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RESEARCH PAPER

Co-limitation of nitrogen and phosphorus causes culm shortness in the aged *Murta (Schumannianthus dichotomus)* plantation

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ABSTRACT

Murta (Schumannianthus dichotomus), a forest species grown in the swamp lands of Eastern India and Bangladesh, is used for weaving traditional bed mat, conventionally known as *Sital Pati*. Although long culm is a desirable trait for *Murta*, culm shortening is a usual phenomenon in the aged plantation. However, the causes of culm shortening were not explored yet. Herein, we conducted a field experiment in five years old plantation using six treatments, *i.e.*, F_1=control, F_2= cow dung @ 1500 kg ha^{-1}, F_3= urea, TSP and MoP @ 13.33, 16.66 and 8.33 kg ha^{-1} respectively, F_4 = combined application of F_2 and F_3, but urea application at two equal splits, F_5= cow dung @ 1500 kg ha^{-1} and urea, TSP and MoP application respectively @ 16.66, 16.66 and 8.33 kg ha^{-1}, urea application in three splits (6.67+6.67+3.33 kg ha^{-1}) and F_6 = combined application of cow dung @ 1500 kg ha^{-1} and urea, TSP, MoP application @ 20, 16.66 and 8.33 respectively, urea application at three equal splits of 6.67 kg ha^{-1}. Results revealed that combined application of organic and inorganic fertilizers (F_5) increased in new plant production rate and plant height. With a second experiment, we investigated which of the nutrients were responsible for culm shortness using three differently aged plantations, *i.e.*, 5, 15 and 25 years of old. Results showed that a combined limitation of N and P was responsible for culm shortness and reduced growth in *Murta*. Thus, our findings will help to maintain productivity of aged *Murta* plantation.

Key words: Culm shortness, *Murta* plant, nutrient deficiency, organic and inorganic fertilizer, plantation species

Introduction

Schumannianthus is a genus of monocotyledonous plants with two species under the family Marantaceae. One of the species, *i.e.*, *S. dichotomus*, is widely grown in the Eastern India and several districts of Bangladesh including greater Sylhet, Noakhali, Barishal and Tangail (Rashid *et al.*, 1993, Islam, 2005). It is a rhizomatous plant with cylindrical stem attaining a height of 3-5 m and a diameter of ~2 cm (Chowdhury and Konwar, 2006; FMP, 1992). Plants are usually harvested twice in a year and the harvests continue for ~40 years. The stripe, collected from culm of the *Murta* plant, is used for weaving the bed mat, which is traditionally known as *Shital Pati* (Chowdhury et al., 2007). *Shital Pati* was listed in the UNESCO representative list of the intangible cultural heritage of humanity, which signifies its importance in the society and culture. Moreover, *Shital Pati* carries a glories history for Bangladesh. For Example, *Shital Pati* of Sylhet was used to decorate the palace of British Queen Victoria (BSCIC, 2018) while it was considered as parallel to the world-famous MOSLIN (a very high quality finest fabrics) for its universal artisan. Additionally, many other handicraft materials are woven including decorated prayer mat, baskets, bags, and novelty items (FAO, 1995). Although these are rural handicrafts, majority of these items are now sold outside of the rural hinterlands for their aesthetic appeal and utilitarian values (Mandal et al., 2014, Mostafa, 2013, Komal E., 2017). Moreover, the return from *Murta* cultivation is comparatively higher than the traditional rice cultivation although it is a labour intensive enterprise. For example, in a study, Rashid et al., (1993) stated that the estimated return from a hectare of Murta cultivation was respectively US$ 917.83 and US$ 3530.12 from raw and processed *Murta* while the return from rice production was US$ 706.00. At national level, the contribution of *Murta* revenue was US$ 6057 during 191-1991 (Banik, 2001) while it is shrinking annual revenue generation of USD 4567 (BBS, 2001). *Murta* has wonderful adaptation capacity to marshy land (Ahmed et al., 2007) facilitating production in the flooded area with significant role in soil erosion control. Therefore, it could be a promising non-woody forest species for Bangladesh particularly in the coastal marshy lands, where hardly any crop is grown.

Continuous harvesting of *Murta* plants for 10 or more years leads to decrease in culm length (Mia et al., unpublished), which is the most important agronomic quality of *Murta* as it determines length or width of the mat. It is unclear what causes the culm shortness in the aged plantations. It is possible that nutritional imbalance or deficiency, either singly or combined, might be responsible for culm shortness (Harpole et al., 2011). While the studies on different aspect of such an important species is very few, the study investigating the cause behind culm shortness of *Murta* is none. In an experiment, the role of organic matter (cow dung) along with nitrogen (N), phosphorus (P) and potassium (K) fertilizer were examined on the growth of *Murta*. We also examined which of these nutrients, either singly or combined might be responsible for culm shortness using another experiment.

Materials and Methods

Experiment I

An experiment was conducted at Kathalia union, Bakerganj Upazila of Barishal district (22°33' N latitude and 90° 20' E longitude) to examine the effect of organic and inorganic fertilizer on the growth and development of *Murta* plantation. The plantation area lies under the agroecological zone 13. A five year plantation was selected for the current experiment. The treatments of the experiment is presented in the Table 1. The treatments were applied in the month of April. Generation of new plants and its height was recorded at different dates.

Table 1. Treatments of the field study

Treatment	Fertilizer application rate (kg ha^{-1})	Acronyms
1. Control	No or organic and inorganic fertilizer	F1
2. Organic fertilizer	Cow dung-15000	F2
3. Inorganic fertilizer	Urea-133 TSP- 166 MoP- 83	F3
4.Combined application of organic and inorganic fertilizer	Cow dung- 1000 Urea 2 split-66.5 and 66.5 TSP-166 MoP- 83	F4
5. Combined application of organic and inorganic fertilizer	Cow dung- 1500 Urea 3 split-66.5, 66.5 and 33 TSP-166 MoP- 83	F5
6. Combined application of organic and inorganic fertilizer	Cow dung- 1500 Urea 3 split-66.5, 66.5 and 67 TSP-166 MoP- 83	F6

Experiment II

The second experiment was conducted in the same location of previous study (experiment I). Three plantation types were selected having three different ages i.e. 5, 15 and 25 years. The age of the plantation was determined based on the farmer's information. The basic soil properties are presented in Table 2. Soil samples were collected from 10 randomly selected places in each plantation types while ten random plants were collected from each plantation. The culm length of different plantation was measured after collection. The collected plant was dried and ground. The plant samples were digested with concentrated HNO_3 (70%, 1:5, w/v) and analyzed for P and K using with an atomic adsorption spectrophotomer (AAS) while the total N was determined using a method proposed by Baethgen and Alley (1989). The collected soil samples were dried and sieved to 4 mm. The pH and electrical conductivity (EC) was measured following standard procedure (1:5, w/v in water). The organic matter content of the soil samples was measured using loss on ignition method (de Benites et al., 2005; Mia et al., 2015). In brief, the soil samples were oven dried at 105°C for 24 hours and the weight was recorded. Next, the samples were heated at 550°C for 4 hours in a furnace oven and the weight was recorded. The fraction (%) of organic matter content was calculated using the following equation after modification from (Mia et al., 2015)-

$$\text{Fraction of organic matter (\%)} = \frac{\text{(Weight loss between 105°C and 550°C)*100}}{\text{Weight of dry soil}}$$

The soil samples were additionally extracted with 1 M KCl (1:10, w/v) for inorganic NH_4^+- N and NO_3^--N determination while they were extracted with acidified NH_4F (1:10, w/v) for available P. Inorganic N and available P were determined using colorimetric method Bray and Kurtz (1945). For K contend determination, soil samples were extracted with 1 M $CaCl_2$ (1:5, w/v) and determined with ASS. Soil cation exchange capacity was determined using ammonia acetate methods. Briefly, 4 g of soil was shaken with 1 M CH_3COONH_4 (pH=7.0) for 30 minutes and the solution was discarded after centrifugation. This step was repeated twice. The extra NH_4^+ not attached to the CEC was removed with three consecutive washings using 70% ethanol. Then, the NH_4^+ was replaced with Na^+ using 1 M CH_3COONa (pH=7.0). This step was repeated twice and the NH_4^+ concentration was measured as discussed above.

Statistical analysis

Plant and soil variables were analyzed following one way analysis of variance using computer program SPSS (version19: Scientific Graphing Software, SPSS Inc., Chicago, IL). For experiment-II, sample identification number was used random factor while age of the plantation was considered as fixed factor. Data were transformed when the model assumptions were not met. Tukey's HSD test was used to separate the means ($p<0.05$).

Results

Experiment I

i. New plant production per clump

After 75 days of fertilizer application, a significant differences in production of new plants in each clump (Fig. 1, $P<0.05$) was observed. The highest number of plants per clump (~3) was observed in the plots receiving combined application of organic and inorganic fertilizer treatment (F_5, *i.e.*, cow dung @ 1500 kg ha^{-1} and urea, TSP and MoP application respectively at a rate

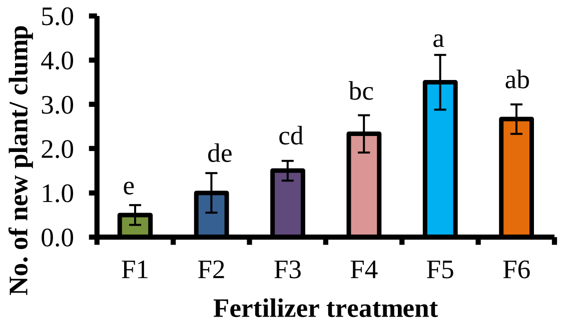

Figure 1. Number of new plants per clump after 75 days of fertilizer application.

For treatments abbreviation see table 1. Different letter indicates significant differences (Tukey's post hoc test, $p<0.05$). Error bar indicates standard error of means and the sample size was 3.

of 16.66, 16.66 and 8.33 kg ha^{-1}, urea application in three splits (6.67+6.67+3.33 kg ha^{-1})) while the lowest number of new plants per clump was recorded in the control treatments.

ii. New plant height

Fertilizer application had significant effects on the culm height of newly developed plants (Fig. 2, $p<0.05$). After 165 days of treatment intervention, the longest plant was observed in the combined application of organic and inorganic fertilizers (F6), which was similar to F5 and F4. However, the shortest plant was observed in the control treatment.

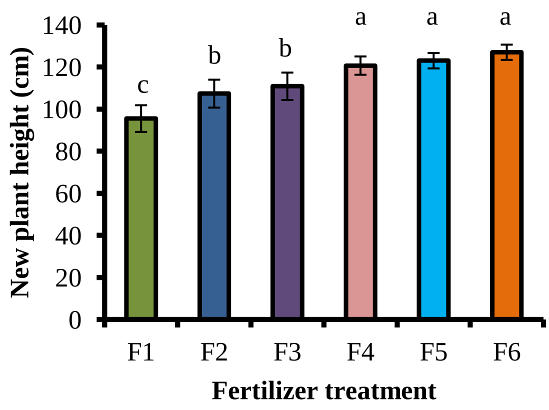

Figure 2. New plant height after 165 days of application of fertilizer

For treatment abbreviation see table 1. Different letter indicates significant differences (Tukey's post hoc test, $p<0.05$). Error bar indicates standard error of means and the sample size was 3.

Experiment II

i. Soil properties and tidal inundation levels of the experimental site

The tidal flooding level during peak period of monsoon ranged from 0.35 to 0.50 m. however, the tidal flooding was similar in the all plantation types. Similarly, the CEC of the soils hovered ~7.5 $cmol_c$ kg^{-1} soil but not varied for different age of the plantation (Table 2). Soil pH was significantly higher in old aged plantations compared to new and mid-aged plantations. The salinity of the different plantation did not varied significantly for age of the plantation.

Table 2. Soil properties and daily tidal inundation level of the experimental site

Plantation age (years)	Tidal flooding level (m) during high tide at monsoon	CEC (cmol kg^{-1} soil)	EC (uS cm^{-1})	pH (H_2O)
5	0.50±0.25	7.52 ±0.35	50±2.5	7.71±0.08b
15	0.50±0.21	6.79±0.29	56±3.7	7.58±0.04b
25	0.35±0.27	7.58±0.75	56±5.8	8.18±0.03a
Level of significance	NS	NS	NS	*

*Significant at 5% level.

ii. Murta yield

a. Plant height

The plant height of *Murta* varied for the age of plantation ($p=0.05$). The longest plant (322 cm) was obtained from 15 years plantation while the shortest (223 cm) was obtained from 25 years plantation (Fig. 3). The Plant height was reduced by 30% in the 25 years old plantation compared to 15 years plantation.

b. Length of first internode and second internode

The length of first internode, which is used for making strip, significantly varied in different aged plantation. Similar to the plant height, the highest length of first internode was observed in 15 years old plantation (p=0.003). However, the length of second internode for different aged plantation was statistically similar (P=0.89, Fig. 4).

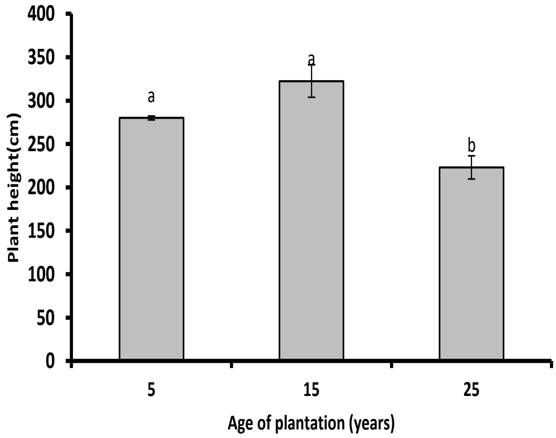

Figure 3. Average plant height of different plantations

Different letter indicates significant differences (Tukey's post hoc test, p<0.05). Error bar indicates standard error of means and the sample size was ten.

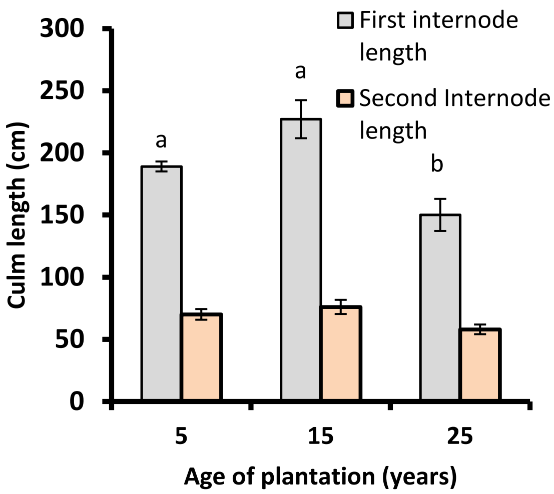

Figure 4. Culm length of plant under different plantations

Different letter indicates significant differences (Tukey's post hoc test, p<0.05). Error bar indicates standard error of means and the sample size was ten.

iii. Nutrient content in soil and plants

a. Organic matter content in soil

There was no significant difference among the plantations in respect of organic matter content (*p=0.68*, Fig. 5). However, it is notable that the organic matter content of soil is quite high, more than 3% for all cases.

Figure 5. Organic matter (%) content of soil under different aged plantation

Error bar indicates standard error of means, N=10.

b. N content in soil and plant

The N content in both soil and plant were significantly higher at 15 years old plantation compared to 25 years plantation, respectively (*p=0.004 and 0.003*). The soil N status was almost double (91% higher) in the 15 years old plantation compared to 25 years old plantation while the plant N status was 150% higher in 15 years old plantation compared to 25 years plantation. However, the N content was of 5 years plantation was statistically similar to 15 years old plantation (Fig. 6a and 6b).

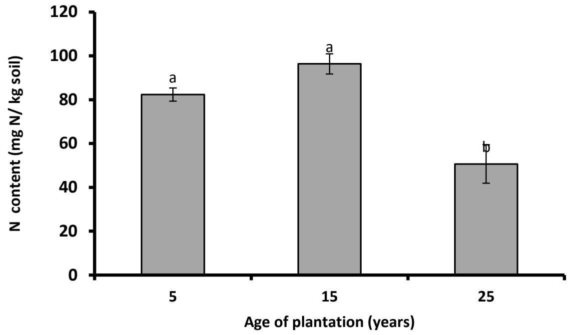

Figure 6a. Cumulative mean available inorganic N content of soil (NH_4^+-N and NO_3^--N) at different plantations

Different letter indicates significant differences (Tukey's post-hoc test, p<0.05). Error bar indicates standard error of means, N=10.

Figure 6b. Total N content in plants of different plantations

Different letter indicates significant differences (Tukey's post-hoc test, p<0.05). Error bar indicates standard error of means and the sample size is N=10.

c. P content in plant:

The P content in plant differed significant for the age of plantation (p=0.004 Figure 7). The P content in plant was 83% higher in 15 years plantation compared to 25 years plantation.

Figure 7. P content in plant of different aged plantations
Different letter indicates significant differences (Tukey's post-hoc test, p<0.05). Error bar indicates standard error of means and the sample size is N=10.

d. K content in soil and plant:

The K content in soil and plant was the same for all the plantations studied (p=0.192 and p=0.416, Figure 8a). K might not be responsible for growth retardation.

Figure 8a. K content in soil at different aged plantation
Different letter indicates significant differences (Tukey's post-hoc test, p<0.05). Error bar indicates standard error of means and the sample size is N=10.

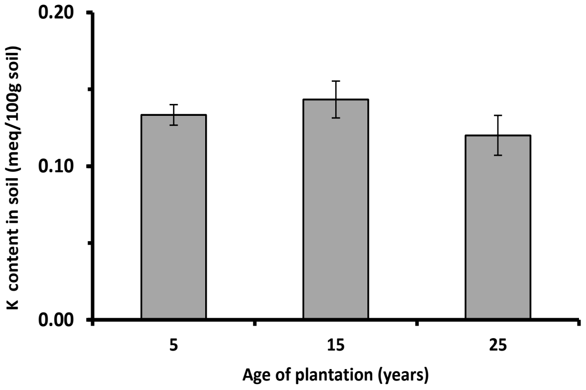

Figure 8b. K content in plant of different aged plantation
Different letter indicates significant differences (Tukey's post-hoc test, p<0.05). Error bar indicates standard error of means and the sample size is N=10.

Discussion

Plant nutrition is shown to be one of the underlying reasons for growth retardation in plantation crop since nutrients are mined from same layers with recurrent harvests. Because, there is a little chance of nutrient recycling. In the first experiment, it was observed that combined application of organic and inorganic fertilizers particularly N, P and K increased generation of new plants (Fig. 1) while it was also observed that the same combinations promoted plant height (Fig. 2). These clearly indicated that the plantations are limited by either of these nutrients (organic matter, N, P and K). As far as we know, there is no such studies to compare our results except one reported by Ara et al. (2000), who found no significant differences of NPK fertilization.

To reveal the underlying cause, second experiment was conducted, where it was observed that the organic matter of the soil in the different aged plantations was quite high and it did not varied significantly for age of the plantation (Fig. 5). So, organic matter might not be responsible for culm shortness. However, the status of organic matter in the old plantation is high suggesting that the plantation might not be deficient in nutrients provided that sufficient nutrients are inflowing from mineralization. It is not unlikely that there is not enough mineralization of organic matter due to limitation of nutrients, particularly nitrogen and phosphorus. Similarly, K did not vary significantly in different aged plantations. Thus, K might not be responsible for variation in culm length and growth (Fig. 8 a and b). However, a significant variation was found in N content in both soil and plant (Fig 6 a and b). Moreover, typical N deficiency symptom was observed in leaf (Plate 1). So, these findings pretend that N might be responsible for the variation in culm length and growth. Lebauer and Treseder, (2008) identified N limitation as one of the most limiting nutrients for net productivity. Similarly, P content was also higher in mid aged plantation while it was low in old aged plantation (Fig. 7). In a review article it has been shown that N and P co-limitation is the cause of reduced productivity in forest systems (Harpole et al., 2011). These findings lead to believe that N and P are two key nutrients that played vital role in growth retardation and culm shortness in *Murta*.

Plate 1. Nitrogen deficiency observed in leaf of old 25 years old plantation

Conclusion

Murta is one of the promising non-woody forest species in Bangladesh. It can deliberately be adopted in the marshy coastal areas of Bangladesh. However, recurrent harvesting of *Murta* leads to nutrient imbalance and consequently the yield is reduced in the aged plantations. For example, culm shortness was observed in many plantation as in case of plantation of Bakergonj, Barishal district. In this study, we investigated the cause of culm shortness. Our results revealed that limitations of N and P caused culm shortness in *Murta*. Therefore, application of N and P fertilizer may increase yield of Murta in the Bakerogonj area although nutritional balance may vary with location and with the level of nutrient mining by plants.

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