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Nursery Growing Media Practice: Impact on Seed Germination and Initial Seedling Development of *Hymenodictyon orixensis* (Roxb.) Mabberley - A Vulnerable Native Tree Species

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Abstract

Hymenodictyon orixensis (Roxb.) Mabberley (locally known as Bhutum in Bangladesh) is both an ecologically and economically valuable multipurpose tree species for afforestation and reforestation programs in Bangladesh. Seed germination and seedling development study of *H. orixense* were conducted to find out the response to different growing medium, e.g., polybag (15×10 cm (T_0) and 20×15 cm (T_1)), sand medium in propagator house (T_2), conventional nursery bed (T_3), and root trainer (T_4) in the Nursery. Consequently, germination behavior and seedling morphological parameters of *H. orixense* were assessed. The results revealed that the sand medium of the propagator house (T_2) provided the highest germination % (58.57±22.30) and the highest germination energy (11.43±2.43) followed by seedlings growing in 20×15 cm polybags (T1) containing forest topsoil and cow-dung at a ratio of 3:1. Except for germination energy, germination values, and germination capacity, other seed biology parameters, particularly imbibition, germination period, germination rate, and plant survival percent in T_1, T_2, T_3, and T_4 were significantly ($p<0.05$) different from T_0. Each phenotypic parameter of seedlings and dry matter of shoot and root significantly differed from control except root length ($p<0.992$). Based on this study, Polybags of 20×15 cm size are regarded as the best medium for quality seedling development of *H. orixense*. The nursery bed (T_3) had the lowest germination performance and developed more inferior quality seedlings. Thereby, 20×15 cm size of polybags with conventional soil and cow-dung media is recommended for maximum germination and to grow the quality seedlings of *H. orixense* in the Nursery.

Key Words: seedling development, afforestation, multipurpose tree species, growing media, germination

Introduction

Bangladesh is a biologically rich sub-tropical country, which has reported 13% of native vascular plants are vulnerable and at risk of extinction due to anthropogenic pressures and habitat destruction (Siddiqui 2007; Ahmed 2008; Hossain et al. 2020). Besides, in the past decades, the country introduced more than 300 exotic species in agri-

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culture and afforestation programs for the demand of maximum production in faster outcomes (Hossain and Pasha 2001). Like other developing countries in Southeast and East Asia, the highest demand in afforestation and reforestation activities in Bangladesh is for fast-growing tree species, often exotics. Thus, the germination ecology and early seedling growth studies of native threatened tree species are widely overlooked compared with common plantation tree species. An additional challenge is a small-scale nursery in the developing countries of Southeast and East Asia has lacks resources in terms of finance, information, and good-quality seedlings development (Harrison et al. 2008).

The seed germination study indicates whether the seed is capable of embryo development, and the selection of seedlings growing media provides the desirable seedlings attributes under favorable conditions (Valladares and Sánchez-Gómez 2006). Besides, individual species have responses to specific growing media regarding seed germination and early seedling development attributes (Aghai et al. 2014).

Hymenodictyon orixense (Roxb.), locally called Buthum, is an important multipurpose tree species belonging to the Rubiaceae family. The native range of this deciduous tree to tropical Asia and extensively found in India, Bangladesh, China, Myanmar, Nepal, Thailand, Vietnam, Malaysia, Indonesia, Philippines, Laos (Govindarajan and Benelli 2016). A medium-sized tree can grow up to 25 meters tall; the green leaves of this plant are decussate, elliptic-ovate, and acute-attenuate at the base, 9-22×6-14 cm. The flowers are subsessile, greenish and the flowering occurs in May-July. The fruits are capsules, woody, brown in color, and 1.2-3×0.5-1.1 cm in size. The seeds are many in one capsule. The bark's color is grey and thick (Ghani 1998; Razafimandimbison and Bremer 2006).

The aqueous extract of *H. orixense* leaf is utilized to produce plant-born silver nanoparticles towards targeted mosquito vectors (Govindarajan and Benelli 2016). Moreover, the leaf of this tree is used for stains and the bark as a remedy for fever. The high-quality wood of *H. orixense* is consumed to make tea chests, various types of brush backs, pencil slats, toys, drums, and matches (Razafimandimbison and Bremer 2006). Different chemical components, including anthraquinones, lucidin, nordamnacanthal, damnacanthal, 2-benzylzanthopurpurin and anthragallol can be extracted from the roots of *H. orixens* (Paramita et al. 2017).

Even though the ecological, economic, and medicinal importance of the species is not introducing in the plantation activities due to the lack of knowledge on seed germination behavior and early seedling development techniques in the Nursery. It is necessary to aid in regenerating *H. orixense* in the nursery practice for conservation and economic production purposes. Seed germination studies on growing media and seedling growing techniques of exotic species are available, e.g., Indira et al. (2000), Alamgir and Hossain (2005), (Iqbal et al. 2007), Salim Awad et al. (2010), Azad et al. (2011b), Sarmin et al. (2014), Sood and Ram (2019), Islam et al. (2019) and other native rare tree species by Khan et al. (2011), Begum et al. (2018), Mariappan et al. (2014), Amoakoh et al. (2017) and Hasnat et al. (2019). But no record is found to study seed germination ecology in different growing media and early seedling growth performance of *H. orixense* in the Nursery. This study is the first report on germination behavior and best-growing media selection for the initial growth performance of *H. orixense* seedlings in the Nursery.

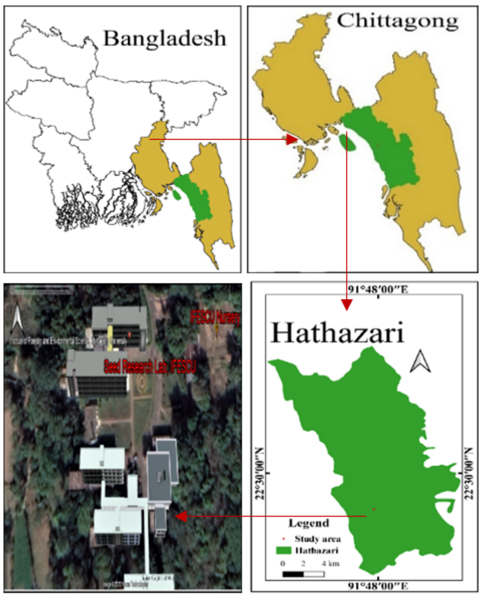

Fig. 1. Location map of "Seed Research Laboratory" and "Nursery" of Institute of Forestry and Environmental Sciences, University of Chittagong (Google Map 2020).

Materials and Methods

Study area, seed collection, and pre-sowing preparation of seed

The experiment has been conducted in the "Seed Research Laboratory" and "Nursery" of the Institute of Forestry and Environmental Sciences (22.4610°N, 91.7959°E), University of Chittagong (IFESCU), Bangladesh over the period from February to August in 2019 (Fig. 1). The average monthly temperature reaches 29.75°C, and the minimum temperature drops at 21.14°C in the study site. The mean yearly rainfall of 2,500-3,000 mm occurs mainly from June to September (Uddin et al. 2008). Ripen fruits of *H. orixensis* were collected from a few mother trees from Madhupur National park (24.7093°N, 90.0685E), Bangladesh. Fruits were dried in open sunlight for three days to thrash the seeds from the fruit capsule. The morphological parameters of the fruit and seed were measured with a centimeter scale and electric balance machine. The average length and width of the seeds were 1.14±0.036 cm and 0.5±0.096 cm respectively (Table 1). Only the healthy seeds were sorted to soak in clean cold tap water at room temperature (25°C) for 24 hours.

Growing media preparation and treatments combination

The polybags (15×10 cm) and (20×15 cm), the sand surface of the propagator house, the nursery bed, and the root trainer were selected as the base for the seedlings growing medium of this experiment. The topsoil (0-20 cm) of the forest floor was collected from the adjoining forest area of the University of Chittagong campus to prepare an open nursery bed and polybag filling. After drying out and well sieved (<3 mm) of collected forest topsoil, decomposed cow-dung was mixed in a ratio of 3:1 to fill up polybags, root trainer, and nursery bed. The propagator house medium was filled with only *Sylhet* sand. This sand is coarser in size (2-3 mm). The medium in the propagator house received higher temperature through the fiberglass roof than outside. Only one seed was sown at every hole in growing media. A completely randomized block design consists of 3 blocks with 7 replications of each four treatments, including control, was carried out in trials. The experimental treatments of the species were –

T_0 (control): seeds sown in polybags of size 15×10 cm or 6"×4'

T_1: seeds sown in polybag size of 20×15 cm or 8"×6"

T_2: seeds sown in the sand medium in the propagator house with increased temperature

T_3: seeds sown in nursery bed (12 m length×1.3 m wide ×16 cm linear pile)

T_4: seeds sown in root trainer (40×26×13 cm or 15.75"×10.25"×5.12" of each fleet).

Maintenance of seedlings

Seedlings reared in the *Sylhet* sand of the propagator house were pricked out after 12 weeks of the last germination and transferred to polybags. Shade was provided on transplanted seedlings to control open sunlight for two weeks. Regular watering and weeding were maintained from seed sown to harvest the seedlings. Temporary thatch and shade were provided over seedlings to save from drying out and wilting of the seedlings during intense sunlight and heavy rainfall during summer and monsoon, respectively.

Germination data record

Germination of seeds was recorded visiting growing media every day from sowing to the end of germination (46 days after seed sown). The imbibition period is the total number of days from seed sowing to the initiation of germination, and the germination period is the total number of

Table 1. The length, width, and weight of fruit and seed of *H. orixense*, and number of seeds per fruit

Parameter	Fruit length (cm)	Fruit width (cm)	Fruit weight (gm)	Seed length (cm)	Seed width (cm)	Weight of 10 seed (gm)	No. of seed/fruit
Average	1.84±0.089	0.46±0.015	0.17±0.009	1.14±0.036	0.5±0.096	0.02±0.004	15±1.22
Range	1.6-2.15	0.43-0.51	0.2-0.14	1-1.19	0.25-0.8	0.01-0.02	11-18

±indicates standard deviation of the means.

days from seed sowing to the end of germination (Alamgir and Hossain 2005). The imbibition and the germination period were recorded from each growing medium. The newly emerged seedlings per day and the total number of germinated seeds were recorded based on 0.5 cm of the cotyledon and hypocotyl growth of the seedlings. Germination rate signifies the viability of specimen seeds (Hasnat et al. 2019). Germination rate and Cumulative germination percentage were calculated as following equations (1) and (2) (Ruan et al. 2002; Almodares et al. 2007), respectively.

$$\textit{Germination percentage}\ (\mathrm{GP}) = \frac{n}{N} \times 100 \quad (1)$$

Where n is the number of germinated seeds and N is the total number of seeds.

$$\textit{Cumulative germination}\ \% = \frac{\textit{Cumulative number of seeds germinated}}{\textit{Number of seeds sown}} \times 100 \quad (2)$$

Germination energy indicates the speed of germination. The germination energy percentage estimated through the daily germination percent at their peak time (Dwivedi 1993). Germination value combines the peak value and the mean daily germination, which shows the efficiency of germination. Germination value calculated according to Czabator (1962) with the following formula -

$$\textit{Germination value} = PV \times MDG \quad (3)$$

Where PV is the peak value of germination and MDG is the mean daily germination.

The Plant survival percentage was determined by counting the total number of seedlings that survived at the end of the experiment to the total number of seeds sown. The germination capacity categorized as Kumar (1999): (i) 100-91%-very good, (ii) 90-71%-good, (iii) 70-51%-average, (iv) 50-31%-poor, (v) 30-21%-very poor and (vi) 20-less than 10%-extremely poor.

Seedling data record

Five randomly selected seedlings in each replication of each treatment were selected for estimation of seedling growth performance. The height and collar diameter of seedlings were recorded every month by measuring with a centimeter scale from April to August 2019. Six months old seedlings were wiped out from the Nursery and spiled at the transition part of root and shoot of seedlings. Shoot length and root length were measured from the collar region to the tip of the juvenile shoot and up to the taproot cap, respectively, with a centimeter scale. The collar diameter was measured using a caliper at the root collar region where roots join the main shoot. Root length was measured using a centimeter-scale and an electric balance measured weight. Leaf length and width were measured with a centimeter scale. Leaf number was counted when seedlings had been harvested. The separated root and shoot portions were oven-dried at 70°C for 48 h until the constant weight was attained. Oven-dry weight was measured with an electric balance.

Vigor measure

The relative ratios of shoot length and root length were calculated following by Rho et al. (1986):

$$R = \frac{Mt}{Mc} \times 100 \quad (4)$$

Where R is the relative ratios, Mt is the mean data of the tested plant, and Mc is the mean data of control.

A balanced root-shoot ratio is a predictor of seedling endurance to planting stress, and the higher value among treatments could improve better performance in the plantation sites (Grossnickle 2012). The root-shoot ratio was determined by dividing the root dry weight by dry shoot weight from all treatments.

Seedling vigor index (Abdul-Baki and Anderson 1973) and Seedling quality index (Dickson et al. 1960) were computed by the following formulas -

$$\textit{Seedling vigor index}\ (\textit{SVI-II}) = \textit{Seedling dry Wt.} \times \textit{Germination} \quad (5)$$

$$\textit{Seedling quality index}\ (\textit{SQI}) = T_{dw} \Big/ \left(\frac{H}{D_c} + \frac{S_{dw}}{R_{dw}} \right) \quad (6)$$

Here, SQI is the seedling quality index, T_{dw} is the total dry weight, H is the seedling height (cm), S_{dw} is the shoot dry weight (gm), R_{dw} is root dry weight.

Statistical analysis

Data analysis was conducted with computer software Microsoft Office Excel 2016 and r-studio version 14.3.1 with agricolae package environment. The analysis of Variance (ANOVA) was examined by Duncan's Multiple Range Test (DMRT) at the Significance level of 5%.

The significant differece of treatment is indicated by using the different letters (a, b, c) as superscript in the results section and in Tables 2 and 3.

Table 2. Influence of different growing media on seed germination behavior of *H. orixensis* in the Nursery

	Imbibition (days)	Germination period (days)	Germination rate	Germination energy (%)	Germination value	Plant survival percent	Germination capacity
Treatment							
T_0 (Polybag I)	$17.72^{b}\pm0.95$	$25.14^{b}\pm1.21$	$42.85^{bc}\pm7.55$	$10^{a}\pm0.00$	$2.99^{ab}\pm0.95$	$42.85^{bc}\pm7.56$	Poor
T_1 (Polybag II)	$17.57^{b}\pm0.78$	$26.57^{b}\pm0.53$	$50.72^{ab}\pm7.86$	$10^{a}\pm0.00$	$3.73^{a}\pm1.23$	$50.72^{ab}\pm7.86$	Very poor
T_2 (SMPH**)	$20.57^{a}\pm2.07$	$42.14^{a}\pm2.19$	$58.57^{a}\pm22.30$	$11.43^{a}\pm2.43$	$3.11^{ab}\pm2.22$	$58.57^{a}\pm22.3$	Average
T_3 (Root trainer)	$20.43^{a}\pm0.54$	$26.28^{b}\pm1.38$	$39.28^{bc}\pm4.49$	$11.42^{a}\pm3.7$	$2.35^{ab}\pm0.62$	$35^{c}\pm6.45$	Poor
T_4 (Nursery bed)	$18.00^{b}\pm0.82$	$26.14^{b}\pm0.69$	$35.72^{c}\pm5.34$	$9.28^{a}\pm1.8$	$2.03^{b}\pm0.50$	$35^{c}\pm5$	Very poor
p value	7.19e-06	204 < 2e-16	0.006	0.275	0.131	0.00219	0.0122
F value	11.78	365.2	4.46	1.35	1.934	5.375	3.84

*Means followed by the same superscript letter(s) in the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at $p < 0.05$. ±indicates standard deviation of the means. **Sand medium in propagator house.

Table 3. Influence of growing media on seedling stem length, root length, total length, leaf length, leaf width, leaf number, shoot dry weight, root dry weight, total dry weight, and root-shoot ratio

Growth parameter	Treatment						
	T_0 (Polybag I)	T_1 (Polybag II)	T_2 (sand medium in Propagator house)	T_3 (Root trainer)	T_4 (Nursery bed)	p value	F value
Length							
Stem (cm)	$27.38^{a}\pm5.84$	$27.87^{a}\pm6.27$	$18.05^{b}\pm3$	$17.04^{b}\pm3.02$	$16.45^{b}\pm1.53$	4.84e-06	12.31
Root (cm)	$19.05^{a}\pm4.11$	$19.42^{a}\pm4.22$	$20.22^{a}\pm5.39$	$19.28^{a}\pm5.44$	$19.15^{a}\pm4.69$	0.992	0.064
Total (cm)	$46.44^{a}\pm8.38$	$47.29^{a}\pm8.92$	$38.27^{b}\pm6.34$	$36.32^{b}\pm6.36$	$35.62^{b}\pm4.29$	0.0059	4.47
Leaf							
Length (cm)	$14.05^{a}\pm2.24$	$14.17^{a}\pm2.25$	$10.81^{b}\pm1.94$	$10.02^{b}\pm2.11$	$11.57^{b}\pm1.18$	0.0007	6.38
Width (cm)	$6.73^{a}\pm1.22$	$6.87^{a}\pm1.27$	$5.15^{b}\pm1.44$	$4.42^{b}\pm1.47$	$5.27^{b}\pm0.94$	0.0039	4.82
Number	$14.85^{a}\pm1.86$	$15.72^{a}\pm1.71$	$15.43^{a}\pm2.82$	$14.42^{a}\pm2.82$	$11.28^{b}\pm1.79$	0.0068	4.346
Dry weight							
Shoot (gm)	$5.47^{a}\pm1.5$	$5.62^{a}\pm1.52$	$2.98^{b}\pm1.15$	$2.98^{b}\pm0.87$	$1.78^{b}\pm0.39$	9.2e-07	14.72
Root (gm)	$8.28^{a}\pm1.16$	$9.27^{a}\pm1.32$	$9.66^{b}\pm1.84$	$3.92^{b}\pm1.74$	$3.16^{b}\pm0.93$	2.3e-13	54.78
Total (gm)	$13.75^{a}\pm2.33$	$14.89^{a}\pm2.11$	$12.64^{b}\pm2.69$	$6.9^{b}\pm2.33$	$4.94^{b}\pm0.62$	8.5e-13	49.55
Vigor							
Root/shoot	$1.57^{a}\pm0.58$	$1.79^{a}\pm0.57$	$1.46^{ab}\pm0.57$	$1.30^{b}\pm0.54$	$1.73^{ab}\pm0.83$	0.0541	2.63
Quality index	$3.24^{a}\pm1.67$	$3.64^{a}\pm1.63$	$2.22^{b}\pm0.97$	$1.99^{b}\pm0.87$	$1.32^{b}\pm0.19$	4.24e-05	13.79
Vigor index	$537^{a}\pm182.04$	$709.46^{a}\pm230.25$	$386.78^{b}\pm144.99$	$245.43^{bc}\pm89.28$	$193^{c}\pm24.75$	2.45e-09	25.8

*Means followed by the same superscript letter(s) in the same column are not significantly different according to Duncan's Multiple Range Test (DMRT) at $p < 0.05$. ±indicates standard deviation of the means.

Results

Germination behavior of H. orixensis seeds treated with different growing media in the Nursery

It was identified that growing media has a significant impact on the seed germination behavior of *H. orixensis* in the nursery condition. Seed imbibition, germination period, germination rate, plant percent, and germination capacity of *H. orixensis* were varied significantly in different potting media, except germination energy percentage and germination value (Table 2). The result showed that the seed sowed in polybag II (T_1) experienced significantly ($p < 0.001$) the shortest imbibition period ($17.57^b \pm 0.78$ days) and the sand media of propagator house (T_2) experienced the longest imbibition period ($20.57^a \pm 2.07$ days).

The significantly longest germination period ($42.14^a \pm 2.19$ days) was witnessed in T_2 than any other growing media. The highest germination rate and the highest germination energy percentage ($58.57^a \pm 22.30$ and $11.43^a \pm 2.43$ respectively) were recorded in T_2. In comparison, the lowest germination rate and the lowest germination energy percentage ($35.72^c \pm 5.34$ and $9.28^a \pm 1.8$) were observed in the nursery bed (T_4).

Cumulative germination percentage climbed from 17th day to 27th day and continued steady rise to the 44th day. The cumulative germination percentage in T_2 was highest on the 44th day after sowing as to other treatments. However, T_1 treatment seeds reached the highest cumulative germination percentage shortly on the 27th day (Fig. 2). The seeds in polybag II (T_1) had maximum germination value ($3.73^a \pm 1.23$) followed by ($3.11^{ab} \pm 2.22$) in (T_2), and the nursery bed (T_4) had minimum germination value ($2.03^b \pm 0.50$) followed by ($2.35^{ab} \pm 0.62$) in T_3. The highest number of seedlings ($58.57^a \pm 22.3$) survived till harvest in T_2 and, the least number of seedlings ($35^c \pm 6.45$ and $35^c \pm 5$) remained alive both in nursery beds (T_2) and root trainer (T_3) respectively.

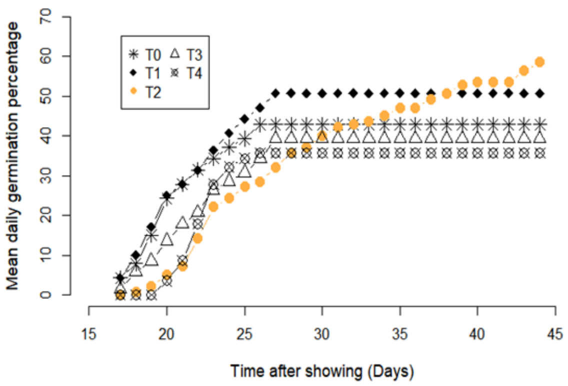

Fig. 2. Effect of different growing media on mean cumulative germination percentage of *H. orixensis*.

Morphological growth parameter of H. orixensis seedlings treated at different growing media in the Nursery

The morphological growth performance of *H. orixensis* seedlings treated with different potting media was examined in Fig. 3. In six months old seedlings, T_1 treatment seedlings attained the maximum seedling mean stem length ($27.87^a \pm 6.27$ cm) followed by control (T_0) and the minimum mean stem length ($16.45^b \pm 1.53$ cm) was obtained in T_4 followed by T_3 where $p < 0.001$.

The overall seedling's mean shoot height increment in T_2, T_3, and T_4 was lower than T_1 and T_0 (Fig. 3). Seedling grown in the sand medium of the propagator house with treatment T_2 demonstrated the highest root length ($20.22^a \pm 5.39$ cm) compared with other growing media (Table 3). Still, the total length of seedlings was highest in

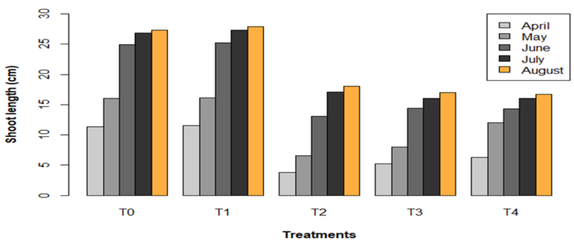

Fig. 3. Shoot height increment of *H. orixensis* seedlings in different growing media in the Nursery at six months age.

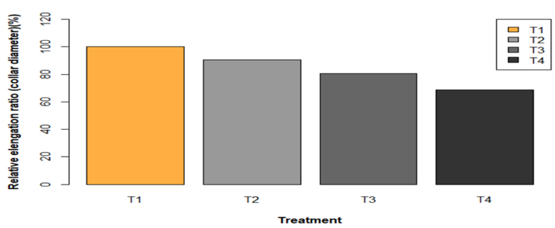

Fig. 4. Relative elongation ratio (RER) of collar diameter with different growing media.

polybag (II). Considering the relative elongation ratio (RER) of collar diameter, the maximum percentage (100.18%) was obtained in T_1, and the minimum percentage (68.61%) was in T_4 (Fig. 4). Both the leaf length ($14.17^a \pm 2.25$ cm) and the leaf width ($6.87^a \pm 1.27$ cm) were highest in T_1, and the lowest ($10.02^b \pm 2.11$ cm) and ($4.42^b \pm 1.47$ cm) were in T_3, respectively (Table 3). The maximum number of leaves ($15.72^a \pm 1.71$) was observed in polybag II (T_1), and the minimum number of leaves ($11.28^b \pm 1.79$) was in the nursery bed (T_4) (Table 3).

Seedling's vigor and dry matter production of H. orixensis treated at different growing media

In the oven-dry weight of seedlings, T_1 seedlings attained the highest shoot dry weight and the highest total dry weight (5.62 ± 1.52 gm and 14.89 ± 2.11 gm), respectively. The lowest shoot dry weight and the total shoot dry weight were attained ($1.78^b \pm 0.39$ gm and $4.94^b \pm 0.62$ gm) respectively in T_4 (Table 3). T_2 seedlings had the maximum root dry weight ($9.66^b \pm 1.84$ gm) followed by T_1 (9.27 ± 1.32 gm), and T_4 attained the lowest root dry weight ($3.16^b \pm 0.93$ gm). T_1 holds the highest root-shoot ratio, the highest quality index, and the highest vigor index ($1.79^a \pm 0.57$, $3.64^a \pm 1.63$, $709.46^a \pm 230.25$ respectively) compared with others growing media and seedling grown in T_3 had the lowest root-shoot ratio ($1.30^b \pm 0.54$). However, the lowest quality index and the vigor index ($1.32^b \pm 0.54$, $193^c \pm 24.75$) were observed in T_4 (Table 3).

Discussion

This study identified that potting media significantly influences seed germination and early physiological growth development of *H. orixensis* in nursery practice. The sand medium in the propagator house enhanced seed germination, and the larger polybag yielded better growth traits and the qualitative seedlings of *H. orixensis* in the Nursery.

Besides the seed structure, environmental factors for instance temperature, light, and humidity of growing media also impact seed germination (Kruk and Benech-Arnold 1998; Osanai et al. 2005). The seed germination rate, cumulative germination percentage, germination energy percentage, and plant percentage substantially increased in the controlled environment of the propagator house. The imbibition and germination periods in the sand medium of the propagator house were longer than other examined growing media (Table 2; Fig. 2). Perhaps, the insufficient water holding capacity of sand substratum delayed the embryo development in the sand medium of the propagator house. Germination rate and plant percentage both in the nursery bed and the root trainer were significantly lower than the propagator house and polybag sand medium. Maybe, it because of the poor aeration and drainage capacity of loamy soil in the nursery bed and the root trainer medium. Furthermore, the air pruning of polybag I and polybag II improved the ventilation and drainage capacity of the loamy soil in the polybag medium, resulting in a better germination capacity than the nursery bed and the root trainer. Multiple reports from the literature support our findings of this study. The results of Dey and Hossain (2019) also reported the maximum germination percentage of *Suregeda multifloria* was in the sand medium of the propagator house. Similarly, Mariappan et al. (2014) recorded the highest germination rate in river sand for *Jatropha curcas* and *Pongamia pinnata*. In addition, Azad et al. (2011a) stated coarse and fine sand better medium than loamy soil for *Phoenix dactylifera*. Moreover, other researchers, e.g., Egharevba et al. (2005), Bahar and Singh (2007), Docker and Hubble (2008), Hassanein (2010), also observed that sand medium provides the highest percentage of seed germination.

In this study, the phenotypic traits (except the root length), the dry biomass, the quality index, and the vigor index of seedlings significantly responded to potting media. But the root-shoot ratio of seedlings had no significant response to the different growing substratum. The size of the container affects the seedling phenotypic traits and vigor of seedlings because it is directly associated with water holding capacity, humidity, and the aeration of the root system of seedlings. Thus, a larger container facilitates the seedlings higher survival rate and the growth of seedling phenotypic parameters (Carlson and Endean 1976; Mexal and Landis 1990). Our findings conclude that the 20×15 cm size polybag developed higher above-ground growth, dry weight materials, root-shoot ratio, quality index, and vigor index of seedlings than other studied growing media. Because the larger size of polybag II provided more nutrients than polybag I and root trainer. Similarly, the below-ground development of seedlings is influenced by the container structure of walls (Aghai et al. 2013). The 2.5 fineness modulus of sand in the medium of the propagator house and the air pruning of polybag (I) and Polybag (II) provided the higher below-ground dry materials production than the nursery bed and root trainer. Perhaps, it because of higher aeration into the soil of sand medium of propagator house and polybag as air pruning potting media promotes the lateral development of roots (Dong and Burdett 1986). The findings of Begum et al. (2018) supports this result, who reported *Swietenia macrophylla* seedlings raised in polybag showed better growth and biomass production compared to the root trainer. The finding of this study was also supported by the result of Ferdousee et al. (2011) who reported polybags give better early growth performance of *Leucaena leucocephala* and *Glicidia sepium* seedlings. Similarly, Islam et al. (2019) reported 20×15 cm polybags are better for *Acacia auriculiformis* seedlings, and Sood and Ram (2019) recorded 23×28 cm polybags for *Oroxylum indicum* seedlings in the Nursery.

Conclusion

Uniform seed germination and quality seedling development study of native tree species are prerequisites for a successful afforestation and restoration program. The outcome of this study confirms the sand medium in the propagator house is the best medium for seed germination, and the 20×15 cm size of polybag is best for the seedling growing of *Hymennodictyon orixens*. Considering the time and cost, the 20×15 cm size of polybag is recommended for large-scale seed germination and quality seedlings development for afforestation and reforestation programs. The open nursery bed and root trainer are not suitable growing media for better seed germination and quality seedlings of *Hymennodictyon orixens*.

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