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Effects of Faecal Sludge and Food Waste Composts on Seed Germination and Initial Growth Performance of *Acacia auriculiformis* (A. Cunn. *ex* Benth.) and *Swietenia mahagoni* (L.) Jacq.

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Abstract

The study was conducted to observe the effects of compost of faecal sludge (FSC) and food waste (FWC) on seed germination and initial growth performance of *Acacia auriculiformis* and *Swietenia mahagoni* seedlings at the nursery of Chittagong University, Bangladesh. Before sowing the seeds, different combinations of FSC and FWC were incorporated with nutrient-deficient natural forest soils. Seed germination and growth parameters of seedlings were recorded after two, three and four month of seed sowing. We observed that seed germination (%) and seedlings growth parameters varied significantly ($p<0.05$) in the soil added with FSC and FWC in comparison to control. The highest germination was observed 88.89% for *A. auriculiformis* in combination of soil and FSC at 3:1 and 92.59% for S. mahagoni where soil combined with FWC at 4:1. The seedling biomass and other growth parameters of *A. auriculiformis* and *S. mahagoni* was also observed with combinations of soil with FSC 3:1 and soil with FWC 4:1. Therefore, the study revealed that the compost of both FS and FW can be a good soil conditioner for the initial growth of forest seedlings and the proven combinations can help to grow quality seedlings in the nursery.

Key Words: *Acacia auriculiformis*, *Swietenia mahagoni*, faecal sludge, food waste compost, germination, growth parameters

Introduction

Faecal sludge (FS) is defined as raw or partially digested, a slurry or semisolid and resulting from the collection, storage or treatment of combinations of excreta and black water, with or without grey water (Moya Diaz-Aguado et al. 2017). FS, mainly managed by onsite sanitation technologies (Carins-Smith et al. 2014) that is collected from septic tanks poses management challenges in urban areas of low income countries. In worldwide, FS treatment end products are used as solid fuels, biogas, soil conditioner, protein, fertilizer and compost (Diener et al. 2014; Gold et al. 2014). Moreover, Gold et al. (2017) reported that dried FS can be used as an act as a solid industrial fuel in industries by providing revenues to sustain FS treatment. In Bangladesh, Water Aid has taken initiative to compost FS

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collected from septic tank in different parts of the country and finally, they are selling the compost to the farmers. In particular, human excreta as an alternative fertilizer, has a higher N content source shows great potential (Andersson et al. 2016a). Processed FS is being reused at various scales in different countries around the world (Persson et al. 2015; Andersson et al. 2016b). As a fertilizer its value is about USD 10 per bag (50 kg), but its application represents an increase in agricultural yield of approximately USD 50, compared to not adding any fertilizer at all (Dagerskog et al. 2014).

On the other side, food waste (FW) is a current worldwide issue and it became a major problem to human if it is not managed properly. Agriculture, household, commercial, institutional, industrial have all contributes to the food waste production. Based on the study by Sujauddin et al. (2008), in Bangladesh, the food waste generation rate is more than 70% from SWM (Solid waste management). Every year, food waste shows an increasing volume. Composting the food waste is able to reduce the waste being disposed in landfill and also help the food industries in managing their wastes. Food waste compost (FWC) contains water-soluble nutrients and is an excellent, nutrient-rich organic fertilizer and soil conditioner. It is used in farming and small scale sustainable, organic farming. FWC can also be tilled directly into the soil or growing medium to boost the level of organic matter and the overall fertility of the soil (EPA 2017).

Currently, in low income countries, FS is dumped into the urban and peri-urban environment, posing great risks to the soil, surface water and groundwater quality (Islam and Hasan 2017; Singha et al. 2017). Similarly, a large proportion of municipal waste is not disposed properly posing a potential environmental threat due to the presence of pathogens and toxic pollutants (Darby et al. 2006; de Araújo et al. 2010; Rohini et al. 2017). Compositing plays an important role in building a resilient farming system, by providing both the energy sources and the nutrients to sustain soil biodiversity (van der Wurff et al. 2016). Compost itself has many beneficial ingredients that are crucial for organism like plants. Instead of reducing the investment to buy synthetic or chemical fertilizer from the outsiders the usage of composts can reduce the anxiousness of people regarding the issues of environmental problems as well as their health (Keener 2010; Hamid et al. 2016).

Iqbal et al. (2007) mentioned that forested sites are increasingly receiving attention as potential sites for the disposal and biological recycling of both wastewater and sludges. Moreover, as forests are not food chain crops, many of the public health concerns and land application regulations should not be as critical as those associated with agricultural sites (Cole et al. 1983). Though much research has been done on the use of sewage sludge as crop fertilizers (Selivanovskaya and Latypova 2006; Iqbal et al. 2007), there is little study on application of FS and FW composts in case of forest seedlings especially in soil conditions of Bangladesh. Thus, the study is an attempt to observe the effects of FSC and FWC in the forest soil on field germination and growth of forest seedlings at nursery level. For the present study, two forest species have been selected namely *Acacia auriculiformis* (Akashmoni) and *Swietenia mahagoni* (Mahagony). *A. auriculiformis* is a fast growing multipurpose tree species and considered as one of the most promising plantation species because of its ability to survive on wide range of degraded environmental condition (Das and Alam 2001; Jahan et al. 2008; Rahman and Hossain 2019), whereas *S. mahagoni* (Mahagony) is a deciduous,

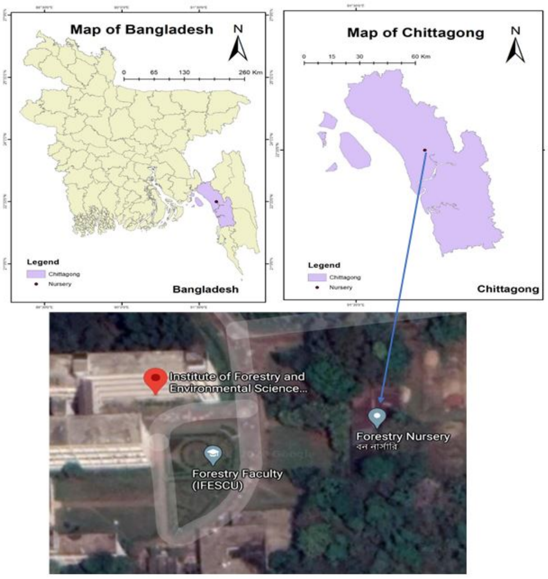

Fig. 1. Map shows the location of the nursery of Institute of Forestry and Environmental Sciences, University of Chittagong (IFESCU) in Bangladesh where the experiment was conducted (Google Maps 2020).

moderate to full light demander species, and peoples of Bangladesh use bare-rooted seedlings in homestead and block plantations because it is highly suitable for large scale timber production (Hossain 2015).

Materials and Methods

Site selection and seed collection

The experiment was carried out in the nursery of the Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh. The University of Chittagong is situated in the South-eastern part of Bangladesh, which lies approximately at the intersection of 90°50' east latitude and 22°30' north longitudes (Gafur et al. 1979) (Fig. 1). The nursery site distinguishes a tropical monsoon climate characterized by hot, humid summer and cool, dry winter. The average annual rainfall of this area is about 2,500-3,000 mm which mostly takes place between June and September. The climate is tropical monsoon with a mean monthly maximum temperature of 29.75°C and a monthly minimum of 21.24°C. The hottest month of 2018 was May with an average daily high temperature of 33°C. Degraded soils were collected from hilly sites of Chittagong University Campus (CUC), Chittagong and were sun dried as well as sieved (<3 mm) to obtain a uniform soil size. The brown hilly soils are sandy loam to sandy clay loam, moderately to strongly acid and poorly fertile with pH<5.5, organic matter<2%, CEC<10 me/100 g and BSP<40% (Osman et al. 2001).

For both species, healthy and diseases free seeds were collected from the same mother tree grown in Chittagong University Campus (CUC) where the mother tree of *A. auriculiformis* is located near the bank of a round pond locally called Goal Pukur Par and *S. mahagoni* is located close to CU main gate. Seeds were extracted manually after sun-drying for several days (24-48 hours) until the seed covering became brown/black (Hegde et al. 2013). After that the seeds were treated by soaking over night in the cold water (Islam et al. 2019).

Experimental design

FSC was collected from Bangladesh Association for Social Advancement (BASA) Shakhipur Pourashava, Tangail and FWC were collected from Unilever Bangladesh Limited, Kalurghat Factory, Chittagong, Bangladesh. The dried FSC and FWC were also sieved (<3 mm) to make free from root splinters and other foreign materials. Then the soil and compost were mixed thoroughly at different ratios. Polybags with 15 cm×10 cm (6" ×4") were used for the experiment. A Completely Randomized Design (CRD) was adopted for a total of seven treatments (Table 1) including control and three replications for each treatment with nine polybags for each replication (e.g. 27 polybags for each treatment and a total of 189 polybags for the whole experiment) for both the species.

Two seeds were sown in each polybag to observe the effects of FSC and FWC on field germination (e. g. a total 54 seeds per treatment and 378 seeds for whole experiment for field germination test) for both the species and after completion of field germination only one seedling (best one) per polybag was maintained to observe the initial growth parameters of seedlings. Partial shade and covering were provided over the nursery to protect the seedlings from strong sunlight and rain. Proper care and maintenance were done from the starting time of sowing seed up to harvesting of seedlings. Watering, removal of weeds, grasses etc. were done regularly.

Assessment of physiological growth parameters

Field germination was recorded daily from the date of seed sown, continuing up to the last field germination of the seed sowing. After two months, three seedlings from each treatment were randomly harvested and carefully collected with entire roots intact. Then growth parameters of seedlings (shoot height, root length, collar diameter, fresh and dry shoot and root weight) were assessed. Collar diameter was measured by using slide calipers. After taking the data

Table 1. The treatments used in the experiment

Group	Treatment
T_0	Control (only 500 g soil)
T_1	333 g soil+167 g FSC (2:1)
T_2	375 g soil+12 5g FSC (3:1)
T_3	400 g soil+10 0 g FSC (4:1)
T_4	333 g soil+167 g FWC (2:1)
T_5	375 g soil+125 g FWC (3:1)
T_6	400 g soil+100 g FWC (4:1)

of the above parameters back, the seedlings were oven dried at 70°C until the constant weight was obtained. Similar assessments were also performed for three and four month old seedlings. The soil and combinations were stored for further analysing the nutritional values. All the data were analyzed statistically by using the computer software package SPSS and were subjected to analysis by Duncan's Multiple Range Test (DMRT). Total dry biomass increment (%) was also calculated by using the following formulae (Iqbal et al. 2007):

$$\text{Total dry biomass increment (\%)} = \frac{\text{Total dry weight of the treatment} - \text{Total dry weight of the control treatment}}{\text{Total dry weight of the control treatment}} \times 100$$

Results

Seed germination

The seed germination percentage and growth parameters of the seedlings significantly ($p < 0.05$) varied in different treatments. For *A. auriculiformis*, the highest germination percentage (88.89%) was observed in treatment T_2 and the lowest (62.96%) in T_0 (Fig. 2). Besides, for *S. mahagoni*, the highest germination percentage (92.59%) in treatment T_5 and the lowest (59.26%) was also in control T_0.

Morphological growth parameters of the seedlings

The effects of FSC and FWC on morphological growth parameters of the seedlings likes shoot height, root length, total length, and collar diameter of seedlings of different ages were shown in

A. auriculiformis seedlings, shoot height (14.43 cm) and

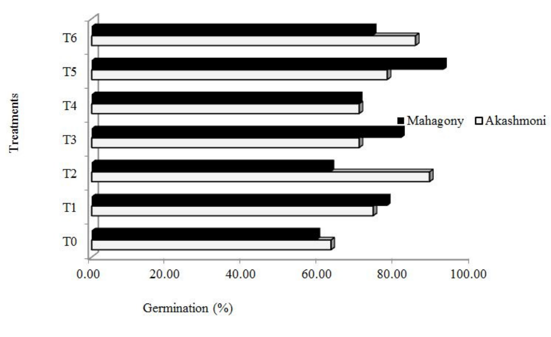

Fig. 2. Effect of FSC and FWC on germination of *A. auriculiformis* (Ahashmoni) and *S. mahagoni* (Mahagony) seeds.

root length (12.17 cm) were found highest in treatment T_2. Besides, the highest total length (26.60 cm) was observed in T_2 and varied significantly ($p < 0.05$). In addition, the highest collar diameter (3.6 mm) was also recorded in the same treatment (Table 2). In case of 3-month-old seedlings, the highest shoot growth (34.30 cm) was also recorded in T_2 and the lowest (23.03 cm) was observed in control, whereas the highest root length (22.30 cm) and collar diameter (4.40 mm) were found in treatment T_6. For 4-month old seedlings, the highest shoot height (48.24 cm), root length (32.30 cm) and total length (80.54 cm) were recorded in treatment T_2 and significantly ($p < 0.05$) varied with that of control. However, the highest collar diameter (6.20 mm) was recorded in T_6 and the lowest in control (Table 2).

Similarly, for 2-month-old *S. mahagoni* seedlings, shoot height (13.54 cm) and root length (12.97 cm) were the highest in treatment T_3. Besides, the highest total length (26.50 cm) was found in T_3, and in addition the highest collar diameter (4.30 mm) was also recorded in the same treatment. Though T_0 and T_2 did not vary significantly ($p < 0.05$) for shoot height and collar diameter, shoot height increased by 0.24 cm and collar diameter decreased by 0.20 cm from treatment T_0 to treatment T_1 (Table 2). In case of 3-month-old seedlings, the highest shoot growth (36.17 cm) was recorded in T_3 and the lowest (25.70 cm) occurred in T_0. Besides, the highest root length (28.63 cm) also found in T_3 followed by 27.44 cm in T_5 and lowest (15.13 cm) in control. In addition, the highest collar diameter (5.13 mm) was recorded in treatment T_5. For 4-month old *S. mahagoni* seedlings, the highest shoot height (51.10 cm), root length (33.90 cm) and total length (85.00 cm) were recorded in T_3 and varied significantly ($p < 0.05$). However, the highest collar diameter (6.53 mm) was also recorded in T_5 followed by control treatment T_0 (4.50 mm) (Table 2).

Fresh and dry matter production

Fresh and dry matter production, e.g. shoot and root fresh weight, total fresh weight, shoot and root dry weight, and total dry weight two species were shown in Table 3. In 2-month-old seedlings of *A. auriculiformis*, shoot fresh and dry weight were found highest (0.79 g and 0.42 g, respectively) as well as total dry weight (0.67 g) were found in T_2 and which was varied significantly ($p < 0.05$) from those

Table 2. Effects of FSC and FWC on shoot length, root length, and collar diameter of *A. auriculiformis* and *S. mahagoni* seedlings of different ages

Age of seedlings	Treatment	Length (cm)						Collar diameter (mm)	
		Shoot		Root		Total			
		AA[1]	SM[2]	AA	SM	AA	SM	AA	SM
2-month old seedlings	T_0	10.17^{c}*	10.63^{b}	8.73^{c}	9.83^{c}	18.90^{c}	20.56^{c}	2.03^{c}	3.3^{b}
	T_1	13.20^{b}	10.87^{b}	10.76^{b}	11.47^{b}	23.96^{b}	22.33^{bc}	2.7^{bc}	3.1^{b}
	T_2	14.43^{a}	11.03^{b}	12.17^{a}	11.74^{b}	26.60^{a}	22.36^{bc}	3.6^{a}	3.4^{b}
	T_3	13.83^{ab}	13.54^{a}	10.83^{b}	12.97^{a}	24.67^{b}	26.50^{a}	3.1^{ab}	4.40^{a}
	T_4	13.46^{b}	11.27^{ab}	11.33^{ab}	12.16^{ab}	24.80^{b}	23.43^{b}	2.93^{ab}	3.60^{ab}
	T_5	13.60^{ab}	13.50^{a}	10.86^{b}	12.77^{a}	24.47^{b}	26.27^{a}	2.90^{ab}	4.10^{ab}
	T_6	13.87^{ab}	11.6^{ab}	11.50^{ab}	12.16^{ab}	25.37^{ab}	23.10^{b}	3.50^{ab}	3.37^{b}
3-month old seedlings	T_0	23.03^{d}	25.70^{d}	16.06^{d}	15.13^{c}	39.10^{d}	40.43^{e}	2.53^{c}	3.47^{c}
	T_1	30.33^{c}	28.10^{c}	19.80^{bc}	26.47^{ab}	50.13^{c}	54.57^{d}	3.43^{b}	4.5^{ab}
	T_2	34.30^{a}	35.33^{ab}	20.90^{b}	26.64^{ab}	55.20^{a}	61.96^{b}	3.80^{ab}	4.46^{ab}
	T_3	33.17^{ab}	36.17^{a}	19.17^{c}	28.63^{a}	52.34^{b}	64.80^{a}	3.87^{ab}	4.74^{a}
	T_4	30.14^{c}	29.30^{c}	18.83^{c}	25.50^{b}	48.97^{c}	54.80^{d}	3.63^{b}	3.77^{bc}
	T_5	32.70^{b}	35.03^{ab}	21.10^{ab}	27.44^{ab}	53.80^{ab}	62.47^{b}	3.70^{b}	5.13^{a}
	T_6	33.34^{ab}	34.37^{b}	22.30^{a}	25.53^{b}	55.64^{a}	59.90^{c}	4.40^{a}	4.53^{ab}
4- month old seedlings	T_0	38.03^{d}	40.06^{c}	22.86^{d}	19.20^{c}	60.90^{e}	59.27^{e}	4.10^{d}	4.50^{b}
	T_1	45.34^{c}	46.67^{b}	27.30^{bc}	28.39^{b}	72.64^{d}	74.96^{d}	4.84^{cd}	5.16^{b}
	T_2	48.24^{a}	50.76^{a}	32.30^{a}	30.63^{ab}	80.54^{a}	81.40^{ab}	5.87^{ab}	5.50^{ab}
	T_3	46.43^{bc}	51.10^{a}	28.56^{b}	33.90^{a}	75.00^{c}	85.00^{a}	5.36^{abc}	5.63^{ab}
	T_4	45.63^{bc}	47.63^{ab}	26.80^{c}	28.46^{b}	72.43^{d}	76.10^{cd}	4.86^{cd}	4.90^{b}
	T_5	47.10^{ab}	48.43^{ab}	30.94^{a}	31.27^{ab}	78.03^{b}	79.70^{bc}	5.17^{bc}	6.53^{a}
	T_6	46.93^{abc}	48.60^{ab}	31.93^{a}	30.6^{ab}	78.86^{ab}	79.20^{bcd}	6.20^{a}	5.40^{ab}

*Followed by the same letter (s) in the same column do not very significantly at $p < 0.05$, according to Duncan's Multiple Range Test (DMRT). [1]AA, *A. auriculiformis*; [2]SM, *S. mahagoni*.

of control. Besides, the root fresh and dry weight were the highest (0.44 g and 0.25 g, respectively) in treatment T_2. Moreover, total fresh biomass was found to be the maximum in T_6 (1.25 g).

When 3-month old seedlings were considered, the highest shoot fresh (5.70 g) and dry weight (3.37 g) and the highest root fresh and dry weight (1.97 g and 1.26 g, respectively) as well as total dry weight (4.63 g) were found in T_2, which significantly differed from that of T_0. In case of 4-month-old seedlings, the highest shoot fresh and dry weight (13.70 g and 7.80 g, respectively) were recorded in T_2 and the lowest (9.60 g and 3.72 g, respectively) in T_0. Fresh and dry root weight was the maximum in T_2 (3.03 g and 1.84 g, respectively). But the lowest root fresh and dry weights were recorded in control T_0. However, total dry biomass increment (%) was highest in T_2 followed by T_6 and T_5 and was positive for all the treatments compared to T_0 treatment.

Similarly, for 2-month-old seedlings of *S. mahagoni*, shoot fresh and dry weight were the highest (0.92 g and 0.56 g, respectively) as well as total dry weight (0.93 g) were found in treatment T_3, and varied significantly ($p < 0.05$) from those of control. Besides root fresh weight and dry weight were the highest (0.66 g and 0.37 g, respectively) in treatment T_3. Moreover, total fresh and dry biomass was found to be the maximum in T_3 (1.58 g and 0.93 g, respectively) as well. When 3-month old seedlings were considered, the highest shoot fresh (6.30 g) and dry weight (3.27 g) and the highest root fresh and dry weight (2.40 g and 1.23 g, respectively) as well as total dry weight (4.50 g) were found in treatment T_3, which significantly different from that of T_0. In case of 4-month-old seedlings, the high-

Table 3. Effects of FSC and FWC on fresh and dry weights of shoot and root of *A. auriculiformis* and *S. mahagoni* seedlings of different ages

Age of seedlings	Treatment	Fresh weight (g)						Dry weight (g)						Total Dry Biomass increment (%)	
		Shoot		Root		Total		Shoot		Root		Total			
		AA[1]	SM[2]	AA	SM	AA	SM	AA	SM	AA	SM	AA	SM	AA	SM
2-month old seedlings	T$_0$	0.52^{d}*	0.65^{d}	0.15^{d}	0.37^{d}	0.67^{e}	1.02^{e}	0.23^{c}	0.38^{d}	0.09^{d}	0.23^{d}	0.32^{d}	0.61^{e}	0	0
	T$_1$	0.63^{c}	0.79^{bc}	0.25^{c}	0.48^{c}	0.88^{d}	1.27^{d}	0.30^{c}	0.46^{bc}	0.18^{bc}	0.27^{c}	0.48^{c}	0.73^{d}	+47.33	+21.53
	T$_2$	0.79^{a}	0.81^{bc}	0.44^{a}	0.61^{a}	1.23^{ab}	1.42^{bc}	0.42^{a}	0.47^{b}	0.25^{a}	0.33^{b}	0.67^{a}	0.80^{c}	+109.39	+33.07
	T$_3$	0.68^{bc}	0.92^{a}	0.40^{ab}	0.66^{a}	1.09^{bc}	1.58^{a}	0.33^{abc}	0.56^{a}	0.18^{bc}	0.37^{a}	0.51^{c}	0.93^{a}	+57.73	+53.9
	T$_4$	0.61^{c}	0.75^{c}	0.33^{b}	0.47^{c}	0.95^{cd}	1.24^{d}	0.32^{bc}	0.42^{cd}	0.16^{c}	0.28^{c}	0.48^{c}	0.70^{d}	+48.7	+15.9
	T$_5$	0.65^{bc}	0.85^{ab}	0.39^{ab}	0.61^{a}	1.04^{c}	1.47^{b}	0.33^{abc}	0.51^{ab}	0.21^{abc}	0.36^{ab}	0.54^{bc}	0.87^{b}	+69.9	+43.96
	T$_6$	0.72^{ab}	0.83^{bc}	0.45^{a}	0.54^{b}	1.25^{a}	1.37^{c}	0.41^{ab}	0.48^{b}	0.23^{ab}	0.33^{b}	0.64^{ab}	0.82^{bc}	+99.76	+35.7
3-month old seedlings	T$_0$	3.16^{d}	4.36^{d}	1.13^{c}	1.46^{d}	4.30^{d}	5.83^{e}	1.60^{c}	2.33^{c}	0.83^{b}	0.83^{c}	2.47^{d}	3.17^{c}	0	0
	T$_1$	4.30^{c}	5.56^{bc}	1.50^{abc}	1.77^{c}	5.80^{c}	7.33^{cd}	2.24^{bc}	2.50^{c}	0.91^{b}	0.93^{bc}	3.16^{cd}	3.43^{c}	+27.67	+8.6
	T$_2$	5.70^{a}	5.81^{b}	1.97^{a}	1.93^{bc}	7.67^{a}	7.75^{bc}	3.37^{a}	2.97^{ab}	1.26^{a}	1.09^{abc}	4.63^{a}	4.06^{ab}	+87.76	+28.14
	T$_3$	5.13^{ab}	6.30^{a}	1.70^{ab}	2.40^{a}	6.83^{ab}	8.70^{a}	2.83^{ab}	3.27^{a}	1.076^{ab}	1.23^{a}	3.90^{abc}	4.50^{a}	+57.9	+41.9
	T$_4$	4.16^{c}	5.50^{c}	1.27^{bc}	1.67^{cd}	5.43^{c}	7.17^{d}	2.56^{ab}	2.61^{bc}	0.86^{b}	0.94^{bc}	3.40^{bcd}	3.53^{bc}	+38	+11.5
	T$_5$	4.53^{bc}	6.13^{a}	1.73^{ab}	2.17^{ab}	6.27^{bc}	8.32^{a}	2.80^{ab}	3.03^{a}	1.03^{ab}	1.14^{ab}	3.83^{abc}	4.17^{a}	+53.86	+31.54
	T$_6$	5.27^{ab}	6.10^{a}	1.80^{a}	2.10^{b}	7.06^{ab}	8.20^{ab}	3.13^{a}	2.93^{ab}	1.07^{ab}	1.11^{abc}	4.26^{ab}	4.05^{ab}	+72.74	+28.16
4- month old seedlings	T$_0$	9.60^{c}	10.13^{d}	1.83^{c}	1.78^{c}	11.43^{d}	11.91^{d}	3.72^{d}	6.03^{c}	0.81^{d}	0.99^{b}	4.53^{d}	7.03^{e}	0	0
	T$_1$	10.02^{c}	12.86^{c}	2.26^{bc}	1.97^{bc}	12.47^{c}	14.83^{c}	4.14^{d}	7.23^{b}	1.33^{bc}	1.26^{ab}	5.47^{c}	8.49^{cd}	+22.28	+20.9
	T$_2$	13.70^{a}	14.16^{b}	3.03^{a}	2.26^{ab}	16.73^{a}	16.43^{b}	7.80^{a}	7.50^{b}	1.84^{a}	1.33^{a}	9.64^{a}	8.83^{bc}	+113.73	+25.74
	T$_3$	12.26^{b}	15.60^{a}	2.56^{ab}	2.70^{a}	14.83^{b}	18.30^{a}	6.23^{c}	8.30^{a}	1.62^{ab}	1.50^{a}	7.85^{b}	9.80^{a}	+75.1	+39.37
	T$_4$	10.03^{c}	12.90^{c}	1.97^{c}	1.89^{bc}	12.00^{cd}	14.79^{c}	4.42^{d}	7.03^{b}	1.10^{cd}	1.03^{b}	5.52^{c}	8.07^{d}	+23.48	+14.84
	T$_5$	12.60^{b}	14.80^{ab}	2.60^{ab}	2.33^{ab}	15.20^{ab}	17.13^{ab}	6.61^{bc}	8.00^{a}	1.37^{bc}	1.40^{a}	7.98^{b}	9.40^{ab}	+78.4	+33.88
	T$_6$	13.03^{ab}	14.27^{b}	2.93^{a}	2.10^{bc}	15.96^{a}	16.37^{b}	7.27^{ab}	8.04^{a}	1.73^{a}	1.37^{a}	9.00^{a}	9.41^{ab}	+100.2	+33.86

*Followed by the same letter (s) in the same^{c}olumn do not very significantly at $p < 0.05$, according to Duncan's Multiple Range Test (DMRT). + value in the parentheses indicate the increased value from control treatment. [1]AA, *A. auriculiformis*; [2]SM, *S. mahagoni*.

est shoot fresh and dry weight (15.60 g and 8.30 g, respectively) were recorded in T_3 and the lowest (10.13 g and 6.03 g, respectively) in T_0. Fresh and dry root weight was the maximum in T_3 (2.70 g and 1.50 g, respectively) whereas the lowest root fresh and dry weights were recorded in control T_0. However, total dry biomass increment (%) was highest in T_3 followed by T_5 and T_6 and was positive for all the treatments compared to T_0.

Discussion

The seedlings raised using treatments will ensure better growth performance when planted in large scale (Islam et al. 2019). Dutta and Hossain (2017) revealed the effects of mixed plantation on initial growth and biomass yield of *Acacia auriculiformis* and *Gmelina arborea* in Bangladesh. However, the present study indicates that the germination percentage, growth parameters of *A. auriculiformis* and *S. mahagoni* seedlings at different combinations of FSC and FWC with soil varied significantly ($p < 0.05$) compared to control. The growth performances were stimulated by the application of such organic fertilizers. It was observed that the highest growth of *A. auriculiformis* and *S. mahagoni* seedlings were found in combination of soil and faecal sludge (3:1 and 4:1, respectively). There are several studies found related to soil enriched with sludge for the germination and growth of the forest seedlings but less studies have found related to FSC and FWC amended soil.

Hossain et al. (2009) and Jobra and Anders (2000) explained that sludge could serve as a good organic fertilizer to maximize plant germination. Selivanovskaya and latypova (2006) mentioned that sludge amendments enhanced the germination and decreased the mortality of the seedlings. The present study was also coincided with the studies from Labrecque et al. (1995) who reports that fast growing species can benefit from sludge amended soil. Iqbal et al. (2007) noticed that residential (soil+residential sludge=1:1) sludge may be used for obtaining maximum and optimum seedling growth of *Leucaena leucocephala*.

Selivanovskaya and Latypova (2006) found that the beneficial effects on the height of the shoots as well as on the length of the roots of pine seedlings were greater in plots with the highest rates of composted sludge, however, in the present study it was found that the root length was the highest in FSC amended soil (3:1) for *A. auriculiformis* and (4:1) for *S. mahagoni*. Moreover, the influence of sludge amended soil on plant growth is positive which is comparable to findings recorded by others (Labrecque et al. 1995; Jobra and Anders 2000; Selivanovskaya and Latypova 2006; Iqbal et al. 2007; Hossain et al. 2009; Hossain et al. 2013). On the other hand, Hossain et al. (2013) observed that soil and industrial sludge (3:1) can be used as fertilizer in nursery for the growth of *S. mahagoni* seedlings.

Conclusions

Improper management of faecal sludge and food waste exist in low income countries like Bangladesh, and thereby these are discharged or dumped untreated into the environment creating public health and environmental problems. The compost of FS and FW can be good soil conditioner but their application in the practical field is limited. These can provide a potential source of nutrients to the seedlings as well as such use can satisfy the needs for environmentally safe disposal. The present study demonstrated that the compost of both FS and FW can be a good soil conditioner for the initial growth of forest seedlings like, *A. auriculiformis* and *S. mahagoni* in the nursery. But it is necessary to assess the suitable proportions of faecal sludge and food waste compost with degraded soil in order to prevent over and under fertilization. Thus, the present study recommends the followings:

- for optimal growth of the seedlings of *A. auriculiformis*, the prescribed mixing ratio of soil and faecal sludge is 3:1 and soil and food waste 4:1 and
- for *S. mahagoni*, the mixing ratio of soil and faecal sludge is 4:1 and soil and food waste 3:1.

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Competing interests

The authors do not have any competing interests.

References

Andersson K, Dickin S, Rosemarin A. 2016b. Towards "Sustainable" Sanitation: Challenges and Opportunities in Urban Areas. Sustainability 8: 1289.

Andersson K, Rosemarin A, Lamizana B, Kvarnström E, McConville J, Seidu R, Dickin S, Trimmer C. 2016a. Sanitation, Wastewater Management and Sustainability: from Waste Disposal to Resource Recovery. United Nations Environment Programme and Stockholm Environment Institute, Stockholm, pp 156.

Cairns-Smith S, Hill H, Nazarenko E. 2014. Working Paper. Urban Sanitation: Why a Portfolio of Solutions is Needed. Boston Consulting Group, Boston, MA, pp 30.

Dagerskog L, Morgan P, Still D, Ochiro B, Ekane N, Henry L, Harawa K. 2014. Food security in Sub-Saharan Africa-What could be the contribution of productive sanitation? In: Sanitation and hygiene in Africa- where do we stand? ; Analysis from the AfricaSan Conference, Kigali, Rwanda (Cross P, Coombes Y, eds). IWA Publishing, London, pp 67-76.

Darby HM, Stone AG, Dick RP. 2006. Compost and Manure Mediated Impacts on Soilborne Pathogens and Soil Quality. Soil Sci Soc Am J 70: 347-358.

Das KD, Alam MK. 2001. Trees of Bangladesh. Bangladesh Forest Research Institute, Chittagong, 342 pp.

de Araújo ASF, de Melo WJ, Singh RP. 2010. Municipal solid waste compost amendment in agricultural soil: changes in soil microbial biomass. Rev Environ Sci Biotechnol 9: 41-49.

Diener S, Semiyaga S, Niwagaba CB, Muspratt AM, Gning JB, Mbéguéré M, Ennin JE, Zurbrugg C, Strande L. 2014. A value proposition: Resource recovery from faecal sludge- Can it be the driver for improved sanitation? Resour Conserv Recycl 88: 32-38.

Dutta S, Hossain MK. 2017. Effects of Mixed Plantation on Growth and Biomass Yield of Two Common Plantation Trees of Bangladesh. J For Environ Sci 33: 22-32.

Environmental Protection Agency (EPA). 2017. Reduce, Reuse, Recycle- US EPA. https://www.epa.gov/recycle. Accessed 20 Dec 2019.

Gafur MA, Karim A, Khan MAA. 1979. Phytosociological Studies of Hills of the Chittagong University Campus. Chittagong Univ Stud Part II 3: 11-28.

Gold M, Ddiba DIW, Seck A, Sekigongo P, Diene A, Diaw S, Niang S, Niwagaba C, Strande L. 2017. Faecal sludge as a solid industrial fuel: a pilot-scale study. J Water Sanit Hyg Dev 7: 243-251.

Gold M, Niang S, Niwagaba CB, Eder G, Murray MA, Diop PS, Strande L. 2014. Results from FaME (Faecal Management Enterprises)- Can Dried Faecal Sludge Fuel the Sanitation Service Chain? In: 37th WEDC International Conference; Hanoi, Vietnam; Sep 15-19, 2014.

Hamid KBBA, Zainudin MHM, Samah MAA, Yunus K. 2016. Improving Composting Process by Controlling Aeration Time. Int J Appl Chem 12: 130-135.

Hegde M, Palanisamy K, Yi JS. 2013. *Acacia mangium* Willd.- A Fast Growing Tree for Tropical Plantation. J For Environ Sci 29: 1-14.

Hossain MK. 2015. Silviculture of Plantation Trees of Bangladesh. Arannayk Foundation, Dhaka, pp 361.

Hossain ML, Huda SMS, Hossain MK. 2009. Effects of industrial and residential sludge on seed germination and growth parameters of *Acacia auriculiformis* seedlings. J For Res 20: 331-336.

Hossain ML, Salam MA, Rubaiyat A, Hossain MK. 2013. Sewage Sludge as Fertilizer on Seed Germination and Seedling Growth: Safe or Harm. Int J Res Manag 3: 136-146.

Iqbal GMA, Huda SMS, Sujauddin M, Hossain MK. 2007. Effects of sludge on germination and initial growth performance of *Leucaena leucocephala* seedlings in the nursery. J For Res 18: 226-230.

Islam MA, Rahman MR, Hossain MK. 2019. Effect of container and potting media on raising quality seedlings of *Acacia auriculiformis* in the nursery. Asian J Agric 3: 26-32.

Islam MS, Hasan M. 2017. Effect of faecal sludge on cabbage production. Int J Agric Res Innov Technol 7: 43-45.

Jahan MS, Sabina R, Rubaiyat A. 2008. Alkaline Pulping and Bleaching of *Acacia auriculiformis* Grown in Bangladesh. Turk J Agric For 32: 339-347.

Jorba M, Andrés P. 2000. Effects of sewage sludge on the establishment of the herbaceous ground cover after soil restoration. J Soil Water Conserv 55: 322-327.

Keener HM. 2010. Challenges and Opportunities in Composting Organic Waste. In: Climate Change and Food Security in South Asia (Lal R, Sivakumar MVK, Faiz SMA, Mustafizur Rahman AHM, Islam KR, eds). Springer, Dordrecht, pp 295-324.

Labrecque M, Teodorescu TI, Daigle S. 1995. Effect of wastewater sludge on growth and heavy metal bioaccumulation of two Salix species. Plant Soil 171: 303-316.

Moya Diaz-Aguado B, Parker A, Sakrabani R. 2017. Maximising the Value of Fertilisers Derived from Source-Separated Human Waste in Antananarivo, Madagascar. In: FSM4 Conference;

Chennai, India; Feb 20-22, 2017. pp 93-94.
Osman KT, Rahman MM, Barua P. 2001. Effects of some forest tree species on soil properties in Chittagong University Campus, Bangladesh. Indian For 127: 431-442.
Persson T, Svensson M, Finnson A. 2015. REVAQ Certified Wastewater Treatment Plants in Sweden for Improved Quality of Recycled Digestate Nutrients. IEA Bioenergy Task 37, Stockholm, pp 4.
Rahman MR, Hossain MK. 2019. Optimal Economic Return and Rotation Period of Large Scale *Acacia auriculiformis* Plantations in Bangladesh. J Biosci Agric Res 20: 1709-1716.
Rohini P, Sarani S, Susmita S. 2017. Characteristics of Faecal Sludge Generated from Onsite Systems Located in Devanahalli. In: FSM4 Conference; Chennai, India; Feb 20-22, 2017. pp 89-90.
Selivanovskaya SY, Latypova VZ. 2006. Effects of composted sewage sludge on microbial biomass, activity and pine seedlings in nursery forest. Waste Manage 26: 1253-1258.
Singh S, Mohan RR, Rathi S, Raju NJ. 2017. Technology Options for Faecal Sludge Management in Developing Countries: Benefits and Revenue from Reuse. Environ Technol Innov 7: 203-218.
Sujauddin M, Huda SMS, Hoque ATMR. 2008. Household solid waste characteristics and management in Chittagong, Bangladesh. Waste Manage 28: 1688-1695.
van der Wurff AWG, Fuchs JG, Raviv M, Termorshuizen AJ. 2016. Handbook for Composting and Compost Use in Organic Horticulture. (Bio Greenhouse COST Action FA 1105 (www.biogreenhouse.org.)