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Assessment of coppicing ability and rooting potential in *Neolamarckia cadamba* (Roxb.) Bosser clones

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ABSTRACT

A study was conducted to assess and maximize the production of coppice shoots and their rooting potential among 20 Neolamarckia cadamba clones to be managed under short rotation. All the N. cadamba clones responded to coppicing by sprouting new growth from the stump in the form of varying numbers of shoots. Quantum of sprouting stumps was used to determine the success of coppicing ability of individual clones. There was no significant relationship between the clones and the time consumed for the sprouting of stumps. Sprouting ability was observed to increase with a corresponding increase with age. Results indicated that the month of May to be the best month for increased shoot output in cadamba clones. Among the 20 clones, clone number 116 recorded the highest rooting potential, and a statistically significant association was observed between the clones and age considering all five ages.

Key Words*:* *Neolamarckia cadamba,* clones, coppicing and Rooting.

INTRODUCTION

Neolamarckia cadamba, a native tree species, is an important member of the Rubiaceae family. Its rapid development has helped it get the nickname "miracle tree" in the common language. The species is found to be native to Papua New Guinea, Vietnam, Singapore, Australia, China and India. Among the common wood-yielding trees, *N. cadamba* (Cadamba) can be used as an alternative in the wood processing industry and other sectors (Jha *et al.*, 2021). The tree may quickly grow to a height of 30 feet because of its straight trunk and quick growth rate. Its economic and ecological importance has led to an increasing interest in cultivating this species through vegetative propagation (Sharma *et al.*, 2020). *N. cadamba* often yields substantial amounts of high quality, rot and fungus resistant wood (Changlun *et al.*, 2020) to ensure the long-term sustainability and productivity of its plantations. Hence, it is crucial to assess the coppicing ability and rooting potential of the clones of this species, which are recommended for cultivation. Clonal selections are also used to select trees with higher productivity (Pal *et al.,* 2023).

Coppicing is the process of cutting a tree to ground level to stimulate the growth of new shoots. It is an important management technique in forestry to maintain a continuous supply of wood for various purposes. The ability of *N. cadamba* clones to coppice and produce new shoots is a desirable trait for plantation establishment and management, as it can decrease the harvesting cycle and increase the productivity of the plantations (Kavitha *et al.*, 2021). Several studies have examined the effects of pruning method, pruning time, stump age, stump height and stump diameter on the responses of coppice shoots (Fombasso and Ambebe, 2019). Rooting potential, on the other hand, refers to the ability of a clone to develop a healthy root system when propagated vegetatively. Given that *N. cadamba* is typically propagated through stem cuttings, it is important to assess the rooting potential of the clones to ensure the successful establishment and growth of the new plants. A high rooting potential is essential for the survival and growth of new plants, especially in challenging environments such as degraded or disturbed land (Suresh Kumar *et al.,* 2019).

Evaluating the coppicing ability and rooting potential of *N. cadamba* clones involves conducting experiments and observations in the field and in controlled environments (Aind *et al.*, 2018). This includes comparing the coppicing

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and rooting success rates of different clones, evaluating the growth performance and survival of new shoots and plants and examining factors that may affect these characteristics, such as edaphic and climatic conditions. Therefore, the current study aims to assess the coppicing ability and rooting potential of selected Cadamba clones, which is crucial for the sustainable management and productivity of its plantations. By selecting and cultivating clones with high coppicing ability and rooting potential, we can ensure a continuous supply of Quality Planting Material (QPM) for promoting commercial plantations, reforestation, and restoration efforts.

MATERIALS AND METHODS

In order to investigate the coppicing ability and rooting potential of *N. cadamba*, based on the results from previous studies, twenty best individual progenies which are highly productive were selected from the progeny trials raised at three different locations viz., Chennai, Neyveli of Tamil Nadu and Panampally of Kerala.

Table 1: Details of selected seed source of promising *N. cadamba*clones

S.No	Original Source name	Seed Source No	Clone no	Location
1	TNNSP	23	13	Narasipuram
2	TNNSP	26	15	Narasipuram
3	TNNSP	28	17	Narasipuram
4	TNNSP	35	22	Narasipuram
5	TNNSP	57	42	Narasipuram
6	TNNSP	58	43	Narasipuram
7	TNNSP	75	60	Narasipuram
8	TNNSP	82	67	Narasipuram
9	TNNSP	95	80	Narasipuram
10	TNNSP	20	105	Chennai
11	TNNSP	39	111	Chennai
12	TNNSP	36	112	Chennai
13	TNNSP	29	113	Chennai
14	TNDRP	2	115	Chennai
15	TNNSP	24	116	Chennai
16	TNDRP	11	127	Chennai
17	ASSM	140	139	Neyveli
18	ANDM	133	140	Neyveli
19	ANDM	116	141	Neyveli
20	KLKN	55	144	Neyveli

(TNNSP – Narasipuram, TNDRP- Devarayapuram, ASSM-Assam, ANDM-Andaman, KLKN-Kerala- Konni)

These clones were planted in nursery mother beds following Randomized Complete Block Design (RCBD) with five replications at spacing of 0.50 cm in the Plant Biotechnology (PBT) Nursery, Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu. Details of the mother clones are given in (Table 1). All the 20 mother plant progenies were observed for their shoot production at a regular interval of 30 days over a period of five consecutive years (2018-2022). The number of sprouting stumps was counted for each mother plant to estimate its percentage of coppice shoot production and it's rooting potential. Rooting ability and the number of coppice shoots produced by each mother plant were recorded at monthly intervals throughout the experimental period of five years. The percentage of shoot production and their rooting potential for every year was also recorded to assess the trend of shoot production and rooting potential over the age of the mother plants. The data recorded were subjected to statistical analysis using Restricted Maximum Likelihood variance components analysis in GenStat software version 9.4. The analysis was conducted to determine the fixed effects of shoot production and rooting potential for various months in a year as well as to understand their performance with age of all the selected 20clones. When the F-value was significant ($p \leq 0.05$) for a given parameter, month and age differences were further investigated using the least significant difference (LSD) statistic.

RESULTS AND DISCUSSION

The results of the analysis showed that both coppicing ability/shoot production and rooting potential had significant effects on the survival rate of *N. cadamba* clones. Coppicing regeneration was observed to take place within 25-30 days after successive coppicing. Coppicing ability and rooting potential were studied from January to December over five years (2018–2022) the examination of the data revealed considerable variation in coppicing capacity and rooting potential among the 20 clones. Significant clonal variation ($p < 0.001$) was observed for coppicing ability among selected *N. cadamba* clones, with a value of 19.62. Significant difference ($p < 0.001$) was observed between months for coppicing ability with a value of 6.03 and there was no statistical significance ($p>0.001$) for the interaction component of Clone and Month (Table 2).

Table 2: Wald tests for fixed effects of Clone and Month for Coppicing Ability in *N. cadamba*

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Clone	372.72	19	19.62	<0.001
Month	66.29	11	6.03	<0.001
Clone*Month	154.41	208	0.74	0.998

Standard error of difference (SEd) = 0.49

Based on the results of prediction mean data of the coppicing ability across various months within selected clones (Table 3), it was observed that the highest number of coppices (2.55) were recorded in clone no 60, while the lowest value was observed in clone no 17 (1.25). Among the months, the month of May exhibited the highest coppicing ability value of 2.06, whereas in January, lowest mean coppicing ability value of 1.31 was recorded. June and October followed the same trend with a value of 1.81. Remarkably, clone no 60 displayed superior performances in coppice shoot production compared to other clones, making it the most efficient for this particular trait. Furthermore, the month of May emerged as the most conducive month to produce more coppicing shoots for mass multiplication.

Table 3: Predicted means of Clone and Month for Coppicing Ability in *N. cadamba*

Clone/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
13	1.83	1.51	0.81	1.63	1.34	1.40	1.19	1.46	1.07	1.93	1.31	1.97	1.45
15	1.12	1.86	2.50	1.83	1.70	2.16	2.02	1.96	1.68	2.02	1.81	2.06	1.89*
17	1.20	1.44	1.53	1.31	1.09	1.33	1.22	1.19	1.04	1.46	1.00	1.23	1.25
22	1.50	1.10	1.07	1.26	1.48	1.53	1.26	1.38	1.15	1.81	1.06	1.29	1.32
42	0.94	0.90	1.20	1.70	1.74	1.40	1.31	1.56	1.11	1.71	1.40	1.67	1.39
43	1.44	1.54	1.23	2.38	2.83	2.09	2.29	2.17	1.67	2.11	2.15	1.97	1.99*
60	2.14	2.84	2.39	1.86	2.59	3.14	2.89	2.04	2.40	3.00	2.40	2.85	2.55*
67	1.53	1.67	1.71	1.51	2.16	1.64	1.11	1.42	1.53	1.79	1.46	2.06	1.63
80	1.01	1.22	1.34	1.68	2.34	2.19	1.51	1.36	2.12	1.45	1.46	2.07	1.64
105	1.08	1.42	1.69	1.57	1.32	1.42	1.32	1.42	1.19	1.20	1.50	1.67	1.40
111	1.42	0.94	1.41	1.36	1.65	1.28	1.43	1.69	1.16	1.53	1.40	1.51	1.40
112	1.30	1.86	1.91	1.49	2.44	2.47	2.33	1.54	1.62	2.12	1.59	1.99	1.89*
113	0.94	1.03	0.96	1.63	1.83	1.08	1.24	1.83	1.16	1.43	1.31	1.28	1.31
115	1.22	2.39	3.31	1.91	3.13	2.26	2.24	1.87	1.74	2.03	1.78	2.49	2.20*
116	1.08	1.07	1.57	1.64	1.88	1.36	1.61	1.19	1.33	1.10	1.10	1.06	1.33
127	1.14	1.90	1.73	2.22	2.11	1.07	1.63	1.68	1.11	1.40	1.44	1.47	1.58
139	1.11	1.38	1.41	1.13	1.42	1.81	1.57	1.50	1.43	1.60	1.30	1.19	1.40
140	1.08	0.85	1.19	1.32	-	1.46	1.42	1.00	1.23	1.13	1.21	1.26	1.20
141	1.49	2.23	2.56	2.64	3.13	2.74	2.69	3.12	2.25	3.08	1.95	2.42	2.53*
144	1.69	1.91	2.49	1.98	2.89	2.41	2.86	2.33	2.38	2.25	1.88	1.95	2.25*
Mean	1.31	1.55	1.70	1.70	2.06*	1.81*	1.76	1.69	1.52	1.81*	1.53	1.77	1.68

**-Significantly higher than the lowest treatment*

The Wald tests for clone and age for coppicing ability exhibited statistically significant values ($p < 0.005$) except for the clone and age interaction component (Table 4).

Table 4: Wald tests for fixed effects of Clone and Age for Coppicing Ability in *N. cadamba*

Fixed term	Wald statistic	d.f.	Wald/d.f.	F pr
Clone	51.19	19	2.69	<0.001
Age	16.26	4	4.06	0.003
Clone*Age	73.03	76	0.96	0.574

Standard error of difference (SEd) = 0.3186

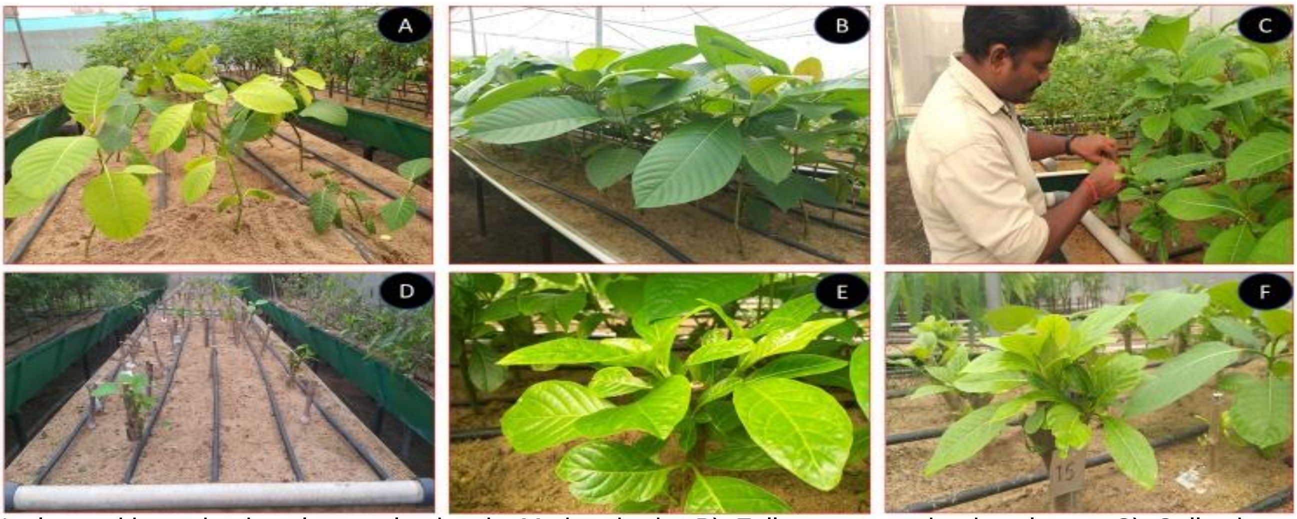
The interactions across various ages within the selected clone's data emphasize (2.55) that the highest coppicing ability was observed in clone no 60, while clone no 17 exhibited the lowest value of 1.25 (Table 4).

Among the selected clones assessed for coppicing ability across various ages, five-year-old clones showed the highest mean value at 1.89, followed by four-year-old clones with 1.78. In contrast, one-year-old clones exhibited the lowest mean value at 1.39. Notably, clone no. 60 demonstrated superior performance in coppice shoot production compared to other clones, particularly in the fifth year (see Table 5). Factors influencing coppicing ability include the presence and activity of buds, the role of growth regulators

Table 5: Predicted means of Clone and Age for Coppicing Ability in *N. cadamba*

Clone/Age	1st Year	2nd Year	3rd Year	4th Year	5th Year	Mean
13	1.27	1.47	1.82	1.06	1.51	1.43
15	1.46	1.27	1.95	1.99	2.49	1.83*
17	1.24	1.31	1.28	1.02	1.17	1.20
22	1.33	1.54	1.54	1.14	1.08	1.33
42	1.33	1.37	1.38	1.28	1.57	1.39
43	2.08	1.84	1.90	2.04	2.32	2.03*
60	1.98	2.50	2.70	2.78	2.60	2.51*
67	1.81	1.43	1.41	1.70	2.06	1.68*
80	1.26	1.49	1.48	1.88	2.04	1.63*
105	1.26	1.36	1.31	1.55	1.58	1.41
111	1.02	1.17	1.39	1.52	1.66	1.35
112	1.48	1.64	1.24	2.56	2.39	1.86*
113	1.39	1.35	1.23	1.11	1.22	1.26
115	1.34	1.81	1.76	2.73	2.72	2.07*
116	1.01	1.17	1.47	1.64	1.34	1.33
127	1.18	1.19	1.48	1.70	2.13	1.53*
139	1.31	1.43	1.22	1.49	1.61	1.41
140	1.08	1.30	1.42	1.32	1.17	1.25
141	1.76	2.67	2.32	2.94	2.56	2.45*
144	1.30	2.45	2.12	2.24	2.63	2.15*
Mean	1.39	1.59	1.62	1.78*	1.89*	1.66

**- Significantly higher than the lowest treatment*



Neolamarckia cadamba clones planting in Mother beds, B) Fully grown cadamba clones, C) Collection of coppice shoots, D) Complete harvesting, E) and F) After harvesting to emerge new coppice shoots

in bud development, stored nutrients facilitating shoot initiation, and seasonal and environmental conditions that affect shoot growth (Cremer, 1973). Moreover, a statistically significant difference was observed for *N. cadamba* clones in relation to rooting potential. There was no significant difference between months and combination of clones and months for rooting potential (Table 6).

Table 6: Wald tests for fixed effects of Clone and Month for Rooting Potential in *N. cadamba*

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
Clone	51.42	19	2.71	<0.001
Month	9.74	11	0.89	0.554
Clone*Month	201.96	208	0.97	0.605

Standard error of difference (SEd) = 15.52

A) Fully grown Neolamarckia cadamba clones in Mother beds, B) Harvested coppice shoots dipped in water, C) Bavistin treatment in coppice shoots, D) After treatment of Bavistin for Coppice shoots, E) Coppice shoots insert the hycopots, F) Hycopot kept under the polytunnel,G) Closed the poly tunnel, H) After 40 days fully rooted coppice shoots, I) Rooted individual coppice shoots

Table 7: Predicted means of Clone and Month for Rooting Potential in *N. cadamba*

Clone/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
13	55.2	70.3	61.9	57.8	37.3	40.9	61.0	70.9	50.9	30.1	44.0	71.7	54.3
15	39.8	49.9	47.4	46.1	49.9	55.6	39.5	39.4	54.8	48.3	48.6	64.9	48.7
17	35.7	51.3	69.4	40.8	42.0	38.2	56.2	62.4	47.7	41.3	69.0	66.6	51.7
22	33.1	70.8	56.2	62.1	58.5	58.3	52.5	42.9	37.1	44.2	60.5	51.0	52.3
42	31.8	60.5	45.1	62.9	60.9	52.4	54.5	39.4	89.2	58.6	49.7	52.2	54.7
43	37.1	39.8	58.1	59.0	45.4	46.3	51.0	50.4	45.5	40.3	40.7	53.3	47.2
60	45.5	42.4	52.4	51.9	47.5	46.8	49.1	49.2	53.7	46.4	48.8	54.8	49.0
67	68.9	38.0	39.8	46.3	52.5	40.9	62.5	70.6	44.9	46.7	69.8	63.5	53.7
80	43.9	44.4	52.1	55.4	48.7	59.2	48.4	61.3	43.5	42.6	43.4	75.8	51.6
105	42.8	38.6	62.4	62.6	54.6	46.0	42.6	48.8	37.8	71.9	59.1	53.3	51.7
111	42.5	56.5	55.3	49.7	50.5	58.9	59.3	41.7	82.7	63.9	56.8	58.0	56.3
112	48.1	54.6	39.8	49.4	44.5	52.2	45.9	44.2	51.8	43.0	63.5	52.7	49.1
113	89.4	73.8	43.9	21.2	45.9	28.9	73.2	87.5	53.7	78.7	47.9	54.7	58.2
115	42.8	49.8	40.8	49.1	36.4	48.8	65.0	66.5	46.2	52.1	57.8	42.1	49.8
116	72.9	75.3	55.7	62.1	53.5	80.3	71.7	58.7	69.8	79.8	59.3	72.9	67.7*
127	38.4	39.7	58.3	60.7	36.2	59.6	54.0	66.2	48.7	50.0	60.8	57.1	52.5
139	56.8	65.7	88.9	39.0	75.8	60.7	33.1	56.3	54.7	44.9	49.8	55.6	56.8
140	57.2	91.7	43.7	44.1	-	42.2	65.4	67.8	61.1	75.5	48.2	59.6	59.7
141	48.0	45.2	51.8	40.8	50.8	52.7	52.0	47.0	58.1	44.6	49.5	41.7	48.5
144	47.0	63.6	58.4	45.0	42.1	48.0	44.6	52.7	38.5	54.3	51.9	42.6	49.1
Mean	48.8	56.1	54.1	50.3	49.1	50.8	54.1	56.2	53.5	52.9	54.0	57.2	53.1

***-** *Significantly higher than the lowest value*

The predicted mean of clone and month for rooting potential revealed that clone no 116 exhibited the highest rooting potential of 67.7 followed by clone no 140 of 59.7, while clone 43 showed the lowest mean value of 47.2. The remaining clones also demonstrated good rooting potential in their interactions. Correspondingly, across all months, there were no significant differences observed, indicating the amenability for rooting potential in *N. cadamba* clones throughout the year (Table 7).

With respect to clonal interactions with the age for rooting potential within chosen *N. cadamba* clones, a significant difference was

Table 8: Wald tests for fixed effects of Clone and Age for Rooting Potential in *N. cadamba*

Fixed term	Wald statistic	d.f.	Wald/d.f.	F pr
Clone	428.23	19	22.54	<0.001
Age	58.52	4	14.63	<0.001
Clone*Age	131.12	76	1.73	<0.001

Standard error of difference (SEd) = 10.71

recorded for clone and age. Furthermore, a statistically significant relationship was found between the combination of clones and age with respect to rooting potential (Table 8).

Out of twenty clones, clone no 113 revealed the highest rooting potential mean of 72.4 followed by clone no116 with a mean value of 67.1, while clone no 43 had the lowest mean value of 46.5 for the rooting potential across different ages. Similarly, no significant differences were observed across all ages, indicating consistently favourable conditions for rooting in *N. cadamba* clones across these five ages (Table 9). Each of these five ages appears to support rooting in *N. cadamba*, suggesting sustained high rooting potential throughout these different age categories. A study that examined the rooting capacity of three *N. cadamba* clones, namely Clone no 116, Clone no 140, and Clone no -113, at varying ages (3, 6, and 9 months) indicated that in comparison to three and six months, the results at 9 months were observed to be higher and in to all three clones exhibited greater rooting potential over age (Nisa *et al.*, 2017).

Table 9: Predicted means of Clone and Age for Rooting Potential in *N. cadamba*

Clone/Age	1st Year	2nd Year	3rd Year	4th Year	5th Year	Mean
13	32.7	58.1	56.5	56.3	60.0	52.7
15	44.9	57.9	49.1	46.6	51.2	49.9
17	58.6	52.6	55.2	51.7	60.0	55.6
22	34.3	51.5	53.9	56.8	59.5	51.2
42	41.1	63.3	49.0	60.1	60.0	54.7
43	38.2	46.1	51.9	43.4	53.1	46.5
60	39.7	50.5	54.1	50.1	49.4	48.7
67	44.2	60.9	55.2	60.7	42.5	52.7
80	42.6	56.2	57.8	49.8	51.9	51.7
105	62.8	57.0	51.3	46.2	52.2	53.9
111	89.9	51.7	58.9	52.3	64.3	63.4*
112	44.9	35.3	63.7	48.9	56.8	49.9
113	55.4	52.9	73.4	90.1	90.0	72.4*
115	54.1	51.2	53.3	44.1	52.9	51.1
116	62.8	76.9	63.0	70.3	62.6	67.1*
127	46.6	48.8	54.4	51.2	61.2	52.5
139	38.2	63.0	52.1	47.6	62.6	52.7
140	58.3	55.0	51.0	56.7	68.5	57.9*
141	42.1	52.1	54.7	45.8	46.5	48.2
144	40.1	50.4	52.2	49.5	49.5	48.3
Mean	48.6	54.6	55.5	53.9	57.7	54.1

***-** *Significantly higher than the lowest value*

The present study proposes that for mass multiplication of promising N. cadamba clones, coppice shoots could be collected from mother plants aged 4 to 5 years, considering both the quantity of shoot production and maximum rooting potential. A similar finding was reported by Sasidharan *et al.* (2015) where high rooting potential was observed in *Tectona grandis L*. from the juvenile stage until maturity. The effectiveness of rooting in larger cuttings can be attributed to higher levels of endogenous auxins, whereas smaller cuttings may exhibit reduced rooting percentages due to lower auxin levels (Palanisamy and Kumar, 1997). Additionally, larger cuttings may store more stem carbohydrates, which could also contribute to their improved rooting success (Tchoundjeu and Leakey, 2001).

CONCLUSION

The present study clearly demonstrates the high coppicing and rooting capacity of *N. cadamba* (Roxb.) Bosser clones. Following a cut, the clones showed great coppicing ability, which paved the way for maximum shoot production as seen by their aggressive regeneration from their stumps. Additionally, the majority of the cuttings from the clones formed roots and survived after being planted, demonstrating the high success rate of the species for rooting. The results of the study indicate the species promising clones have potential applications in agro forestry and reforestation. Further research in this area may lead to identify and develop successful planting techniques resulting in the establishment of large-scale *N. cadamba* clonal plantation, which will be vital for promoting conservation and sustainable use of natural resources.

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REFERENCES

Aind, A. and Sharma, S. (2018) Assessment of coppicing ability and rooting potential of *Neolamarckia cadamba* clones in the Uttarakhand Himalayas, India. *International Journal of Innovative Science and Research Technology*, **3(2)**: 43-49.

Changlun, W.L., Samsudin, Z., Numee, L., Ariffin, J., Alias, S.A., Nafarizal, M., Ramachandran, S., Das, B. and Lima, R. (2020) Assessment of coppicing and vegetative propagation of *Neolamarckia cadamba* (Roxb.) Bosser using cuttings and root suckers. *Indian Journal of Forestry*, **43(4)**: 375-386.

Cremer, K.W. (1973) Ability of *Eucalyptus regnans* and associated evergreen hardwoods to recover from cutting or complete defoliation in different seasons. *Australian Forest Research*. **2**: 9–22.

Fombasso, S. and Ambebe, T. F. (2019) Evaluating the impact of climate change on the growth, yield and nutrient uptake of *Neolamarckia cadamba* in tropical ecosystems. *International Journal of Climate Change Strategies and Management*, **11(4)**: 503-520.

Jha, P.C. (2021) Spatial analysis of *Neolamarckia cadamba* (Roxb.) an important indigenous tree species in an Indo-Gangetic alluvial plains landscape in Bihar, India." *Current Science*, **120(2)**: 308-318.

Kavitha, M., Ramachandra, K.K., Kumar Singh, B. and Balu, B. (2021) Evaluating coppicing ability and biomass productivity of selected clones of *Neolamarckia cadamba* (Roxb.) Bosser. *BioResources*, **16(1)**: 998-1006.

Nisa, P., Ahmaruzzaman, M., Karim, M. A., Quayyum, M. A. and Rahman, M. L. (2017) Rooting capacity of three *N. cadamba* clones in response to different rooting techniques and growth regulators. *Ceylon Jour. of Science*, **46(4)**: 255-264.

Pal, A., Saha, S., Chowdhury, A., Hazra, P. and Dutta, A. (2023) Diversity, distribution and conservation of *Neolamarckia cadamba* (Roxb.) Bosser in India. *Journal of Forestry Research*, **34(3)**: 515-527.

Palanisamy, K.and Kumar, P. (1997) Effect of position, size of cuttings and environmental factors on adventitious rooting in neem (Azadirachta indica A. Juss). *Forest Ecology and Management*, **98(3)**:277-280.

Sasidharan P.V., Sasidharan M.V., Pradeep A.K. and Ratna E.V. (2015) Maturity duration and rooting potential of different clonal Teak (*Tectona grandis* L.) progenies. *Indian Journal of Forestry,* **38(1)**: 29-36.

Sharma, S., Kumar, S. and Panigrahi, S. (2020) Effect of provenance and clones on coppicing ability of Neolamarckia cadamba in a clonal seed orchard. *SilvaeGenetica*, **69(3-4)**: 105-113.

Suresh Kumar, P., Sudarsanam, G., Anbalagan, M. and Jayanthi, J. (2019) Effects of reduced dose of fungicide and insecticide on insect diversity and arthropod biological control potential of neem-based agroforestry in *Neolamarckia cadamba* (Roxb.) Bosser. *Qualitative Journal of Plant and Agro.y Research*, **4(2)**: 29-36.

Tchoundjeu, Z. and Leakey, R.R.B. (2001) Vegetative propagation of *Lovoa trichilioides*: effects of provenance, substrate, auxins and leaf area. *Journal of Tropical Forest Sciences*, **13**:116–129.