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Research paper

Performance evaluation of moss rooftop greening prototype in a confined space☆

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ABSTRACT

This research presents performance evaluation of moss rooftop greening prototype in a confined space using an experimental chamber. The chamber was utilized to simulate performance of prototype in reducing temperature inside a building. Two simulated environments were set as low and high-temperature treatment. Moss plant (*Sphagnum* sp.) was used. Performance was evaluated by using *Lab* color, photosynthesis and CO_2 absorption rate. The results concluded that prototype could reduce temperature inside confined space from 1.5 to 2.9 °C. *L* and *b* parameters were applicable to detect the color patterns. The high-temperature had no effect on while low-temperature treatment decreased photosynthetic and CO_2 absorption rate. These results concluded that the prototype could be applied as a rooftop greening material in tropical environment of Yogyakarta, Indonesia.

1. Introduction

Rooftop greening prototype using moss plant (*Sphagnum* sp.) was developed for Eco-agro-tourism program in Merapi Disaster Prone Area (MDPA), Yogyakarta, Indonesia (Ushada et al., 2012). It is a plant grown in a panel which is utilized for a narrow open space in a rooftop building. The panel consists of plant and hydroponics media which is suitable to attach in the narrow open space. The existence of plant evapo-transpiration contributes in the reduction of the temperature inside the building. The existence of bio-physical processes such as evapo-transpiration in a greening material contributes to make air freshness and mitigate the urban heat island effect (Ushada and Murase, 2009a, 2009b; Ushada et al., 2012). The expected advantage of rooftop greening is to increase the percentage of open green space in MDPA.

The expected economic impact is to support the implementation of strategic plan of Indonesian cooperatives and small-medium enterprises as the fundamental industry in contributing the regional economy (Anonim, 2010). Eco-agro-tourism is an empowerment program of Micro-Small-Medium Enterprises (MSME) by maintaining air freshness, teaching culinary and converting the place into a tourism spot. Fig. 1 indicates some MSME in MDPA which is potential for eco-agro-tourism program.

A prototype is a tool for the evaluation of design requirement. Rooftop greening prototype must be evaluated to meet the design requirement. Four design attributes were most preferred by consumer are 'Eye catching', 'Comfortable', 'Capability as air freshener' and 'Absorbing water' (Ushada and Murase, 2009b; Ushada et al., 2012).

The surface texture and color of moss greening material is the critical quality considered by consumers (Ushada and Murase, 2009a) and are essential for the acceptance of product (Ushada et al., 2012). Since Ushada et al. (2007) has analyzed the surface texture of greening material, we evaluate the surface color in this research.

The *Lab*, or CIE *Lab*, color space is an international standard for color measurements, adopted by the Commission Internationale d'Eclairage (CIE) in 1976. The *Lab* color measurement is appropriate to detect quality of object surface (Hunterlab, 2008). It was not only applied for the food product (Leon et al., 2006), but also potential for application in other products (Hunterlab, 2008). Uemura et al. (2003) has found the positive correlation between RGB color of

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Fig. 1. Culinary and motel spot in MDPA.

Sunagoke moss (*Rhacomitrium japonicum*) and photosynthesis rate under closed controlled environment.

Some methods of performance evaluation were developed for the moss greening material as non-destructive method for canopy measurement (Ushada et al., 2007), watchdog model for quality evaluation (Ushada and Murase, 2009a) and modeling consumer preference (Ushada and Murase, 2011), but none of them were applicable to the surface color, photosynthesis and CO_2 absorption.

Confined space is an interior space which is designed to simulate a local environment control system (Takahashi et al., 2002). The confined space makes the atmospheric factors such as temperature and humidity controllable through the entire interior space. Confined space is observable and controllable to simulate the closed environment inside a building. In this research, we used the confined space to simulate the performance of prototype in reducing temperature inside the building.

The research objectives are: 1) To develop an experimental chamber for performance evaluation of moss rooftop greening prototype in a confined space; 2) To evaluate the performance based on *Lab* color measurement, photosynthesis and CO_2 absorption rate.

2. Materials and methods

2.1. Materials

Wild moss was collected from the supplier in Jalan Bantul, Yogyakarta Special Region. Then, it was proliferated and cultivated as greening material using the method by Ushada et al. (2012). Subsequently, the cultivated moss was assembled to the rooftop panel. The size of a unit of rooftop greening prototype is $35 \times 50\ cm^2$ as shown in Fig. 2. This unit is used as a module for the application of rooftop greening material in MSME culinary as shown in Fig. 3.

2.2. Methodology

As shown in Fig. 4, the performance evaluation method is divided into 5 steps:

Fig. 2. A unit of rooftop greening prototype.

2.2.1. Confined space design and construction

An experimental chamber of closed controlled system was established for simulating a confined space as shown in Fig. 5a and b. The temperature treatment in a confined space can be controlled by varying temperatures and light intensity with constant flow rates of the air blown by a fan.

The dimension of chamber is $75 \times 60 \times 75\ cm^3$. A combination of albizia and melamine particle board was used as an insulating material. The chamber interior was equipped with a fan (Sekai HFN 1050, 10 inch/25 cm, 220 V/50 Hz 40 Watt). Two light bulbs were used as heat sources (Philips Softone, 60 Watt 220–240 V).

2.2.2. Confined space test

The confined space test was conducted without existence of greening material and wind blown by a fan. The chamber was tested with the variation of temperature and light intensity. Air temperature changed according to the amount of available heat from the light bulbs.

2.2.3. Prototype evaluation

Prototype was evaluated to acquire the information about performance of prototype to reduce the temperature inside confined space as shown in Fig. 6a and b. Temperature is one of the critical factors in the moss growth (Ushada and Murase, 2006). Ushada et al. (2006) identified that the surface temperature of moss greening shows the specific pattern during 360 min of experiment in the extreme environment. Therefore 600 min were set for these experiments as the adjustment in the confined space environment.

Table 1 indicates simulated treatment of controlled environment system. It was adapted from data of natural environment 2007–2010 in Yogyakarta, Meteorology and Weather Station Yogyakarta, Indonesian Meteorological, Climatological and

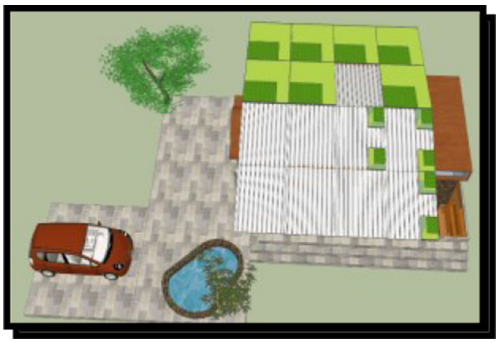

Fig. 3. Design of rooftop greening material.