Decaying Utricularia-biomass versus soil-based substrate for production of high quality pre-transplanted rice seedlings using floating seedbeds

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Abstract

Rice growing season at riparian wetlands in Indonesia is started at the end of rainy season before floodwater completely subsides. However, available materials for nursery substrate are limited during flooding period of the wetlands. This study aimed to evaluate three available and affordable substrates for producing high quality rice seedlings. The three substrates evaluated were decaying biomass of Utricularia vulgaris (DBUV); mixed of soil and U. vulgaris biomass plus biochar (S+BV); and soil amended with biochar (S+B). Rice seedling preparation was done using modified floating seedbeds, adjusted specifically for light weight load of the evaluated substrates. Results of this study indicated that seedlings sown on DBUV substrate were significantly taller than those on S+B or DBUV substrate at 21 DAS. Roots of seedlings sown on DBUV substrate exhibited minimum broken root tips, when they were pulled off the substrate, while more broken root tips were observed in those sown on S+BV and S+B substrates, causing significantly more shorter intact roots. Broken root tip was closely related to substrate porosity. DBUV substrate had significantly higher porosity than S+BV and S+B substrates. There were no significant differences in number of leaves and chlorophyll concentration index (CCI) among seedlings grown on all substrates. Better performance of seedlings grown on DBUV substrate was more pronounced on 21-day-old seedlings; therefore, it is recommended to farmers to use DBUV substrate and do transplanting of rice seedlings to paddy field at age of 21-day-old.

Keywords: floating culture; transplanting; marginal land; rice cultivation; inland swamp; seedling age; traditional agriculture; indigenous knowledge; floodwater; biochar.

Abbreviations: CCI_chlorophyll concentration index; DAS_days after sowing; DBUV_decomposed biomass of Utricularia vulgaris; PVC_polyvinyl chloride; S+BV_mixed of soil and U. vulgaris biomass plus biochar; S+B_soil amended with biochar; SSW_specific substrate weight;

Introduction

Rice is the most important crop for smallholder farmers at riparian wetlands in Indonesia. In fact, most of farmers at this wetland ecosystem solely grow rice. This crop is commonly grown once annually due to very narrow suitable period of rice growing season. Local farmers very rarely grow rice twice per year. Therefore, cropping intensity is low (Kartika et al., 2018a). Rice growing season at this ecosystem is started after floodwater has subsided to less than 15 cm and harvested during dry season (Lakitan et al., 2018).

Rice seedlings should be transplanted to paddy field as early as possible to avoid drought stress during reproductive growth phase at the end of growing season (Kartika et al., 2018b). Use of floating seedbeds is a strategy for providing transplanting-ready seedlings at the earliest time possible, since this practice can be conducted while floodwater is still too deep for direct planting. Other seedling preparation methods can only be practiced after floodwater has fully subsided.

Rice seedlings are preferably transplanted at age of 2- to 3-week-old. Rice yield was reported to be significantly affected by seedling age at transplanting (Sowmyalatha et al., 2017; Liu et al., 2017; Reuben et al., 2016). Average time-lapse between floodwater at 15-cm depth to fully subside is around 2 weeks. Therefore, difference in starting time of rice cultivation between floating seedbed method and soil-grown seedlings is about 1 month. This one-month period can be very critical in rice cultivation at the riparian wetlands due to possible drought stress experienced by rice plants during the subsequent dry period.

Knowledge on negative effect of drought stress to rice yield has been well established (Mostajeran and Rahimi-Eichi, 2009), including the severity of the stress effect during reproductive growth phase (Bernier et al., 2007). Many efforts have been studied to minimized impact of drought stress on rice plants (Blum, 2009). Breeding for drought tolerant rice has been continuously pursued (Venuprasad et al., 2007). This possible threat of drought stress during reproductive growth stage has been anticipated by local farmers by early seedling preparation using the floating seedbed.
In rice transplanting practiced by local farmers, the seedlings are directly pulled off the growing substrate in clumps. Subsequently, it causes damage to roots of seedling. More damage is commonly observed on seedlings grown on compact and/or relatively dry substrates. Additional damage can occur during separating seedlings to be planted from its clump during transplanting process. More damage is observed in older seedlings since their roots have heavily intertwined between one to the others at the nursery. Therefore, age of seedling at time of transplanting and physical characteristic of substrate should be carefully considered in producing good quality rice seedlings.

Bilderback et al. (2005) noticed that important physical characteristic of growing substrate was having adequate pore spaces for allowing water drainage and creating well-aerated root zone. In addition, Bhat et al. (2014) suggested that a good growing substrate should also contain nutrients to sustain initial plant growth.

Objective of this study is to develop reliable and affordable practices for producing high quality rice seedlings for transplanting to paddy field at riparian wetlands in Indonesia. The study was focused on comparing among different nursery substrates and evaluates appropriate age of the rice seedlings at time of transplanting.

Results and Discussion

Dynamic changes in seedling height

Height of rice seedlings was a very important characteristic for rice cultivation at riparian wetlands. Taller seedling is preferred for overcoming variation in depth of floodwater at time of transplanting to paddy field. Results of this study indicated that significant difference in height amongst seedlings grown on different substrates was observed on day 5, 7, 9, and 21 (Table 1). There was a dynamic weekly change in height amongst seedlings grown on different substrates. Seedlings grown on DBUv substrate exhibited slower growth during the first week but steadily grew to become the tallest seedling at the end of the third-week period. Seedlings sown on mixed substrate of soil and U. vulgaris biomass plus biochar (SUv+B substrate) exhibited slower early growth (at the first week) than seedlings grown on the other two substrates. During early second week, seedlings sown on soil amended with biochar (S+B substrate) grew significantly faster as indicated by taller seedlings than those sown on the other two substrates.

The source of nutrients for supporting seedling growth shifted from endosperm to nursery substrate as seedling growth progressed. Aslam et al. (2015) suggested that nutrients contained in the substrate, especially nitrogen, affected rice seedling growth as indicated by increment of seedling height. In case of DBUv substrate, as decomposition of U. vulgaris biomass progressed, by which more nutrients were released and became available for supporting seedling growth. Increase in nutrient availability during the third-week period contributed to faster growth of rice seedlings grown on DBUv substrate.

Addition of biochar as amendment to SUv+B or S+B substrate at rate of 1 g/L and 0.25 g/L, respectively, enhanced seedling growth during the first week but did not sustain beyond the second week period (Table 1). Glase et al. (2002) reported that biochar was capable of increasing germination and vegetative growth. In this study; however, even if biochar has ability to increase solubility of nutrients, rice seedling growth relied more directly on adequate concentration of the essential nutrients. High soil moisture increased solubility of nutrients with or without biochar.

In this study, we realized through direct observation that fine-sized biochar is also soluble in the water. Therefore, significant portion of applied biochar in floating seedbed system was dissolved in water, since the growing substrate was water-saturated and in direct contact with water underneath the raft in this floating system. Amount of applied biochar was gradually depleted at the third week period. Therefore, fine-sized biochar is not suitable as an amendment for nursery substrate in floating seedbed system.

No effect of substrate on number of seedling leaves

In this research, the average number of leaves was not significantly different amongst rice seedlings grown on three types of substrates (Fig 1). It seems that number of leaves at seedling stage in rice is predominantly driven by genetic rather than environmental factors. Seedlings grown on DBUv substrate developed their third and fourth leaves, insignificantly earlier than those grown on the other two substrates. However, this could be an indication that differences in number of leaves might become significant during later stage of vegetative growth.

Lakitan et al. (2018) found that number of leaves at late vegetative growth stage was higher in rice plants grown on biochar-treated soil. Kartika et al. (2018a) also reported that biochar affected leaf area ratio. Moreover, there were significantly higher leaf area index in rice plants at edge rows compared to those at internal rows in 4:1 Jajar-Legowo planting system (Kartika et al., 2018b). These findings justified that non-genetic factors influenced leaf development at later vegetative growth stage.

Less broken roots in porous substrate

The root length was measured after the roots were pulled out of the substrate and washed. Pulling roots of seedling out of the substrate is done for simulating a common practice by local farmers during transplanting process. Root damage was higher in high density substrate (or low substrate porosity). Result of this study indicated that root length of the seedlings was significantly affected by substrates (Fig 2).

During the first week, roots of seedling grown on S+B substrate were longer than those grown on SUv+B and DBUv substrates. However, root length of all seedlings was not significantly different during the second week. Interestingly, during the third week, roots of seedlings grown on DBUv substrate were longer than those grown on SUv+B and S+B substrates. Shorter roots of the seedlings grown on SUv+B and S+B substrates were mainly due to significant damages (broken) of the roots at time they were pulled out of the substrates.

Quality of rice seedlings was not solely evaluated based on physical appearance of above-ground organs but also depended on level of damages to the root at time of the seedlings were pulled out of their substrate during transplantation. The substrate density played a significant
Table 1. Significant differences in height of rice seedling sown on different growing substrates on selected dates during the first 3-week period.

| Substrate | Age of seedling (day) | 5    | 7    | 9    | 21   |
|-----------|-----------------------|------|------|------|------|
| DB_Uv     | 2.81 ± 0.345 a        |      |      |      |      |
| SUv+B     | 1.96 ± 0.391 b        |      |      |      |      |
| S+B       | 2.93 ± 0.350 a        |      |      |      |      |

Growing substrate did not significantly affect seedling height on other observed days during the first 3-week period. Data are presented as means ± standard deviation. The means followed by similar letter within each column were not significantly different at LSD_{0.05}.

Fig 1. Number of leaves in rice seedlings grown on different growing substrate using floating seedbed during the first 3-week period. A = DB_Uv substrate; B = SUv+B substrate, and C = S+B substrate.

Table 2. Leaf chlorophyll concentration index (CCI) of rice seedling grown on floating seedbed using different nursery substrates.

| Substrate | Age (day) | 7    | 14   | 17   | 21   | 24   |
|-----------|-----------|------|------|------|------|------|
| DB_Uv     | 25.66 ± 2.67 a | 27.23 ± 2.81 a | 22.40 ± 2.53 a | 23.83 ± 1.20 a | 21.46 ± 1.50 a |
| SUv+B     | 24.83 ± 0.83 a | 24.76 ± 0.20 ab | 22.73 ± 1.60 a | 21.73 ± 1.00 a | 20.83 ± 0.62 a |
| S+B       | 26.80 ± 2.20 a | 21.96 ± 1.55 b | 20.96 ± 0.76 a | 21.16 ± 1.55 a | 19.36 ± 1.54 a |

Data are presented as means ± standard deviation. The means followed by similar letter within each column were not significantly different at LSD_{0.05}.

Fig 2. Differences in average length of intact roots after being pulled out of growing substrate. Asterisk indicated that length of intact root was significantly affected by types of substrate used. A = DB_Uv substrate; B = SUv+B substrate, and C = S+B substrate.

Table 3. Specific substrate weight, seedling density, shoot/root ratio, and total dry matter of rice seedling grown on floating seedbed using different growing substrate.

| Substrate | Specific substrate weight (kg.m^{-2}) | Seedling density (cm^{-3}) | Shoot/root ratio | Total dry matter (g) |
|-----------|---------------------------------------|-----------------------------|------------------|----------------------|
| DB_Uv     | 19.36 ± 4.10 a                        | 7.84 ± 3.93 a               | 0.41 ± 0.06 a    | 13.61 ± 1.57 a       |
| SUv+B     | 31.40 ± 1.66 b                        | 7.61 ± 2.33 a               | 0.37 ± 0.16 a    | 13.95 ± 0.84 a       |
| S+B       | 36.16 ± 1.76 c                        | 8.03 ± 1.58 a               | 0.31 ± 0.04 a    | 13.81 ± 0.89 a       |

Data are presented as means ± standard deviation. The means followed by similar letter within each column were not significantly different at LSD_{0.05}.
contribution to root damage in rice seedlings. Length of recovered intact root in rice seedling grown on the most porous substrate of DBUV was significantly higher than those planted on the more compacted SUV+B and S+B substrates. Wilson et al. (2001) reported that composition of growing substrate with different porosity level greatly influenced the quality of seedlings. Porous substrate of DBUV allows root to grow with lower resistance compared to more compact substrates. Addition of biochar into substrate was meant to increase its porosity (Glaser et al., 2002). Bruun et al. (2014) stated that biochar facilitated root development by providing a wider or additional pore space. Furthermore, Abiven et al. (2015) reported that biochar increased root area, root depth, and smooth root development. Similarly, Yang et al. (2015) also reported that biochar applications improved root properties, including length, volume, average diameter, number of root tips and root forks. Biochar-amended substrates (SUv+B and S+B) were successful in allowing roots to protrude through the substrate, yet this substrate still caused significant damage to roots at time of the seedlings were pulled out of the substrate during transplanting process. Since broken part of the roots mostly occurred at younger tissues near root tips, then length of recovered intact roots in SUv+B and S+B substrates were shorter than those in DBUV substrate (Fig 2).

The leaf chlorophyll was not affected by different substrates

Leaf chlorophyll concentration index (CCI) is commonly used as indicator for plant health and leaf nitrogen content. CCI in rice seedlings up to 21 days old was not significantly different regardless of substrates (Table 2). The CCI of seedlings grown on DBUV substrate were consistently higher (but not statistically different) than those grown on SUv+B and S+B substrates, except at 14 DAS, when CCI of seedlings grown on DBUV substrate was significantly higher than CCI of seedlings grown on S+B substrate. Brunetto et al. (2012) found that CCI value declined as plant got older unless nitrogen fertilizer was applied. Although, it was not statistically significant, there was a trend that CCI gradually decreased as rice seedling grew to 3-week-old. The CCI has been used as reliable proxy for leaf nitrogen and chlorophyll content (Monostori et al., 2016; Yang et al., 2018; Huang et al., 2017). Gradual decrease of CCI indicated that nitrogen availability in nursery substrates has slowly depleted as rice seedlings grew approaching end of the third week period.

Substrate effect on seedling morphological characteristics

Porosity of a substrate can be estimated by measuring specific weight of the substrate. Porous substrate has lower specific weight and, reversely, compact substrate has high specific weight. DBUV substrate was the most porous substrate among the three substrates used in this study. Measurements on specific substrate weight (Table 3) confirmed that porosity of substrates used in this study was significantly different. Specific weight of DBUV substrate was significantly lower than those of SUv+B and S+B substrates. Specific weight of SUv+B substrate was also significantly lower than that of S+B substrate. Therefore, amongst the three substrates used, the most porous was DBUV substrate, while the most compact was S+B substrate, and the mixed SUv+B substrate was in between the previous two substrates. Despite of differences in their porosity, nursery substrate did not significantly affect seedling density, shoot/root ratio, and total dry matter (Table 3).

In this study, similarity in seedling density regardless of substrate porosity differences was associated with similar viability rate and sowing density of seeds. Similar shoot/root ratio indicated that during the first 3-week-period, rice seedlings planted on different nursery substrates allocated similar portion of assimilates between shoot and roots. Despite differences observed on seedling height and root length, total dry weight of the seedlings sown on different substrates were not significantly different during the first 3-week period on floating seedbeds.

Materials and Methods

Plant materials, raft construction, and substrate preparation

Ciherang rice variety was used in this experiment. Ciherang is one of popular rice variety grown by local farmers in Indonesia and also commonly grown at riparian wetlands in South Sumatra. Ciherang is not a hybrid variety; therefore, local farmers can reproduce and use seeds from their previous harvest to be planted at the next growing season. The experiment on use of floating seedbed for rice seedling production was conducted in 2017 at an off-campus research facilities in Jakabaring (104°46’44” E; 3°01’35” S), Palembang, Indonesia. Floating rafts and nursery substrates were prepared 5 days earlier before seed sowing. The rafts were made of biomaterial consisted of leaf blades and spongy base of local...
swamp sedge, identified as *Scleria poaeformis* RETZ. Average length of the leaf blade was about 1.5 meters. These long leaves were stitched together to form suitable raft as floating seedbed for rice seedling production. The raft was tested for its stability and carrying capacity (buoyant force) in outdoor experimental pools. Test procedures were conducted according to Siaga et al. (2018). Carrying capacity of the raft was varied, depending on thickness of the raft. In our study, the double-layered raft had ability to withstand loads up to 32.56 kg.m⁻².

Three different substrates were evaluated in this research. The substrates were: (1) made of decomposed biomass of local aquatic plants (*Utricularia vulgaris* L.), denoted as DBUV substrate; (2) mixture of soil and decomposed *U. vulgaris* biomass at 1:1 v/v plus biochar at rate of 0.25 g/L of the mixed media, denoted as SUV+B substrate; and (3) soil amended with biochar at rate of 1 g/L, denoted as S+B substrate (Fig 3). Biochar used was wood biochar, crushed from chunky to fine powder, passed through 1 mm screen.

**Procedures of rice seed sowing**

Frames made of polyvinyl chloride (PVC) pipes were placed on the raft for separating among the three different substrates and for holding the substrates from falling off the raft. Then, perforated water-permeable plastic layer was placed within each frame prior to placing the nursery substrates. The most crucial part was the bottom part of the substrate which should have been in direct contact with water surface for keeping the substrate moisture content at optimum level for supporting rice seedling growth. Based on specific weight of each substrate, thickness of the substrate varied from 1.5 to 2.0 cm to set up the required condition, i.e. bottom part of the substrate in direct contact with water surface. Upper surface of growing substrates was leveled before seeds were sown. Seeds were soaked in water for separating and excluding low quality seeds. Then, the good quality seeds were kept for two days in multi-layer wet clothes as a hydro-priming treatment. At end of the two-day hydro-priming, most of seeds were germinated and their radicles protruded seat coat. The primed seeds were evenly dispersed on leveled nursery substrate. Sowing density was 3 kg rice seeds per square meter. After the seeds were sown, the rafts were covered with white perforated plastic sheets for three days to protect seeds from wild bird attack.

**Measurement of chlorophyll concentration index (CCI)**

CCI was measured on healthy leaves at 7, 14, 17, 21, and 24 DAS using a chlorophyll meter (Konica Minolta SPAD-502 Plus). Measurements were taken at around 9.00 am when the leaves were at turgid condition and all morning dews on leaf surface had fully evaporated. Measurement was cancelled on rainy days. Data were recorded based on average of three different leaves for representing each treatment in each block.

**Experimental design and statistical analysis**

Experimental design used was Randomized Block Design. Three outdoor experimental pools were used, each assigned as a block. Treatments consisted of three different nursery substrates, i.e. DBUV, SUv+B, and S+B substrates. Each of the substrate was randomly placed on one of three rafts within each experimental pool. In total, nine rafts made of swamp sedge *Scleria poaeformis* were used for the three treatments and three blocks. Data on growth parameters and CCI of the rice seedlings were collected daily from 4 to 21 DAS. The analysis of variance was carried out using the SAS application for testing significant effect of treatments (the nursery substrates) on selected primary and secondary growth parameters of rice seedlings sown on floating seedbeds. If the treatments significantly affected any of growth parameters, further test was performed using the Least Significant Differences test at p < 0.05 (LSD0.05) for specifying differences amongst treatments.

**Conclusion**

Considering quality of seedlings produced and availability of required biomaterials, use of DBUV substrate was the most appropriate practice in floating rice seedling production in riparian wetlands. On the other hand, application of fine sized biochar to water-saturated nursery substrate in floating seedbed system should not be employed, since the biochar was gradually dissolved in water.

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**References**

Abiven S, Hund A, Martinsen V, Cornelissen G (2015) Biochar amendment increases maize root surface areas and branching: a sholvelomics study in Zambia. Plant Soil. 395(1-2): 45-55.

Aslam MM, Zeeshan M, Irum A, Hassan MU, Ali S, Hussain R, Ramzani PMA, Rashid MF (2015) Influence of seedling age and nitrogen rates on productivity of rice (*Oryza sativa* L.): A review. Amer J Plant Sci. 6: 1361-1369.

Bernier J, Kumar A, Ramaiah V, Spaner D, Atlin G (2007) A large-effect QTL for grain yield under reproductive-stage drought stress in upland rice. Crop Sci. 47(2): 507-516.

Bhat N, Albaho M, Suleiman M (2014) Growing substrate composition influences growth, productivity and quality of organic vegetables. Sch J Agric Vet Sci. 1(1): 6-12.

Bilderback TE, Warren SL, Owen JS, Albano JP (2005) Healthy substrates need physcals too. HortTechnology 15(4): 747–751.

Blum A (2009) Effective use of water (EUW) and not water-use efficiency (WUE) is the target of crop yield improvement under drought stress. Field Crop Res. 112(2-3): 119-123.

Bruun EW, Petersen CT, Hansen E, Holm JK, Hauggaard-Nielsen H (2014) Biochar amendment to coarse sandy subsoil improves root growth and increases water retention. Soil Use Management. 30: 109–118.
Brunetto G, Trentin G, Ceretta CA, Girotto E, Lorensini F, Moiato A, Mosser GRZ, de Melo GW (2012) Use of the SPAD-502 in estimating nitrogen content in leaves and grape yield in grapevines in soils with different texture. Amer J Plant Sci. 3(11): 1546-1561.

Glaser B, Lehmann J, Zech W (2002) Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal: A review. Biol Fert Soils. 35(4): 219-230.

Huang J, Zhu D, Chen H, Xiang J, Wang Y, Zhang Y, Kawano M, Orihashi K (2017) Nondestructive and rapid determination method of nitrogen content of rice leaves. China Rice. 23(2): 18-20.

Kartika K, Lakitan B, Sanjaya N, Wijaya A, Kadir S, Kurnianingsih A, Widuri LI, Siaga E, Meihana M (2018a) Internal-edge row comparison in jajar legowo 4:1 rice planting pattern at different frequency of fertilizer applications. Agrivita J Agric Sci. 40(2):222-232.

Kartika K, Lakitan B, Wijaya A, Kadir S, Widuri LI, Siaga E, Meihana M (2018b). Effects of particle size and application rate of rice-husk biochar on chemical properties of tropical wetland soil, rice growth, and yield. Aust J Crop Sci. 12(5):817-826

Lakitan B, Alberto A, Lindiana L, Kartika K, Herlinda S, Kurnianingsih A (2018) The benefits of biochar on rice growth and yield in tropical riparian wetland, South Sumatera, Indonesia. CMUJ Nat Sci. 17(2):111-126

Liu Q, Zhou X, Li J, Xin C (2017) Effects of seedling age and cultivation density on agronomic characteristics and grain yield of mechanically transplanted rice. Scientific Reports 7:14072.

Monostori I, Árendás T, Hoffman B, Galiba G, Gierczik K, Szira F, Vágújfali A (2016) Relationship between SPAD value and grain yield can be affected by cultivar, environment and soil nitrogen content in wheat. Euphytica 211(1):103-112.

Mostajeran A, Rahimi-Eichi V (2009) Effects of drought stress on growth and yield of rice (Oryza sativa L.) cultivars and accumulation of proline and soluble sugars in sheath and blades of their different ages leaves. Agric Environ Sci. 5(2): 264-272.

Reuben P, Katambara Z, Kahimba FC, Mahoo HF, Mbungu WB, Mhenga F, Nyarubamba A, Maugo M (2016) Influence of transplanting age on paddy yield under the system of rice intensification. Agric Sci. 7(3): 154-163.

Siaga E, Lakitan B, Hasbi, Bernas SM, Wijaya A, Lisda R, Ramadhani F, Widuri LI, Kartika K, Meihana M (2018) Application of floating culture system in chili pepper (Capsicum annuum L.) during prolonged flooding period at riparian wetland in Indonesia. Aust J Crop Sci. 12(5): 808-816

Sowmyalatha BS, Ramachandra C, Krishnamurthy N, Shivakumar N (2017) Influence of seedling age on growth and yield of rice (Oryza sativa L.) under mechanized system of rice intensification (MSRI). J Progressive Agric. 8(2): 40-45.

Venuprasad R, Lafitte HR, Atlin GN (2007) Response to direct selection for grain yield under drought stress in rice. Crop Sci. 47(1): 285-293.

Wilson SB, Stoffella PJ, Graetz DA (2001) Use of compost as a media amendment for containerized production of two subtropical perennials. J Environ Hort. 19: 37-42.

Yang H, Yang J, Li FH, Liu N (2018) Replacing the nitrogen nutrition index by spad values and analysis of effect factors for estimating rice nitrogen status. Agron J. 110(2): 1–10.

Yang L, Liao F, Huang M, Yang L, Li Y (2015) Biochar improves sugarcane seedling root and soil properties under a pot experiment. Sugar Tech. 17(1): 36-40.