International Journal of

Agricultural Research

ISSN 1816-4897

Academic Journals Inc.

www.academicjournals.com

OPEN ACCESS International Journal of Agricultural Research

ISSN 1816-4897
DOI: 10.3923/ijar.2020.9.18

Research Article
Effects of Different Media Composition on Growth and Productivity of *Oryza sativa* L.

Deyra Eka Pratiwi, Muhammad Athar Hafizhat Isbindra, Auliya Rahmah Fachrudin, Liony Dea Naungi Sasita, Robert Manurung and Muhammad Yusuf Abduh

School of Life Sciences and Technology, Institut Teknologi Bandung, Jalan Ganesha 10, 40132 Bandung, Indonesia

Abstract
Background and Objective: Rice is a major staple food in Asia and its productivity is very much influenced among others by the composition of growing media. This study was carried out to investigate the effect of different growing media composition on the growth and productivity of *Oryza sativa* var. INPARI 30 Ciherang Sub-1. **Materials and Methods:** Cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 was carried out using a water recirculation system in a screen house located at Institut Teknologi Bandung, Jatinangor with a light intensity of 17000-20000 lux, temperature of 25-31 °C and relative humidity of 35-65%. The composition of the growing media was varied to determine the best combination of soil, sand, cocopeat, biochar and compost on water holding capacity, plant height, number leaves, number of tillers, number of effective tillers, weight of biomass and productivity of the harvested rice. **Results:** The growing media composition highly influenced plant growth and productivity of the harvested rice. Best results were obtained when *Oryza sativa* var. INPARI 30 Ciherang Sub-1 was cultivated using soil: compost: biochar (a ratio of 2:2:1) with an estimated rice productivity of 0.18 kg m^{-2} per harvest. **Conclusion:** It was concluded that an appropriate combination of soil, biochar and compost may be recommended as a growing media for cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 using a water recirculation system.

Key words: Biochar, cocopeat, sand, *Oryza sativa*, productivity

Citation: Deyra Eka Pratiwi, Muhammad Athar Hafizhat Isbindra, Auliya Rahmah Fachrudin, Liony Dea Naungi Sasita, Robert Manurung and Muhammad Yusuf Abduh, 2020. Effects of different media composition on growth and productivity of *Oryza sativa* L. Int. J. Agric. Res., 15: 9-18.

Corresponding Author: Muhammad Yusuf Abduh, School of Life Sciences and Technology, Institut Teknologi Bandung, Jalan Ganesha 10, 40132 Bandung, Indonesia Tel: +62 22 251 1575

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food of 50% of world's population with a global productivity around 518 million t/year[1-3]. As the population grows, the need for rice continues to increase, while the amount of arable land that can be used for cultivation of various types of crops is limited. One of the ways to overcome this issue is to replace soil with other growing media for growing seedlings. Over the past decades, a lot of studies have been conducted to investigate the effect of different growing media on growth and productivity of different plants[4-6].

Appropriate type of growing media and its dosage are crucial to provide mechanical supports to the plants as well as water and mineral for growth and development of the plants[7]. One types of growing media that has been considered as a promising alternative is biochar due to its ability as nutrient retention so that plants can access the nutrients better[8]. In a study by Nemati *et al.*[9], biochar increases pH and cation-exchange capacity as well as decreases nutrient leaching up to 11%.

In addition to biochar, coco peat has been reported as one of the best substrates in soilless culture medium[10,11]. Coco peat is made of shredded coconut husks and has the ability as water and air retention. Coco peat is a hormone-rich medium that offers plants an ideal rooting medium and provides protection against root diseases and fungus[11]. Unlike peat moss that is rapidly depleted due to excess use, coco peat is a completely renewable resources which is an additional advantage for its application as a growing medium.

Compost is also one of the substrates typically used in growing medium because it contains a high organic matter and has a positive effect of the physical, chemical and biological properties of soils[12-14]. It has been reported that compost improves the structure of soil that decreases crust formation, surface runoff and erosion. The application of compost results in a higher volume of bonding space, residual and storage pores but a reduced volume of residual and storage pores which eventual results in a higher value of total porosity[15]. In addition, compost increases water retention and hydraulic conductivity of soil[16].

Systematic studies that investigate the effects of different combination of biochar, coco peat and compost together with soil and sand on plant growth cultivated using a water recirculation system are still very scarce. Hence, this study was carried out to determine the best combination of soil, sand, coco peat, biochar and compost on water holding capacity, plant height, number leaves, number of tillers, number of effective tillers, weight of biomass and productivity of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 cultivated using a water recirculation system.

MATERIALS AND METHODS

The seeds of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 was obtained from Balai Besar Penelitian Tanaman Padi Indonesia (Indonesian Center for Rice Research), Sukamandi, West Java. The growing medium used in this study consisted of ultisol soil, biochar and coco peat as well liquid nano-silica (brand name: Tenaz) were obtained from a local shop in Tanjungsari West Java. Compost used in this study was obtained from a compost processing facility at Institute Teknologi Bandung whereas coastal sand used in this study was obtained from a Cirebon, West Java.

Cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1: The cultivation of *Oryza sativa* L. var. INPARI 30 Ciherang Sub-1 was conducted in 20 L pots placed inside a screen house located at Institut Teknologi Bandung-Jatinangor Campus, Sumedang, West Java, Indonesia from January-May, 2018. Initially, all the substrates were for the growing media were mixed thoroughly according to composition shown in Table 1 before placed inside the cultivating containers. The seeds were germinated on a wet damp sack and after that sown using trays before transplanted into the pots that have been filled with the growing medium (one seedling/ container). Every cultivation condition was replicated in 6 pots. The bottom part of the pots was perforated (5 spots) to allow excess water came out from the containers. The excess water from each pot was contained inside a vessel placed under each pot. Each pot was watered daily with water at 50% of the water holding capacity of the growing media as shown in Table 1. The collected excess water was added with tap water to ensure that each container received the same amount of water every day.

Table 1: Composition of growing media and amount of water input for the cultivation of *Oryza Sativa* var. INPARI 30 Ciherang Sub-1 at Sumedang, West Java

Treatments	Composition	Water input (mL/day)
P	Soil:compost (1:1)	1675
PII	Soil:compost (1:2)	2240
PIII	Soil:compost: biochar (2:2:1)	1765
PIV	Soil:compost: biochar (1:2:2)	1765
PV	Soil:compost: biochar (2:2:1)+nano-silica	1255
PVI	Soil:compost: biochar (1:2:2)+nano-silica	1255
PVII	Sand:compost: biochar (2:2:1)	1579
PVIII	Sand:compost: biochar (1:2:2)	1199
PXI	Sand:compost: cocopeat (2:2:1)	1475
PX	Sand:compost: cocopeat (1:2:2)	1195

Data measurement: Plant height, number of leaves, number of tillers, number of effective tillers were measured periodically throughout the cultivation period. At the end of the cultivation period, the biomass was harvested and the weight of shoot and root were determined. Excess water for each pot was measured every day based on the volume of water that was drained through the bottom part of the pots.

Temperature, relative humidity, light intensity and wind velocity were measured once/week (08.00). Temperature and relative humidity were measured by using a thermo hygrometer (PCE-313 A, UK). Light intensity was measured by using a standard portable lux meter (Milwaukee MW 700, Hungary) whereas the wind velocity was measured by using a digital anemometer (Benetech GM 816, USA). Soil moisture was determined using a soil tester (Takemura DM-5 and DM-15, Japan) whereas the pH of soil was measured using a 4 in 1 digital pH moisture sunlight soil meter (KC 300, China). The soil moisture and pH were measured once every week (08.00)

The nutrient content in the water was determined at Water Quality Laboratory, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung. The nutrient content in soil and harvested biomass was analyzed at Raksa Buana Analytical Chemistry Laboratory (Bandung, West Java, Indonesia).

Statistical analysis: The evapotranspiration rate was calculated using the Penman-Monteith Eq.[17]:

$$ET_0 = \frac{0.408\Delta\left(R_n - G\right) + \gamma \frac{C_n}{T+273} U_2\left(e_s^{o} - e_a\right)}{\Delta + \gamma\left(1 + C_d U_2\right)} \quad (1)$$

$$ET_{crop} = ET_0 \cdot K_c \quad (2)$$

Where:

ET_0 = Potential evapotranspiration rate (mm/day)
R_n = Net irradiance (MJ/m^2/day)
G = Heat transfer to soil (MJ/m^2/day)
C_n = A numerator constant
U_2 = Wind velocity in m/sec (measured at an elevation of 2 m above the ground)
e_s^{o} = Saturated vapor pressure (kPa)
e_a = Actual vapor pressure (kPa)
C_d = A denominator constant
T = Temperature (°C)
ET_{crop} = Actual evapotranspiration rate in mm/day
K_c = Plant coefficient

The calculated evapotranspiration rate using Eq. 1 was multiplied with the surface area of the container (0.07065 cm^2) used in this study to obtain evapotranspiration rate (mL/day).

Water holding capacity (mL/day) of the growing media can be calculated[6] using the Eq. 3:

$$\text{Water holding capacity} = (W_I - W_E) + (W_A - ET_{crop}) \quad (3)$$

Where:

W_I = Provided water input in mL/day
W_E = Excess water (mL/day)
W_A = Accumulated water in the container since the previous day (mL/day)
ET_{crop} = Actual evapotranspiration rate (mL/day)

The wet and dry weight of rice roots, wet and dry weight of stems, weight of dry-milled and dry-harvested grains were measured by using an analytical balance (Precisa ES220 A, Swiss) at the end of the cultivation period (125-140 days after planting). The dry weight was obtained by drying the samples in an oven (Heratherm, Thermo Scientific, USA) at 70°C until the weight was constant. The moisture content of samples was calculated[6] using Eq. 4:

$$\text{Moisture content (\%)} = \frac{(ww - dw)}{ww} \times 100 \quad (4)$$

where, ww and dw are wet weight (g) and dry weight (g) of the samples, respectively.

RESULTS

Effect of growing media composition on the water holding capacity: The microclimate conditions particularly light intensity, temperature and relative humidity in the cultivation area were measured regularly throughout the cultivation period with average values of 17000-20000 lux, 25-35°C, 35-65%, respectively. The water holding capacity of the growing media investigated in this study was periodically measured and the results are shown in Fig. 1. The highest value of water holding capacity value at the end of cultivation period was recorded by PII (14147 mL) whereas the lowest value of water holding capacity was recorded for

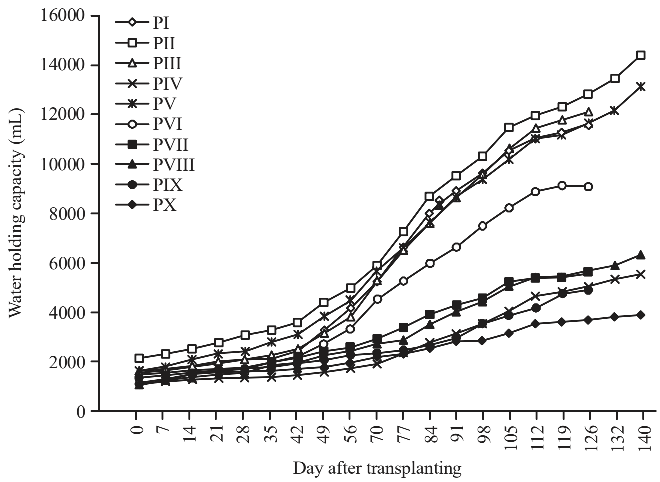

Fig. 1: Average water holding capacity of growing media for the cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 at Sumedang, West Java

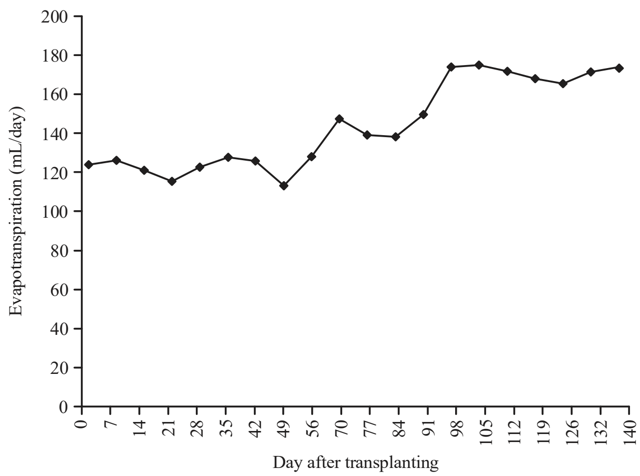

Fig. 2: Average evapotranspiration rate of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

PX (3897 mL). The evapotranspiration rate of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 shown in Fig. 2 lies in the range of 1.6-.5 mm/day (equivalent to 116 mL/day to 175 mm/day) with an average of around 1.9 mm/day (equivalent to 116 mL/day to 137 mm/day).

Effect of growing media composition on plant growth: Figure 3-6 show the effect of media composition average plant height, number of leaves, number of tillers and number of effective tillers. From Fig. 3, it can be observed that PIII had the highest average plant height (97 cm) whereas the lowest was observed from PIX with average plant height of 74 cm. Based on Fig. 4, the highest average number of leaves (221 leaves) was obtained from PIII after 84 days of transplanting and eventually reached a final average value approximately 150 leaves. A similar number of leaves was also achieved by the plants from PVIII, PII, PI. Figure 5 shows the average number of tillers whereas Fig. 6 shows the average number of effective tillers. The highest number of tillers (43 tillers) were also recorded from PIII.

Effect of growing media composition on productivity of biomass: At the end of the cultivation period, the plants were harvested and the weight of root and shoot (above ground biomass) was determined and the results are shown in Fig. 7. The average weight of the root varies from 27-417 g/pot whereas the average weight of the shoot varies from 60-331 g/pot. Figure 8-9 show the total content of nitrogen and silicon dioxide in the growing media. From the figure, it can be observed that highest total content of nitrogen (0.9%)

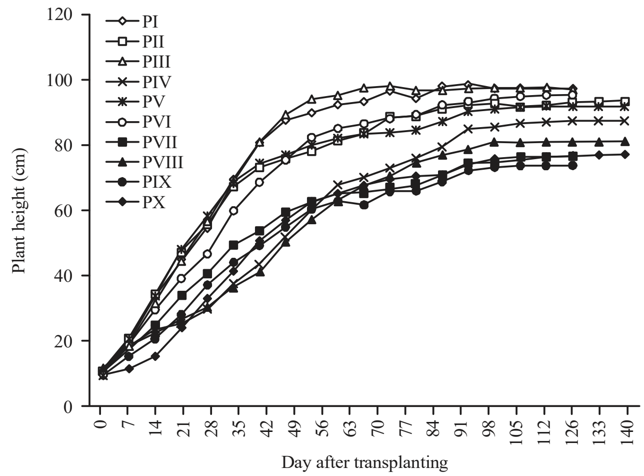

Fig. 3: Average plant height of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

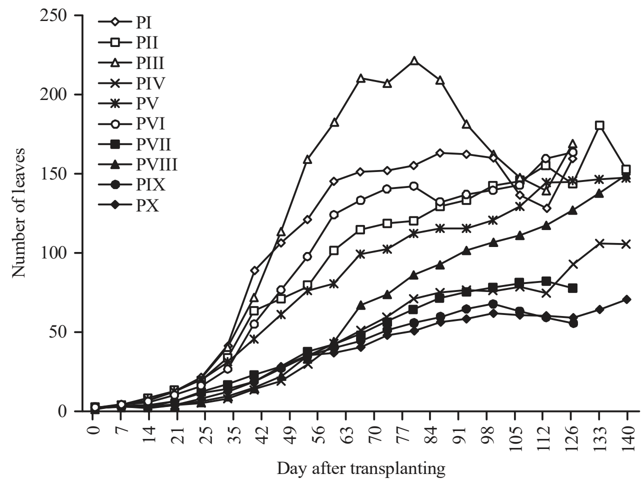

Fig. 4: Average number of leaves of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

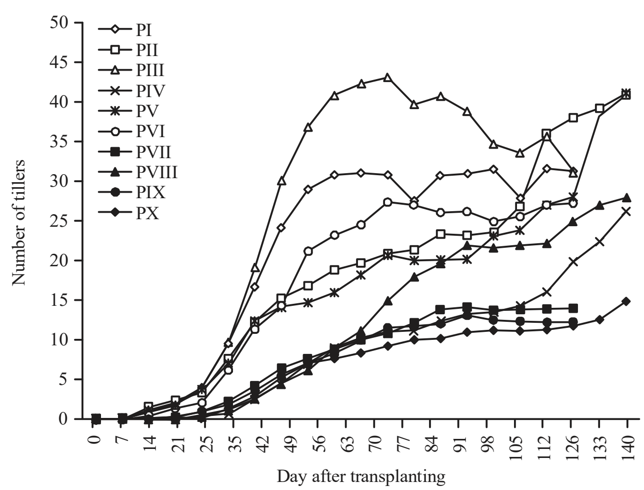

Fig. 5: Average number of tillers of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

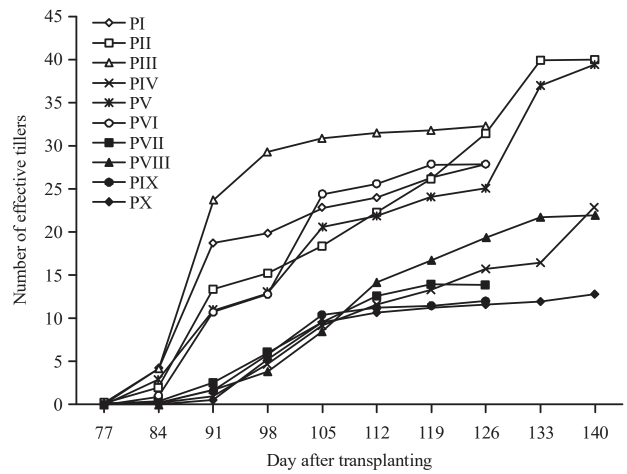

Fig. 6: Average number of effective tillers of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

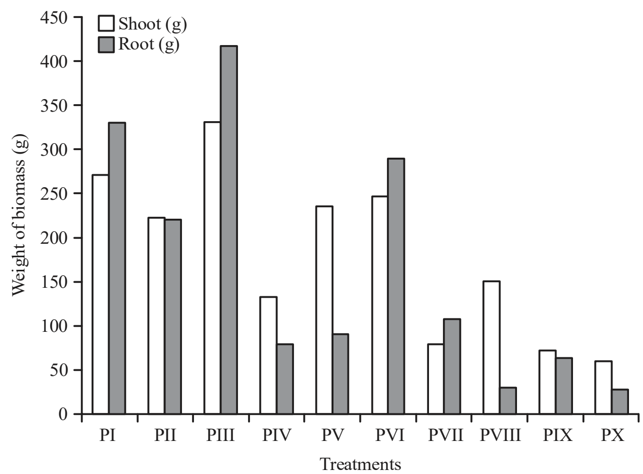

Fig. 7: Average biomass weight of harvested *Oryza sativa* (shoot and root) var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

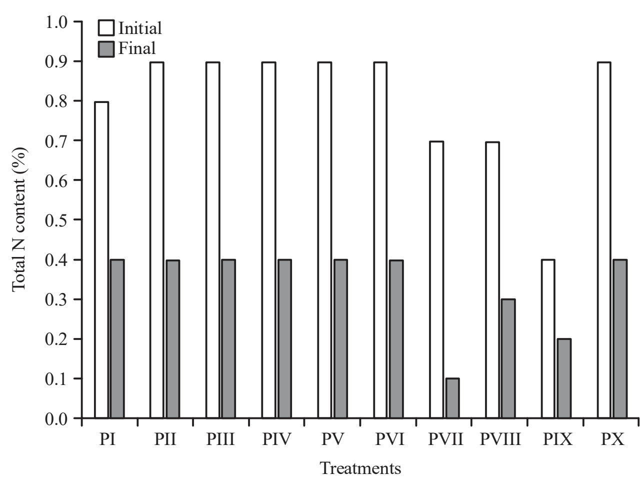

Fig. 8: Initial and final nitrogen content in growing media used for the cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

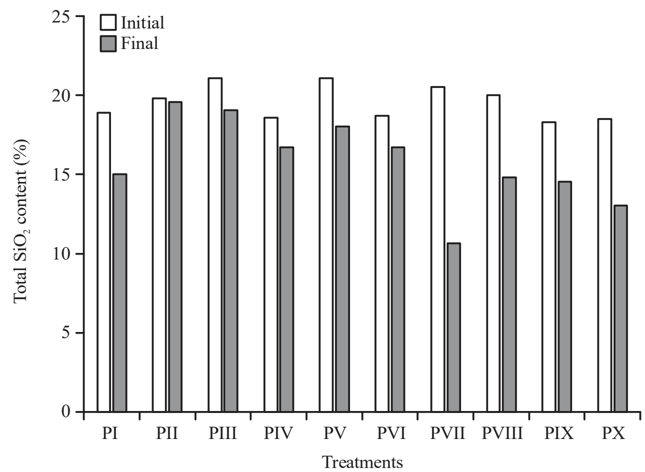

Fig. 9: Total content SiO_2 in the growing media for the cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

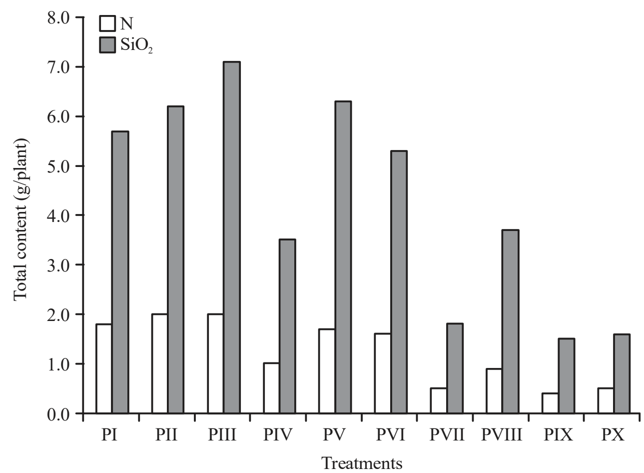

Fig. 10: Total content of N and SiO_2 content in harvested shoot of *Oryza Sativa* var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

was available in the growing media of PII, PIII, PIV, PV, PVI and PX whereas the highest total content of silicon dioxide (21.2%) was available in the growing media of PIII and PV.

The total content of nitrogen and silicon dioxide in the harvested shoot was also determined and the results are shown Fig. 10. Plants from PIII had the highest amount of silicon dioxide (7.1 g/plant) and nitrogen (2 g/plant) as a result of higher nitrogen and silicon dioxide content in the growing medium (PIII) and able to be absorbed by the plants. Plants from PIII had the highest the highest percentage of filled grains (92%) and the highest productivity of dry milled grains with (63 g/pot/harvest) as shown in Fig. 11.

DISCUSSION

The growing media composition highly influenced plant growth and productivity of the harvested rice. Best results were obtained when *Oryza sativa* var. INPARI 30 Ciherang Sub-1 was cultivated using soil:compost:biochar (a ratio of 2:2:1) with an estimated rice productivity of 0.18 kg m^{-2}/harvest. This value is comparable with the productivity of milled grain reported by Indonesian Central Bureau of Statistics, 3.4 t ha^{-1} of rice which is equivalent to 0.11 kg m^{-2}/harvest. In another study by Siddiq *et al.*[18], a maximum productivity of 4.55 t ha^{-1} of rice which is equivalent to approximately 0.15 kg m^{-2}/harvest was reported when different rice cultivars were cultivated using a

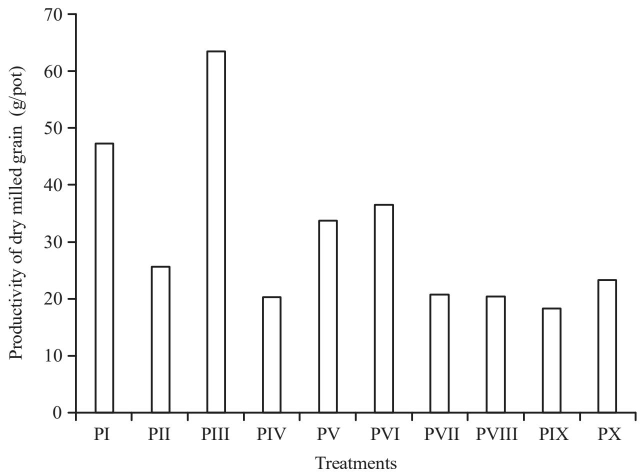

Fig. 11: Average productivity of dry milled grain of *Oryza sativa* (shoot and root) var. INPARI 30 Ciherang Sub-1 cultivated at Sumedang, West Java

conventional growing media particularly soil with different rates of nitrogen, phosphorus and potassium.

A relatively higher estimated productivity of rice was obtained in this study most probably due to the optimum composition of the growing media comprising of soil, compost and biochar apart from the added fertilizer during the cultivation period. In addition, a water recycling system applied in this study contributes to the recycling of nutrients into the plants for better plant growth that would otherwise losses in the conventional paddy field. As such highlights that appropriate composition of soil:compost:biochar (a ratio of 2:2:1) determined in this study is promising to be investigated in a large scale.

The results obtained in this study are supported by the microclimate conditions during the cultivation period that was still within tolerable range of optimum light intensity (20000-50000 lux), temperature (24-31°C) and relative humidity (33-90%) for the cultivation of *Oryza sativa* reported in the literature[18,19]. The wind velocity was almost negligible because the cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 was carried out inside a closed screen house.

The physiological growth of plant is highly influenced by the amount of water available in the growing media which is related to the ability of the growing media to hold water. All the growing media used in this study had a water input of approximately 1200 mL/day and higher as recommended by Food and Agriculture Organization of the United Nations to increase the ability of the growing media to hold enough water for the growth of plants despite of water loss due to water plant uptake, evapotranspiration and percolation.

The highest value of water holding capacity value at the end of cultivation period was recorded by PII which may be caused by the presence of compost that contributes to a higher volume of bonding space, residual and storage pores increase water retention[15,16]. The lowest value of water holding capacity was recorded for PX which may be caused by the presence of sand that has a relatively low waterproof capacity[20].

The amount of water in the growing media is also highly influenced by the evapotranspiration rate throughout the cultivation period. The evapotranspiration rates were still within range of 1-7 mm/day reported by previous studies[21,22]. According to Zotarelli *et al.*[23], evapotranspiration is strongly influenced by air temperature, relative humidity, wind speed and light intensity. As such is also observed in this study that the highest evapotranspiration rate occurred when the light intensity was the highest (20000 lux) throughout the cultivation period.

The provision of biochar in PIII positively affected plant height due to the increased nutrition available to the plants[24,25]. It has been reported by Zia *et al.*[26], the silica content found in biochar could increase plant growth especially the growth of stems and tillers. The number of effective tillers was influenced by the availability of nutrients in the soil[27], the number of tillers and the number of leaves. The growth of tillers was strongly influenced by the use of nitrogen, especially in the initial phase[28].

The addition of biochar could increase the resistance of nitrogen element by preventing nitrate discharges which can increase soil nitrification thereby increasing the availability of N for the plants[29]. The silica contained in biochar could also increase the number of tillers. Hence, the addition of biochar in the growing media improves soil quality to promotes a better plant growth particularly the root and shoot[30].

A higher content of nitrogen and silicon dioxide in PIII promotes a better plant height, number of leaves, number of tillers, effective number of tillers and consequently a better average biomass weight and productivity of dry milled grains as well. The final total content of nitrogen and silicon dioxide decreased as compared to the initial values indicates that the nutrients were being absorbed by the plant for plant growth.

A lower plant height for PIX may be due to a relatively high amount of sand in the growing media as compared to the other growing media. The sand may still contain salt the that could inhibit plant growth[31] that also results in lower number of leaves, tillers and effective tillers. A relatively low amount of harvested biomass for plants from PX may be due to a larger amount of cocopeat in the growing medium. The presence of tannin in the cocopeat act as barrier in absorption of nutrition and consequently hinders plant growth[32].

CONCLUSION

Cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 using a water recirculation system and different growing media composition had been studied. The growing media composition highly influenced plant growth and productivity of the harvested rice. Best results were obtained when *Oryza sativa* var. INPARI 30 Ciherang Sub-1 was cultivated using soil:biochar:compost (a ratio of 2:1:2) with an estimated rice productivity of 0.18 kg m^{-2} per harvest. It can be concluded that an appropriate combination of soil, biochar and compost may be recommended as a growing media for the cultivation of *Oryza sativa* var. INPARI 30 Ciherang Sub-1 using a water recirculation system.

ACKNOWLEDGMENT

This study was financially supported by a research grant (P3MI KK ATB 2017) from Institut Teknologi Bandung.

SIGNIFICANCE STATEMENT

This study discover the optimum media composition on growth and productivity of *Oryza sativa* L. cultivated using a water recirculation system that can be beneficial for paddy farmers. This study will help the researcher to uncover the critical areas of soilless cultivation of paddy and recycling of nutrients in the growing media that many researchers were not able to explore. Thus, a new theory related to recycling of nutrients in growing media and other related issues may be arrived at.

REFERENCES

1. Muthayya, S., J.D. Sugimoto, S. Montgomery and G.F. Maberly, 2014. An overview of global rice production, supply, trade and consumption. Ann. N. Y. Acad. Sci., 1324: 7-14.
2. Nath, A., M.A. Kashem and S. Ali, 2018. Growth and yield performance of boro rice (BRRI dhan58) under different fertilizer and agronomic management in wetland. Int. J. Agric. Res., 13: 54-57.
3. Vijayakumar, M., S. Ramesh, B. Chandrasekaran and T.M. Thiyagarajan, 2006. Effect of system of rice intensification (SRI) practices on yield attributes yield and water productivity of rice (*Oryza sativa* L.). Res. J. Agric. Biol. Sci., 2: 236-242.
4. Manh, V.H. and C.H. Wang, 2014. Vermicompost as an important component in substrate: Effects on seedling quality and growth of muskmelon (*Cucumis melo* L.). APCBEE Procedia, 8: 32-40.
5. Mehmood, T., I. Bibi, M. Shahid, N.K. Niazi and B. Murtaza *et al.*, 2017. Effect of compost addition on arsenic uptake, morphological and physiological attributes of maize plants grown in contrasting soils. J. Geochem. Explor., 178: 83-91.
6. Truong, H.D., C.H. Wang and T.T. Kien, 2017. Study on effects of different medium compositions on growth and seedling quality of two tomato varieties under greenhouse conditions. Commun. Soil Sci. Plant Anal., 48: 1701-1709.
7. Radha, T., A. Ganeshamurthy, D. Mitra, K. Sharma, T. Rupa and G. Selvakumar, 2018. Feasibility of substituting cocopeat with rice husk and saw dust compost as a nursery medium for growing vegetable seedlings. Bioscan, 13: 659-693.
8. Parr, J.F. and L.A. Sullvian, 2011. Phytolith occluded carbon and silica variability in wheat cultivars. Plant Soil., 342: 165-171.
9. Nemati, M.R., F. Siamrd, J.P. Fortin and J. Beaudoin, 2015. Potential use of biochar in growing media. Vadose Zone J., Vol. 14, No. 6. 10.2136/vzj2014.06.0074.
10. Hussain, A., K. Iqbal, S. Aziem, P. Mahato and A.K. Negi, 2014. A review on the science of growing crops without soil (soilless culture): A novel alternative for growing crops. Int. J. Agric. Crop Sci., 7: 833-842.
11. Pill, W.G. and K.T. Ridley, 1998. Growth of tomato and coreopsis in response to coir dust in soilless media. HortTechnology, 8: 401-406.
12. Khater, E.S.G., 2015. Some physical and chemical properties of compost. Int. J. Waste Resourc., Vol. 5, No. 1. 10.4172/2252-5211.1000172.
13. Fichtner, E.J., D.M. Benson, H.G. Diab and H.D. Shew, 2004. Abiotic and biological suppression of *Phytophthora parasitica* in a horticultural medium containing composted swine waste. Phytopathology, 94: 780-788.
14. Hargreaves, J.C., M.S. Adl and P.R. Warman, 2008. A review of the use of composted municipal solid waste in agriculture. Agric. Ecosyst. Environ., 123: 1-14.

15. Głąb, T., 2014. Water retention and repellency of a sandy soil amended with municipal compost. Compost Sci. Util., 22: 47-56.
16. Ramos, M.C., 2017. Effects of compost amendment on the available soil water and grape yield in vineyards planted after land levelling. Agric. Water Manage., 191: 67-76.
17. Monteith, J.L. and M.H. Unsworth, 1990. Principles of Environmental Physics. 2nd Edn., Edward Arnold, New York.
18. Siddiq, S., A. Anayat, A. Sattar, M.A. Ali and M. Yaseen, 2011. Response of different rice (*Oryza sativa* L.) cultivars to different NPK levels in the central cropping zone of Punjab. Agric. Sci. Digest., 31: 155 -160.
19. Jing, Q., H. van Keulen, H. Hengsdijk, W. Cao, P.S. Bindraban, T. Dai and D. Jiang, 2009. Quantifying N response and N use efficiency in Rice-Wheat (RW) cropping systems under different water management. J. Agric. Sci., 147: 303-312.
20. Yu, O.Y., B. Raichle and S. Sink, 2013. Impact of biochar on the water holding capacity of loamy sand soil. Int. J. Energy Environ. Eng., Vol. 4. 10.1186/2251-6832-4-44.
21. Tabbal, D.F., B.A.M. Bouman, S.I. Bhuiyan, E.B. Sibayan and M.A. Sattar, 2002. On-farm strategies for reducing water input in irrigated rice, case studies in the Philippines. Agric. Water Manage., 56: 93-112.
22. Abdullahi, A.S., M.A.M. Soom, D. Ahmad and A.R.M. Shariff, 2013. Characterization of rice (*Oryza sativa*) evapotranspiration using micro paddy lysimeter and class "a" pan in tropical environments. Aust. J. Crop Sci., 7: 650-658.
23. Zotarelli, L., M.D. Dukes, C.C. Romero, K.W. Migliaccio and K.T. Morgan, 2010. Step by step calculation of the penman-monteith evapotranspiration (FAO-56 method). Institute of Food and Agricultural Sciences. University of Florida. http://edis.ifas.ufl.edu/pdffiles/ae/ae45900.pdf
24. Karhu, K., T. Mattila, I. Bergstrom and K. Regina, 2011. Biochar addition to agricultural soil increased CH_4 uptake and water holding capacity-results from a short-term pilot field study. Agric. Ecosyst. Environ., 140: 309-313.
25. Cuong, T.X., H. Ullah, A. Datta and T.C. Hanh, 2017. Effects of silicon-based fertilizer on growth, yield and nutrient uptake of rice in tropical zone of Vietnam. Rice Sci. 24: 283-290.
26. Zia, Z., H.F. Bakhat, Z.A. Saqib, G.M. Shah and S. Fahad *et al*., 2017. Effect of water management and silicon on germination, growth, phosphorus and arsenic uptake in rice. Ecotoxicol. Environ. Saf., 144: 11-18.
27. Divya, G., K.P. Vani, P.S. Babu and K.S. Devi, 2017. Yield attributes and yield of summer pearl millet as influenced by cultivars and integrated nutrient management. Int. J. Curr. Microbiol. Applied Sci., 6: 1491-1495.
28. Chu, G., Z. Wang, H. Zhang, J. Yang and J. Zhang, 2016. Agronomic and physiological performance of rice under integrative crop management. Agron. J., 108: 117-128.
29. Darusman, Syahruddin, Syakur and Manfarizah, 2017. Biochar and Tillage systems influenced on soil physical properties. Aceh Int. J. Sci. Technol., 6: 68-74.
30. Liu, Z., B. Dugan, C.A. Masiello and H.M. Gonnermann, 2017. Biochar particle size, shape and porosity act together to influence soil water properties. PloS One, Vol. 12, No. 6. 10.1371/journal.pone.0179079.
31. Skogerboe, G.V. and W.R. Walker, 1972. Salinity control measures in the Grand valley. Proceedings of National Conference on Managing Irrigated Agriculture to Improve Water Quality, May 16-18, 1972, US Environmental Protection Agency and Colorado State University, Colorado.
32. Madusari, S., 2018. The effects of soil amended with solid fibrous waste on the morphological quality of oil palm (*Elaeis guineensis* Jacq.) seedling. J. Applied Sci. Adv. Technol., 1: 15-22.