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Influence of Exogenous Fertilizer Application on Growth of *Calamus thwaitesii* Becc. and *Hook*. f. at Nursery Stage

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ABSTRACT

The present investigation was carried out at Sampaje Forest Nursery, Karnataka State Forest Department, Kodagu district, Karnataka, India during 2017. The study aimed at understanding the effect of conventional (organic and inorganic fertilizers) and bio-fertilizers on the growth rate of the Calamus thwaitesii seedlings in the nursery stage. Different dosages of fertilizers, such as Vermicompost, Pongamia cake, Di-Ammonium Phosphate (DAP), Muriate of Potash (MOP), Azospirillum, Micorrhiza, *Bassilus mucilaginous* (KSB) and *Bassilus megatherium* (P SB) was applied to five-month-old seedling at the nursery stage and growth parameters were recorded at 30 days interval till 150 days. The results revealed that 1.5 g of Di-Ammonium Phosphate with 1.5 g of Muriate of Potash at 150 days interval showed the best result for shoot height (53.85 cm), collar diameter (14.81 mm), number of leaves (8) and fresh root and shoot weight (11.5 g and 23.8 g respectively). Among the bio-fertilizers the highest volume index value (9521.62 cm^3) was observed in for KSB (10 g)+Mycorrhizal culture (10 g) followed by Azospirillum (10 g)+PSB (10 g) +Mycorrhizal culture (10 g) (9287.20 cm^3). The Phosphate and Potassium rich fertilizers or phosphate and potassium solubilizing bacteria were found to enhance the growth of *Calamus thwaitesii* seedlings in the nursery stage.

KEYWORDS: Bio-fertilizers, Calamus, early-growth, nutrient management, nursery

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1. INTRODUCTION

Rattans (canes) are long slender stemmed climbing palms exploited for their flexible stems. At the global level, cane distribution is restricted to moist tropical and subtropical regions, especially in Asia. Worldwide there are 12 genera of rattans comprising 556 reported species. The largest genus is Calamus, with 374 species. In India, they are represented by five genera and 51 species occurring in the tropical evergreen, semi-evergreen and moist deciduous forests of the Western Ghats, Eastern Himalayas, and the Andaman Islands (Lakshmana, 1995; Anonymous, 2004; Ashwath et al., 2022). Species of Calamus distributed in the Western Ghats region of the southern peninsula are a high-value non-timber forest product, primarily used for making furniture, baskets, and handicraft items and important raw material of the cottage industry contributing employment to approximately 1,00,000 people in the state of Kerala alone (Bhat et al., 1989).

Rattans are preferred as a natural material for craft and furniture because of their durability, elasticity, lightweight, lustre, colour, and flexibility (Bhat et al., 1992). With the application of heat, a cane can be bent into different shapes without affecting the material's inherent structural properties. Rattans have an important regulatory ecosystem service in evergreen forest, i.e., innumerable pinnate leaves, which extend up to two meters in length, with their mosaic arrangement play a major role in intercepting the splash effect of rains and improving the water-holding capacity of the soil (Dransfield et al., 1981; Dransfield et al., 2005; Govaerts and Dransfield, 2005; Henderson and Henderson, 2007; Baker and Dransfield, 2008). They also play a vital role in enriching the fertility of the soil by their leaf litter, which adds to the organic content of the soil (Lakshmana, 1995).

Regeneration of rattans in the forest ranges from poor to profuse. There are species found in large colonies, which bear abundant fruit and occupy the open forest, while others are found in small patches with poor regeneration (Anonymous, 2004; Ashwath et al., 2022, Lakshmana et al., 2022). Poor regeneration of rattans is one of the major threats to the existence of this resource in its natural populations. It is estimated that over 90% of the world's rattan requirement is extracted from its natural populations (Ravikanth et al., 2002). These threats are further aggravated by the fact that rattans are dioecious and come to fruition only after about 10-14 years.

In the post-independence period, factors such as injudicious exploitation, unscientific harvesting, habitat degradation, and plantation activities in the hills have resulted in serious depletion of rattan genetic resources in the region, poor regeneration in natural forests, and consequently increased gap between demand and supply (Ramanatha, 1995). Due to the shrinkage of wild rattan resources and non-availability of raw materials, the rural industrial units are either closed down or forced to receive their supplies from far away Assam and Andaman Islands, causing a significant increase in the prices of cane products and jeopardizing the livelihood of workers involved in the local extraction and processing of canes. Species of *Calamus* species are dioecious, seed set is poor and seed availability in the disturbed habitats is uncertain.

Due to poor germination and seed production of *Calamus thwaitesii*, establishing large nurseries become a challenging task, and also seedling growth was observed to be very slow (Renuka, 2008). The reduced growth and plant development, the demand is not met at the local industry level. Therefore, the present study was devised to enhance the growth rate of the *Calamus thwaitesii* seedlings by nutrient management in the nursery stage, and also to understand the effect of conventional (organic and inorganic fertilizers) and bio-fertilizers on seedling growth.

2. MATERIALS AND METHODS

2.1. Location of the experimental site

The present investigation was carried out during May to October, 2017 Sampaje Forest Nursery of Karnataka State Forest Department, Kodagu district, which falls under the hill zone (Zone 9) of Karnataka State, India. Sampaje is situated at 12° 29' 35.1"N latitude and 75° 33' 58.7"E longitudes and at an altitude of 145 MSL with a tropical humid climate. The monthly mean maximum temperature varied from 31°C to 35°C and the mean monthly minimum temperature varied from 23°C to 27°C during the study period. The mean annual rainfall was 4283 mm, most of which receive between May to November.

2.2. Treatments and Experimental Design

Five months old uniform seedlings of *Calamus thwaitesii* raised in poly bags were selected for the study. Treatments were imposed to understand the effect of conventional fertilizers (organic and inorganic) and bio-fertilizers on the seedling growth in the nursery stage (Table 1). The experiment was laid by following the Completely Randomised Block Design with three replications.

The whole study was carried out in two sets of different experiments by treating the plants with conventional fertilizers and bio-fertilizers. The specified quantity of organic and inorganic fertilizers was applied to each seedling in the form of Di-Ammonium Phosphate, Muriate of Potash, Vermicompost and Honge cake (*Pongamia pinnata* cake) in different doses as basal application. The required quantity of different doses of N, P and K were given after thoroughly dissolving in the water. The requisite quantity of bio-fertilizers was measured and mixed with the soil before transplanting the seedling to polybags.

Table 1: Details of the treatment combinations

Organic and inorganic fertilizers treatment combinations		Bio-fertilizer treatment combinations	
No.	Treatment (quantity seedling^{-1})	No.	Treatment (quantity seedling^{-1})
T_1	Control	T_1	Control
T_2	Vermicompost (10% of potting mixture)	T_2	Azospirillum (10 g)+Micorrhizal culture (10 g)
T_3	Honge cake (10% of potting mixture)	T_3	PSB (10 g)+Micorrhizal culture (10 g)
T_4	Honge cake (5% of potting mixture)	T_4	KSB (10 g)+Micorrhizal culture (10 g)
T_5	0.50 g (DAP)+0.50 g (MOP)	T_5	Azospirillum (10 g)+PSB (10 g)+Micorrhizal culture (10 g)
T_6	0.75 g (DAP)+0.75 g (MOP)	T_6	Azospirillum (10 g)+KSB (10 g)+Micorrhizal culture (10 g)
T_7	1.00 g (DAP)+1.00 g (MOP)	T_7	Azospirillum (10 g)+PSB (10 g)+KSB (10 g)+Micorrhizal culture(10 g)
T_8	1.25 g (DAP)+1.25 g (MOP)		
T_9	1.50 g (DAP)+1.50 g (MOP)		

Honge cake: *Pongamia pinnata* cake; DAP: Di-Ammonium Phosphate; MOP: Muriate of Potash; PSB: *Bassilus megatherium*; KSB: *Bassilus mucilaginosus*

2.3. Observations

The growth parameters like plant height (cm), collar diameter (mm), and the number of leaves were recorded at 30 days intervals up to 150 days. Measurements were taken in 3 replications with each treatment contacting 10 plants. At the end of the experiment the shoot and root dry biomass (g) was recorded through destructive sampling, by randomly selecting six seedlings from each treatment.

Volume Index Increment (cm^3): The volume index of each seedling was calculated for both initial and final observations using the formula:

Volume index = d^2h ----------- (1)

Where, d = Collar diameter of the seedling, h= Height of the seedlings

Sturdiness Quotient: The sturdiness quotient was determined as the indicator of the strength of the seedlings to adverse climatic conditions (Ritchie, 1984).

Sturdiness Quotient=(Shoot length (cm)/Collar diameter (cm))----------(2)

Seedling quality index: Dickson et al., (1960) gave the formula to calculate seedling quality based on morphological traits and seedling biomass.

Seedling quality index=(Total seedling dry weight (g)/(Plant height (cm)/(Collar diameter (cm)+Shoot dry weight (g)/(Root dry weight (g)) --------(3)

The data obtained on each parameter was subjected to analysis of variance (ANOVA) by following Completely Randomised Block Design as described by Anonymous (1978) to assess the effectiveness of the various treatments tried and expressed at 95% confidence level. Data on all growth parameters were analysed using the SPSS software (V2.1).

3. RESULTS AND DISCUSSION

The application of any fertilizers to the plants at any stage of the developmental phase plays a significant role in nutrient supply to ensure better growth and yield at later stages. Among the farming communities both organic, inorganic nutrient suppliers are commonly used with rare actions of bio-fertilization. The application of nutrients not only help to maintain fertility status but also improve the physical, chemical and biological properties of the soil which in turn reduces the load on soil (Gopikumar et al., 2003). In most of the studies organic and inorganic fertilizers have been primarily valued as important sources of N, P, K and also serve as a potential source of micronutrients like iron, zinc, boron etc., (Singh et al., 2019). The studies show enhanced growth and development in cane seedlings in the early growth period as a result of adding biofertilizers (Kalegore et al., 2018; Patil and Krishna, 2016; Rai and Shukla, 2015).

3.1. Effect of organic and inorganic fertilizers on the growth of the seedlings

3.1.1. Seedling height

The height of the seedlings plays an important role and it is also proved that height is the important parameter for farmers choice in seedling selection at nursery stages for planting. In the present study, the combinations of organic and inorganic fertilizers in different dosages were applied to the seedlings as a result, a substantial increase in the seedling height was observed with a significant effect on the height of the seedlings (Table 2). But due to overdosage in T_3, all the seedlings attained causality. This could be because of the allelopathic chemicals present in the honge cake which was also observed by Narwal (2010). However, the minimum

Table 2: Effect of inorganic/organic fertilizers on the increment of height (cm), collar diameter (mm) and average number of leaves in *Calamus thwaitesii* at nursery stage

	Treat-ment/ Days	T_1	T_2	T_4	T_5	T_6	T_7	T_8	T_9	SEm±	CD*
Height*	Initial	20.87	18.53	19.37	21.62	19.94	19.44	19.39	21.12	0.88	NS
	30 D	25.70 (23.14%)	20.84 (12.46%)	21.09 (8.87%)	27.52 (27.28%)	26.24 (31.59%)	25.09 (29.06%)	24.20 (24.80%)	26.48 (25.37%)	1.30	3.90
	60 D	30.34 (45.37%)	24.52 (32.32%)	22.26 (14.91%)	31.90 (47.54%)	31.31 (57.02%)	30.18 (55.24%)	29.00 (49.56%)	32.39 (53.36%)	1.41	4.25
	90 D	36.29 (73.88%)	25.36 (36.85%)	22.35 (15.38%)	38.98 (80.29%)	37.38 (87.46%)	39.26 (101.95%)	36.17 (86.53%)	41.80 (97.91%)	1.50	4.51
	120 D	39.68 (90.12%)	28.68 (54.77%)	23.13 (19.41%)	43.35 (100.50%)	41.86 (109.95%)	46.08 (137.03%)	40.94 (111.13%)	46.86 (121.87%)	1.67	5.01
	150 D	46.11 (120.93%)	37.30 (101.29%)	26.09 (34.69%)	50.13 (131.86%)	48.35 (142.47%)	49.73 (155.81%)	47.11 (142.96%)	53.85 (154.97%)	2.12	6.37
Collar diam-eter*	Initial	5.909	4.638	4.785	5.649	5.403	5.353	5.498	6.415	0.289	0.866
	30 D	7.085 (19.90%)	5.377 (15.93%)	5.028 (5.08%)	6.971 (23.40%)	7.512 (39.03%)	7.164 (33.83%)	8.071 (46.80%)	7.991 (24.57%)	0.469	1.405
	60 D	7.058 (19.44%)	6.145 (32.49%)	5.580 (16.61%)	7.034 (24.52%)	8.133 (50.53%)	7.467 (39.49%)	8.831 (60.62%)	8.082 (25.99%)	0.467	1.398
	90 D	9.721 (64.51%)	6.294 (35.71%)	5.608 (17.20%)	9.982 (76.70%)	9.897 (83.18%)	10.225 (91.01%)	9.950 (80.97%)	10.777 (68.00%)	0.402	1.204
	120 D	12.401 (109.87%)	8.120 (75.08%)	5.697 (19.06%)	11.893 (110.53%)	10.350 (91.56%)	11.549 (115.75%)	10.747 (95.47%)	14.121 (120.12%)	0.503	1.507
	150 D	13.995 (136.84%)	9.128 (96.81%)	6.644 (38.85%)	13.472 (138.48%)	13.264 (145.49%)	13.643 (154.87%)	13.419 (144.07%)	14.815 (130.94%)	0.491	1.471
No. of leaves#	Initial	4.0 (2.233)	3.0 (2.016)	3.0 (2.097)	4.0 (2.251)	4.0 (2.206)	4.0 (2.180)	4.0 (2.165)	4.0 (2.236)	0.026	NS
	30 D	5.0 (2.417)	4.0 (2.160)	3.0 (2.122)	5.0 (2.422)	5.0 (2.394)	5.0 (2.389)	5.0 (2.343)	5.0 (2.445)	0.026	0.077
	60 D	5.0 (2.534)	4.0 (2.276)	3.0 (2.054)	5.0 (2.507)	5.0 (2.463)	5.0 (2.445)	5.0 (2.417)	5.0 (2.494)	0.030	0.091
	90 D	6.0 (2.623)	4.0 (2.313)	3.0 (1.921)	6.0 (2.620)	5.0 (2.476)	6.0 (2.578)	6.0 (2.594)	6.0 (2.569)	0.048	0.143
	120 D	7.0 (2.756)	5.0 (2.401)	3.0 (2.042)	6.0 (2.728)	6.0 (2.683)	6.0 (2.683)	6.0 (2.607)	7.0 (2.720)	0.046	0.137
	150 D	7.0 (2.797)	5.0 (2.512)	5.0 (2.360)	7.0 (2.765)	7.0 (2.793)	7.0 (2.776)	7.0 (2.752)	8.0 (2.866)	0.050	0.151

CD*: CD(p=0.05); *Parenthetical values: % increase seedling from the initial value of the seedling in 30 days of intervals; # Parenthetical values are square root transferred

height growth of the seedlings was observed in T_4, which is evident that honge cake has shown some allelopathic effect on the seedlings. The maximum height (53.85 cm) was observed in T_9, at 150 days with an increase of 154.97% which indicates that in the nursery stage for better growth of the *Calamus thwaitesii* seedling require a higher quantity of Phosphate and Potassium rich fertilizer combinations. Similarly, Saravanan et al., 2012 reported the application of diammonium phosphate and 0.25 g of muriate of potash resulted in maximum height growth of *Casuarina equisitefolia* seedlings. Adnan et al. (2020) evidenced that application of P and K had a significant effect on all growth parameters by producing maximum height, collar diameter, number of leaves, leaf area and root length in maize.

3.1.2. Collar diameter

The effect of nine different organic and inorganic fertilizer combinations on the collar diameter of the seedlings showed significant variation (Table 2). Collar diameter was highest (14.81 mm) in T_9 at 150th days after imposing treatment to the seedlings with an increase of 130.94%. However, the maximum percentage of the increment (154.87%) was recorded in T7 from initial to final collar diameter at 150th day. This could be attributed to the fact that *Calamus thwaitesii* seedling requires a higher quantity of Phosphate and Potassium rich fertilizer combinations. Mishra and Bahadur, 2019 reported enhanced growth, yield and quality of guava on application of chemical fertilizers, bio-fertilizers and organic manure. Similar to seedling height, the minimum collar diameter was recorded in T_4 which is evident that honge cake has shown some allelopathic effect on the seedlings.

3.1.3. Number of leaves

The main function of a leaf is to produce food for the plant by photosynthesis. Hence, leaves play an important role in the growth and development. Number of leaves in a seedling determines the photosynthetic rate as well as assimilation ability of the seedlings. The data indicate a significant difference (Table 2) in the number of leaves from 30 and 150 days after imposing treatment. The maximum number of leaves (8 leaves) were observed in the T_9 on the 150th day. The results of the present investigation are on par with the studies conducted by Abod and Siddiqui (2002) stating that the application of ammonium sulphate, triple superphosphate and muriate of potash enhanced the height, collar diameter and total weight of teak seedlings at the nursery stage. Application of urea and SPS (superphosphate simple) increased the seedling height, the number of leaves, collar diameter, leaf area and biomass in *Khaya ivorensis* at the nursery stage (Egbewole et al., 2018).

3.1.4. Biomass of seedlings under different organic and inorganic fertilizer treatments

For successful field survival, the biomass of the seedlings is one of the major considerations. It includes both the shoot as well as root biomass. The findings of biomass increment in the present study revealed a significant increase in the biomass of the seedlings in all the treatments except T_3 (Figure 1a). The fresh root and shoot weight of the seedlings was maximum (11.05 g and 23.80 g respectively) in T_9. Total fresh weight biomass was also highest (34.85 g) in T_9 and the lowest total fresh biomass accumulation was observed in the T_4. The dry weight of the root and shoot differed significantly among the treatments and it was highest in T_9 (3.93 g and 7.85 g respectively). The total dry weight of the seedlings also showed a significant difference among all the treatments and the maximum was recorded

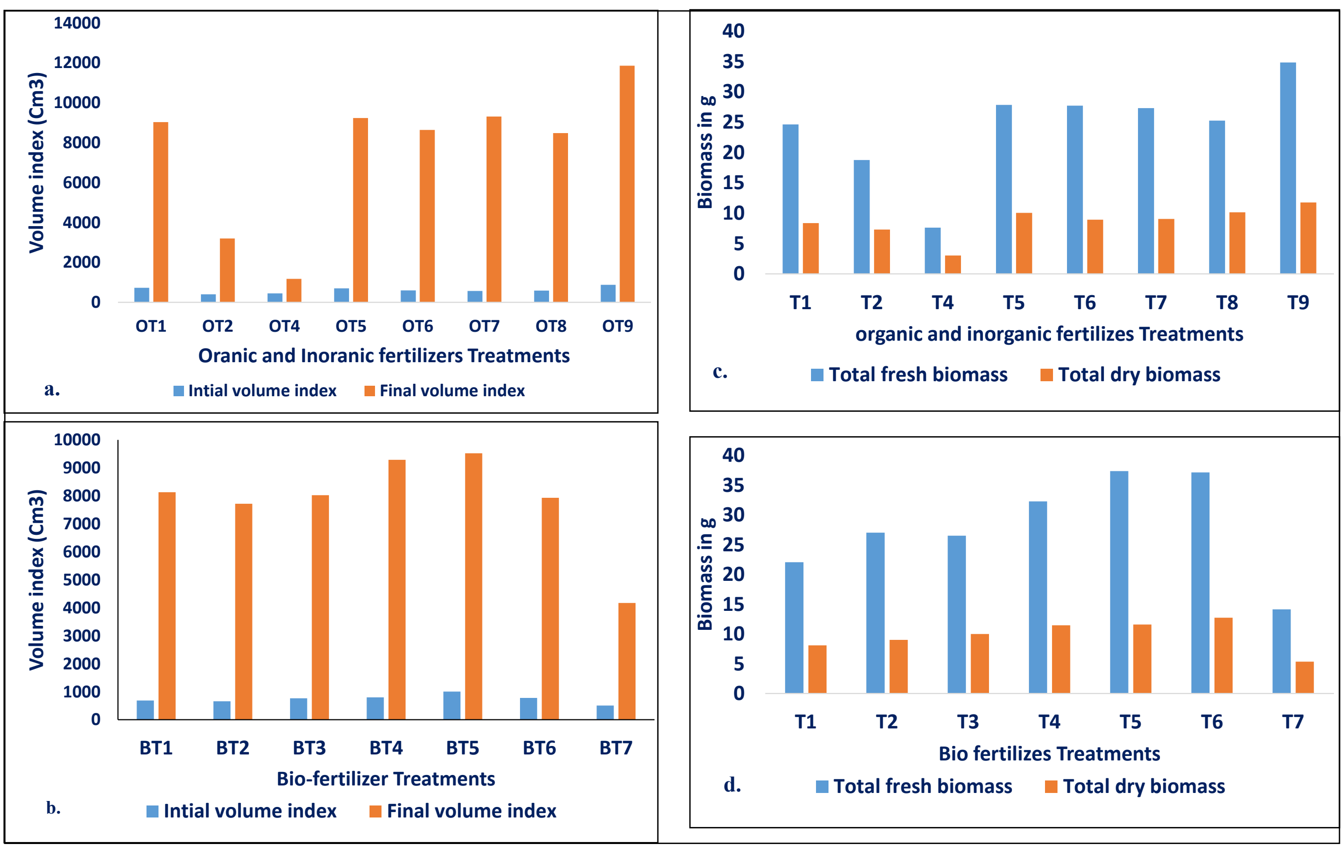

Figure 1: Treatment effect on biomass production and volume index; Biomass of the seedlings in different combinations of organic and inorganic fertilizers (a) and bio-fertilizers (b); Volume index of seedlings under organic and inorganic fertilizers (c) and bio-fertilizers (d)

in T_9 (11.78 g) and minimum (3.45 g) in T_4. From this, it is evident that the *Calamus thwaitesii* required a higher concentration of Phosphate and Potassium rich fertilizer combinations. Similar results were recorded by Bhardwaj et al. (1991), that is the application of N, P and K significantly produced higher dry biomass compared to control in *Robinia pseudoacacia* seedlings. Tiwari and Saxena (2003) reported that the application of urea and single super phosphate enhanced the shoot and root dry weight in *Dalbergia sissoo* seedlings.

3.2. *Effect of bio-fertilizers on the growth of the seedling*

3.2.1. *Seedling height*

A significant increase in the total height growth of seedlings was observed in all the treatments of bio-fertilizer combinations. The existence of the significant effect (except in the first 30 days) by bio-fertilizers on seedling height is evident from the study (Table 3). The maximum height (52.34 cm) was observed in T_4 at 150 days with an increase of 138.91%. In the case of organic and inorganic fertilizers highest increase of height growth was found in the phosphorus and potassium fertilizes just like that in bio-fertilizers maximum height was observed in the potassium solubilizing bacteria hence the results confirmed that *Calamus thwaitesii* required a rich quantity of phosphorus and potassium nutrients in the soil for its better growth. There is number of studies that support these results (Raman et al., 2008). A similar study was conducted by Adnan et al. (2020) reported enhanced biomass in maize by application of phosphate-solubilizing bacteria.

3.2.2. *Collar diameter*

Collar diameter is considered as the best morphological measurement of seedlings quality as reflected in planting performance. The effect of seven different bio-fertilizer combinations on the collar diameter measured from 30 to 150 days after imposing treatment was found to be significant (Table 3). Collar diameter was highest (13.32 mm) in T_4 at 150 days after imposing the treatment on the seedlings with an increase of 120.86%. A similar study was conducted on the tree species by Saravanan et al. (2012) reported that the combined application of *Frankia+Azospi rillum+Phosphobacterium* enhanced the growth parameters and biomass in seedlings of *Casuarina equisetifolia.*

3.2.3. *Number of leaves*

The effect of bio-fertilizers on the number of leaves from 30 to 150 days of treatment indicates a significant difference (except in 60 days). The maximum number of leaves (7 leaves) were observed in the T_4 on the 150th day (Table 3). A similar study was conducted by Adnan et al (2020) reported enhanced growth, number of leaves, shoot to root ratio, biomass in maize by application of phosphate-solubilizing bacteria.

3.2.4. *Biomass of seedlings under different bio-fertilizer treatments*

The effect of bio-fertilizers on the biomass of the seedlings showed a significant difference in fresh and dry biomass accumulated in the seedlings. The fresh root and shoot weight of the seedlings was maximum (12.90 g and 24.45 g respectively) in T_5 followed by T6 (Figure 1b). Total fresh weight biomass was also highest (37.36 g) in T_5 and the lowest total fresh biomass accumulation was observed in T_7. The dry weight of the root and shoot differed significantly among the treatments and it was highest in T_5. The total dry weight of the seedlings also showed a significant difference among all the treatments and maximum was recorded in T_5 (11.58 g) and minimum (5.340 g) in T7. A similar study was conducted by Verma et al. (2009) reported that mycorrhizal inoculation increased the plant height, dry matter and root length of *Prosopis cineraria* seedlings. Adnan et al., (2020) reported enhanced biomass in maize by application of phosphate-solubilizing bacteria.

3.3. *Volume index*

Volume index increment of the seedlings was calculated using the diameter and height of the seedlings, as a measure of seedling growth. The effect of organic and inorganic fertilizers on the volume of the seedlings is depicted in Figure 1c. The highest volume index value (11864.10 cm^3) was observed in the T_9 followed by T_5 (9313.30 cm^3) and T_7 (9239.27 cm^3). On the other hand, a substantial increase in the Volume index was observed under all the treatments but due to over dosage in the T_3, all the seedlings attained causality. The effect of bio-fertilizers on the volume of the seedlings is depicted in Figure 1d.

Among the bio fertilisers the highest volume index value (9521.62 cm^3) was observed in the T_5 followed by T_4 (9287.20 cm^3) and T_1 (8128.93 cm^3). The lowest volume index (4171.47 cm^3) was observed in the T_7. The finding was on par with the results of Oskarsson et al. (2006) who recorded an increased volume index of seedlings of *Betula pubescens*, *Larix sibirica* and *Picea sitchensis* which were subjected to NP fertilization.

3.4. *Seedling quality parameters index*

Assessment of quality of seedlings is necessary to understand the outplanting efficiency of the seedlings. Among the important criteria of the quality seedlings, the total height of the seedling is considered as a key factor. Seedlings with a larger shoot mass have a greater photosynthetic capacity and potential for growth. Shoot mass must be in balance with root mass for optimum seedling quality. Seedlings with larger root mass tend to grow healthy and survive better than those with smaller root mass. Root mass, however, does not always reflect root fibrosity, since a seedling with many fine roots can have the same mass as a seedling with a large

Table 3: Effect of bio-fertilizers on the increment of height (cm), collar diameter (mm) and average number of leaves in *Calamus thwaitesii* at nursery stage

	Treat-ment/ Days	T_1	T_2	T_3	T_4	T_5	T_6	T_7	SEm±	CD (p=0.05)
Height*	Initial	20.804	20.391	19.000	21.908	21.709	20.767	19.084	0.849	NS
	30 D	25.854 (24.27%)	25.387 (24.50%)	24.844 (30.76%)	26.760 (22.15%)	27.027 (24.50%)	25.038 (20.57%)	22.234 (16.51%)	0.995	NS
	60 D	29.606 (42.31%)	29.896 (46.61%)	29.249 (53.94%)	31.244 (43.61%)	31.336 (44.35%)	29.482 (41.97%)	25.356 (32.87%)	1.066	3.195
	90 D	35.087 (68.66%)	35.369 (73.45%)	34.520 (81.68%)	36.758 (67.78%)	37.158 (71.16%)	35.018 (68.62%)	28.583 (49.77%)	1.074	3.221
	120 D	39.813 (91.37%)	40.200 (97.15%)	39.091 (105.74%)	42.424 (93.65%)	43.044 (98.28%)	40.820 (96.56%)	32.289 (69.19%)	1.152	3.455
	150 D	45.262 (117.56%)	46.987 (130.43%)	47.711 (151.11%)	52.340 (138.91%)	49.920 (129.95%)	48.029 (131.28%)	37.032 (94.05%)	1.637	4.908
Collar diam-eter*	Initial	5.731	5.644	6.346	6.031	6.801	6.134	5.145	0.241	0.723
	30 D	7.217 (25.93%)	7.123 (26.20%)	7.097 (11.83%)	7.539 (25.00%)	7.707 (13.32%)	7.326 (19.43%)	5.598 (8.80%)	0.305	0.916
	60 D	9.021 (57.41%)	9.018 (59.78%)	8.336 (31.36%)	8.748 (45.05%)	9.284 (36.51%)	8.506 (38.67%)	5.90 (14.77%)	0.381	1.141
	90 D	9.623 (67.91%)	9.298 (64.74%)	9.251 (45.78%)	9.618 (59.48%)	10.501 (54.40%)	9.075 47.95(%)	6.873 (33.59%)	0.422	1.265
	120 D	10.567 (84.38%)	10.792 (91.21%)	10.742 (69.27%)	11.139 (84.70%)	12.118 (78.18%)	10.924 (78.09%)	8.022 (55.92%)	0.384	1.152
	150 D	13.326 (132.52%)	12.692 (124.88%)	12.909 (103.42%)	13.320 (120.86%)	13.803 (102.96%)	12.818 (108.97%)	10.616 (106.34%)	0.467	1.400
No. of leaves#	Initial	4.00 (2.100)	4.00 (2.046)	4.00 (2.052)	4.00 (2.116)	4.00 (2.089)	4.00 (2.063)	3.00 (1.883)	0.019	NS
	30 D	5.00 (2.262)	4.00 (2.202)	4.00 (2.223)	5.00 (2.268)	5.00 (2.316)	5.00 (2.233)	4.00 (2.050)	0.025	0.076
	60 D	5.00 (2.370)	5.00 (2.340)	5.00 (2.377)	6.00 (2.567)	5.00 (2.34)	5.00 (2.359)	4.00 (2.092)	0.093	NS
	90 D	6.00 (2.487)	6.00 (2.519)	6.00 (2.509)	6.00 (2.514)	6.00 (2.549)	6.00 (2.479)	4.00 (2.239)	0.034	0.101
	120 D	6.00 (2.577)	7.00 (2.660)	6.00 (2.639)	7.00 (2.698)	6.00 (2.639)	6.00 (2.656)	5.00 (2.308)	0.031	0.094
	150 D	6.00 (2.537)	7.00 (2.652)	7.00 (2.739)	7.00 (2.735)	7.00 (2.795)	7.00 (2.722)	5.00 (2.404)	0.024	0.073

CD*: CD(p=0.05); *Parenthetical values: % increase seedling from the initial value of the seedling in 30 days of intervals; # Parenthetical values are square root transferred

taproot. Shoot to root ratio measures the balance between the transpiration area (shoot) and the water-absorbing area (root) of the seedlings (Haase, 2007).

The sturdiness quotient was determined as the indicator of the strength of the seedling to adverse climatic conditions. The sturdiness quotient was estimated in different treatments depicted in Figure 2a and Figure 2b. The data revealed that seedlings with T_2 are sturdier than the other treatments. The maximum value was recorded by the seedlings under T_2 (4.19) followed by the T_4 (3.98) and T_6 (3.87) among the organic and inorganic fertilizers. Under the bio-fertilizer application, seedlings under T4 are sturdier

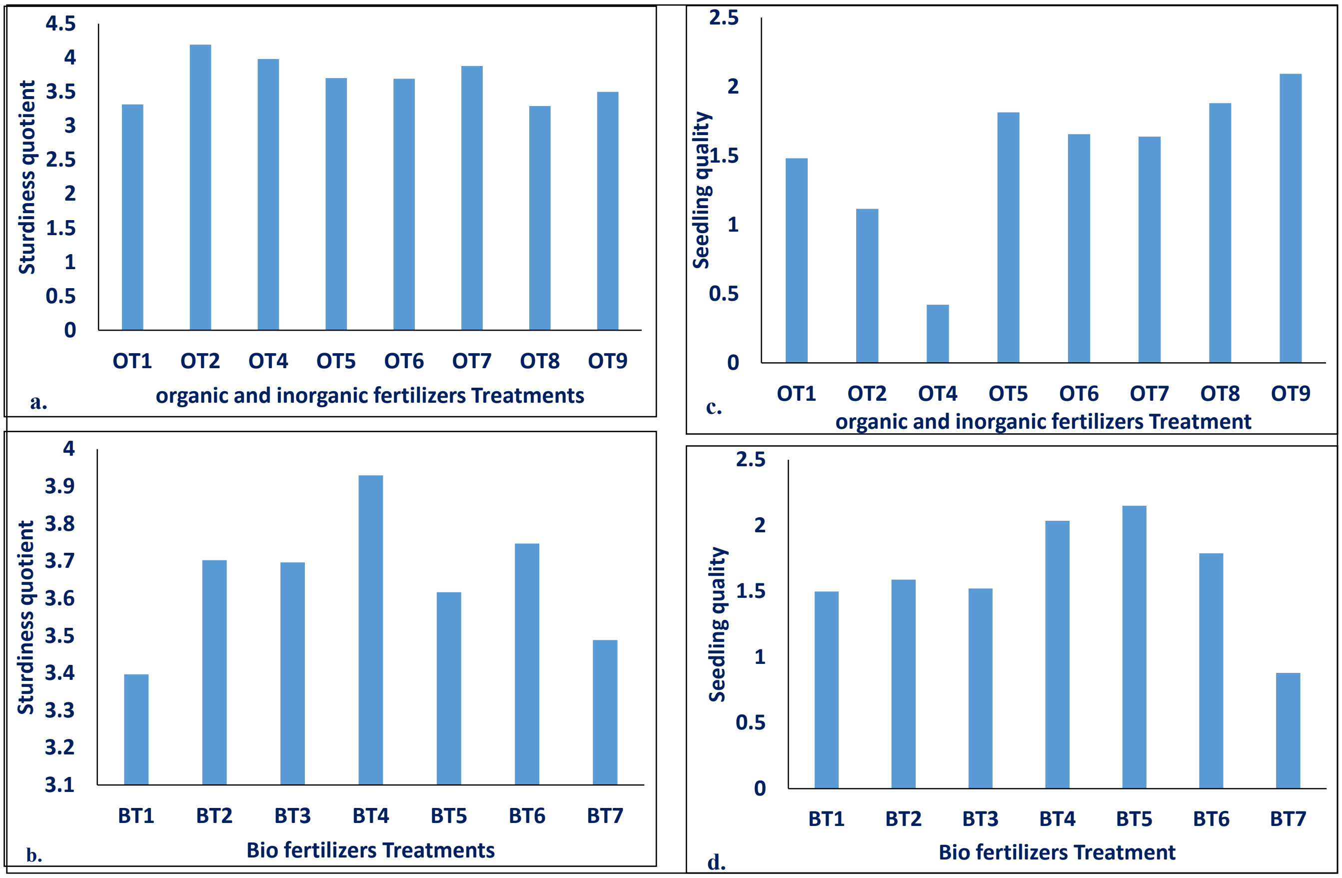

Figure 2: Effect of organic and inorganic fertilizers (a,c) and bio-fertilizers (b,d) on sturdiness quotient (a,b) and seedling quality (c, d)

than the other treatments. The maximum value was recorded by the seedlings under T_4 (3.92) followed by the T_6 (3.74) and T_2 (3.70). Based on morphological traits and seedling biomass the overall Seedling quality index was estimated in different treatments depicted in Figure 2c and Figure 2d. Among the organic and inorganic fertilizers highest seedling quality index (2.09) was recorded in the T_9 followed by T_8 and T_9. However, the lowest seedling quality was recorded in the T_4 compared with other treatments. Under bio-fertilizer treatments, the highest seedling quality index (2.15) was recorded in the T_5 followed by T_4 and T_6. However, the lowest seedling quality index (0.88) was recorded in the T_7. A similar study was conducted by Warrier et al. (2013) carried out a study to investigate the effects of different treatments on *Casuarina equisetifolia, Ailanthus excelsa* and *Tectona grandis* seedlings in closed chambers. The results revealed that *A. excelsa* and *C. equisetifolia* had a significant positive effect on shoot characteristics and chlorophyll contents and teak registered a significant effect in shoot characters and seedling quality index.

3.5. Suitable organic and inorganic fertilizers and PGPR on seedlings growth

In Conventional fertilizers treatments, T_9 (1.5 g DAP+1.5 g MOP seedlings^{-1}) was shown the best result where height, collar diameter, the average number of leaves and biomass of the seedlings was increased. Hence, in case of conventional fertilizers, T_9 is recommended for the better growth performance of the *Calamus thwaitesii* seedlings in nursery stages. In the case of Bio-fertilizers T_4 (KSB (10 g)+Mycorrhizal culture (10 g) seedling^{-1}) and T5 (Azospirillum (10 g)+PSB (10 g)+Mycorrhizal culture (10 g) seedling^{-1}) shows the best result compared with the other treatments. Hence T_4 and T_5 is recommended for the better growth performance of the *Calamus thwaitesii* seedlings in nursery stages. But based on the results and the present scenarios of pollution it is advised that Instead of using the chemical fertilizers, we can recommend bio-fertilizers which gives the same result as that of chemical fertilizers.

4. CONCLUSION

Devised to enhance the growth rate of the *Calamus thwaitesii* by nutrient management, and to understand the effect of conventional and bio-fertilizers on seedling growth. Among the fertilizers, 1.50 g of DAP, 1.50 g of MOP, KSB (10 g)+Mycorrhizal culture (10 g) and Azospirillum (10 g)+PSB (10 g)+Mycorrhizal culture were suitable for enhanced growth of the cane seedlings. Therefore, it is recommended to use the Phosphate and Potassium rich fertilizer or Phosphate solubilizing bacteria and Potassium solubilizing bacteria to supplement the Potassium and Phosphate nutrients for better growth.

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