm, planted in vermiculite media and grown under mist chamber conditions came out to be the best combination to get significant and fruitful results.

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