Regular Article
pISSN: 2288-9744, eISSN: 2288-9752
Journal of Forest and Environmental Science
Vol. 35, No. 1, pp. 25-30, March, 2019
https://doi.org/10.7747/JFES.2019.35.1.25

JFES
Journal of Forest and Environmental Science

Effects of Biomaterials Mixed with Artificial Soil on Seedling Quality of *Fraxinus Rhynchophylla* in a Containerized Production System

Huong Thi Thuy Dao, Woo Bin Youn, Si Ho Han, Jeong Min Seo, Aung Aung, Ji Young An and Byung Bae Park*
Department of Environment and Forest Resources, Chungnam National University, Daejeon 34134, Republic of Korea

Abstract

The composition of artificial soil in a containerized seedling production plays an important role in seedling quality as well as environmental issues. We investigated the effects of different types of biomaterials and mixed ratio with artificial soil on the growth of *Fraxinus rhynchophylla* seedlings. Soil medium was supplemented with 3 levels (0%, 10%, 20%) of pine bark, mushroom sawdust and rice husk. Root collar diameter (RCD), height growth, and biomass have significantly increased when rice husk was applied. Compared with the control, RCD and height growth showed highest in 20% rice husk treatment with an increase of 5.7% and 17.6%, respectively. In contrast, the treatments of pine bark and mushroom sawdust showed lower results in growth parameters (RCD, height growth, and total biomass) than control. Seedling quality index was also highest at the 20% rice husk treatment, but there was not statistically different among treatments. Our results suggested rice husk can be substituted up to 20% of substrates for containerized *F. rhynchophylla* seedling production system.

Key Words: biomaterials, by-products, quality index, seedling growth

Introduction

Use of containers is one of efficient methods to produce nursery crops (Simmons and Derr 2007). Cultivation by container production has many advantages, including less damage occurring to the root system when transplanted, helping seedlings establish better after transplanting, decreased labor and land acquisition costs for production, increased product availability and longevity (Mathers et al. 2007). A growing media, which is one of the critical influences in a containerized seedling production, can contain two or more materials, rather than a single ingredient. Highly valuable materials such as soil, peat, sand, perlite and vermiculite are generally used as substrates (Tinus and McDonald 1979; Landis et al. 1990). These substrates help to hold on adequate air space and the water-holding ability during plant production so that growing conditions remain advantage for plant growth (Jackson et al. 2009).

The mixed of the materials in artificial soil in a containerized seedling production plays an important role in changing the soil properties as well as economic values. Nowadays, many recycled organic materials used in the greenhouse production are tree barks, composted yard, garbage and animal wastes, rice and peanut husk, mushroom compost, and cotton gin trash (Li et al. 2009). The use of these materials as soil amendments to achieve benefits in terms of plant performance and soil amelioration have been studied in the recent years and good effects have been ob-

Received: August 10, 2018. Revised: March 4, 2019. Accepted: March 4, 2019.

Corresponding author: Byung Bae Park

Department of Environment and Forest Resources, Chungnam National University, Daejeon 34134, Republic of Korea
Tel: 82-42-8215747, Fax: 82-42-8257850, E-mail: bbpark@cnu.ac.kr

tained (Garg et al. 2005). For example, rice husk is the main by-product of agriculture from rice milling industry, covering about one-fifth of the harvested weight of rice crops (Beagle 1978), which improves not only crop performance but also soil physical properties (Anikwe 2000). Similarly, pine bark is a common and popular substrate in container production (Guerrero et al. 2002; Warren and Bilderback 2004), which provides good aeration and has a higher ability to absorb cations than the field soil (Simmons and Derr 2007). Besides, mushroom sawdust has been identified as an alternative to peat to protect environment, conserve natural resources and reduce nutritional requirements of seedlings and containerized plants (Medina et al. 2009; Eudoxie and Alexander 2011).

Some biomaterials, such as bark, rice husk, mushroom sawdust, have been used in agricultural field, but rarely used in forestry nursery. The purpose of this study was to investigate the effects of mixing materials with different ratios on the growth and quality of *Fraxinus rhynchophylla* in a containerized seedling production system. This research can extend our knowledge on which and how much biomaterial should be applied for *F. rhynchophylla* to obtain the most effective result in containerized production system.

Materials and Methods

Study site and species

Our study was implemented in a greenhouse with a total area of 728 m^2 at Forest Technology and Management Research Center, in Pocheon, Republic of Korea (37°45′N, 127°10′E). This is an automatic greenhouse facilitated with fertilization, irrigation, ventilation and environmental control system. The mean temperature was 13.8°C and the mean relative humidity was 65.5% in 2017.

F. rhynchophylla seeds used in our study were germinated in nursery during early March 2017 and transplanted to the cells of tray in late March 2017.

Experimental design

Seedlings were grown in cells of the tray, which has the size of 32 cm×40 cm with 20 cells. Tray's cells are cylinder with 6.8 cm in diameter and 15 cm in depth and have a volume of 400 mL.

We used mushroom sawdust, pine bark and rice husk as three biomaterials in the current study. Pine bark was delivered from Wood Distribution Center in Donghae city, Gangwon province; mushroom sawdust was from Forest Mushroom Research Center in Yeoju city, Gyeonggi province; and carbonized rice husk was purchased from the market. The materials were then pulverized using a pulverizer with mesh size of 2 mm in factory of department of Biobased Materials at Chungnam National University, Daejeon, Republic of Korea. The cells were filled with artificial soil, which was mixture of peatmoss, perlite, vermiculite at a ratio of 1:1:1 by volume, following the recommendation for growth of tree seedlings in a containerized seedling production system (Landis et al. 1990). The physical and chemical properties of mixed biomaterials with growing media such as pH, EC and bulk density were shown in Table 1.

The 3×3 combined experimental design was applied to test the effects of three different biomaterials and three mixed ratios on growth and quality of *F. rhynchophylla* seedlings. Soil was supplemented with 0% for the control, 10% and 20% in volume of each biomaterial. The control treatment was set with full artificial soil in volume of 400 mL. The treatments of 10% mixed biomaterial were established by mixing 40 mL of pine bark, mushroom sawdust or rice husk with 360 mL of artificial soil. To get 20%

Table 1. The physical and chemical properties of three biomaterials after mixing with artificial soil (Aung et al. 2019; Seo et al. 2019)

Biomaterials	Control	Mushroom sawdust		Pine bark		Rice husk	
Mixed ratio		10%	20%	10%	20%	10%	20%
pH	5.8	5.4	5.0	4.5	4.9	5.0	5.2
EC (dS m^{-1})	0.13	0.11	0.15	0.18	0.12	0.15	0.15
Bulk density (g cm^{-3})	0.36	0.44	0.43	0.40	0.36	0.38	0.37

mixed ratio, 80 mL of three biomaterials was incorporated with 320 ml of artificial soil. Each treatment was replicated five times in a completely randomized design. After artificial soil was mixed with different ratios of three biomaterials, *F. rhynchophylla* seedlings were transplanted into the cells in late March 2017. The trays were then put on a platform, which was elevated 60 cm above the greenhouse floor.

Growth measurements

We measured seedling growth in response to each treatment during August and October 2017. The innermost 6 seedlings were chosen from each tray as samples for growth measurement. Height was measured from the base to the tip of the highest branch of sample seedlings. Digital caliper was used to measure the root collar diameter of the seedlings from 1cm above the ground. Height was measured in cm and root collar diameter in 0.01 mm (Thompson and Schultz 1995). Seedlings were harvested in October and separated to root, stem and leaf. Roots were washed in clean water to remove all soil particles. Then, all parts of seedlings were dried at 65°C for 48 hours to constant weight. After that, aboveground and belowground dry weights were recorded. We used the method suggested by Sestak et al. (1971) to calculate total mass production and ratio of aboveground to belowground biomass.

Quality index calculation

The Dickson quality index－DQI (Dickson et al. 1960) was used as a tool for evaluating seedling quality and calculated as follows:

$$(DQI = SD) / (HD + SR)$$

where SD is seedling's total dry weight (g), HD is the ratio of seedlings height (cm) to root collar diameter (mm), and SR is the ratio of shoot weight (g) to root dry weight (g) (Deans et al. 1989; Binotto et al. 2010; Cho et al. 2017).

Statistical analysis

Two-way analysis of variance (ANOVA) with Duncan's multiple comparison tests was applied to analyze the effects of biomaterials with mixing ratios on seedling height, root collar diameter, total dry weight, and quality index measured in October 2017. All probabilities were tested at a significance level of 0.05.

Results

Seedling height

The seedling height was significantly influenced by biomaterials and mixed ratio ($p < 0.05$). The height was highest at 20% rice husk followed by control, mushroom sawdust 10%, pine bark 10%, rice husk 10%, mushroom sawdust 20% and lowest at 20% pine bark (Fig. 1).

Root collar diameter

Root collar diameter followed the same trend with seed-

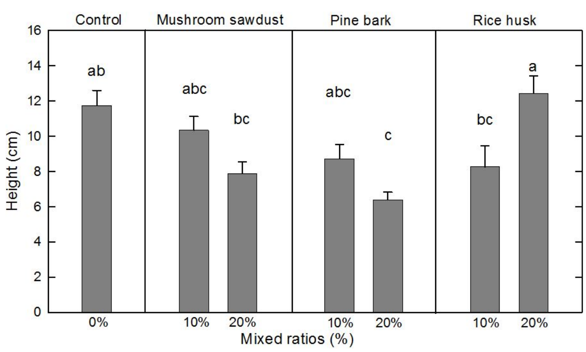

Fig. 1. Height growth of *Fraxinus rhynchophylla* applied with 3 biomaterials and 3 mixed ratios in a containerized seedling production system. Different letters represent significant differences ($p < 0.05$) between treatments. Vertical bars represent one standard error of the mean ($n=5$).

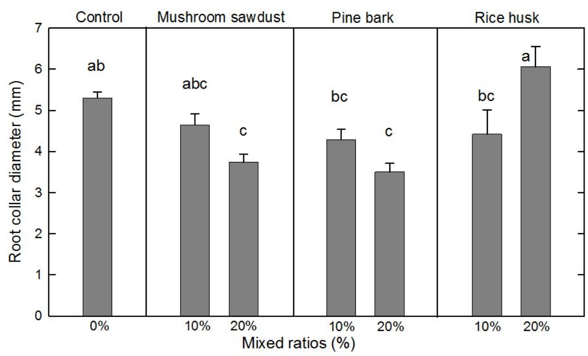

Fig. 2. Root collar diameter growth of *Fraxinus rhynchophylla* applied with 3 biomaterials and 3 mixed ratios in a containerized seedling production system. Different letters represent significant differences ($p < 0.05$) between treatments. Vertical bars represent one standard error of the mean ($n=5$).

ling height with highest *F. rhynchophylla* diameter observed in treatment applied with 20% rice husk. The lowest root collar diameter was resulted in 20% mushroom sawdust and 20% pine bark treatments (Fig. 2).

Seedling biomass

The amount of leaf, stem, and root dry biomass showed highest at 20% rice husk treatment followed by control treatment with 46.4 and 44.2 g/tree, respectively. Total dry biomass was observed to be lowest at 20% mushroom sawdust treatment. There was no difference showed among other treatments (Fig. 3).

The highest proportion in the root biomass was shown at 20% rice husk treatment with an increase of 10.6% compared with control indicating that root system was developed well in this treatment (Table 2).

Seedling quality index

Quality index of *F. rhynchophylla* was ranged from 9.1 to 11.2. The highest one was shown at 20% rice husk, followed by 20% pine bark and lowest at 20% mushroom sawdust, but there were no statistical differences among treatments (Fig. 4)

Discussion

In our study, treatments of biomaterials and mixed ratio are significant for most measured parameters on *F. rhynchophylla* seedlings (Figs. 1-4). All the measured parameters (height, root collar diameter, total biomass, and seedling quality index) consistently showed the highest results in 20% rice husk treatment. Our findings are in agreement with Mori (1994), who reported that charcoaled rice husks

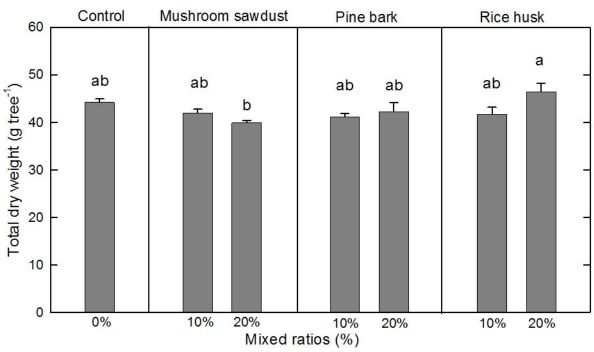

Fig. 3. Total dry weight of *Fraxinus rhynchophylla* applied with 3 biomaterials and 3 mixed ratios in a containerized seedling production system. Different letters represent significant differences ($p<0.05$) between treatments. Vertical bars represent one standard error of the mean (n=5).

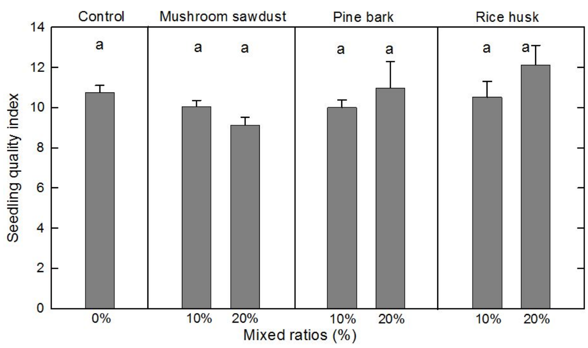

Fig. 4. Seedling quality index of *Fraxinus rhynchophylla* applied with 3 biomaterials and 3 mixed ratios in a containerized seedling production system. Different letters represent significant differences ($p<0.05$) between treatments. Vertical bars represent one standard error of the mean (n=5).

Table 2. Leaf, stem, root dry weight and biomass allocation of *Fraxinus rhynchophylla* applied with 3 biomaterials and 3 mixed ratios in a containerized seedling production system. Parentheses represent one standard error of the mean (n=5)

Biomaterials	Mixed ratio (%)	Leaf ($g/tree^{-1}$)	Stem ($g/tree^{-1}$)	Root ($g/tree^{-1}$)	R/S ratio[a] (%)	L/A ratio[b] (%)
Control	0	11.0 (0.1)	18.0 (0.2)	15.1 (0.6)	38.0 (0.2)	51.8 (1.9)
Mush-room	10	10.7 (0.1)	17.3 (0.3)	14.0 (0.5)	38.2 (0.6)	50.1 (1.5)
	20	10.6 (0.2)	17.3 (0.1)	12.0 (0.3)	38.0 (0.3)	43.3 (0.8)
Pine bark	10	10.6 (0.2)	17.5 (0.2)	13.1 (0.5)	37.7 (0.1)	46.5 (1.1)
	20	11.2 (0.5)	17.5 (0.3)	13.5 (1.2)	39.0 (0.7)	46.7 (3.1)
Rice husk	10	10.9 (0.4)	17.3 (0.2)	13.5 (0.9)	38.5 (0.6)	47.5 (2.3)
	20	11.4 (0.4)	18.4 (0.4)	16.7 (1.3)	38.1 (0.6)	55.9 (3.7)

[a]R/S ratio: Root to shoot ratio; [b]L/A ratio: Leaf to aboveground ratio.

could induce the growth of *Scleroderma sp*. seedlings substantially in the nursery.

It was reported that transplant shock in spruce plantations can be equal to 1 or 2 years of growth loss in planted spruce seedlings (Vyse 1981), so reduction of transplant shock is necessary for better survival and growth of seedlings. Jacobs et al. (2005) reported positive relationships between seedling root biomass and field performance. In our study, we observed highest root biomass (16.7 g/tree) in 20% rice husk treatment, which can be expected best field performance. Evans and Gachukia (2007) verified that fresh rice hulls could be used to provide drainage and air-filled pore space which can lead to better root growth. Sambo et al. (2008) indicated that all of the ground rice hulls had a higher air-filled pore space than peat from 10% to 20% (Bunt 1988; Jenkins and Jarrell 1989) or at least 45% (Boertje 1984). Rose et al. (1991) reported same results with our finding that seedlings with larger root-volume category (>13 cm^3) resulted significantly greater height growth than those with smaller category (<9 cm^3) in a study using Douglas-fir (*Pseudotsuga menziesii*).

Mattsson (1997) signified that there are two types of seedling quality assessment: morphological and physiological, in which morphological quality is based on height, stem diameter, root mass, shoot mass, and shoot: root ratio, whereas physiological quality is based on the internal functions of seedling (for example: water potential, mineral nutrition). Growing plant in containers can change growth, function and morphology of root systems (Mathers et al. 2007). Even though seedlings' height and root collar diameter are commonly evaluated features in seedling quality, aboveground morphology is not always an exact predictor of performance after out-planting (Chavasse 1977). Belowground parts can usually be assessed as more accurate indicator for seedling quality (Davis and Jacobs 2005). Our study resulted highest in both above and belowground biomass in 20% rice husk treatment, and consequently, quality index too. Better growth of belowground parts (root system) could adapt well in new environment, leading to successful establishment of forest plantations. To adapt and establish well in initial year of planting is the most important factor for survival of seedlings in the field. Lordan et al. (2013) stated soil amendment with rice husk substrate enhanced soil conditions, supporting a better soil environment for root activity and thereby resulted in better plant performance. Our study can conclude that 20% rice husk treatment to be the best for out-planting of *F. rhynchophylla* seedlings.

Conclusion

We suggest to apply 20% rice husk to growing media for *F. rhynchophylla* in order to improve seedling quality, which can translate better survival and performance of transplants for successful forest restoration. Further research for mixing biomaterials to growing media should concentrate on using 20% rice husk mixed ratio to different tree species other than *F. rhynchophylla*, because interesting outcomes could be resulted due to different nature of tree species.

Acknowledgments

This study was carried out with the support of 'R&D Program for Forest Science Technology (Project No. 2018112D10-1920-BB01)' provided by Korea Forest Service (Korea Forestry Promotion Institute - KoFPI). We would like to thank KoFPI for supporting Huong Thi Thuy Dao to study in Republic of Korea.

References

Anikwe MAN. 2000. Amelioration of a Heavy Clay Loam Soil with Rice Husk Dust and its Effect on Soil Physical Properties and Maize Yield. Bioresour Technol 74: 169-173.

Aung A, Youn WB, Seo JM, Dao HTT, Han SH, Cho MS, Park BB. 2019. Effects of three biomaterials mixed with growing media on seedling quality of *Prunus sargentii*. For Sci Technol [E-pub] doi: 10.1080/21580103.2018.1557564.

Beagle EC. 1978. Rice-Husk Conversion to Energy. Food and Agriculture Organization, Rome.

Binotto AF, Lúcio AD, Lopes SJ. 2010. Correlations Between Growth Variables and the Dickson Quality Index in Forest Seedlings. CERNE 16: 457-464.

Boertje GA. 1984. Physical Laboratory Analyses of Potting Composts. Acta Hortic 150: 47-50.

Bunt Ac. 1988. Media and Mixes for Container-Grown Plants: A Manual on the Preparation and Use of Growing Media for Pot Plants. Unwin Hyman, London.

Chavasse CGR. 1977. The Significance of Planting Height as an Indicator of Subsequent Seedling Growth. N Z J For 22:

283-296.

Cho MS, Meng L, Song JH, Han SH, Bae K, Park BB. 2017. The Effects of Biochars on the Growth of *Zelkova Serrata* Seedlings in a Containerized Seedling Production System. For Sci Technol 13: 25-30.

Davis AS, Jacobs DF. 2005. Quantifying Root System Quality of Nursery Seedlings and Relationship to Outplanting Performance. New For 30: 295-311.

Deans JD, Mason WL, Cannell MGR, Sharpe AL, Sheppard LJ. 1989. Growing regimes for bare-root stock of Sitka spruce, Douglas fir and Scots pine. 1. Morphology at the end of the nursery phase. For Suppl 62:53-60.

Dickson A, Leaf AL, Hosner JF. 1960. Quality Appraisal of White Spruce and White Pine Seedling Stock in Nurseries. For Chron 36: 10-13.

Eudoxie GD, Alexander IA. 2011. Spent Mushroom Substrate as a Transplant Media Replacement for Commercial Peat in Tomato Seedling Production. J Agric Sci 3: 41-49.

Evans MR, Gachukia MM. 2007. Physical Properties of Sphagnum Peat-Based Root Substrates Amended with Perlite or Parboiled Fresh Rice Hulls. HortTechnology 17: 312-315.

Garg RN, Pathak H, Das DK, Tomar RK. 2005. Use of Flyash and Biogas Slurry for Improving Wheat Yield and Physical Properties of Soil. Environ Monit Assess 107: 1-9.

Guerrero F, Gascó JM, Hernández-Apaolaza L. 2002. Use of Pine Bark and Sewage Sludge Compost as Components of Substrates for *Pinus Pinea* and *Cupressus Arizonica* Production. J Plant Nutr 25: 129-141.

Jackson BE, Wright RD, Seiler JR. 2009. Changes in Chemical and Physical Properties of Pine Tree Substrate and Pine Bark During Long-term Nursery Crop Production. HortScience 44: 791-799.

Jacobs DF, Salifu KF, Seifert JR. 2005. Relative Contribution of Initial Root and Shoot Morphology in Predicting Field Performance of Hardwood Seedlings. New For 30: 235-251.

Jenkins JR, Jarrell WM. 1989. Predicting Physical and Chemical Properties of Container Mixtures. HortScience 24: 292-295.

Landis TD, Tinus RW, McDonald SE, Barnett JP. 1990. Containers and Growing Media. U.S. Dept of Agriculture Forest Service, Washington, DC.

Li Q, Chen J, Caldwell RD, Deng M. 2009. Cowpeat as a Substitute for Peat in Container Substrates for Foliage Plant Propagation. HortTechnology 19: 340-345.

Lordan J, Pascual M, Fonseca F, Villar JM, Rufat J. 2013. Use of Rice Husk to Enhance Peach Tree Performance in Soils with Limiting Physical Properties. Soil Tillage Res 129: 19-22.

Mathers HM, Lowe SB, Scagel C, Struve DK, Case LT. 2007. Abiotic Factors Influencing Root Growth of Woody Nursery Plants in Containers. HortTechnology 17: 151-162.

Mattsson A. 1997. Predicting Field Performance Using Seedling Quality Assessment. New For 13: 227-252.

Medina E, Paredes C, Pérez-Murcia MD, Bustamante MA, Moral R. 2009. Spent Mushroom Substrates as Component of Growing Media for Germination and Growth of Horticultural Plants. Bioresour Technol 100: 4227-4232.

Mori S. 1994. Effect of Charcoaled Rice Husks on the Growth of Dipterocarpaceae Seedlings in East Kalimantan with Special Reference to Ectomycorrhiza Formation. J Jpn For Soc 76: 462-464.

Rose R, Atkinson M, Gleason J, Sabin T. 1991. Root Volume as a Grading Criterion to Improve Field Performance of Douglas-Fir Seedlings. New For 5: 195-209.

Sambo P, Sannazzaro F, Evans MR. 2008. Physical Properties of Ground Fresh Rice Hulls and Sphagnum Peat Used for Greenhouse Root Substrates. HortTechnology 18: 384-388.

Seo JM, Park BB, Han SH, Youn WB, Aung A, Dao HTT, Cho MS. 2019. The Effects of Additive Biomaterials and Mixed-ratio in the Growing Medium on the Growth of *Quercus serrata* Container Seedlings. Korean J Agric Sci (in press).

Sestak Z, Catský J, Jarvis PG. 1971. Plant Photosynthetic Production. Manual of methods. Dr. W. Junk NV, Hague.

Simmons LD, Derr JF. 2007. Pendimethalin Movement through Pine Bark Compared to Field Soil. Weed Technol 21: 873-876.

Thompson JR, Schultz RC. 1995. Root System Morphology of *Quercus Rubra L.* Planting Stock and 3-Year Field Performance in Iowa. New For 9: 225-236.

Tinus RW, McDonald SE. 1979. How to Grow Tree Seedlings in Containers in Greenhouses. USDA Forest Service, Fort Collins.

Vyse A. 1981. Growth of Young Spruce Plantations in Interior British Columbia. For Chron 57: 174-180.

Warren SL, Bilderback TE. 2004. Irrigation Timing: Effect on Plant Growth, Photosynthesis, Water-Use Efficiency and Substrate Temperature. Acta Hortic 644: 29-37.