

## GREEN MANURE POTENTIALS OF WATER HYACINTH AND SEWAGE SLUDGE: THE SEED GERMINATION AND SEEDLING GROWTH TRIALS OF *ALBIZIA SAMAN*

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**Abstract.** Water hyacinth is a fast-growing weed in Bangladesh and across the world. The removal of this weed involves a considerable cost to the farmers. Similarly, municipal sewage sludge disposal is also a cost-intensive public burden. However, a combination of the two might appear to be a potential source of plant nutrients and can have synergistic effects on the production of healthy forest tree seedlings. *Albizia Saman* seed germination and its seedling growth were observed against different permutations of water hyacinth and sewage sludge. A ratio of 1:1 of the two showed the best results in seed germination and subsequent seedling growth. The mixture resulted in the highest germination rate (90%), the highest collar diameter (7.87 mm), the longest root length (54 cm), and the highest number of nodes (57) and leaves (13). The study provided important information on how to convert burdensome weeds and wastes into nutritional manure in agriculture and forestry.

**Keywords:** biomass, invasive, nutrient, organic fertilizer, seedling growth, water weed.

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### 1. Introduction

Water hyacinth (*Eichhornia crassipes*), a free-floating, sometimes rooted, freshwater perennial hydrophyte belonging to Pontederiaceae family, is considered a significant economic and ecological burden in many sub-tropical and tropical countries of the world [6, 21, 26]. It is capable to double its biomass in as little as five days [31]. Thus, it is listed as one of the fast reproductive plants and the worst aquatic weed in the world [13, 15, 55]. It is a serious threat to biodiversity [24] for its nature of invasion of the aquatic habitats [27, 52]. Its habitat ranges from tropical desert to rainforest zones [24]. It is pervasive throughout Southeast Asia, Southeastern United States, Central and Western Africa, and Central America [4, 6, 21, 26]. Given its favorable growth in wide range of ecological conditions, it has been reported to have invaded the freshwater systems in over 50 countries in the world. As in the other tropical countries, it has become highly invasive in Bangladesh too [31]. If this weed could be used as a growth and development medium for producing healthy forest tree seedlings, it

might revolutionize the forest nursery business and reforestation efforts in the country. Such an alternative use of water hyacinth is expected to help add organic matter and nutrients to nursery soils and reduce the use of inorganic fertilizers.

The chemical composition of water hyacinth depends strongly on its environment since it takes up nutrients from its habitat [40]. The chemical analyses confirmed high nutrient contents in water hyacinth [1]. The fresh hyacinth contains 95.5% moisture, 3.5% organic matter, 1.0% ash, 0.20% K<sub>2</sub>O, 0.04% N, and 0.06% P<sub>2</sub>O<sub>5</sub> [14, 15]. On a zero-moisture basis, it consists of 75.8% organic matter, 1.5% N, and 24.2% ash [10, 20]. Since water hyacinth accumulates nitrogen and phosphorus in its roots and the roots represent 20 per cent of its wet weight, it might be a potential source of organic fertilizer [9, 39]. Some studies [45, 46] also claimed that water hyacinth contains high level of growth hormones such as gibberellins in its roots. Thus, the plant has been found useful as a source of plant nutrient in agriculture [8, 14, 20, 28, 38].

Alongside the usage of weed-borne manure, using organic waste as a fertilizer is also common. Municipal sewage sludge is a by-product of sewage treatment processes [44]. Land-filling and land application of the sewage sludge are suggested as the most economic sludge disposal method [30, 32, 44], since this application has a great incentive from the viewpoint of its green fertilizer value [44]. Generally, sewage sludge is composed of organic compounds, macronutrients, a wide range of micronutrients, non-essential trace metals, organic micro pollutants, and microorganisms [23]. The macronutrients in sewage sludge serve as a good source of plant nutrients and the organic constituents provide beneficial soil conditioning properties [25]. Sludge amendment of soil improves its physical properties such as aggregate stability [35], water holding capacity [11, 49], porosity [49], and soil chemical properties such as pH [33, 51], humus content [23], soil organic carbon [22], electrical conductance [12, 49], N and P [12, 47, 54], and cation exchange capacity [48, 49]. Sewage sludge application to soil enables the recycling of nutrients and may eliminate the need for commercial fertilizers in croplands [47].

Given the potential nutrient contents of water hyacinth and sewage sludge, a numbers of studies were conducted to test the compost-potentials of water hyacinth and sewage sludge for agricultural crops. Lata and Veenapani [24] carried out an experiment to test the growth of *Brassica juncea* under water hyacinth manure. Offor et al [34] determined the effect of water hyacinth in a crude oil polluted soil using okra as a test crop. According to Vidya and Girish [53], water hyacinth compost has positive impact on wheat production. Iqbal et al [18] found significant effect of municipal and residential sludge on seed germination and growth of *Leucaena leucocephala* seedlings. Hossain et al [16] reported significant increase in seed germination and growth of *Acacia auriculiformis* seedlings. However, the impacts of the combination of water hyacinth and municipal sewage sludge have not been tested in the production of healthy seedlings of any forest tree species other than *Acacia auriculiformis* so far; even though the co-composts of water hyacinth with other organic residues such as sewage sludge were found to significantly increase crop yields [2, 3, 41, 43]. Thus, we hypothesized that the combination of the two might have a

synergistic impact on the production of healthy seedlings for forest tree species. With this, this study was an effort to test the efficacy of the combination of water hyacinth and municipal sewage sludge and to find out the optimal ratio of the two to help grow quality seedlings for an important forest trees species, *Albizia saman*, in Bangladesh. The study is expected to provide vital information on the possible source of a potential organic fertilizer which in turn will reduce the application of inorganic fertilizers in the forest nurseries. In addition to this, the invasion of aquatic systems by water hyacinth would be reduced effectively.

## **2. Materials and methods**

### ***2.1. Site of Experiment***

The experiment was conducted at the research nursery of the Institute of Forestry and Environmental Sciences, University of Chittagong (IFESCU), Bangladesh. The absolute location of the study area lies approximately at the intersection of 91°50'E and 22°30'N. The university area is characterized with tropical monsoon climate. The dry and cold season is from November to March; Pre-monsoon is from April to May which is hot and humid. The sunny and monsoon season is from June to October, which is warm, cloudy and wet. Relative humidity is 64% in February and 95% in June [17].

### ***2.2. Seed Collection and Media Preparation***

*Albizia saman*, popularly known as rain tree, was selected for the study since it is a fast-growing and popular forest tree species for the plantation programs in Bangladesh. The reason for such selection might be the country's need for a quick green coverage. The seeds were collected from the plus trees of the species available in the Chittagong University campus. The control was the soil, which was normally used for seedling growing activities in the IFESCU nursery. The water hyacinth was collected from the ponds of the nearby villages and the municipal sewage sludge was collected from municipal drainage system of the Chittagong City Corporation, Bangladesh. Media samples were collected 4-5 weeks before sowing the seeds in the experimental blocks. The water hyacinth was covered with gunny bags and left in the open sun for the water hyacinth to rot. The rotten hyacinth was dried in the sun and was converted to small granular fragments using a 3 mm sieve. Collected sludge was dried in the open Sun. After drying of sludge, it was also strained through the same sized sieve to make them free from root splinters and other foreign materials.

### ***2.3. Treatments and Experimental Design***

The soil, sludge, and water hyacinth were mixed properly by weight at different ratios as reported in Table 1. The dried and sieved media were filled into poly bags of size 6'' × 4''. There were 10 treatments (T1 through T10) and one control (T0) in the experiment. In each treatment twenty seeds (two seeds in each poly bag) were sown with no pretreatment. After completion of the germination, excess seedlings of inferior quality or un-germinated seeds were removed from the poly bags to observe the initial growth parameters of the seedlings. Each of the

treatments was replicated thrice. Thus, a total of 330 poly bags, 660 seeds, and 330 seedlings were used in the experiment. The poly bags were arranged in a Complete Randomized Block Design (CRBD). The details of the treatments, their composition, and the replications are explained in Table 1.

**Table 1.** Composition and combination of treatments used in the experiment.

Treatments	Composition	Ratio (by weight)	No. of Replications	No. of seeds	No. of seedlings
T0	Normal soil	1	3	20	10
T1	Sludge	1	3	20	10
T2	Sludge: Hyacinth	1: 1	3	20	10
T3	Soil: Sludge: Hyacinth	1:1:1	3	20	10
T4	Soil: Sludge	1:1	3	20	10
T5	Soil: Sludge	2:3	3	20	10
T6	Soil: Sludge	3:2	3	20	10
T7	Soil :Hyacinth	1:1	3	20	10
T8	Soil: Hyacinth	3:2	3	20	10
T9	Soil: Hyacinth	2:3	3	20	10
T10	Hyacinth	1	3	20	10

#### **2.4. Measuring Germination Rate and Seedling Growth Performance**

The germination rate and growth performance of *Albizia saman* seedlings up to four months old were measured. Average height and number of leaves at 15 days interval till the end of the experiment were measured and at the end of the experiment, shoot height, root length, collar diameter, number of leaf, number of nodes, shoot fresh weight, root fresh weight, leaf fresh weight, shoot dry weight, root dry weight, leaf dry weight, total fresh and dry biomass production, root-shoot ratio of the seedlings of *Albizia saman* were measured and calculated. The germination percentage was calculated as: (the total number of seeds germinated divided by the total number of seeds sown)  $\times 100$ . The means of germination percentage found in each of the treatments and controls were compared using the error bars assuming a 5% level of significance. The same comparison was conducted for collar diameter, lengths of root, shoot, and the whole seedlings, and number of nodes and leaves produced by the seedlings. The performance of fresh and dry weight production and root-shoot ratio development was compared across the treatments and control using the Duncan's Multiple Range Test (DMRT).

#### **2.5. Selection of Favorable Treatments**

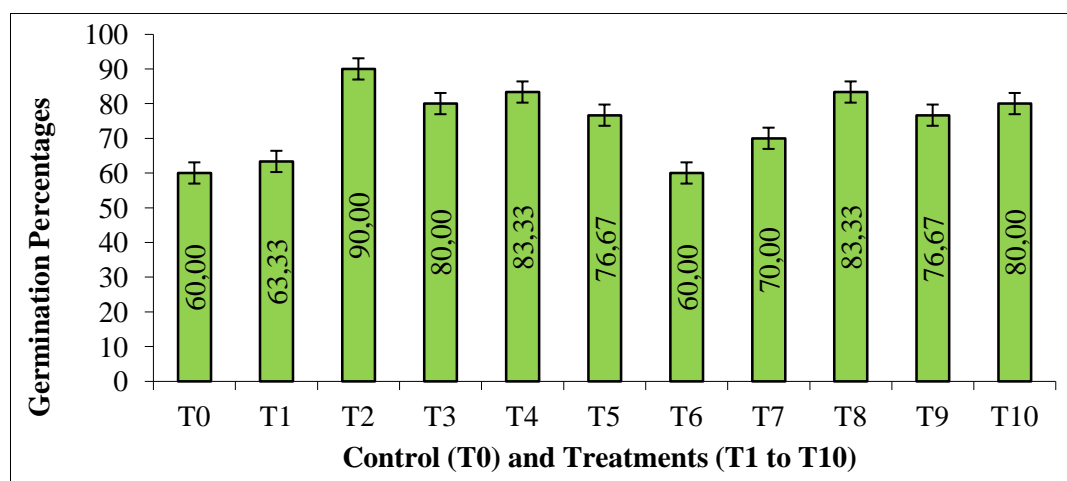
We tested a number of seedling growth attributes to be varyingly affected by the treatments. Due to this variation in treatment effects, we wanted to single out the treatment(s) that could be considered the best for the germination of *Albizia saman* seeds and subsequent seedling growth. For this purpose, we assigned weights to the treatments based on their effects on seed germination and other growth attributes of seedlings. For each of the attribute of the seedlings, four treatments with highest impacts on the mean growth were selected. This was followed by the selection of the unique treatment that was significantly the best in

affecting the growth attribute under consideration. If a unique treatment was identified, it was given the whole weight of 1.00 while each of the remaining three had the weight of 0.00. If a significantly unique treatment was not available, each of the four treatments was given the equal weight of 0.25. Then the combined weight of each of the treatments was determined by summing up the weights of the treatment across all growth attributes of the seedling. The treatment(s) with the highest combined weight was (were) chosen to be the most favorable treatment(s) for the growth and development of *Albizia saman* seedlings.

### 3. Results and discussion

#### 3.1. Germination Status

Different treatments showed varying degrees of impacts on the seed germination percentage of *Albizia saman*. Treatment T2 showed the highest rate of germination (90%) which was followed by T4 (83.33%), T8 (83.33), T3 (80%). However, the mean germination percentage in T2 was significantly greater than that in other treatments (Figure 1). All these four treatments resulted into significantly higher percentage of seed germination compared to what the control (T0) did (60%). Thus, it can be concluded that, the germination percentage was significantly enhanced by the treatments used in the experiment. Iqbal et al [18] found significant positive effect of different types of municipal and residential sludge on seed germination and growth of *Leucaena leucocephala* seedlings in the nursery. According to Hossain et al [16], industrial and residential sludge showed increased rate of seed germination and growth of *Acacia auriculiformis* seedlings. Another study conducted by Offor et al [34] determined the effects of water hyacinth mulch as bio-stimulant in a crude oil polluted soil using okra as a test crop. They observed that Okra plants grown in the crude oil polluted soil amended with water hyacinth mulch significantly enhanced okra seed germination at 4, 8 and 12 days after planting compared to the control. Iqbal et al [18] found significant effect of different types of municipal and residential sludge on seed germination and growth of *Leucaena leucocephala* seedlings in the nursery.



**Figure 1.** Germination percentages of seedlings of *Albizia saman* in different treatments.

### 3.2. Collar Diameter Development

Out of the ten treatments of the experiment, the highest collar diameter of the seedlings was given by the treatment T2 (7.87 mm). It was followed by T1 (7.47 mm), T5 (7.23 mm), T4 (7.16 mm), and T9 (7.11 mm). Collar diameter growth as shown in the treatment T2 differed significantly from that shown in T4 and T5. The difference between the performance of T2 and T1 was not significant. However, all the treatments ensured significantly higher collar diameter growth compared to that showed in the control (Figure 2). Since collar diameter is a quality parameter for seedlings [5, 19, 50], any of these four treatments ensured the production of good quality seedlings of *Albizia saman*. Our finding was in line with the finding of Sanni and Adesina [42]. They reported that water hyacinth manure had significantly increased the stem girth of *Celosia argentea* three weeks after manure application. Osoro et al [36] have also opined that plants grown in soil amended with water hyacinth compost had a higher and significantly different root collar diameter of 9.23 mm compared to that in the control on the 45<sup>th</sup> day after emergence.

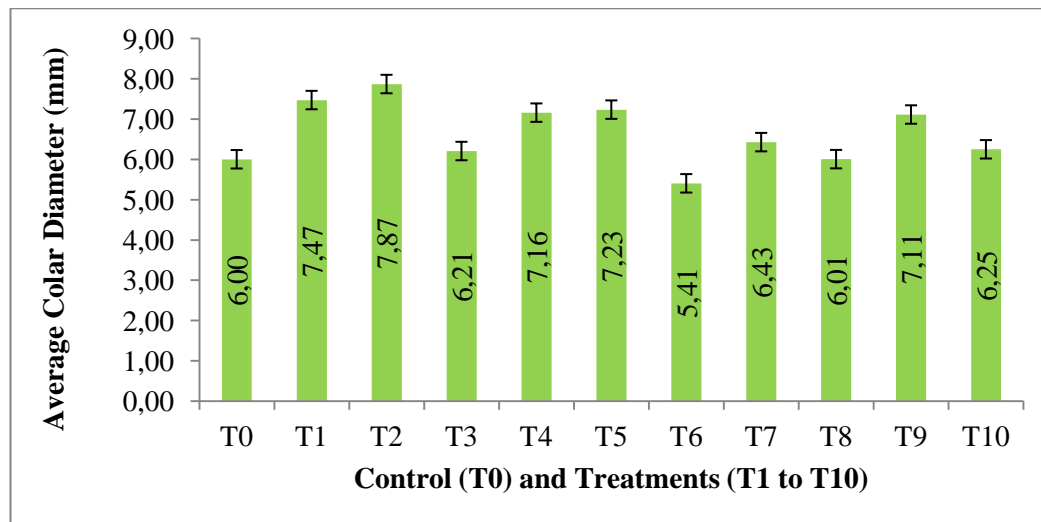
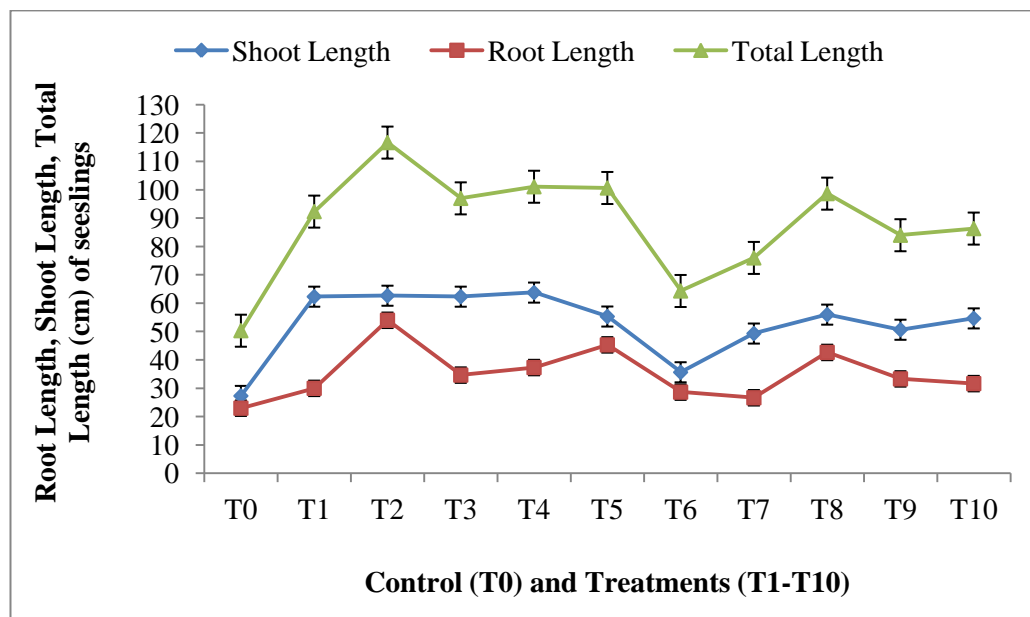


Figure 2. Average collar diameters of four months old *Albizia saman* seedlings in different treatments.

### 3.3. Root-Shoot Growth

Figure 3 shows how the lengths of the shoot and root of *Albizia saman* seedlings responded to different treatments. Length of shoot of four month old seedlings was the largest in T4 (63.77 cm) which was significantly higher than that in T0 (27.33 cm). The shoot length in T4 was closely followed by that in T2 (62.67 cm), T3 (62.33 cm) and T1 (62.33 cm). Even though all these treatments showed better results compared to T0, the difference among these was not significant (Figure 3). In contrast to this, the impact of the treatment T2 on root growth was unique. The longest root was resulted in treatment T2 (54 cm) which was significantly different from the root lengths resulted in T5 (45.33 cm), T8 (42.67 cm), and T4 (37.33 cm) (Figure 3). These two combined, the total length of the seedlings was

the largest also in the treatment T2 (116.67 cm), which was saintly different from the total seedling length showed in treatments T4 (101.10 cm), T5 (100.66 cm) and T8 (98.67) (Figure 3). In a similar study Mamun [29] identified the highest root length (21.20 cm) of two months old seedlings of *Albizia saman* grown on the media using municipal sewage sludge. Iqbal et al [18] have also reported that the six month old seedlings of *Leucaena leucocephala* showed maximum root growth (43.89 cm) in 50% residential soil and 50% normal soil.

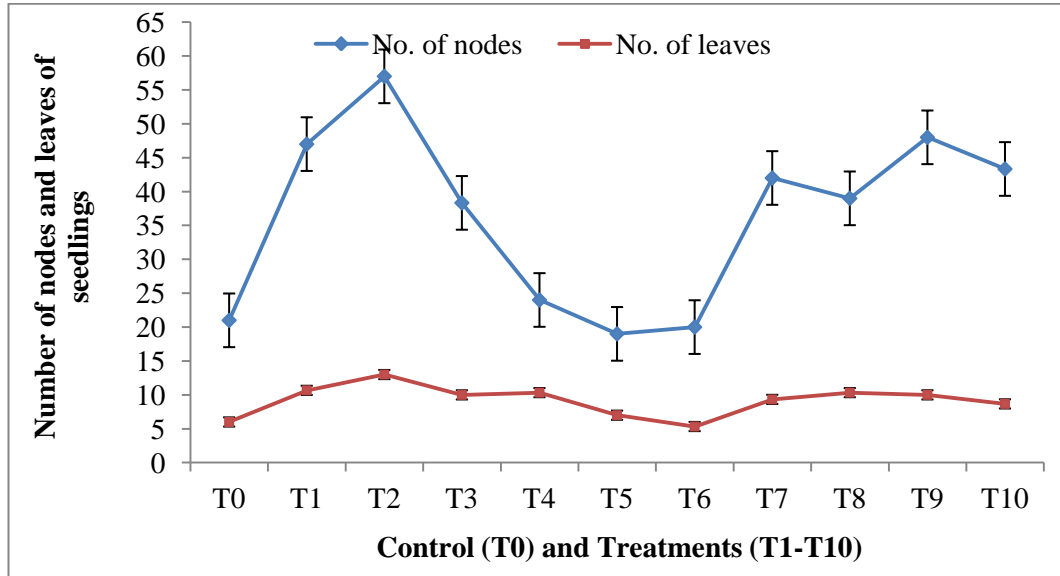


**Figure 3.** Effects of different treatments on the growth of root and shoot of *Albizia saman* seedlings.

### 3.4. Leaf Development

Figure 4 clearly portrays that the effect of treatment T2 on the number of nodes development was unique. Average number of nodes developed in T2 was the highest (57), which was significantly greater than that in all other treatments. However, the number of nodes in T2 was followed by that in T9 (48), T1 (47), and T7 (42). All these treatments showed significant improvements on node development compared to what T0 showed (21). One exceptional result was showed by the treatments T5 and T6. Average number of node development has reduced in these treatments from the control level. Figure 4 also focused on how the number of leaves responded to the variations in treatments. Again, T2 has shown the best and unique performance among all the treatments when number of leaves in the seedlings was considered. The highest number of leaves was reported in treatment T2 (13). It was followed by T1, T4, T8 with 11, 10, and 10 leaves, respectively. Here again, except treatment T6, all the treatments showed significant improvement in the leaf development. The results of our study was in agreement with the studies of Sanni and Adesina [42] and Iqbal et al [18]. They

opined that *Leucaena leucocephala* showed its best performance (12.8 leaves per seedling) in producing leaves while soil and sludge are used at a ratio of 1:1 as growth medium.



**Figure 4.** Effects of different treatments on the Number of nodes and leaves of seedlings of *Albizia saman* seedlings.

### 3.5. Comparison of Biomass

Table 2 describes how the total fresh weight and dry weight (biomass) differed in different treatments in the experiment. Total average fresh weight of the four month old whole seedling (root weight plus shoot weight) was the highest in treatment T2 (68.66 gm). It was followed by the weight in treatments T1 (58.93 gm), T9 (48.56 gm), and T3 (45.23 gm). None of the treatments differed significantly from one another. Thus, a unique treatment could not be identified to be the best for fresh biomass growth. Total dry weight was the highest also in treatment T2 (28.47 gm). However, the dry biomass in treatment T2 also did not differ from that in T1 (25.95 gm), T8 (22.43 gm), and T4 (21.86 gm) (Table 2). Root-Shoot Ratio (RSR) of the dry biomass was the highest in treatment T9 (0.67). It was closely followed by the RSR in T10. However, these two did not differ significantly. These were followed by the RSR in T8 (0.52) and T2 (0.52) (Table 2). However, a unique treatment also was unavailable to be the best. A similar study [37] reported better shoot and root growth by dry biomass of *Pistacia lentiscus* for the growing media based on the composted sewage sludge.

### 3.6. Identification of the Best Treatment

Table 3 summarizes the overall impacts of all the treatments on the growth and development of *Albizia saman* seedlings. Based on the weights given on treatments in the experiment, three treatments (T2, T4, T1) were found to help produce better quality seedlings compared to the control (T0). However, the effects of the treatments T3, T5, T8, T9, and T10 did not significantly differ from



that of the control. Of the better three, the highest weight was gained by treatment T2 (5.00). It was followed, although distantly, by T1 (0.75) and T4 (0.75).

**Table 2.** Effects of sludge and water hyacinth on fresh and dry weights of shoot and root of *Albizia saman*.

Treatments	Fresh Weight (gm)			Dry Weight (gm)			RSR <sub>DW</sub>
	Shoot	Root	Total	Shoot	Root	Total	
T0	7.04c	4.90b	11.94bc	3.93c	2.10b	6.03bc	0.53b
T1	39.5ab	19.43ab	58.93ab	18.17ab	7.77ab	25.94ab	0.42d
T2	46.36a	22.60a	68.66a	18.67a	9.80a	28.47a	0.52bc
T3	29.7abc	15.53ab	45.23abc	14.17abc	7.20ab	21.37abc	0.51c
T4	35.6ab	16.50ab	52.1ab	14.93abc	6.93ab	21.86abc	0.46cd
T5	22.27abc	13.27ab	35.54abc	11.27abc	5.73ab	17.00abc	0.51c
T6	12.23bc	6.50ab	18.73abc	6.57bc	2.63b	9.20bc	0.40d
T7	21.13abc	12.50ab	33.63abc	9.17abc	4.30ab	13.47abc	0.47cd
T8	32.64ab	18.93ab	51.57ab	14.80abc	7.63ab	22.43abc	0.52bc
T9	27.83abc	20.73ab	48.56abc	12.67abc	8.47ab	21.14abc	0.67a
T10	27.33abc	17.67ab	45.00abc	11.97abc	7.50ab	19.47abc	0.62a

Notes. Numbers followed by the same letter(s) in the same column do not vary significantly at  $P < 0.05$ , according to Duncan's Multiple Range Test (DMRT), RSR<sub>DW</sub> = Root-Shoot Ratio for dry weights (gm/gm).

**Table 3.** Comparative performance of different treatments in the growth of *Albizia saman* seedlings.

Seedling Attributes	Treatment selection		Score of the selected treatments										
	Order <sup>a</sup>	Uni-que <sup>b</sup>	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Germination (%)	T2>T4≥ T8≥T3	T2	..	..	1.00	0.00	0.00	..	..	..	0.00	..	..
Collar diameter	T2≥T1 ≥T5≥T4	None	..	0.25	0.25	..	0.25	0.25	..	..	..	..	..
Shoot length	T4≥T2≥ T3≥T1	None	..	0.25	0.25	0.25	0.25	..	..	..	..	..	..
Root length	T2>T5≥ T8≥T4	T2	..	..	1.00	..	0.00	0.00	..	..	0.00	..	..
No. of nodes	T2>T9≥ T1≥T7	T2	..	0.00	1.00	..	..	..	..	0.00	..	0.00	..
No. of leaves	T2>T1≥ T4≥T8	T2	..	0.00	1.00	..	0.00	..	..	..	0.00	..	..
Total Biomass	T2≥T1≥ T8≥T4	None	..	0.25	0.25	..	0.25	..	..	..	0.25	..	..
RSR <sub>DW</sub>	T9≥T10 ≥T0≥T2	None	0.25	..	0.25	..	..	..	..	..	..	0.25	0.25
Combined	..	..	0.25	0.75	5.00	0.25	0.75	0.25	0.00	0.00	0.25	0.25	0.25

<sup>a</sup>Based on comparison of means at  $P = 0.05$ ; <sup>b</sup>If a certain treatment is significantly the best among the four at  $P = 0.05$ ; > means preferred to; ≥ means at least as good as; RSR<sub>DW</sub> = Root-Shoot Ratio for dry weights (gm/gm)

So, we conclude that T2 came out to be the single most treatment that ensured the production of best seedlings of *Albizia saman*. Lata & Veenapani [24] carried out an experiment to find out the response of water hyacinth manure on growth attributes and yield of *Brassica juncea*. The study concluded that the growth of *Brassica juncea* was more pronounced with 50% water hyacinth manure and productivity with 100% water hyacinth manure treatment. According to Vidya and Girish [53], water hyacinth compost has positive response on wheat production. Chukwuka and Omotaya [7] found that *Tithonia* and water hyacinth combination significantly increase in status of micronutrients elements (Ca, K, Na and P) in nutrient depleted soil. Results indicated that different combination of Municipal solid waste and water hyacinth compost treatments stimulated sesame growth [2]. However, we could not verify with any study the overall growth of forest tree seedlings including *Albizia saman* under water hyacinth compost or sewage sludge or a combination thereof. Thus, our study has produced new information on the growth media for forest tree seedlings.

#### 4. Conclusion

Considering the cost effectiveness and environment friendliness, farmers are moving towards replacing inorganic fertilizers with organic manures for growing agricultural crops. Organic fertilizer is being produced from plant and animal biomass, municipal waste, and domestic solid waste. In tropical countries, water hyacinth is considered a threat to aquatic biodiversity since the weed is incredibly reproductive and highly invasive to aquatic ecosystems. Similarly, in developing countries, the treatment and disposal of municipal sewage sludge are environmentally risky and increasingly cost-intensive. Given its richness in macro- and micro-nutrients for plant growth, using it as organic manure in agricultural crop production is considered as an elegant solution to the problems.

The present study has highlighted the use of municipal sewage sludge and water hyacinth as a media for seed germination and seedling growth of *Albizia saman*. The best result was given by the 1:1 mixture of hyacinth to sewage sludge. The other combinations we found supporting healthy growth of *Albizia saman* were 1:1 of soil to sewage and 100% sludge only. Thus, we recommend that, a 50%-50% mixture of water hyacinth and sewage sludge can be used as the best medium for germination and subsequent growth of the *Albizia saman* seedlings. We also recommend producing other forest tree seedlings under similar mixture of these media. Similar findings will help concrete the idea of commercial production of bio-fertilizers from water hyacinth and sewage sludge.

The safe disposal of hazardous waste has been a challenge for both industry and the governments. Application of sewage sludge as a potential media to boost up production for agricultural crops and forest tree seedlings can be a strategy to face this increasing challenge. On the other hand, water hyacinth is a common hazard almost every rural water hole in Bangladesh, which can be turned into organic manure. This can be used as an alternative to inorganic fertilizers in the days of fertilizer scarcity. This weed is fast-growing and can be a rich source of nutrient to many plants. Our findings proved that these unconventional as well as

hazardous waste or weeds can be converted to important nutrient source in the nursery for growth of healthy forest tree seedlings. Thus, producing bio-fertilizers from water hyacinth and sewage sludge is cost saving for nursery owners and an excellent way to reduce environmental hazards.

Water hyacinth is a fast-growing invasive weed in Bangladesh. This study has made it evident that this weed can be converted into an important organic fertilizer as an admixture with municipal sewage sludge. Government and nongovernment organizations or private entrepreneurs can come forward to train farmers on how to commercially produce green manure from water hyacinth and sewage sludge at a low cost. However, large scale commercial production of forest tree seedlings should be preceded by similar further trials to find out the response of other forest tree seedling growth to water hyacinth and municipal sewage sludge manure applications. This will widen the scope of the use of water hyacinth and municipal sewage sludge as a potential source of plant nutrients.

### **Conflict of Interest**

The authors declare that there is no conflict of interest regarding the publication of this paper.

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