THE JOURNAL OF AGRICULTURE AND NATURAL RESOURCES SCIENCES

Journal homepage: http://www.journals.wsrpublishing.com/index.php/tjanrs

Online ISSN: 2383-238X Print ISSN: 2423-4397

Original Article

Species Interactions, Initial Growth Performance and Biomass Productivity of Acacia *auriculiformis* and *Swietenia macrophylla* in Tropical Mixed Plantations

Shourav Dutta and Mohammed Kamal Hossain

Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong-4331, Bangladesh

Abstract

The study was carried out in the Seed Research Laboratory and nursery of the Institute of Forestry and Environmental Sciences, Chittagong University (IFESCU), Bangladesh to assess the effects of mixed plantings of *Acacia auriculiformis* (A) and *Swietenia macrophylla* (S) on initial growth during February to November, 2015. The treatments consist of two pure planting plots (100% A and 100% S) and five mixed planting plots (1A:1S, 1A:2S, 1A:3S, 2A:1S and 3A:1S) of two common forest plantation tree species. In nursery, seeds were sown in a randomized blocks with three replicates of seven treatment plots. Periodic increments on height (cm), collar diameter (cm) and leaf/phyllode number of the seedlings was taken in every month and continued up to 10 months. At the age of 10 months of the experiment, it was found that *S. macrophylla* seedlings were significantly tallest (90.43 cm) when planted with *A. auriculiformis* in a proportion of 1A: 3S, whereas *A. auriculiformis* were tallest in the pure 100% *Acacia* plot, with an average mean height 135.4 cm. Maximum collar diameter (1.14 cm) was recorded for *S. macrophylla* in the mixed plots 2A:1S. Fresh, air dry and oven dry weight of shoots and roots of the seedlings were found significantly (p<0.05) highest in 1:1 mixed plot for *S. macrophylla*. *S. macrophylla* showed highest quality index when mixed with *Acacia* in a proportion of 1:1, with an average value of 6.06. The findings suggested that in comparison to pure plots of the fast growing species, mixtures had significantly (p<0.05) better growth and biomass.

Keywords: *Acacia auriculiformis,* biomass, Bangladesh, mixed plantations, species interactions, *Swietenia macrophylla*

Introduction

Tropical forests of Bangladesh are unique and irreplaceable ecosystems with their incomparable variety of plant and animal species (Dutta and Hossain, 2016; Myers, 1980).

Corresponding Author: Shourav Dutta < shourav.forestry@gmail.com >

How to Cite this Article: Dutta, S., and Hossain, M.K. (2018). Species Interactions, Initial Growth Performance and Biomass Productivity of Acacia *auriculiformis* and *Swietenia macrophylla* in Tropical Mixed Plantations. *The Journal of Agriculture and Natural Resources Sciences,* 5(1), 29-42.

Retrieved from http://www.journals.wsrpublishing.com/index.php/tjanrs/article/view/406

Article History: Received: 2016-06-16 Accepted: 2016-08-15

But, the natural forests of Bangladesh have been facing a serious onslaught that a large portion of it has already been lost during the last four decades due to population pressure and unscientific management, leaving the country with only a small percentage of forest cover (Anon, 1992; Dutta *et al*., 2015; Hassan, 1995). Massive failures of established plantations and land degradation have resulted in continuous depletion of forest resources. To reduce the gap between demand and supply of forest products and manage plantations more successfully, it is an urgent need to increase the yields of such plantations. A mixed plantation with suitable species combination can help to solve these problems (Aryal *et al*., 1999).

Species mixture can produce a greater amount of biomass per unit area of land because competition between individuals is reduced and the space is utilized more effectively (Aryal *et al*., 1999; Montagnini *et al*., 1995). *A. auriculiformis*, a nitrogen fixing species, has becoming a common plantation tree in the rural Bangladesh and provide considerable economic and social benefits (Hossain, 2008). Nitrogen fixing *A. auriculiformis* and *Swietenia macrophylla* (non–nitrogen fixing species) are two exotic species extensively planted in forests, marginal lands, institutes, roadsides, railway sites, field borders and homesteads of Bangladesh (Hosssain, 2008). The present study was aimed to investigate the effects of mixed plantings of N–fixing tree species (*A. auriculiformis*) with a non–N fixing tree (*S. macrophylla*) on their growth and biomass.

Materials and Methods

Experiment site

The study was conducted in the nursery bed of the Institute of Forestry and Environmental Sciences, University of Chittagong (IFESCU) campus, Chittagong, Bangladesh. The experimental design was carried out over a period of ten months from February to November, 2015 in the IFESCU nursery. The experimental site (nursery) lies approximately at the intersection of 91°50′ east longitude and 22°30′ north latitude (Khan *et al*., 2004). The nursery sites enjoys a tropical monsoon climate characterized by hot, humid summer and cool, dry winter (Mahmood *et al*., 2005). The average monthly mean temperature varied 29.75°C maximum and between 21.14°C minimum (Ahmed, 1990). The annual rainfall in the nursery is 2500–3000 mm which mostly takes place between June and September (Gafur *et al*., 1979). Relative humidity was generally the lowest (64%) in February and highest (95%) in June–September (Mahmood *et al*., 2005).

Planting and soil materials

Seeds of *Acacia auriculformis* (Akashmoni) and *Swietenia macrophylla* (Mahagony) were collected from the Bangladesh Forest Research Institute (BFRI), Chittagong, Bangladesh in the month of February, 2015. The soils collected from the barren hills of the University Campus was sieved well (< 3mm) and then fill up the seed bed. The soil used in the nursery was moderately coarse to fine textured. It has a grey to olive grey colour, sandy loams sub soil with moderate coarse structure.

Experimental plot design

Seedlings were raised in a randomized blocks with three replicates of seven treatment plots. Two pure planting plots of *A. auriculformis* and *S. macrophylla* along with five mixed planting plots of two species (*Acacia* × *Swietenia)* were established. The treatment details were as follows:

- Two pure planting plots – P_1 (100% A) and P_2 (100% S)
- Five mixed planting plots – M_1 (1A:1S), M_2 (3A:1S), M_3 (1A:3S), M_4 (2A:1S), M_5 (1A:2S).

Each plot was 200 cm × 60 cm in size with 30 seedlings at a spacing of 20 cm × 20 cm

(seedling to seedling distance: 20 cm) **(Fig.1).**

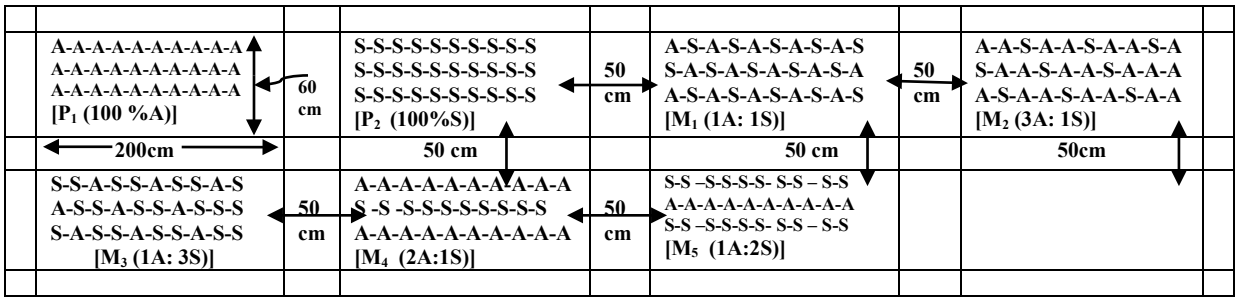

Fig.1: Experimental plot designs in the IFESCU nursery
Note: A = *A. auriculiformis* and S = *S. macrophylla*

Measurement of growth parameters in the nursery

The seedlings were allowed to grow for ten months from the time of seed sowing. Five representative seedlings from each species were selected from each replication of a treatment for measuring physical parameters. Periodic measurements on height of the seedlings was taken in every month from the ground to the tip of the highest bud and continued up to 10 months. Similarly, collar diameter and leaf number was taken along with height up to 10 months. Shoot height was measured from collar region to the tip of seedling at each reading time. Collar diameter was measured at the collar region transitional zone between root and shoot of the seedlings with a vernier caliper. Total number of nodes and branch on the stem of seedlings from each replication was counted and average number was calculated.

Harvesting and growth data collection in the seed research laboratory

Five randomly selected seedlings of each species were uprooted carefully from each mix plot and ten seedlings from each pure plantation plot at 10 months after germination. The uprooted seedlings were than washed to clear the root region off all soil particles. The data on shoot length, shoot diameter, branch number, leaf number, tap root length; lateral root length, tap root diameter, and number of lateral roots were recorded. Fresh weight of the stem, root and leaves were measured after removal of all water from the root portion of the washed seedlings. Stem, root and leaves were kept in open air in laboratory condition for 2 weeks to air dry the samples. After air drying the weight was measured again to get air dry weight of stem, root and leaves. Then the samples were oven dried at 70°C for 72 hours and after that oven dry weight of shoot, root and leaf of the seedlings were measured. The quality index (QI) as developed by Dickson *et al*. (1960) to quantify seedlings morphological quality was calculated as follows:

$$QI = \frac{Seedling\ dry\ weight\ (g)}{[Height\ (cm)/\ Diameter\ (mm) + Shoot\ dry\ weight\ (g)/\ root\ dry\ weight\ (g)]}$$

Determination of interspecies competition

The effect of interspecies competition was determined by comparing aboveground plant biomass for individual species in pure and mixed plots. Difference in plant biomass yield was calculated based on same plant density. The effect of competition on changes in plant biomass (PB_{diff}, expressed in g per plant) for a given species when mixed with other tree species was calculated using the equation proposed by Gathumbi *et al*. (2004):

$$PB_{diff} = PB_{mix} - \frac{1}{2} PB_{pure}$$

Where,
PB_{mix} = Plant Biomass (g per plant) of species grown in mixture with another species,
PB_{pure} = Plant Biomass (g per plant) of the same species grown in pure stand.

Statistical analysis

The periodic height increment, collar diameter, leaf number, shoot length, shoot diameter, branch number, tap root length, lateral root length, tap root diameter, number of lateral roots were compared among three species of each planting plots and also between pure and mixed species plots of the species. Analysis of variance and tests for means ($p \leq 0.05$) were run using the means of each variable from each of the three replicate plots. All the data collected were analyzed statistically by using the computer software package SPSS and were subjected to analysis by Duncan's Multiple Range Test (DMRT).

Results

Initial growth performance of Acacia auriculiformis at the nursery

Results from periodic measurement of height of the *A. auriculiformis* seedlings showed that, there was no significant difference in monthly height increment for *A. auriculiformis* in mixed plantation with *S. macrophylla* though highest value of height increment per month for *A. auriculiformis* was recorded in P_1 (15.04 cm) and lowest value was recorded in M_4 (13.41 cm) (Fig. 2). In the mixed plots, the order of height increment for *A. auriculiformis* was $P_1 > M_2 > M_1 > M_5 > M_3 > M_4$.

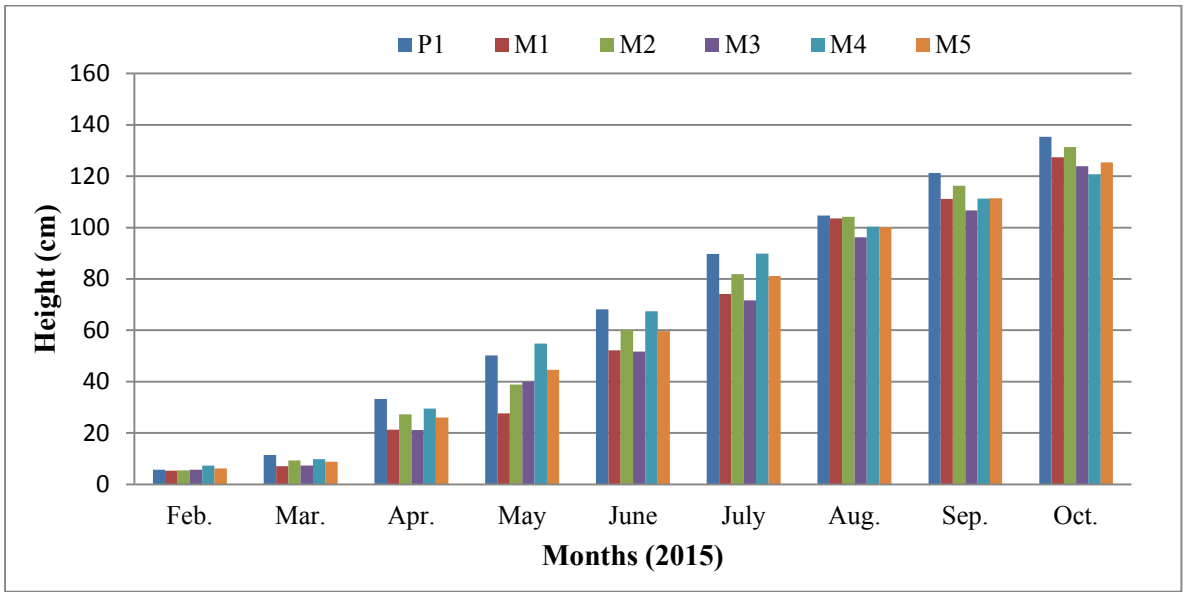

Fig. 2: Periodic height (cm) increment of *A. auriculiformis* seedlings in the treatment plots

Results from periodic measurement of collar diameter of the *A. auriculiformis* seedlings showed that, there was no significant difference in monthly collar diameter increment for *A. auriculiformis* in mixed plantation with *S. macrophylla* though highest value of collar diameter increment per month was recorded in M_1 (0.122 cm). But, *A. auriculiformis* showed highest growth performance in the mixture (1.10 cm) with *S. macrophylla* than pure plantation (1.04 cm). In the mixed plots, the order of monthly collar diameter increment for *A. auriculiformis* was $M_1 > M_2 > M_5 > P_1 > M_4 > M_3$ (Fig. 3).

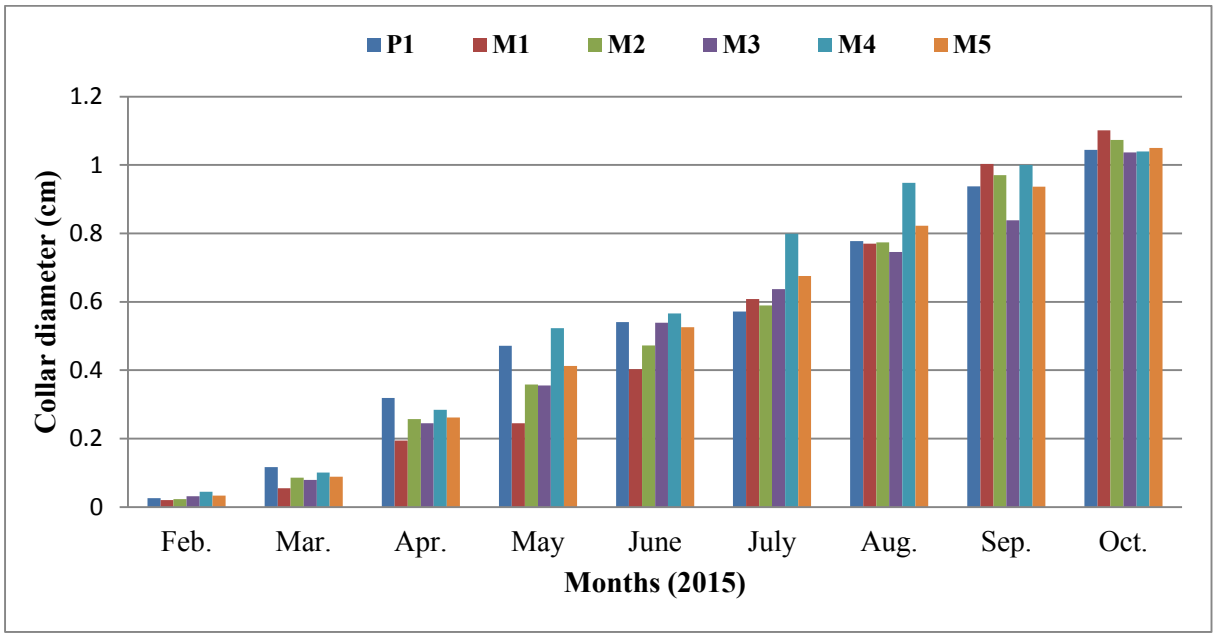

Fig. 3: Periodic collar diameter (cm) increment of *A. auriculiformis* seedlings in the treatment plots.

The present study showed that, there was significant difference in phyllode increment per month for *A. auriculiformis* in the mixed plantation with *S. macrophylla.* Highest number of phyllodes (99) after 9 month was recorded in M_4. *A. auriculiformis* showed lowest phyllode (94) in the pure than mixed plantation with *S. macrophylla* (99). In the mixed plots, the order of phyllode increment for *A. auriculiformis* was $M_4 > P_1 > M_5 > M_2 > M_1 > M_3$ (Fig. 4).

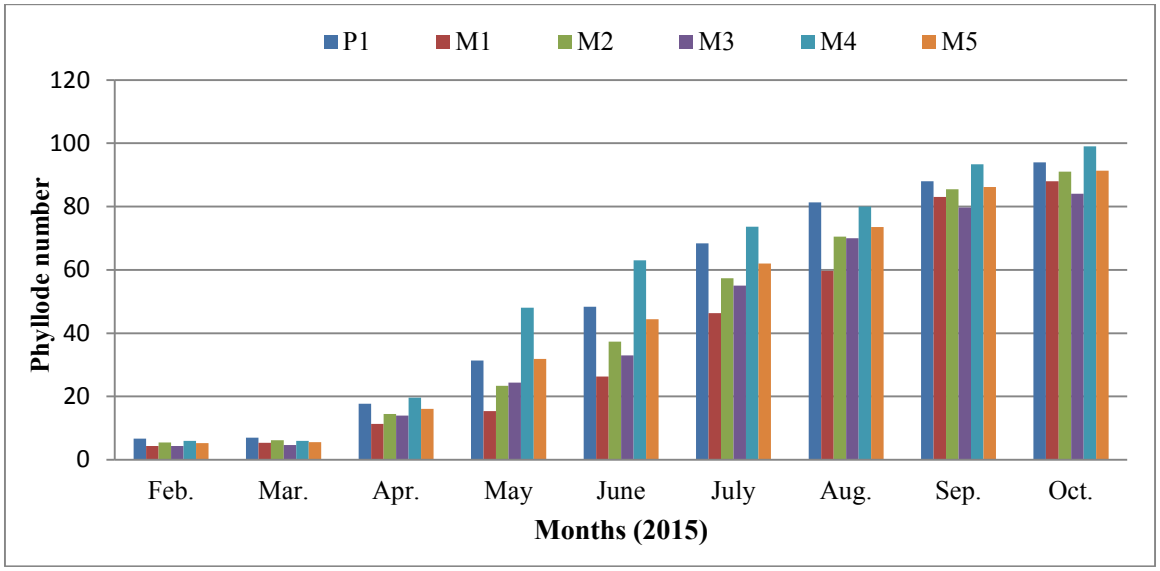

Fig. 4: Growth of phyllode (number) of *A. auriculiformis* seedlings in the treatment plots.

Initial growth performance of *Swietenia macrophylla* at the nursery

Results from periodic measurement of height of the *S. macrophylla* seedlings showed that, there was no significant difference in height increment per month in mixed plantations with *A. auriculiformis* though highest value (10.04 cm) of monthly height increment was recorded in M_3. *S. macrophylla* showed maximum growth performance in mixed plantation (90.43 cm) with *A. auriculiformis* than pure (87.81 cm). Highest value (90.43 cm) of height was recorded for *S. macrophylla* in mixed M_3 plot (Fig 5)**.** In the mixed plots, the order of height increment

for *S. macrophylla* was $M_3 > M_2 > P_2 > M_5 > M_4 > M_1$.

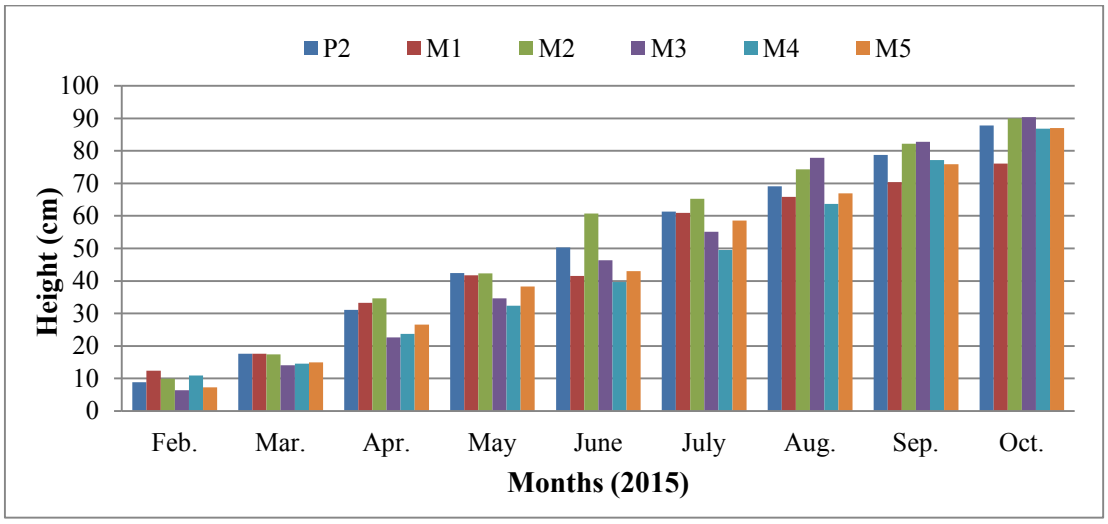

Fig.5: Periodic increment of height (cm) of *S. macrophylla* seedlings in the experimental plots.

S. macrophylla showed better collar diameter (1.141 cm) growth performance in the mixture with *A. auriculiformis* than pure plantation (0.910 cm) though there was no significant difference in collar diameter increment per month in mixed plantation with *A. auriculiformis*. Highest value (1.141 cm) of collar diameter was recorded in M_4 plot and lowest value (0.934 cm) in M_3 plot (Fig.6). Among the all plots, the order of collar diameter increment for *S. macrophylla* was $M_4 > M_2 > M_1 > M_5 > M_3 > P_2$.

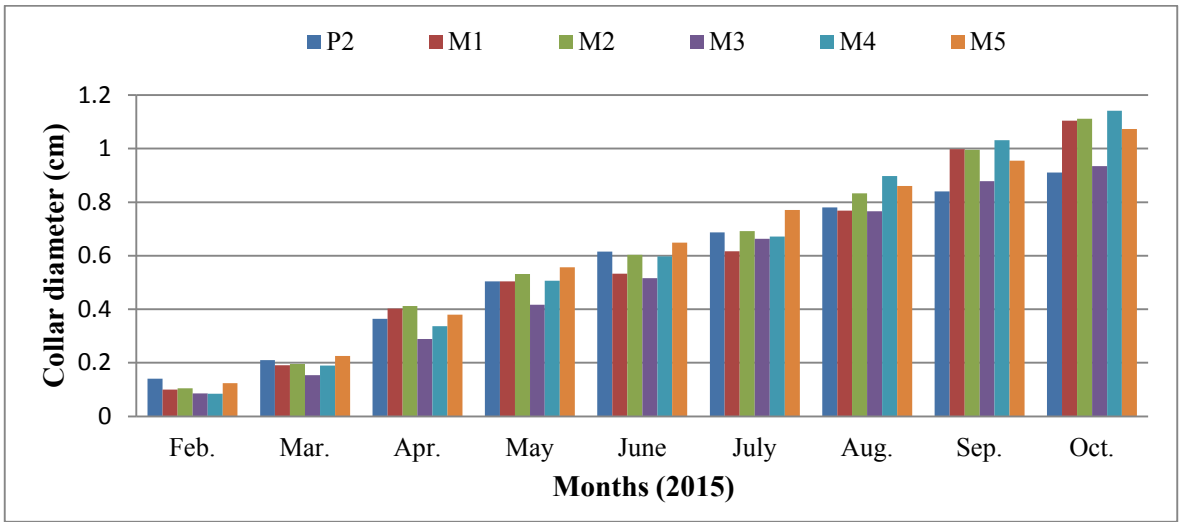

Fig. 6: Periodic increment of collar diameter (cm) of *S. macrophylla* seedlings in the experimental plots.

The present study showed that, there was significant difference in monthly leaf increment for *S. macrophylla* in the mixed plantation with *A. auriculiformis*. Highest numbers of leaves (67) after 9 month were recorded in M_2 and lowest number (58) in M_5. *S. macrophylla* showed highest (64) leaf number in the mixed plantation – M_2 than in pure – P_2 (56). In the all plots, the order of leaf increment for *S. macrophylla* was $M_2 > M_1 > M_4 > M_3 > M_5 > P_2$ (Fig. 7).

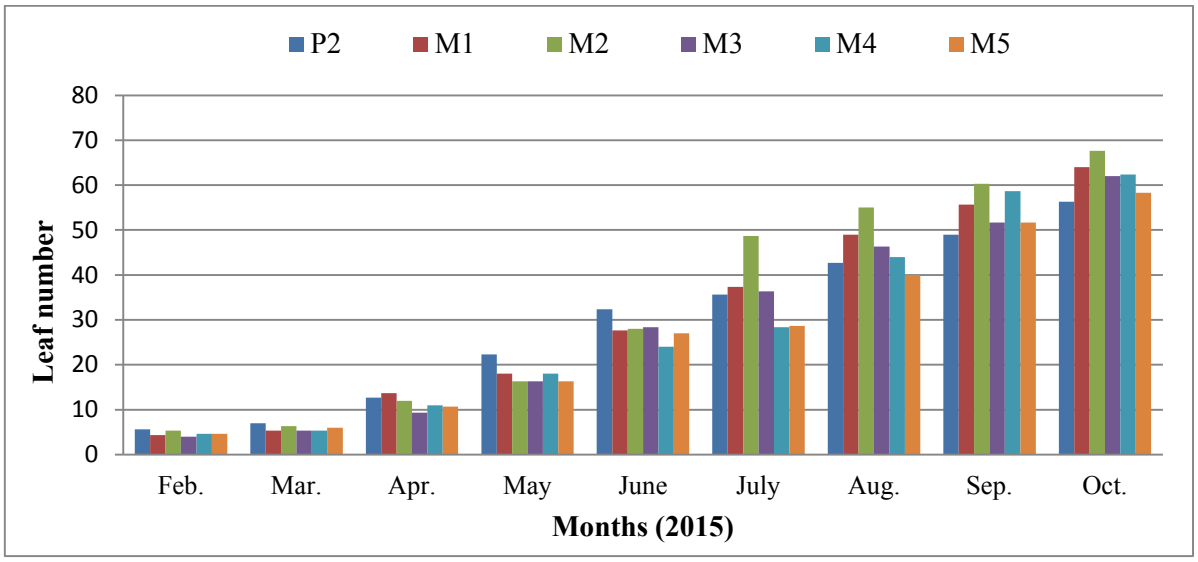

Fig.7: Growth of leaf (number) of *S. macrophylla* seedlings in the experimental plots

Seedling morphological character of Acacia auriculiformis

Results of variance analysis for morphological characteristics of intercropping *A. auriculiformis* seedlings are represented in Table 1. The result of variance analysis for seedling morphological character after 10 months of *A. auriculiformis* revealed that the effect of planting pattern was significant ($p < 0.05$). After 10 months, significantly ($p< 0.05$) highest mean shoot length (163. 27 cm) was in observed in mixed plot M_5 followed by M_3 (149.97 cm) and P_1 (149.53 cm). Akashmoni showed highest shoot length in mixed plantation with Mahagony than pure plantation. Maximum collar diameter (1.31 cm) was found in M_1 followed by M_3 (1.27cm), M_5 (1.237cm) and M_4 (1.21 cm). Akashmoni showed better collar diameter increment at 10 months in mixed plots than pure plantation (1.14 cm). Maximum branch number (10.33) was found in the mixed M_3 plot than pure (8.34). Highest number (150) of phyllodes was found in the M_5 plot followed by M_2 (111), M_4 (108) and P_1 (98). Highest mean lateral roots (29.67) for Akashmoni were observed in M_1, followed by M_2 (27.66) and M_3 (26.67). Akashmoni showed approximately same tap root diameter in both pure P_1 (1.07 cm) and mixed M_4 plantation (1.067 cm). Highest tap root length (32.87 cm) was observed in pure P_1 plot followed by mixed plantations– M_1 (30.6 cm), M_3 (29.86 cm) and M_4 (28.97 cm) for Akashmoni. Maximum lateral root length (44.63 cm) for Akashmoni was found in M_5 followed by M_3 (42.48 cm) and P_1 (36.8 cm)

Table 1: Stem height, collar diameter, branch no, leaf number, lateral root number, tap root diameter, tap root length and lateral root length of *A. auriculiformis* in pure and mixed planting plots at 10 months after germination

Treatments	Shoot				Root			
	Stem ht. (cm)	Collar dia. (cm)	Branch no.	Leaf no.	Lateral root no.	Tap root diameter (cm)	Tap root length (cm)	Lateral root length (cm)
P_1	149.53^{de*}	1.14^{bc}	8.34^{abc*}	98.33^{ab}	21^{abcd}	1.07^{e}	32.87^{b}	36.8^{cd}
M_1	143.4^{cde}	1.31^{c}	6.35^{abc}	96.34^{ab}	29.67^{cd}	0.99^{de}	30.6^{ab}	20.9^{abc}
M_2	135.17^{bcde}	0.97^{abc}	7^{abc}	111.67^{b}	27.66^{cd}	0.94^{cde}	17.93^{a}	26.45^{bcd}
M_3	149.97^{de}	1.27^{c}	10.33^{c}	93^{ab}	$26.67b^{cd}$	1.04^{e}	29.86^{ab}	42.48^{d}
M_4	130^{bcde}	1.21^{bc}	5^{abc}	108^{b}	35^{d}	1.067^{e}	28.97^{ab}	21.96^{abc}
M_5	163.27^{e}	1.237^{c}	9^{bc}	150^{c}	20.65^{abcd}	0.97^{de}	21.83^{ab}	44.63^{d}

(*) Means followed by the same letter(s) in the same column are not significantly different at P< 0.05 (DMRT).

Seedling morphological character of S. macrophylla

Results of variance analysis for morphological characteristics of intercropping *S. macrophylla* seedlings are represented in **Table 2**. The result of variance analysis for seedling morphological character after 10 months of *S. macrophylla* revealed that the effect of planting pattern was significant ($p < 0.05$). After 10 months, significantly ($p< 0.05$) highest mean shoot length (103. 56 cm) was observed in mixed plot M_5 followed by P_2 (100.1 cm) and M_3 (96.7 cm). *S. macrophylla* showed highest shoot length in mixed plantation with *A. auriculiformis* than pure plantation. Maximum collar diameter was found in M_4 (1.27 cm) followed by M_5 (1.22 cm), M_2 (1.21 cm) and M_4 (1.19 cm). *S. macrophylla* showed better collar diameter increment at 10 months in mixed plots than pure plantation (1.13 cm). Maximum mean branch number (4.67) was found in the mixed plot M_4 than pure (1.0). Highest number (75) of leaves was found in the M_2 plot followed by M_1 (72.33), M_3 (72) and M_4 (70). Highest mean lateral roots (38.33) for *S. macrophylla* were observed in P_2, followed by M_4 (37.68) and M_1 (35.78). *S. macrophylla* showed approximately same tap root diameter in both pure and mixed plantations. Highest mean tap root length (27.87 cm) was observed in M_4 and lowest in M_6 (20.97 cm). Maximum mean lateral root length (28.07 cm) for *S. macrophylla* was found in M_4 followed by P_2 (24.4 cm) and M_1 (22.75 cm) and M_5 (22.39 cm).

Table 2: Stem height, collar diameter, branch no, leaf number, lateral root number, tap root diameter, tap root length, lateral root length and nodule number of *S. macrophylla* in pure and mixed planting plots at 10 months after germination

Treatment	Shoot				Root			
	Stem ht. (cm)	Collar dia. (cm)	Branch no.	Leaf no.	Lateral root no.	Tap root diameter (cm)	Tap root length (cm)	Lateral root length (cm)
P_2	100.1^{a*}	1.13^{a}	1.0^{a}	61.0^{a}	38.33^{b}	0.85^{a}	26.93^{b}	24.4^{b}
M_1	86.57^{b}	1.19^{ab}	1.0^{a}	72.33^{b}	35.78^{b}	0.99^{a}	24.5^{ab}	22.75^{ab}
M_2	103.56^{a}	1.21^{b}	1.33^{a}	75.67^{b}	35.0^{ab}	1.04^{a}	24.17^{ab}	19.83^{ab}
M_3	96.7^{a}	1.13^{a}	0.67^{a}	72.0^{b}	29.33^{ab}	1.03^{a}	24.17^{ab}	16.72^{ab}
M_4	95.07^{a}	1.27^{b}	4.67^{b}	70.0^{ab}	37.68^{b}	0.87^{a}	27.87^{b}	28.07^{b}
M_5	95.24^{a}	1.22^{b}	0.68^{a}	64.68^{a}	25.66^{ab}	0.804^{a}	24.27^{ab}	22.39^{ab}

(*) Means followed by the same letter(s) in the same column are not significantly different at $p< 0.05$ (DMRT).

Biomass productivity of A. auriculiformis seedlings

At the time of *A. auriculiformis* seedling harvest, the highest fresh weight (113.91g) was recorded in M_3 followed by 105.83g in M_2 and 103.07g in P_1. Compared with pure plot, the fresh weight of stem, root and leaves were also significantly higher in mixed plots (**Table 3**).

Table 3: Fresh matter comparison of *A. auriculiformis* seedlings in pure and mixed plots

Treatments	Fresh weight (g)			
	Stem	Root	Leaf	**Total**
P_1	45^{ab*}	20.06^{cd}	38.07^{ab}	103.07^{ab}
M_1	36.47^{ab}	14.51^{abc}	30.43^{a}	81.39^{ab}
M_2	45.34^{ab}	18.53^{bcd}	42^{ab}	105.83^{abc}
M_3	52.83^{bc}	19.06^{bcd}	42.01^{ab}	113.91^{bc}
M_4	29.48^{ab}	14.11^{abc}	26.6^{a}	70.18^{ab}
M_5	42.57^{c}	17.26^{d}	36.87^{b}	96.64^{c}

(*) Means followed by the same letter(s) in the same column are not significantly different at P< 0.05 (DMRT).

The result of variance analysis for dry weight of *A. auriculiformis* revealed that the effect of planting pattern was significant ($p < 0.05$). Mean comparison using Duncan multiple range test (DMRT) showed that the highest amount of yield for dry weight obtained in mixed plot M_3. Compared to pure plot (50.76 g), the dry masses of stem, root and leaves were also significantly higher in M_3 (53.37g). The result of analysis of variance revealed that planting patterns had significant effect on the yield of *A. auriculiformis* (Table 4).

Table 4: Biomass productivity of *A. auriculiformis* seedlings in pure and mixed planting plots at 10 months after germination

Treatments	Air dry weight (g)				Oven dry weight (g)			
	Stem	Root	Leaf	**Total**	Stem	Root	Leaf	**Total**
P_1	28.05^{abc*}	13.43^{bcd}	22.3^{ab}	63.87^{ab}	23.25^{bcd}	10.06^{cde}	17.48^{ab}	50.76^{bcd}
M_1	21.67^{ab}	10.83^{abc}	17.25^{ab}	49.75^{a}	17.38^{abc}	7.64^{abcd}	14.10^{ab}	39.13^{abc}
M_2	24.84^{ab}	12.93^{bcd}	20.37^{ab}	58.16^{a}	18.48^{abc}	10.82^{de}	16.1^{ab}	45.407^{abc}
M_3	29.88^{bc}	13.78^{cd}	23.44^{ab}	67.09^{ab}	25.17^{cd}	9.34^{bcde}	18.84^{ab}	53.37^{cd}
M_4	18.1^{ab}	10.83^{abc}	15.84^{a}	44.77^{b}	12.83^{abc}	7.70^{abcd}	11.32^{a}	31.87^{abc}
M_5	24.27^{c}	12.56^{d}	19.87^{b}	56.67^{a}	18.81^{d}	9.28^{e}	26.79^{b}	43.54^{d}

(*) Means followed by the same letter(s) in the same column are not significantly different at $P< 0.05$ (DMRT).

Biomass productivity of S. macrophylla seedlings

The result of variance analysis for fresh weight of *S. macrophylla* revealed that the effect of planting pattern was significant ($p < 0.05$). Mean comparison using Duncan multiple range test (DMRT) showed that the highest amount of yield for fresh weight obtained in mixed plot (M_1). At the time of *S. macrophylla* seedlings harvest, the highest fresh weight was recorded 156.03 g in M_1 followed by 135.67g in M_2 and 134.24g in M_5. Compared with pure plot (126.27 g), the fresh weight of stem, root and leaves were also significantly higher in mixed plots (**Table 5**).

Table 5: Fresh matter/ biomass comparison of *S. macrophylla* seedlings in pure and mixed plots

Treatments	Fresh weight (g)			
	Stem	Root	Leaf	**Total**
P_2	53.41^{b*}	18.37^{bc}	54.52^{b}	126.27^{b}
M_1	66.01^{b}	24.68^{c}	65.33^{b}	156.03^{b}
M_2	55.17^{b}	21.5^{bc}	59.03^{b}	135.67^{b}
M_3	40^{b}	15.04^{b}	46.70^{b}	101.77^{b}
M_4	37.64^{ab}	17.57^{b}	44.94^{b}	100.13^{b}
M_5	57.85^{b}	20.83^{bc}	55.56^{b}	134.24^{b}

(*) Means followed by the same letter(s) in the same column are not significantly different at $P< 0.05$ (DMRT).

Compared to pure plot (58.14g), the dry masses were also significantly higher (70.83 g) in mixed plot M_1. The dry masses of stems, roots and leaves were also significantly higher in M_1 for *S. macrophylla* in comparison to pure. Among the mixed plots, maximum (70.83 g) dry weight was found in M_1 followed by M_2 (65.12 g), M_5 (60.48 g) and M_4 (50.30 g) (**Table 6**).

Table 6: Biomass productivity of *S. macrophylla* seedlings in pure and mixed planting plots at 10 months after germination

Treatments	Air dry weight (g)				Oven dry weight (g)			
	Stem	Root	Leaf	Total	Stem	Root	Leaf	Total
P_2	31^{b*}	12.15^{b}	28.71^{b}	71.86^{b}	25.05^{b}	10.01^{bc}	23.08^{b}	58.14^{b}
M_1	37.4^{b}	16.57^{c}	35.50^{b}	89.42^{b}	27.67^{b}	13.05^{d}	30.11^{b}	70.83^{b}
M_2	33.26^{b}	14.47^{bc}	32.45^{b}	80.16^{b}	25.79^{b}	11.85^{cd}	27.48^{b}	65.12^{b}
M_3	25.69^{b}	11.53^{b}	25.35^{b}	62.57^{b}	19.81^{b}	8.073^{b}	19.06^{b}	46.95^{b}
M_4	24.67^{ab}	12.88^{b}	24.99^{b}	62.55^{b}	18.34^{b}	11.12^{cd}	20.85^{b}	50.30^{b}
M_5	33.31^{b}	13.47^{bc}	28.3^{b}	75.08^{b}	24.64^{b}	10.67^{bcd}	25.21^{b}	60.48^{b}

(*) Means followed by the same letter(s) in the same column are not significantly different at $P< 0.05$ (DMRT).

Effects of Inter–species competition

The effect of interspecies competition was determined by comparing aboveground plant biomass. Biomass yield differed significantly among mixed plots **(Fig. 8).** The highest biomass production (33.72 g) was obtained in mixed (M_1) plot while the least (14.81 g) was obtained in M_3 mixed plot.

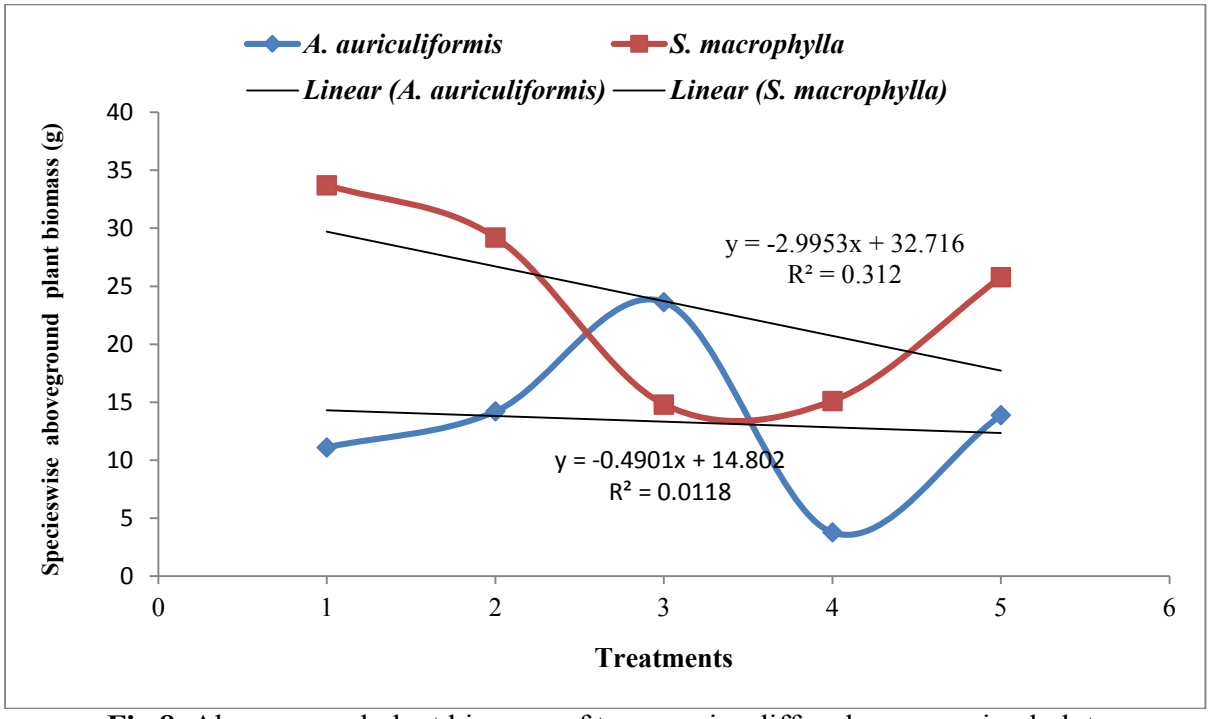

Fig.8: Aboveground plant biomass of two species differed among mixed plots

A. auriculiformis biomass per tree was positively affected by mixing with *S. macrophylla* in M_1 to M_5 plots. The shoot biomass production for *S. macrophylla* was decreased (14.82 g) when mixed with *A. auriculiformis* in 1A:3S proportion (Fig.9).

Quality Index (QI)

The present study revealed that at the time of harvesting the quality index was highest for *S. macrophylla* (6.06) followed by *A. auriculiformis* (1.75) (Fig.10).

Maximum quality index (1.75) was calculated for *A. auriculiformis* in M_3 followed by P_1 (1.66), M_1 (1.56) and M_2 (1.52) (Table 7). Highest quality index (6.06) was calculated for *S.*

macrophylla in M_1 followed by M_2 (4.98) and M_4 (4.57) (Table 8).
S. macrophylla was showed better morphological quality through quality index in the mixed plots than in pure plots (Fig. 11).

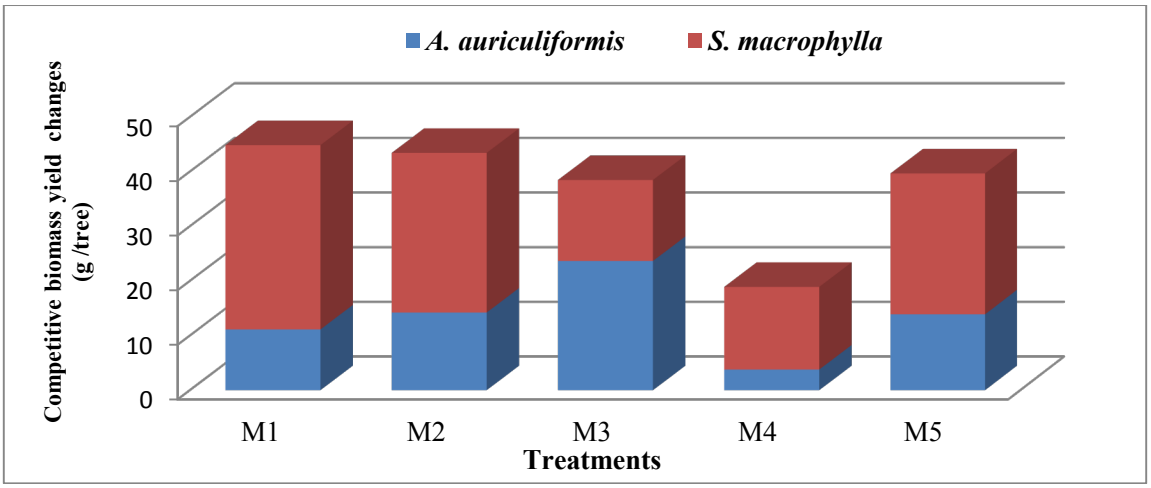

Fig 9: Effect of competition on aboveground biomass in mixed plots.

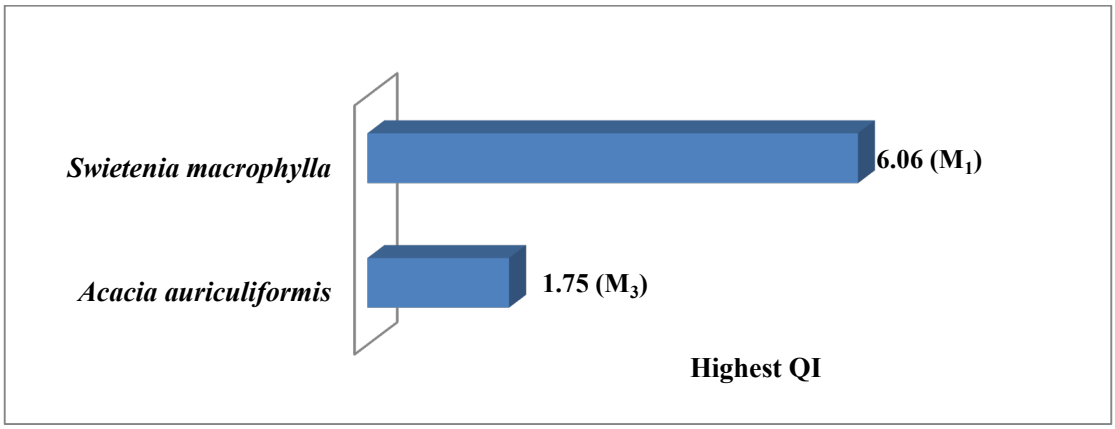

Fig.10: Highest Quality Index (QI) of *A. auriculiformis* and *S. macrophylla* seedlings at 10 months after germination.

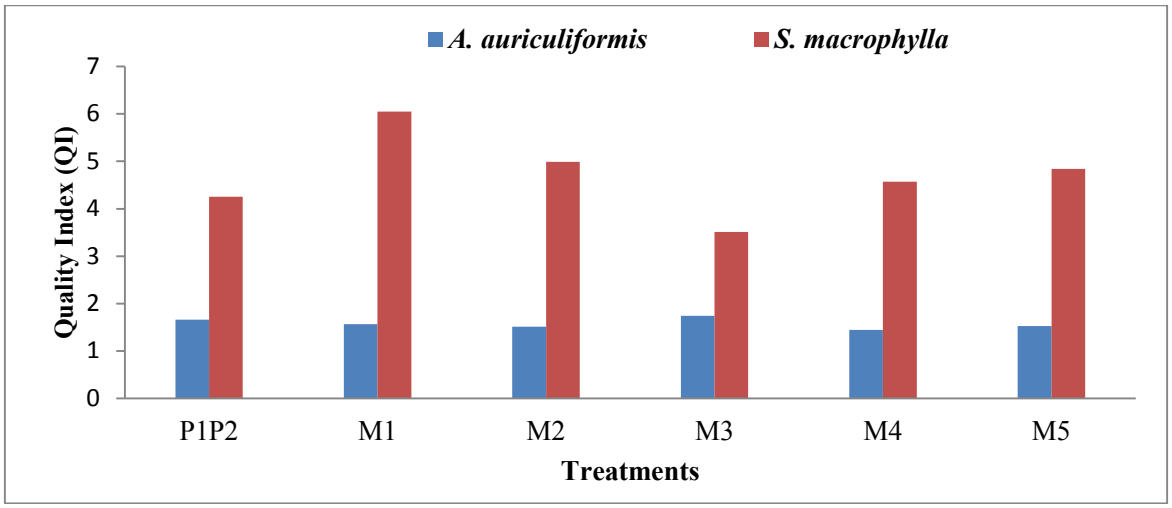

Fig.11: Comparative Quality Index (QI) of two species in the experimental plots after harvesting

Table 7: Quality Index of *A. auriculiformis* in pure and mixed plots at ten months after germination

Treatments	Seedling dry weight	Height (cm)	Collar dia. (mm)	Ht (cm)/ Collar dia (mm)	Shoot dry weight (g) [S.D.W.]	Root dry weight (g) [R.D.W.]	S.D.W./ R.D.W.	Ht/Coll.dia. + S.D.W./R.D.W.	QI
P_1	50.79	149.53	11.4	13.13	40.74	10.07	4.07	30.59	1.66
M_1	39.13	143.4	13.1	10.94	31.48	7.64	4.12	25.05	1.56
M_2	45.41	135.17	9.7	13.93	34.58	10.82	3.19	30.04	1.51
M_3	53.36	149.97	12.7	11.80	44.02	9.34	4.71	30.65	1.75
M_4	31.85	130	12.1	10.74	24.16	7.70	3.14	22.07	1.44
M_5	43.54	163.27	12.37	13.19	34.25	9.29	3.68	28.62	1.52

Table 8: Quality Index of *S. macrophylla* in pure and mixed plots at ten months after germination

Treatments	Seedling dry weight	Height (cm)	Collar dia. (mm)	Ht (cm)/ Collar dia (mm)	Shoot dry weight (g) [S.D.W.]	Root dry weight (g) [R.D.W.]	S.D.W./ R.D.W.	Ht/Coll.dia. + S.D.W./R.D.W.	QI
P_2	58.14	100.1	11.3	8.87	48.13	10.02	4.80	13.69	4.21
M_1	70.83	86.57	11.9	7.28	57.78	13.05	4.43	11.71	6.06
M_2	65.12	103.56	12.1	8.56	53.27	11.87	4.49	13.06	4.98
M_3	46.96	96.7	11.3	8.56	38.89	8.08	4.81	13.38	3.51
M_4	50.31	95.07	12.7	7.48	39.18	11.12	3.52	11.01	4.57
M_5	60.48	95.24	12.2	7.81	49.85	10.64	4.68	12.49	4.84

Discussion

The initial growth performance of *A. auriculiformis* and *S. macrophylla* in the experiment showed that both the species performed better in combinations than in pure plantations. Compared with pure plantation, performance of *S. macrophylla* was significantly higher when it was planted with *A. auriculiformis* in a proportion of 1:1. *S. macrophylla* also showed best performance in the mixture with *A. auriculiformis* in 3:1 and 1:3 ratios.

The present investigation indicating that biomass yield of the non-nitrogen fixing species was greater in mixed plantation than pure stands which are similar to those of other findings (Binkley 1992, Debell *et al*. 1989). Binkley (1992) reported that introductions of *Alnus rubra* into *Pseudotsuga menziesii* stands in the northwestern U.S. and Debell *et al*. (1989) resulting that introduction of *Albizia falcataria* into *Euclyptus saligna* stands in Hawaii produced greater biomass yield per hectare of the non-nitrogen fixing species in mixture.

The present study recorded beneficial effects on height growth on non- nitrogen fixing species (*S. macrophylla)* in mixture with *Acacia auriculiformis* have also been reported when *Eucalyptus sieberi, E. botryoides* and *E. sideroxylon* were planted with *A. longifolia* in Victoria, Australia (FAO 1992).

From the present study it was found that compared with pure plantation, performance of non-nitrogen fixing *S. macrophylla* was significantly higher when it was planted with nitrogen fixing *A. auriculiformis* in a proportion of 50:50 (1:1 ratio) which was similar to Aryal *et al*. (1999). A study conducted by Aryal *et al*. (1999) reported performance of non-nitrogen fixing *Eucalyptus* was significantly higher when it was planted with *Albizia procera* in a proportion of 50:50.

The reasons for better initial growth performance of *A. auriculiformis* in mixed plantations than in pure plots may be due to greater intra-specific competition among the seedlings for various resources in mixed than in pure plots.

Results from the periodic measurement of height of *A. auriculiformis* seedlings showed that the highest value of monthly height increment was recorded 15.04 cm for nitrogen fixing *A. auriculiformis* which was lower in comparison to Aryal *et al*. (1999). According to the report of Aryal *et al*. (1999), nitrogen fixing *Albizia procera* increased 16 cm monthly in height.

Conclusion

The initial results of present investigation showed enhanced growth, biomass and soil fertility improvement in mixed plantations in comparison to pure plantations. The present findings would be so much helpful to carry out further investigation on the tolerance, survival, growth of established plantations of different N-fixing and non-N fixing species to acidic and alkaline soils before recommending them for large scale afforestation programs. Both the species included in the present study are extensively used in different forestry particularly plantation programs of Bangladesh.

These findings would be useful for successful afforestation/plantation programs. But, these results are based on 10–month old saplings only. So, it is too early to assess the exact performance of these species and the inferential power of the results is limited. Further study needs to be conducted to compare growth performance, and biomass increase between mixed and pure plantations. Though the present study was conducted in the nursery, the findings also applicable or project in the long term and large scale plantations.

References

Anonymous, 1992. Global Biodiversity: status of the earth's living resources. WCMC, Chapman and Hall, London. 585 pp.

Aryal U.K., M.K. Hossain, B. Koirala, M.A.U. Mridha, H.L. Xu, and H. Umemara, 1999. Effect of Pure and Mixed Planting of *Eucalyptus camaldulensis* Dehnh. and *Albizia*

procera (Roxb.) Benth. on Growth, Biomass Yield and Soil Fertility. In: Nature Farming and Sustainable Environment, Vol. II. pp. 57–62.

Binkley, D. 1992. Mixture of nitrogen–fixing and non–nitrogen fixing tree species. In: Cannell *et al*., (1992) (infra), pp. 99–123.

DeBell, D.S., C.D. Whitesell, and T.H.Schubert. 1989. Using N_2–fixing *Albizia* to increase growth of *Eucalyptus* plantations in Hawaii. *Forest Science*, 35: 10–13.

Dickson, A., A. L. Leaf, and J. F. Hosner. 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. Forestry Chronicle, 3**3**: 10–13.

Dutta, S., and M. K. Hossain. 2016. Infestation of *Imperata Cylindrica* L. and its Impacts on Local Communities in Secondary Forests of Sitakunda Botanical Garden and Eco- Park, Chittagong, Bangladesh. Int. J. Conserv. Sci., **7** (1): 167-180.

Dutta, S., M. K. Hossain, M. A. Hossain, and P. Chowdhury. 2015. Exotic Plants and their usage by Local Communities in the Sitakunda Botanical Garden and Eco-Park, Chittagong, Bangladesh. Forest Research, 4: 136.

Food and Agriculture Organization of the United Nations (FAO). 1992. Mixed and pure forest plantations in the tropics and subtropics. Forestry Paper no. 103. FAO, Rome, Italy, 152 pp.

Gafur, M.A., A. Karim, and M. A. A. Khan. 1979. Physiological Studies of hills of Chittagong University Campus. Chittagong University Studies, Part II, Science, 3: 11–28.

Gathumbi, S.M., G. Cadisch, and K. E. Giller. 2004. Improved fallows: effects of species interaction on growth and productivity in monoculture and mixed stands. Forest Ecol. Manag., 187: 267–280

Hassan, M. M. 1995. Biodiversity Conservation and Management in Bangladesh: A state of the art, Review. ICIMOD, Kathmandu, Nepal Hill.

Hossain, M. K. 2008. The Contribution and Critics of Exotic Species in the Plantation Forestry of Bangladesh. **In:** Chauhan, S.K., Gill, S.S., Chauhan, R. and Sharma S.C. (eds.), Exotics in Indian Forestry, Agrotech Publishing Academy, Udaipur, India, pp. 324-335.

Khan, B. M., M. A. Hossain, M. M. Hossain, and M. K. Hossain. 2004. Performance of Eleven Multipurpose Tree Legume Seedlings Grown in the Hill Soils under Nursery Conditions in Bangladesh. Int. J. Agri. Biol., Vol. 6, No. 2, pp.346–349

Mahmud, S., A. T. M. R. Hoque, and M. Mohiuddin. 2005. Nodulation Behaviour and Biomass Productivity of Three Leguminous Plant Species at Nursery Stage in Chittagong University Soils. Res. J. Agri. Bio. Sci. **1**(1): 89–93.

Montagnini, F., E. Gonzalez, and C. Porras. 1995. Mixed and pure forest plantations in the humid neotropics: a comparison of early growth, pest damage and establishment costs. Commonwealth Forestry Review, 74(4): 306–314.

Myers, N. 1980. Conservation of Tropical Moist Forests. National Academy of Sciences, Washington, DC. 205p.