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Use of Six Planting Media on Shallow Bed and Plant Container Systems to The Growth and Yield of Sweet Potato *(Ipomoea batatas* L.) for Roof Garden

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ABSTRACT

Roof garden is an alternative to overcome food security through breeding crops and horticultures of fruits and vegetables. Research aimed to determine the yield of sweet potatoes that planted through various planting medium on roof garden by using shallow bed and plant container bag system. The research was conducted in Malang by applying two planting systems, such as shallow bed (direct cropping) and plant container bag on the same planting medium. Randomized Block Design (RBD) with six treatments of planting medium and four replications was adopted in this experiment. Six planting media were 1) Soil only, 2) Soil + Charcoal, 3) Soil + Cocopeat, 4) Soil + Compost, 5) Soil + Manure, and 6) Soil + Moss. Each combination of soil was one to one (1:1). Analysis of Variance (ANOVA), Least Significant Difference (LSD) and T-test were used at 5% for each to examine data. Length of crop, leaf area, numbers of tuber, fresh weight of tuber, dry weight of tuber, and total dry weight of plants were observed variables. Results showed that the application of soil and manure (1:1) as planting medium for shallow bed system on roof garden concept increased numbers of tuber, fresh weight of tuber, dry weight of tuber, and dry weight of Sweet Potato (*Ipomoea batatas* L.) compared to container bag system with the same planting medium.

Keywords: charcoal; manure; soil; planting system.

INTRODUCTION

The increasing population in Indonesia has been followed by the increasing development of settlements and decreasing field area for farming. By the increasing population in Indonesia that almost reach 257.9 million and projected populations about 305.5 million in 2035 along with urbanization rate for about 0.209% (Badan Pusat Statistik, 2014). This trend moves to high dense settlements that exploit available land. However, some efforts have been done to preserve equilibrium between vegetation and urban buildings, as well as settlements in order to create comfortable environment. Therefore, city layout arrangement is required to settle the increasing numbers of greenery at urban area. Roof garden could create more beautiful and shaded landscapes, as heat insulator, absorb pollutant gases, prevent ultraviolet radiation, and reduce noise. Roof garden will increase green-open space on multistoried buildings at urban area and increase green ratio for population at the area of 0.75 ha garden per 1,000 inhabitants (Afroz, 2016). A number of research has been done to increase roof garden capacity. In the research of Energy efficiency and environmental benefits of rooftop gardens by (Connelly and Liu, 2005), stated that roof gardens offer many benefits to an urban area. It can reduce energy demand on space conditioning hence GHG emissions. Roof gardens could also help to improve rain water management, thus improving the quality of the run-off. Part of the rain is

stored in the growing medium temporarily, and will be taken up by the plants and returned to the atmosphere through evapotranspiration. In addition, rooftop gardens can provide additional green space in urban areas, and increase property values. Moreover, roof garden may overcome food security through crop breeding, as well as horticultural farming, such as fruits and vegetables.

Sweet potato is one of important crops and agricultural commodities, which contains of carbohydrate. Sweet potato has an important role as food reserves instead of rice and maize. Sweet potato has greater opportunity due to its high consumption level, whereas it is consumed by almost population in Indonesia. At the suburban areas in Indonesia, sweet potato is considered as secondary staple food, while at the urban areas, sweet potato has been processed into crispy chips and other snacks for industrial interests. Sweet potato contains higher content of starch, sugars, proteins, vitamin C, ascorbic acid as well as phosphorus, calcium and magnesium (Krochmal-marczak et al., 2014). Sweet potatoes can help reducing nutritional problems and can be especially recommended for diabetics (Krochmal-marczak et al., 2014). Therefore, sweet potato is highly potential to be developed.

Existence of such roof garden may increase the load. Piles of soil and plants may increase the material loads, wind load, and additional load of water on roof of the buildings (Nayeem, 2014). Soil is usually used as planting medium for the sweet potato. However, the use of soil as planting medium for sweet potato on the roof garden may burden structure and construction of the roof, so that it requires lightweight growth medium as an alternative in order to produce higher productivity of the sweet potato. Sweet potato can be grown in containers, but the space for the tubers is more restricted than in the shallow beds, but the advantage is the optimum use of the nutrients (Boland, 2005). A shallow bed consists of a thin layer of soil that is regularly watered, preferably with direct sunlight and a good growing medium. Extensive roof gardens are established with mineral growing media, the first are primarily important in areas with poor precipitation (Oberndorfer et al., 2007). An extensive roof garden can retain storm water and allow its gradual run-off from the roof. Thus, good drainage should be concerned in the roof garden to produce optimal plant growth. The hypothesis of this research was the use of soil and manure (1:1) by shallow bed system on roof garden concept could increase the yield of sweet potato (*Ipomoea batatas* L.).

MATERIALS AND METHODS

The research was conducted at University of Brawijaya in Malang, East Java. Indonesia, ca. 500 meter above sea level (masl) from January to March 2016. Geographically, it`s located at coordinate 112°06’ – 112°07’ East Longitude and 7°06’ – 8°02’ South Latitude. Several tools were used in this research such as digital camera, ruler and tape, planter bag of 25 liters, scales, oven, and knife. Ninety six sweet potato cuttings of Sari variety (as planting materials), soil, charcoal, cocopeat, compost, manure, and moss (as planting media), 2.3 g Urea per plant, 3.5 g NPK fertilizer per plant, Lannate pesticide, Ripcord pesticide, and irrigation water were prepared in this experiment. Weight of the planting medium was weighed by using scales. Weights of diverse types of planting medium were presented on Figure 1.

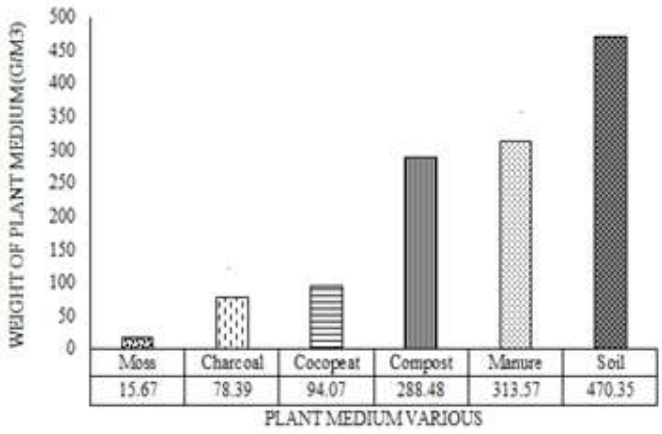


Figure 1. Weight of each planting medium on roof garden

Two planting systems, such as shallow bed (direct planting) on the first experiment and container bag for the second experiment were adopted for six types of planting medium. Randomized Block Design (RBD) was adopted for both planting systems. There was six types of planting medium and four replications, i.e.: soil medium only, and five combinations of soil. Five combinations of soil were soil and charcoal, cocopeat, compost, manure, and moss with composition for each one to one (1:1).

There were some observed variables in this experiment. It's were length of plant, leaf area, number of tuber, fresh weight of tuber, dry weight of tuber, and total dry weight of plant. Analysis of variance (ANOVA) was used to analyze data. If there were found significance, the Least Significant Difference (LSD) test at 5% is used. T-test was also used to compare between shallow bed and container bag systems.

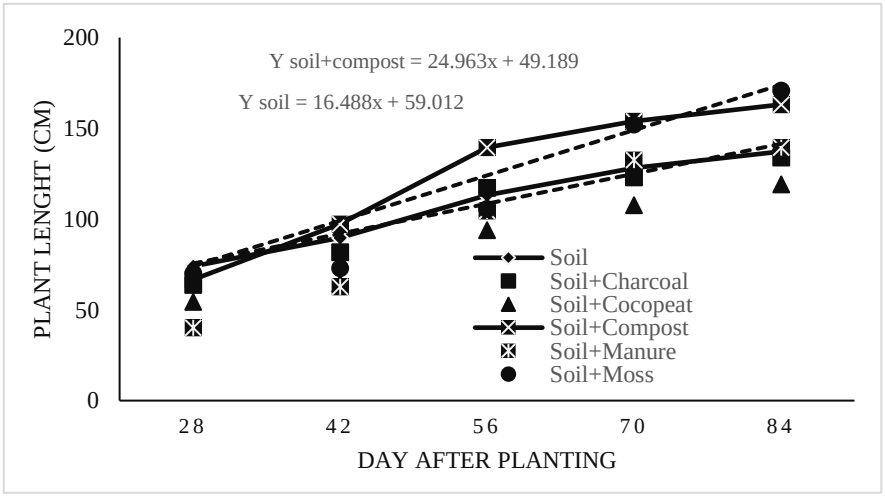
RESULTS AND DISCUSSIONS

The results showed that media composition influenced the length of sweet potato plants (Figure 2). On shallow bed and container bag plant systems, the treatment of soil + compost has a higher sweet potato length than soil media, soil + cocopeat and soil + charcoal husk. At 84 days after planting (dap), the length of sweet potato plant on soil + compost has the same yield as on soil + manure and soil + moss. Application of compost contained organic material can improve soil conditions. In addition, the compost is leaf litter, as well as animal feces that have undergone the decomposition process by decomposing microorganisms, so it can be utilized to improve soil properties and can accelerate the rate of plant growth

Compost has adequate nutrients, which increase the plant's growth to be optimal. Compost contains more microorganisms and the application of additional compost into the soil may trigger the microorganism to develop and produce much CO_2 (Arslan et al., 2008), which will be used for photosynthesis, so that the plants will grow faster. The available nitrogen will be absorbed by the roots and it will promote the formation of vegetative parts faster due to the meristem tissues have cellular division, elongation and enlargement of new cells, as well as protoplasm, so that the plant will grow optimal (Näsholm et al., 2009).

On shallow bed system, the highest leaf area of the sweet potato was resulted from 28 to 84 daps by the application of soil + compost and the leaf area were increased. While on plant container bag system, growth of leaf area during observation from 28 to 84 dap showed linear percentage pattern, in which at 84 daps,

leaf areas of the sweet potato by the application of soil + compost and soil + manure did not show any significant difference with the application of soil, soil + cocopeat and soil + charcoal, but they showed significant difference by the application of soil + moss (Figure 3). The increasing leaf area due to the increasing numbers of leaf may be related the competition to intercept light among leaves (Craine and Dybzinski, 2013). During the observation, leaf area increases due to the increasing formation of new leaves and numbers of leaf, which are proportionate to the increasing leaf area. Nitrogen is one of essential elements for the plant growth, which is mostly required for formation and development of vegetative parts of the plant, such as leaf, stem, and root (Zong-Min et al., 2012). Furthermore, the application of organic materials may improve physical, chemical, and biological properties of the soil (Gulyás and Füleky, 2013). It is due to organic materials have nutritional functions, in which organic material is one of nutrient sources for plants, such as N, P, K and S; biological function refers to trigger organism's activities in the soil; and physical function refers to form excellent structure that will improve aeration and drainage in the soil.



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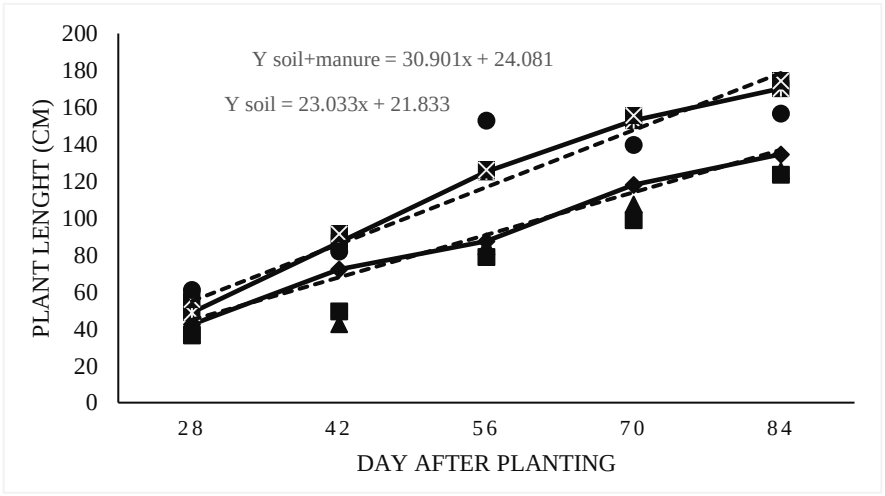
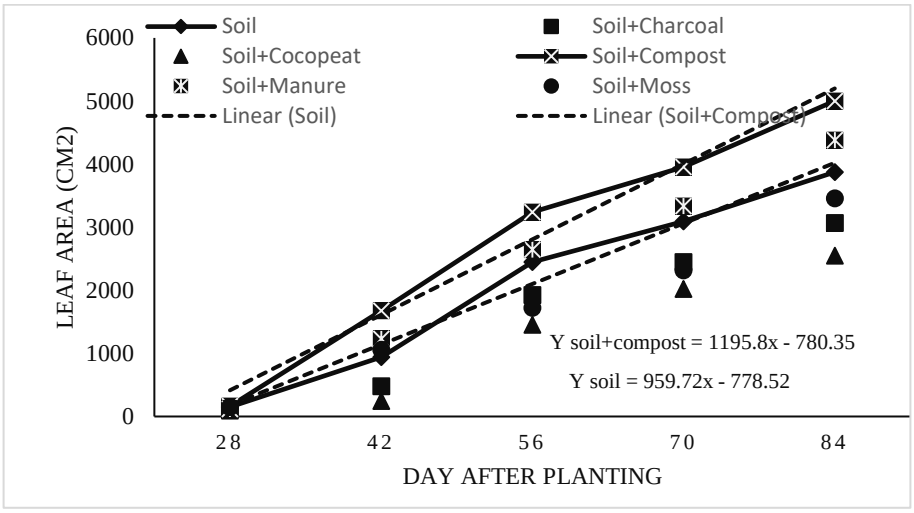


(b)

Figure 2. Length of Sweet Potato (*Ipomoea batatas* L.) crop on Roof Garden by Shallow Bed System and Plant Container Bag System



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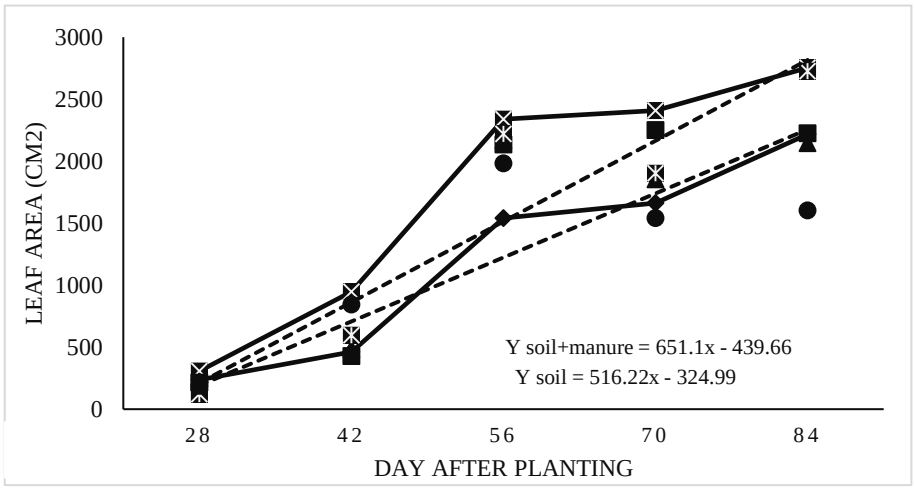

(b)

Figure 3. Leaf Area of Sweet Potato (*Ipomoea batatas* L.) on Roof Garden by Shallow Bed System (a) and Plant Container Bag System (b)

Results of the research on shallow bed system showed that the application of diverse planting mediums affected on fresh weight and dry weight of tubers per plant (Table 1). Fresh weight of tubers per plant by the treatment of soil + manure showed higher yield than the treatment of soil + cocopeat, soil + moss and soil, but fresh weight of tuber by the treatment of soil + manure was comparable to fresh weight of tuber by the treatment of soil + charcoal and soil + compost, but if it is observed in accordance with lighter weight of planting medium, soil + charcoal is considered as lighter medium and has requirements for optimal growth and development of the plant. Planting medium of soil + charcoal has higher fresh weight of tuber and dry weight of tuber in comparison with other lighter planting mediums, such as: soil + cocopeat and soil + moss. Charcoal medium has better air circulation, easily bind the water and uneasily to be in clumps.

Fresh weight of total plants by the treatment of soil + manure showed higher yield than other treatments, but fresh weight of total plants by the treatment of soil + manure did not show significant

difference with fresh weight of total plants by the treatment of soil + compost. Therefore, it can be said that sweet potato contains different water content and element. It was due to treatment of different medium may create different absorption of water and photosynthate partition. Fresh weight is affected by water content in cells of the plant, in which the levels are affected by environmental factors, such as temperature and humidity, while dry weight of the plant is more referred to status of the plant's growth (Kusumaningrum et al., 2007). Dry weight of total plants showed that the treatment of different mediums affected on dry weight of sweet potato. It showed that the accumulation of organic compounds which synthesized by the plants among treatments were different.

Table 1. Yield Component of Sweet potato in Order to Increase the Yield of Sweet Potato (*Ipomoea batatas* L.) through Different Types of Planting Medium on Roof Garden by the Application of Plant Container Bag System

Treatment	Yield Component			
	Number of Tuber	Fresh Weight of Tuber (g/plant)	Dry Weight of Tuber (g/plant)	Dry Weight of Plant (g/plant)
Shallow Bed System				
Soil	5.5	298.81 a	37.78 bc	66.84 b
Soil+Charcoal	4.25	295.18 a	29.63 a	39.90 a
Soil+Cocopeat	6.5	266.80 a	34.79 abc	43.58 a
Soil+Compost	5.25	323.66 ab	41.19 c	71.38 b
Soil+Manure	6.25	409.08 b	31.55 ab	52.19 ab
Soil+Moss	5	264.81 a	34.49 abc	40.89 a
LSD 5 %	ns	88.4	6.79	20.14
Plant Container Bag System				
Soil	6.00 c	215.60 d	35.98 c	61.08 e
Soil+Charcoal	3.75 ab	194.29 cd	33.54 c	56.10 d
Soil+Cocopeat	3.00 a	107.47 ab	20.19 ab	33.19 a
Soil+Compost	4.25 b	120.06 b	22.95 b	60.69 e
Soil+Manure	3.00 a	54.52 a	13.86 a	49.07 c
Soil+Moss	3.75 ab	147.36 bc	27.36 bc	38.97 b
LSD 5 %	1.01	62.435	8.69	3.26

Notes : numbers followed by different letter in the same column show significant difference on LSD test of 5% on standard error 5%; ns = not significant

Table 1 showed that types of planting medium do not affect on number of tuber against the shallow bed system, but significantly affect on number of tuber by the application of plant container bag system. The planting medium types affect on fresh weight of tuber, dry weight of tuber, and dry weight of plant by the application of shallow bed system and plant container bag system. Number of tuber, on plant container bag system and soil medium, showed higher yield than other treatments. However, soil medium has heavier weight in comparison with other treatments (Figure 1). Even though charcoal may reduce the yield, in comparison with the treatment of soil medium, but charcoal is lighter medium and may produce higher tubers than other lighter mediums. Moss is the lightest medium in comparison with charcoal and cocopeat, but charcoal could produce the greatest number of tuber following soil

medium. It is due to charcoal may increase soil porosity, so that the soil will be looser and it will increase ability of the soil to absorb water, and it is black, therefore, it could absorb the light effectively and, of course, the tubers will grow optimal and facilitate the roots to pass through the medium easily due to porous property of charcoal, therefore the potential roots that will become tuber, could pass through the soil optimally. Moss is more fibrous because it has been mixed with soil, so that the roots will be difficult to pass through the soil and it would produce deeper concave tuber. Relatively high weight of soil in comparison with other planting mediums was due to soil capacity in absorbing water and greater aggregate mass of the soil. Verticultural breeding, light medium that can be used as alternative to reduce the load is combination between compost and soil, soil and moss, as well as soil and charcoal (Kuhn and Peck, 2003). Temperature of planting medium comprises of soil = 28℃, soil + cocopeat = 24℃, soil + moss = 25℃, soil + manure = 25℃, soil + compost = 26℃, soil + charcoal = 20℃. Temperature of the soil affects on the tuber growth, and high temperature may inhibit the tuber growth (Harwati, 2008).

Number of tuber, which was resulted from soil medium, showed higher yield in comparison with other medium. Besides that, temperature of the medium may affect on the tuber growth. Soil + charcoal has the lowest temperature in comparison with other medium compositions, but it does not make growth and development of the tuber to be more optimal. Types of media influence the fresh weight and number of leaf for crop (Sitawati et al., 2016). It was due to contents of the medium affect on the tuber formation. Each medium has different content, so that the tuber may absorb different nutrients as well. Besides that, if it is compared with light planting medium, moss medium produces low value due to moss is light and fibrous, however, moss (bryophyte) is mostly found on humid places, sheltered from the sunlight, and attach on bark of the tree. Such moss substitutes soil, which could store water and has lower temperature than the soil. Meanwhile, soil has heavier weight and higher temperature, due to weight of the soil volume may affect porous space of the soil and tend to have higher temperature. Improper temperature may inhibit the growth of root and apex radicis may have different form due to branching may keep growing to the apex radicis, so that the movement space for the tuber growth will be difficult or inhibited. The roof garden may functions to reduce runoff and air contaminant filter, as well as aesthetic purpose (Hastuti and Anggraini, 2010).

Results of the research on shallow bed system showed that soil + manure has higher fresh weight of tuber than on soil medium, soil + charcoal, soil + cocopeat and soil + moss, but it has the same yield with planting medium of soil + compost. While on plant container bag system, soil medium shows higher fresh weight of tuber than using soil + manure, soil + compost, soil, soil + cocopeat and soil + moss. Besides soil medium, soil + charcoal have identical fresh weight of tuber with the application of soil medium. Dry weight of plant, by the application of soil + compost and soil on shallow bed system, showed higher yield than other treatments, but it did not show significant difference with the application of soil + manure. On plant container bag, higher yield of dry weight of plant was shown by the application of soil + charcoal. Inhibition in early stage of growth may reduce biomass production significantly (Rahayu, 2006). Dry

weight of plant reflects accumulation of organic compounds, which is synthesized from inorganic compounds, particularly water and carbon dioxide. The absorbed nutrients may contribute in increasing dry weight of plant. Dry weight of plant is a result of efficiency in absorbing and utilizing sun radiation, which is available during the planting period by canopy of the plant (Kastono et al., 2005). Soil + manure contain much water in comparison with other medium. Manure is source of macronutrients and micronutrients for plants. However, based on light planting medium, soil + moss have low values for fresh and dry weights of tuber. Moss is dry moss, which is used to substitute soil or fiber for orchids and marcottage plant (Muhit, 2010). Moss, which is usually used as planting medium, is derived from ferns that are mostly found in forests. Moss is mostly used as planting medium from nursery period to flowering period. Such medium is porous, which enables the roots to grow freely. According to its properties, moss medium affords to bond water and well drainage and aeration systems. Dry weight of plant is a result of efficiency in absorbing and utilizing sun radiation, which is available during the planting period by canopy of the plant (Kastono et al., 2005). At 105 daps, fresh weight of tuber per plant showed similar yield, in which the highest values were obtained by the treatment of soil + manure, whereas the highest yield of dry weight of tuber per plant were obtained by the application of soil + compost.

Results of observation on shallow bed system showed that types of planting medium may affect on shape of the sweet potato and quality of the tuber. Based on criteria of excellent and qualified shape of tuber, it must have oval shape and broadened at the end of the tuber. By the treatment of soil medium, yield of tuber showed big to medium sizes and oval shape; on soil + charcoal, the yield of tuber showed big and round shape; on soil + cocopeat, the tuber has medium and round shape. The treatment of soil + compost produced medium and oval tubers; soil + manure produced small and round tuber; and soil + moss produced cylindrical tuber. Soil has solid structure, so that it may affect the tuber's shape, big and oval. Moss is porous, which enables the roots to grow and develop freely, but by the application of soil + moss, the yield of tuber has cylindrical shape due to the medium has been mixed with soil, so that soil + moss become fibrous and it makes the roots have difficulty to penetrate the medium, so that the tuber has cylindrical shape (Prameswari et al., 2014). The application of soil + charcoal produced big and round tubers due to charcoal may increase soil porosity, so that the soil becomes loose and it will increase ability of the soil to absorb water. Therefore, the roots will easily penetrate the medium and produce round and big tubers.

Fresh weight and dry weight of total plants showed significant difference of yield among treatments. Fresh weight is affected by water content in cells of the plant, which is affected by environment, such as temperature and humidity, so that dry weight of plant shows status of the plant's growth (Kusumaningrum et al., 2007). Total dry weight of plant reflects accumulation of organic compounds, which have been synthesized from inorganic compounds, particularly water and carbon dioxide. The absorbed nutrients may contribute in increasing total dry weight of plant. Dry weight of plant is a result of efficiency in absorbing and utilizing sun radiation, which is available during the planting period by canopy of the plant (Kastono et al., 2005).

Results of observation on total fresh weight at 105 daps showed that the composition of soil + manure, on average, has the highest values in comparison with other medium. Organic materials were derived from three sources, such as manure, green manure, and remains of the planted greeneries. Manure is the source of macronutrients and micronutrients. Total dry weight of the sweet potato, during observation at 105 daps, showed the highest values, on average, by the composition of soil + compost, in comparison with other mediums. It is due to the application of soil + compost has the fastest and highest vegetative growth. Vegetative growth may affect on total dry weight of the plant (Rahayu, 2006).

The application of soil + manure produced the highest yield compared to other planting media. The application of soil + manure on different planting systems, shallow bed and plant container bag, on roof garden has provided different yields as well, in which the application of soil + manure on shallow bed system has produced higher yield for fresh weight of tuber, dry weight of tuber, and dry weight of plant in comparison with the application of soil + manure on plant container bag system (Figure 4). Compositions of soil + manure, which were applied in this research, have decomposition process. In general, the application of organic fertilizer is intended to regain nutrients, improve soil structure, and increase organic materials in the soil. Manure has some benefits, for example, it could restore soil fertility by improving physical, chemical, and biological properties of the soil (Berry, 2015).

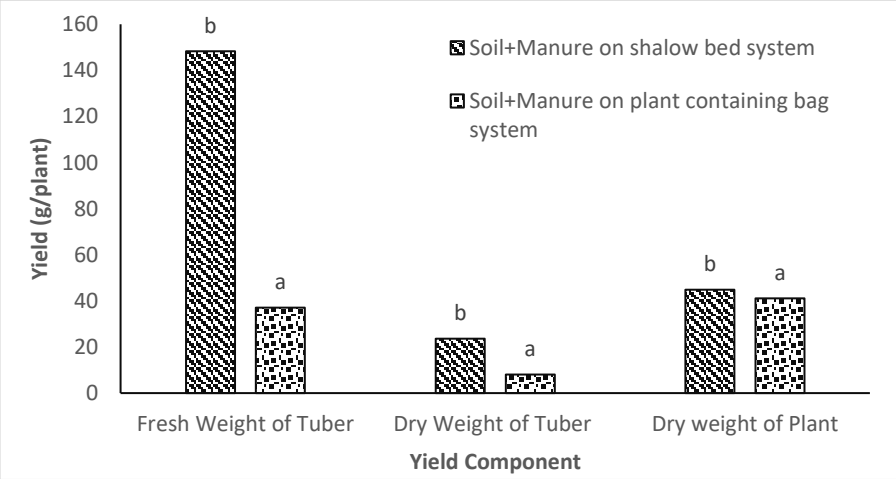

Figure 4. Yield Component of Sweet Potato in order to Increase Yield of Sweet Potato (*Ipomoea batatas* L.) through Different Types of Planting Medium on Roof Garden by the Application of Shallow Bed System and Container Bag Planting System. (a) Shallow bed system, (b) plant container bag system at 140 daps.

CONCLUSIONS

The application of soil and manure (1:1) through shallow bed system by the concept of Roof Garden could increase number of tuber, fresh weight of tuber, dry weight of tuber, and dry weight of sweet potato (*Ipomoea batatas* L.) plant in comparison with the application of soil and manure (1:1) on plant container bag system.

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