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RESEARCH ARTICLE

Influence of propagule type and plant growth regulators on growth, foliage yield and economic performance of spiny coriander (*Eryngium foetidum* L.)

A. Samad[1*], B. Singh[2], P. R. Gajurel[2]

Abstract

Eryngium foetidum L. is an aromatic leafy herb valued as a spice, condiment, and medicinal plant, although its commercial cultivation remains limited because of inadequate propagation practices. A field experiment was conducted during 2018 and 2019 to evaluate the influence of different vegetative propagules and plant growth regulators on plant growth, foliage production, and economic returns. Among the propagules tested, suckers measuring 7 to 10 cm in length exhibited superior establishment and growth compared with stem cuttings. Application of 500 ppm indole-3-butyric acid (IBA) and 500 ppm indole-3-acetic acid (IAA) produced significant improvements in plant height, number of leaves, leaf area, leaf area index, foliage yield, and profitability. The treatment combination comprising 7 to 10 cm suckers treated with 500 ppm IBA recorded the highest foliage yield (2258.34 kg ha^{-1}), gross return (₹590 thousand ha^{-1}), and benefit-cost ratio (5.76), while performance remained statistically comparable with suckers treated with 500 ppm IAA. Correlation analysis demonstrated a strong positive association between foliage yield and major growth attributes. The findings indicate that vegetative propagation using suckers in combination with either 500 ppm IBA or 500 ppm IAA offers a practical, rapid, and cost-effective technique for large-scale multiplication and profitable commercial cultivation of this underutilized culinary herb.

Keywords: Foliage yield, Growth regulator, Mandhonia, Sucker, Benefit:Cost ratio

Introduction

Eryngium foetidum L., commonly known as spiny coriander or culantro, is a perennial aromatic herb belonging to the family Apiaceae (Fig. 1). Owing to its distinctive aroma and flavour, the crop is widely valued as a leafy spice and condiment in traditional cuisines across tropical and subtropical regions. The herb is known by different vernacular names, including *Mandhonia* and *Bandhonia* in Assamese and *Bangladhonia* and *Bilatidhonia* in Bengali (Singh *et al.*, 2014). Besides its culinary importance, the plant possesses considerable medicinal value and is recognized as a rich source of vitamins, minerals, carotenoids, phytosterols and natural antioxidants (Ramcharan, 1999; Paul *et al.*, 2011; Singh *et al.*, 2013).

In recent years, increasing consumer preference for natural flavouring agents and health-promoting foods has enhanced the commercial importance of *E. foetidum*. Its leaves are extensively used for seasoning curries, soups, chutneys, salads, sauces and several processed food products because of their characteristic pungent aroma and essential oil content. In addition to its culinary applications, the species has attracted considerable attention from the food and pharmaceutical industries owing to the presence of biologically active compounds with antioxidant and therapeutic potential (Rodrigues *et al.*, 2022).

[1]Ph D Scholar, Department of Forestry, North Eastern Regional Institute of Science and Technology (Deemed to be University), Nirjuli-791109, Arunachal Pradesh, India

[2]Professor, Department of Forestry, North Eastern Regional Institute of Science and Technology (Deemed to be University), Nirjuli-791109, Arunachal Pradesh, India

***Corresponding Author:** A. Samad, Ph D Scholar, Department of Forestry, North Eastern Regional Institute of Science and Technology (Deemed to be University), Nirjuli-791109, Arunachal Pradesh, India, E-mail: asamad969@gmail.com

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Despite its economic importance, the cultivation of spiny coriander remains largely unorganized in many parts of Northeast India. The crop is generally maintained in household gardens on a limited scale, while a substantial proportion of the produce marketed locally is collected directly from natural habitats. Such indiscriminate harvesting from the wild may threaten natural populations and restrict the sustainable availability of quality planting material. Adoption of scientific cultivation practices would therefore not only promote conservation of this valuable herb but also provide an additional source of income for farmers in the region (Devi *et al.*, 2016).

Although the crop has considerable scope for commercial production and export to meet the growing demand of ethnic communities in different parts of the world, its cultivation has not expanded proportionately. One of the major constraints is the limited availability of quality planting material. Propagation through seeds is often unreliable because of poor germination, irregular seed availability and comparatively high seed cost. Farmers therefore frequently depend on vegetative propagules such as suckers and offshoots for establishing new plantations (Mozumder *et al.*, 2012). Efficient vegetative propagation techniques capable of producing vigorous and uniform planting materials are therefore essential for large-scale commercial cultivation.

Plant growth regulators play an important role in promoting root initiation, improving establishment and enhancing vegetative growth of propagated materials. Likewise, removal of flowering shoots has been reported to divert assimilates towards leaf development, thereby improving foliage production in *E. foetidum* (Rodrigues *et al.*, 2022). However, systematic information regarding the combined influence of different propagule types and growth regulator treatments on plant growth, foliage yield and economic returns under the agro-climatic conditions of Northeast India is still limited.

Accordingly, the present investigation was undertaken to evaluate the performance of stem cuttings and suckers treated with different concentrations of indole-3-butyric acid (IBA) and indole-3-acetic acid (IAA). The study aimed to identify an efficient, economical and farmer-friendly propagation technique capable of improving growth, foliage yield and profitability of *Eryngium foetidum*, thereby facilitating its commercial cultivation in the region.

Materials and Methods

The field experiment was conducted during 2018 and 2019 at the Forestry Nursery of the North Eastern Regional Institute of Science and Technology (Deemed to be University), Nirjuli, Arunachal Pradesh, India (27°07′38″ N latitude, 93°44′19″ E longitude; 112 m above mean sea level). The experimental site comprised sandy, well-drained soil with a pH of 5.9 and an organic carbon content of 0.07%. Initial soil analysis

Fig 1: *Eryngium foetidum* plant

indicated available nutrient contents of 0.07% nitrogen, 0.25% phosphorus and 0.36% potassium. Before planting, well-decomposed farmyard manure was incorporated into each experimental bed at the rate of 5 kg per bed to improve soil fertility.

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications. Two experimental factors were evaluated. Factor A consisted of two types of vegetative propagules: S_1 (7–10 cm stem cuttings) and S_2 (7–10 cm suckers). Factor B comprised seven growth regulator treatments, including distilled water as the control together with different concentrations of indole-3-butyric acid (IBA) and indole-3-acetic acid (IAA): G_0 (control), G_1 (500 ppm IBA), G_2 (1000 ppm IBA), G_3 (1500 ppm IBA), G_4 (500 ppm IAA), G_5 (1000 ppm IAA) and G_6 (1500 ppm IAA). The interaction of these two factors resulted in 14 treatment combinations (T_1–T_{14}).

Stem cuttings measuring 7 to 10 cm were prepared from healthy herbaceous shoots while maintaining their natural polarity (Fig. 2). Suckers of the same length were obtained by trimming excess roots and leaves before treatment. The

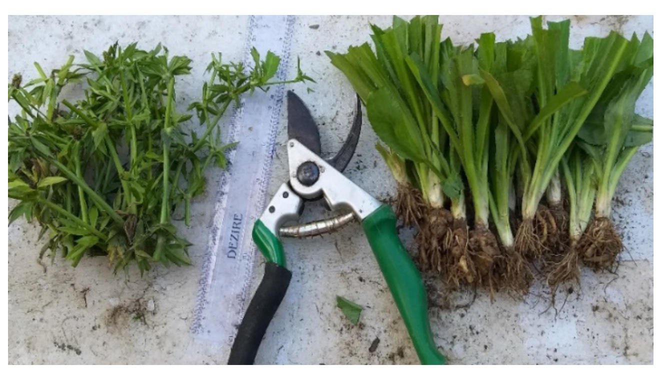

Fig 2: S1=7-10 cm Stem cutting; S2 = 7-10 cm Suckers

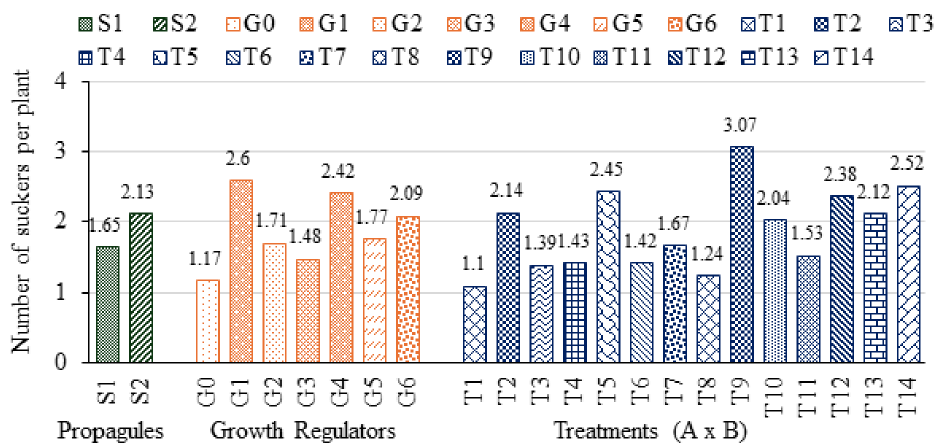

Fig. 3: Effect treatments on number of suckers of *Eryngium foetidum*

basal ends of both propagule types were immersed in their respective growth regulator solutions using the quick-dip technique before planting. A total of 672 propagules were planted in 1 × 1 m beds at a density of 16 propagules per bed. Irrigation was provided twice weekly throughout the experimental period to maintain adequate soil moisture.

Growth observations were recorded periodically from five randomly selected plants in each experimental unit. Plant height, number of suckers, number of leaves, leaf length and leaf width were measured following standard procedures. Leaf area was estimated using the regression equation

$$\text{Leaf Area (cm}^2) = 0.89 \times (L \times W)$$

Where, L represents leaf length (cm) and W denotes leaf width (cm). The regression coefficient (0.89) was derived from calibration against leaf area measured by the graph-paper method. Leaf Area Index (LAI) was subsequently determined as

$$\text{LAI} = \frac{\text{Leaf area per plant}}{\text{Ground area occupied by the plant}}$$

Economic performance of each treatment was assessed by estimating gross return, net return and the benefit-cost ratio (BCR). Gross return was calculated from foliage yield per hectare and prevailing market price. Net return was obtained by subtracting the total cost of cultivation from the gross return, while the benefit-cost ratio was computed as the ratio of gross return to the total cultivation cost.

Experimental data collected during both years were pooled after confirming homogeneity and analysed statistically using analysis of variance (ANOVA) as described by Gomez and Gomez (1984). Treatment means were compared at the 5% level of significance, and correlation analysis was performed to examine the relationships between foliage yield and associated growth attributes.

Results and Discussion

Effect of propagule type and growth regulators on plant growth

The pooled analysis of two years demonstrated that both the type of propagule and the concentration of plant growth

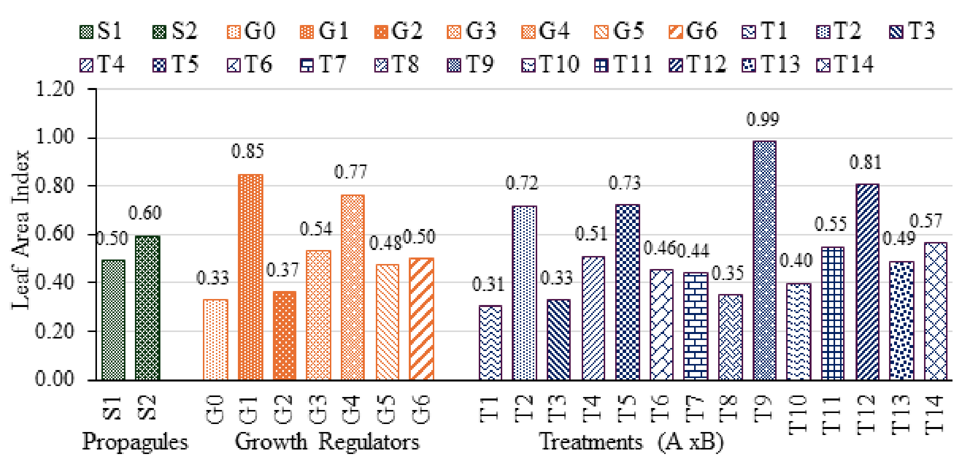

Fig. 4: Effect treatments on leaf area index of *Eryngium foetidum*

Table 1: Effect of treatments on growth and yield attributes of *Eryngium foetidum*

	Plant height (cm)	*Number of leaves per plant*	*Length of leaf (cm)*	*Width of leaf (cm)*	*Leaf Area (cm^2)*
			Factor A (Propagules)		
S_1 = 7 - 10 cm Stem cutting	12.43	10.36	11.87	2.74	29.35
S_2 = 7 - 10 cm Suckers	14.44	11.12	12.27	2.94	32.53
S Em ±	1.01	0.38	0.20	0.11	1.59
CD (0.05)	0.73*	0.72*	0.49*	0.14*	2.17*
			Factor B (Growth regulators)		
G_0 = Distilled water (control)	10.96	9.04	10.03	2.52	22.44
G_1 = 500 ppm IBA	16.92	12.72	14.88	3.15	41.70
G_2 = 1000 ppm IBA	11.33	9.83	10.27	2.50	22.93
G_3 = 1500 ppm IBA	13.12	11.07	11.72	2.88	30.03
G_4 = 500 ppm IAA	15.99	11.79	14.10	3.25	40.72
G_5 =1000 ppm IAA	13.72	9.90	11.80	2.81	29.58
G_6 = 1500 ppm IAA	12.00	10.80	11.75	2.79	29.16
S Em ±	0.87	0.48	0.69	0.10	2.91
CD (0.05)	1.36*	1.35*	0.92*	0.28*	4.06*
			Treatments (A x B)		
$T_1 = S_1$ + control	10.50	8.69	10.09	2.42	21.70
$T_2 = S_1$ + 500 ppm IBA	15.50	11.85	14.45	2.95	37.85
$T_3 = S_1$ + 1000 ppm IBA	10.67	9.50	10.27	2.34	21.49
$T_4 = S_1$ + 1500 ppm IBA	11.59	10.72	11.69	2.84	29.48
$T_5 = S_1$ + 500 ppm IAA	14.58	11.19	14.10	3.24	40.60
$T_6 = S_1$ + 1000 ppm IAA	12.23	9.80	11.59	2.79	28.78
$T_7 = S_1$ + 1500 ppm IAA	11.92	10.75	10.95	2.62	25.55
$T_8 = S_2$ + control	11.42	9.38	9.97	2.62	23.20
$T_9 = S_2$ + 500 ppm IBA	18.34	13.09	15.30	3.35	45.56
$T_{10} = S_2$ + 1000 ppm IBA	12.00	10.17	10.27	2.67	24.37
$T_{11} = S_2$ + 1500 ppm IBA	14.64	11.42	11.75	2.92	30.59
$T_{12} = S_2$ + 500 ppm IAA	17.39	12.39	14.10	3.25	40.86
$T_{13} = S_2$ + 1000 ppm IAA	15.20	10.00	12.00	2.84	30.37
$T_{14} = S_2$ + 1500 ppm IAA	12.09	10.85	12.54	2.94	32.77
S Em ±	0.67	0.34	0.48	0.08	2.06
CD (0.05)	1.9*	1.91*	1.30*	0.39*	5.74*

* $P < 0.05$

regulators exerted a significant influence on the vegetative growth of *Eryngium foetidum* (Table 1). Their interaction also produced statistically significant differences for all growth-related characters evaluated.

Plants established from 7–10 cm suckers (S_2) exhibited superior vegetative growth compared with those propagated through 7–10 cm stem cuttings (S_1). Mean plant height reached 14.44 cm in sucker-derived plants, whereas stem cuttings attained 12.43 cm. Among the growth regulator treatments, 500 ppm IBA (G_1) produced the tallest plants (16.92 cm), followed closely by 500 ppm IAA (G_4) with 15.99 cm, while untreated plants showed the least height. The interaction treatment T_9 (S_2 + 500 ppm IBA) resulted in the maximum plant height (18.34 cm), remaining statistically comparable with T_{12} (S_2 + 500 ppm IAA).

The enhanced plant height observed in sucker-propagated plants may be attributed to their greater physiological vigour and superior reserve food materials, which favour rapid establishment and efficient translocation of assimilates during early growth. Auxin application probably promoted cell elongation and root initiation, leading to improved nutrient uptake and subsequent vegetative development. Similar observations have been reported by Mozumder *et al.* (2012, 2016).

Table 2: Effect of propagules and growth regulators on foliage yield and economics of *Eryngium foetidum*

	Foliage yield per plant (g/plant)	Foliage yield per ha (Kg/ha)	Gross Return ('000 ₹ /ha)	Net Return ('000 ₹/ ha)	Benefit: Cost Ratio
Factor A (Propagules)					
S_1 = 7 - 10 cm Stem cutting	7.04	652.62	241.14	122.89	1.66
S_2 = 7 - 10 cm Suckers	9.65	1549.86	419.60	301.35	3.94
S Em $\pm$	1.31	448.62	89.23	89.23	1.15
CD (0.05)	0.64*	95.83*	58.36	58.36	0.25
Factor B (Growth regulators)					
G_0 = Distilled water (control)	6.44	682.42	263.48	145.23	1.73
G_1 = 500 ppm IBA	10.69	1547.50	407.38	289.13	3.93
G_2 = 1000 ppm IBA	7.26	941.00	309.05	190.80	2.39
G_3 = 1500 ppm IBA	7.85	992.92	313.13	94.88	2.52
G_4 = 500 ppm IAA	9.39	1321.25	344.75	226.50	3.35
G_5 =1000 ppm IAA	7.95	1062.92	342.25	224.00	2.70
G_6 = 1500 ppm IAA	8.81	1160.67	332.58	214.33	2.95
S Em $\pm$	0.54	105.47	21.21	21.21	0.27
CD (0.05)	1.18*	179.28*	109.18	109.18	0.46
Treatments (A x B)					
$T_1 = S_1$ + control	6.10	438.33	159.00	40.75	1.12
$T_2 = S_1$ + 500 ppm IBA	7.95	836.67	224.75	106.50	2.13
$T_3 = S_1$ + 1000 ppm IBA	6.80	587.00	273.60	155.35	1.49
$T_4 = S_1$ + 1500 ppm IBA	6.77	612.50	322.75	204.50	1.55
$T_5 = S_1$ + 500 ppm IAA	7.70	783.34	301.00	182.75	1.99
$T_6 = S_1$ + 1000 ppm IAA	6.67	625.84	206.50	88.25	1.59
$T_7 = S_1$ + 1500 ppm IAA	7.29	684.67	200.40	82.15	1.74
$T_8 = S_2$ + control	6.78	775.00	367.95	249.70	2.35
$T_9 = S_2$ + 500 ppm IBA	13.44	2258.34	590.00	471.75	5.76
$T_{10} = S_2$ + 1000 ppm IBA	7.72	1295.00	344.50	226.25	3.29
$T_{11} = S_2$ + 1500 ppm IBA	8.92	1373.34	303.50	185.25	3.49
$T_{12} = S_2$ + 500 ppm IAA	11.08	1859.17	388.50	270.25	4.72
$T_{13} = S_2$ + 1000 ppm IAA	9.22	1500.00	478.00	359.75	3.81
$T_{14} = S_2$ + 1500 ppm IAA	10.33	1636.67	464.75	346.50	4.15
S Em $\pm$	0.56	150.32	39.68	39.68	0.38
CD (0.05)	1.68*	253.55*	154.40	154.40	0.65

* $P < 0.05$

A comparable response was observed for sucker production. Plants raised from suckers produced a significantly higher number of secondary suckers (2.13 per plant) than stem cuttings (1.65 per plant) (Fig. 3) The highest sucker production was obtained with 500 ppm IBA, and the interaction T_9 recorded the maximum value (3.07 suckers per plant). Enhanced sucker formation under auxin treatment may be associated with improved vegetative vigour and increased availability of photosynthates for the initiation and development of new shoots. These findings agree with those reported by Reddy *et al.* (1997).

Leaf production also responded favourably to the treatments. Sucker-derived plants produced more leaves (11.12 per plant) than stem cuttings (10.36 per plant). The application of 500 ppm IBA resulted in the highest leaf number (12.72 per plant), closely followed by 500 ppm IAA, whereas the control treatment produced the fewest leaves. Among all treatment combinations, T_9 recorded the highest leaf number. Similar trends were evident for leaf length and leaf width, indicating that auxin application, particularly at lower concentrations, promoted vigorous leaf development. These observations are consistent with previous reports

Table 3: Correlation coefficient of different parameters in *Eryngium foetidum*

Parameters	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	1.000	0.770*	0.866*	0.870*	0.862*	0.890*	0.905*	0.825*
2		1.000	0.786*	0.823*	0.822*	0.845*	0.856*	0.858*
3			1.000	0.887*	0.871*	0.893*	0.947*	0.798*
4				1.000	0.913*	0.987*	0.971*	0.724*
5					1.000	0.960*	0.949*	0.766*
6						1.000	0.988*	0.761*
7							1.000	0.818*
8								1.000

1. Plant height (cm); 2. Number of suckers; 3. Number of leaves per plant; 4. Leaf length (cm); 5. Leaf width (cm); 6. Leaf area (cm2); 7. Leaf Area Index (LAI); 8. Foliage yield per plant (g/plant). * $P < 0.05$

by Moniruzzaman *et al.* (2009), Qamruzzaman *et al.* (2011), Mozumder *et al.* (2016) and Mozumder *et al.* (2020).

Leaf area and leaf area index (LAI), which are reliable indicators of photosynthetic efficiency and canopy development, also differed significantly among treatments. Plants propagated through suckers recorded a larger mean leaf area (32.53 cm^2) than those propagated through stem cuttings (29.35 cm^2) (Fig. 4). Application of 500 ppm IBA produced the maximum leaf area (41.70 cm^2), while the interaction treatment T_9 recorded the highest value (45.56 cm^2). A similar pattern was observed for LAI, where sucker propagation combined with 500 ppm IBA achieved the greatest index. The larger assimilatory surface developed under these treatments probably enhanced light interception and photosynthetic efficiency, thereby contributing to improved plant growth. Comparable findings have been reported by Saud *et al.* (1997) and Dey *et al.* (2019).

Effect on foliage yield

Foliage yield was markedly influenced by both propagule type and growth regulator treatment (Table 2). Plants established from suckers produced a significantly higher foliage yield (9.65 g plant^{-1}) than those raised from stem cuttings (7.04 g plant^{-1}). Among the growth regulator treatments, 500 ppm IBA recorded the maximum foliage yield (10.69 g plant^{-1}), whereas untreated plants produced the lowest yield. The interaction treatment T_9 (S_2 + 500 ppm IBA) achieved the highest foliage yield (13.44 g plant^{-1}).

A similar response was observed when yield was expressed on a hectare basis. Sucker propagation substantially increased foliage production (1549.86 kg ha^{-1}) compared with stem cuttings (652.62 kg ha^{-1}). Among the interaction treatments, T_9 produced the highest foliage yield (2258.34 kg ha^{-1}), followed by T_{12}, both of which significantly outperformed the remaining treatments. The superior productivity obtained from sucker-derived plants treated with lower concentrations of auxins can be attributed to their better establishment, vigorous vegetative growth and larger photosynthetic surface, resulting in greater biomass accumulation.

Correlation analysis further demonstrated that foliage yield was positively and highly significantly associated with plant height, sucker production, leaf number, leaf dimensions, leaf area and leaf area index (Table 3). These strong relationships indicate that improvements in vegetative growth directly contributed to enhanced foliage production. Similar associations between growth traits and yield have been documented by Casey *et al.* (2004), Moniruzzaman *et al.* (2009), Mozumder *et al.* (2012, 2016, 2020), Yatung *et al.* (2014) and Hossain *et al.* (2017).

Economics of cultivation

Economic analysis clearly demonstrated the practical advantage of using sucker propagules together with appropriate auxin treatments. Compared with stem cuttings, sucker-derived plants generated substantially higher gross return, net return and benefit-cost ratio (Table 2). Average gross return increased from ₹241.14 thousand ha^{-1} in stem cuttings to ₹419.60 thousand ha^{-1} in sucker-propagated plants, accompanied by a corresponding improvement in net return and profitability.

Among the growth regulator treatments, 500 ppm IBA proved to be the most remunerative. However, the highest economic return was achieved by the interaction treatment T_9, which recorded a gross return of ₹590.00 thousand ha^{-1}, a net return of ₹471.75 thousand ha^{-1} and a benefit-cost ratio of 5.76. The favourable economic performance of this treatment primarily resulted from its superior foliage yield and improved vegetative growth, both of which increased marketable biomass without proportionately increasing production costs. Similar economic advantages of improved crop management practices have also been reported by Moniruzzaman *et al.* (2007), Hossain *et al.* (2017) and Mozumder *et al.* (2020).

Conclusion

The present investigation demonstrated that both the type of vegetative propagule and the application of plant growth regulators significantly influenced the growth, foliage yield and economic performance of *Eryngium foetidum* under the agro-climatic conditions of Arunachal Pradesh. Among the propagation materials evaluated, 7–10 cm suckers consistently outperformed stem cuttings with respect to vegetative growth, foliage production and profitability.

Treatment of suckers with 500 ppm indole-3-butyric acid (IBA) proved to be the most effective, although its performance remained statistically comparable with 500 ppm indole-3-acetic acid (IAA) for most of the growth and yield parameters. These treatments produced superior plant height, leaf development, foliage yield and benefit-cost ratio compared with the untreated control and the higher concentrations of both growth regulators. Correlation analysis further established that foliage yield was strongly and positively associated with all major vegetative growth attributes, highlighting the importance of vigorous canopy development in achieving higher productivity.

The findings indicate that vegetative propagation using 7–10 cm suckers treated with 500 ppm IBA or 500 ppm IAA provides a practical, rapid and economically viable technique for large-scale multiplication of *Eryngium foetidum*. Adoption of this propagation protocol may facilitate commercial cultivation, improve planting material availability, enhance farmers' income and contribute to the wider utilization and conservation of this valuable underutilized culinary herb in Northeast India and similar agro-ecological regions.

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