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Physicochemical properties of different organic substrate mixtures and their effects on growth and yield of sweet pepper (*Capsicum annuum* L.) cultivars

M. Jahedur Rahman[1*], Md. Shahjahan Ali[2], Farzana Islam[2], Most. Zannat Zakia[3]

[1]Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh

[2]PhD Fellow, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesm

[3]MS Fellow, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh

*Corresponding author address: Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh

Tel: +880 1716 590216

E-mail: jrahman04@yahoo.com

Abstract

Carbonized rice husk, coco peat and sawdust are considered as good growing substrate components, but high water holding capacity causes poor air-water relationship, thus affecting oxygen diffusion to roots. Incorporation of coarser materials into these substrate components could improve aeration status. The present experiment aimed to assess the physicochemical properties of four growing substrate mixtures (M_1 = 50% coco peat + 45% bora + 5% shodo, M_2 = 50% coco peat + 45% perlite + 5% shodo, M_3 = 50% carbonized rice husk + 45% perlite + 5% shodo and M_4 = 50% sawdust + 45% perlite + 5% shodo) and their effects on growth and yield of two sweet pepper cultivars (V_1 = 'Papari new-E-red', V_2 = 'AVRDC PP045-6006'). Results revealed that pH, electrical conductivity (EC), air-filled porosity (AFP) and wettability were higher in M_3, whereas bulk density and dry weight were higher in M_1 and the lowest in M_3. Improved properties of M_3 and M_2 positively reflected in growth, dry weight, yield and mineral compositions in leaves of sweet pepper. Furthermore, V_2 showed significantly better growth and higher yield as compared to V_1 cultivar. Therefore, we concluded that incorporation of coarser materials improved physicochemical properties of carbonized rice husk (M_3) followed by coco peat (M_2) that positively influenced the growth and yield of sweet pepper cv. 'Papari new-E-red'.

Keywords: Carbonized rice husk; Coco peat; Sawdust, Growth; Dry weight, Tissue mineral contents

1. Introduction

Use of suitable growing substrate is essential for production of high quality horticultural crops. It directly affects the development and later maintenance of the functional rooting system. A good growing medium provides a sufficient support to the plant, serves as reservoir for nutrients and water, allows oxygen diffusion to the roots and permits gaseous exchange between the roots and atmosphere outside the root substrate (Abad et al., 2002; Argo, 1998; Bunt, 1988; Richards and Beardsell, 1986). Many soilless materials are widely available in the tropics, for example coco peat, carbonized rice husk, and sawdust, etc. These materials are mainly agricultural byproducts obtained after the extraction of fiber from the coconut husk, paddy and saw mills and maybe used as horticultural growing substrates. As a growing medium, coco peat can be used to produce a number of crop species with acceptable quality in the tropics (Yahya et al., 1997). Coco peat is considered as a good growing substrate component with acceptable pH, electrical conductivity (EC) and other chemical attributes (Abad et al., 2002). However, coco peat has been recognized to have high water holding capacity which causes poor air-water relationship, leading to low aeration within the medium and it affects the oxygen diffusion to the roots.

Carbonized rice husk maybe used as horticultural growing substrate although it has the problem of air-water relationship. Rice hull is often incinerated to form fine charcoal-like dust. When it is used as a component for growing substrate, it might behave like fine sand. However, it is lighter and sterile and may contain some nutritional elements. Carbonized rice husk induced faster cell division and differentiation for root formation (Moe, 1988) and it was the best growing substrate for chrysanthemum cutting (Budiartoa et al., 2006). Aside its use in nursery production, it maybe used as soilless growing media for sweet pepper production.

Sawdust is used as growing substrate and is available in almost all over the world and it could be renewable. Wood residues (i.e., sawdust and bark) have been used in containers for growing ornamentals (Klett et al., 1972). But microorganisms involved in decomposition of raw wood residues are more efficient than higher plants in nitrogen absorption and assimilation (Alexander, 1961). Large amount of nitrogen must, therefore, be added to wood residues used as media to grow plants. This problem can be solved, however, by composting residues before using them for growing substrates (Still et al., 1974). Furthermore, decomposition of old sawdust is not necessary for using as growing substrates. However, physical and chemical properties of these substrate components are highly dependent on their processing technique and handling. It is desirable to improve physical and chemical properties of them before using as growing substrates.

Incorporation of coarser materials into the substrate components could improve the aeration and drainage status of the substrate mixtures (Bunt, 1988; Richards and Beardsell, 1986; Sambo et al., 2008). Perlite (Islam, 2008; Sambo et al., 2008), bora (volcanic soil), and shodo (burnt clay loam soil), the possible coarser materials can be used to improve the air-water relationship of the substrate components. Possible combinations of different components can improve the physical and chemical properties of growing substrate. Furthermore, a suitable combination of different growing substrate components positively influences the growth and yield of horticultural crop production like sweet pepper as a test crop. Thus, the objectives of the study were to assess the chemical and physical properties of different substrate mixtures, and their effects on growth, plant dry weight, yield, and mineral composition in leaves of sweet pepper.

2. Materials and methods

Plant materials and growing condition

The experiment was conducted at the greenhouse of the Experimental Farm, University of Miyazaki, Japan from November 2010 to June 2011. The transplanting and final harvesting dates were 25th November 2010 and 10th June 2011, respectively. Seeds of sweet pepper cv. ‘Papri new-E-red’ (Marutane Seed Co., Kyoto, Japan) and ‘AVRDC PP046-6006’ (AVRDC-The World Vegetable Centre, Taiwan) were selected on the basis of yield performances under high temperature condition (Rahman and Inden, 2012). Two 18 cm, sixth leaf stage 8-week-old seedlings were transplanted 20 cm apart into 40 L containers containing different mixtures Each row consisted of 18 containers and treated as a replication. Two edge rows were grown to reduce the border effects. The first 3-flowers were removed from all plants at anthesis to promote vegetative growth. Plants were pruned to form four main stems. The nutrient solution was applied to the crop by ultra drip irrigation tube for each replication and treatment. The nutrient solution applied was measured with a flow meter, installed in a water delivery unit designed for independent control of each treatment. A standard nutrient solution was used in this experiment according to Rahman and Inden (2012).The pH and electrical conductivity (EC) of 6.0 and 2.8 $dS \cdot m^{-1}$, respectively were maintained during experiment. The nutrient composition of the solution was NO_3-N, P, K, Ca, Mg, and S of 17.0, 7.8, 8.7, 9.9, 6.0 and 6.0 me L^{-1}, respectively, and Fe, B, Zn, Cu, Mo, and Mn of 3.0, 0.5, 0.1, 0.03, 0.025 and 1.0 mg L^{-1}, respectively. The average minimum and maximum temperatures during the cultivation period were 18±2 °C and 22±2 °C, respectively.

Experimental design and treatments

The experimental design was a 4×2 factorial design with three replications. Two factors of this experiment were four substrate mixtures (viz., M_1 = 50% coco peat + 45% bora + 5% shodo, M_2= 50% coco peat + 45% perlite + 5% shodo, M_3= 50% carbonized rice husk + 45% perlite + 5% shodo, and M_4 = 50% sawdust + 45% perlite + 5% shodo), and two sweet pepper cultivars (viz., V_1 = ‘Papri new-E-red’ and V_2 = ‘AVRDC PP046-6006’). Four substrate mixtures (M_1, M_2, M_3 and M_4) were used as completely randomized design with four replications for determination of physical and chemical properties.

Data collection

Properties of growing substrate

The selected properties of growing substrate, namely initial pH and EC, bulk density, water retention, wettability, air-filled porosity and dry weight of substrate mixture were measured. Samples of substrate mixtures were collected accordingly after preparation and then put to specific determination of the properties.

pH and EC

The pH and EC values for all media before planting were determined according to Yahya et al.

(2009). For pH, 10 g of media was mixed with 50 mL distilled water, agitated for 30 min and left standing for 24 h. For EC, 40 g of media was mixed with 80 mL distilled water, shaken for 15 min and left for 60 min. The mixtures were filtered before the measurements. A pH meter (pH/COND Meter, D-54, Horiba Ltd., Kyoto, Japan) was used to measure pH and EC.

Bulk density ($g{\cdot}cm^{-3}$)

Bulk density was determined by using the core method (Teh and Jamal, 2006). In brief, the substrate mixtures in the core rings were saturated by allowing water to diffuse into the substrate for two days. The samples were oven-dried at 105°C for 24 h and recorded their weights. The bulk density (ρb) was calculated as the following formula, $\rho b = (W_b - W_r)/(\pi h_t d^2/4)$, where W_b is the weight of oven dried substrate mixture and core ring (g), W_r is the weight of the core ring (g), h_t is the core ring height (cm) and d is the core ring diameter (cm).

Water retention (%)

Water retention was measured by using 1 L plastic pot with hole at the bottom. A blotting paper was placed to cover the hole at the bottom and the empty pot with the blotting paper was weighed. After filling the pot with the oven dried substrate mixtures it was reweighed with substrate mixtures. The pots were put in the plastic trays with water until the mixtures were wet through 24 h. Then the pots were stood in a beaker so that the water could be drained out freely by gravity. Finally the pots were weighted and the water retention was measured using the following formula, water retention (%) = $\{(Ws - W_d)/W_d\} \times 100$, where W_s-weight of water saturated substrate mixture (g), W_d-weight of oven dried substrate mixture (g).

Wettability ($mL{\cdot}L^{-1}$)

Wettability was measured by soaking the pot filled with 1 L of oven dried substrate mixtures in standing water of 2 cm deep in plastic trays (Yahya et. al, 1997). The level of water was maintained by adding more water into the trays to ensure sufficient water for wetting the substrate mixtures. The degree of wettability was monitored hourly for 6 h by weighing the substrate mixture. The increase in moisture content with time was calculated by subtracting the wet weight of the substrate from its dry weight.

Air-filled porosity (%)

Air-filled porosity (AFP) was determined using saturation and drainage method at 2 h and 6 h after saturation. The pots filled with 1 L of the respective substrate mixtures were subirrigated by immersing them in the water. The substrate mixture was considered saturated when the water has appeared on the surface. The saturated substrate mixture was removed quickly to a funnel with a 500 mL cylinder. The volume of water drained from the pot was supposed to be replaced by an equivalent volume of air into the substrate mixture. The percentage of AFP calculated by the following formula:

$$\text{AFP (Volume \%)} = \frac{\text{Volume of water drained (mL)} \times 100}{\text{Volume of substrate mixture (mL)}}$$

Vegetative growth and yield parameters

Main stem diameter at the 6th leaf point and approximately 12 cm from the ground level, stem length of four shoots for each plant, and leaf number per plant were measured at the end of the experiment. Fruit fresh weight, number of fruit per plant, blossom-end rot (%BER, by umber of fruit) and yield per plant were recorded during the experiment.

Leaves tissue analysis

At the end of the experiment, leaves were washed with deionized water and dried at 70 °C for 96 h for determination of mineral compositions. The dried leaf samples were ground and digestion was done according to Rodushkin et al. (1999). NO_3-N, PO_4^{3-}, Ca^{2+}, K^+, Mg^{2+}, SO_4^{2-}, Na^+ and Cl^- were analyzed using HPLC ion analyzer (IA 300, TOA DKK Corporation, Japan); for anion, PCI-205 column was used and mobile phase of 1.8 mM Na_2CO_3 and 1.7 mM$NaHCO_3$ at 1.0 mL·min^{-1} were used; for cation, PCI-322 column was used and mobile phase of 6 mM Methanesulfonic acid at 1.0 mL·min^{-1} were used. Manganese (Mn) and iron (Fe) were analyzed using RQflex® 10 (Merck chemicals, Germany). Zinc (Zn) was analyzed using spectrophotometer (DR 2800, HACH Company, USA) at 620 nm.

Statistical analysis:

Data were analyzed separately by one-way analysis of variance (ANOVA) for growing substrate mixture properties and two-way ANOVA for growth and yield parameters using SPSS version 16.0 for Windows and the differences among means were determined by Tukey's test at $P \leq 0.05$.

3. Results and Discussion

Properties of substrate mixtures

Initial pH and EC

Table 1. Initial pH and EC of four substrate mixtures (before planting).

Substrate mixtures	pH		EC ($dS \cdot m^{-1}$)	
M_1	6.34	c^z	0.08	b
M_2	6.13	c	0.10	b
M_3	7.38	a	0.19	a
M_4	6.68	b	0.11	b
P	<0.001		<0.001	

^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. M_1= 50% coco peat + 45% bora + 5% shodo, M_2= 50% coco peat + 45% perlite + 5% shodo, M_3= 50% carbonized rice husk + 45% perlite + 5% shodo, M_4= 50% sawdust + 45% perlite + 5% shodo. *P* represents the level of significance of one-way ANOVA.

The initial pH and EC are two important properties of any growing substrate mixture as these parameters directly influence the availability and indicate inherent nutrients status in the substrates, respectively. Variations in the mixture components markedly affected the initial pH and EC among the substrate mixtures (Table 1). The highest pH was recorded in M_3 treatment followed by others. Meanwhile, the lowest pH was recorded in M_2, which was statistically similar to that of M_1. Blom (1983) stated that most of the plants grow best in slightly acidic pH ranges of 6.2- 6.8 in soil based substrate formulations and 5.4-6.0 in soilless substrate. Furthermore, different plant species (and cultivars) have different pH range for optimal growth but overall the optimum pH of the soilless substrate for adequate availability of essential plant nutrients is around 6.0 (Yahya et al., 2009). Our result revealed that the initial pH of the substrate mixtures of M_3 and M_4 were relatively higher than optimum and that could be optimized by mixing of acid based fertilizers before planting. Meanwhile, M_1 and M_2 had optimum pH level for growth of sweet pepper. The carbonized rice husk (M_3 treatment) is alkaline in nature owing to its higher potassium content. Very low pH values could result in toxic concentration of ions such as aluminum, zinc and copper, while chemical bindings can occur at pH above 7.5 (Nappi and Barberis, 1993). All these phenomena lead to nutrients unavailability to the plants. The optimum pH of container substrate formulations differs with plant species, but a pH of 5.0-6.5 can be tolerated by most of the plants (DeBoodt and

Verndonck, 1972; Hans et al., 2005). Our present result agreed with these results.

Regarding EC, M_3 possessed the highest initial EC (0.191 dS m^{-1}), while M_1 had the lowest EC (0.082 dS m^{-1}), which was statistically similar to that of others. The EC values reflected the total inorganic ion concentration in the extracts of substrate mixtures. Higher EC of M_3 reflected that carbonized rice husk contained relatively higher concentration of soluble salts, which could support initial plant growth. Similarity to our results, Yahya et al. (2009) reported the higher initial EC of burnt rice hull mixture. High EC above 3.5 mS cm^{-1} in substrate formulations causing poor plant growth (Hans et al., 2005 ; Lemaire et al., 1985; Eames, 1977). EC value below 2.0 mS cm^{-1} is generally considered optimal to support the plant growth in container production systems (Milks et al., 1989). In our experiment, EC values for all the treatments did not exceed the higher values of EC. The results also indicated that EC value of M_3 treatment could help better initial growth of sweet pepper, but the initial pH value for this substrate was bit higher than the optimum level and that could be minimized by applying acid based fertilizers or by incorporating weak acid before planting.

Bulk density

Table 2. Bulk density, water retention and dry weight of four substrate mixtures (before planting).

Substrate mixtures	Bulk density ($g \cdot cm^{-3}$)		Water retention (%),		Dry weight ($g \cdot L^{-1}$)	
M_1	0.41	a^z	149.60	d	369.38	a
M_2	0.24	b	302.48	a	216.03	b
M_3	0.20	c	269.78	b	202.38	b
M_4	0.22	bc	248.48	c	195.18	b
P	<0.001		<0.001		<0.001	

^{z}Means with different letters are significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA.

Bulk density differed significantly among the substrate mixtures (Table 2). The incorporation of bora and shodo into coco peat increased the bulk density (M_1 treatment). Meanwhile the lowest bulk density was found in M_3 treatment. Result obtained was consistent with the result by Islam (2008) who found that the bulk density of loose rice husk charcoal (burnt rice hull) was significantly lower than coco peat. The bulk density differed most likely due to the variation in particle-size distribution of the materials (Richards and Beardsell, 1986).

Bilderback et al. (2005) suggested that the acceptable range of bulk density for substrate is 0.19 to 0.70 $g \cdot cm^{-3}$. In our experiment, all the treatments had the bulk density within the acceptable range. Substrate mixture with low bulk density is required for frequently irrigated greenhouse to avoid oxygen deficiency. Furthermore, it can provide easier mixing and transportation than those of substrate with high bulk density. In this respect, substrate mixture containing carbonized rice husk (M_3) could be more suitable for adequate aeration into the root zone of the plant.

Water retention

Results pertaining to water retention of four growing substrate mixtures are shown in Table 2. The volume of water held by different substrate mixtures differed significantly among the treatments. The highest water retention was recorded in M_2 treatment and the lowest was in M_1. This might be due to its high proportion of macropores in which much of the water is lost by gravity. On the other hand, M_2 containing high proportion of micropores had the highest water retention. Differences in available water holding capacity of the substrate could be due to their total porosity and type of pores (Bunt, 1988). Loss of water through gravity forces can be reduced incorporating finer particle into the substrates. Sambo et al. (2008) reported that substrate composed of ground rice hull with smaller particle size had smaller total pore space, and it contained more available water. But in our experiment, M_2 treatment contained finer particles than other treatments. Furthermore, the second highest water holding capacity was found in M_3 treatment. Our result revealed that the water holding capacity of M_2 and M_3 were comparatively greater and it can help in sustaining root development by releasing nutrients to the plant as and when needed.

Dry weight of substrate mixtures

Significant variation was found among different treatments for dry weight of substrate mixtures (Table 2). The highest dry weight observed in M_1 treatment, while the lowest in M_4. Dry weight of substrate is an important criterion for easy mixing and transportation. It also affects construction materials for soilless culture. The grower can make hydroponic structure with low-cost materials, if the dry weights of substrate mixtures become low. The results obtained from the present study indicated that carbonized rice husk (M_3) and sawdust (M_4) based substrate can facilitate the growers to construct hydroponic structure with low-cost materials. Furthermore, it can help easy mixing and reusing as growing substrate.

Air-filled porosity

Table 3. Air-filled porosity (AFP) of four substrate mixtures at 2 and 5 h after drainage.

Substrate mixtures	Air-filled porosity (%) at different times after drainage	
	2 h	5 h
M_1	26.88 a	28.85 a
M_2	21.80 b	23.33 b
M_3	16.69 c	17.71 c
M_4	23.67 b^z	25.30 b
P	<0.001	<0.001

^{z}Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA.

The air-filled porosity (%AFP) of the substrate mixtures differed significantly at both of 2 h and 5 h after drainage (Table 3). The substrate mixture of M_1 had significantly higher %AFP than that of other substrate mixtures at both of 2 h and 5 h after drainage. Meanwhile, the lowest %AFP was found from M_3 treatment. This result indicated that water rapidly removed by gravitational forces from M_1 treatment after saturated condition. Aeration depends mainly on the size of pores in a substrate mixture (Yahya et al., 2009). Water remains in the small pores after drainage by gravitational force, while large pore becomes empty and it is filled with air. Increasing the proportion of large pores allows more aeration after drainage has stopped (Handreck and Black, 2007). Richards and Beardsell (1986) found that exclusion of particles greater than 2 mm from a mixture of pine bark: sand: brown coal improved total water, available water and days to wilting without creating unfavorable level of aeration. Our result agreed with these results and it was indicated that M_3 treatment had higher proportion of small pore spaces that improved available water for the plant and decreased %AFP.

Wettability

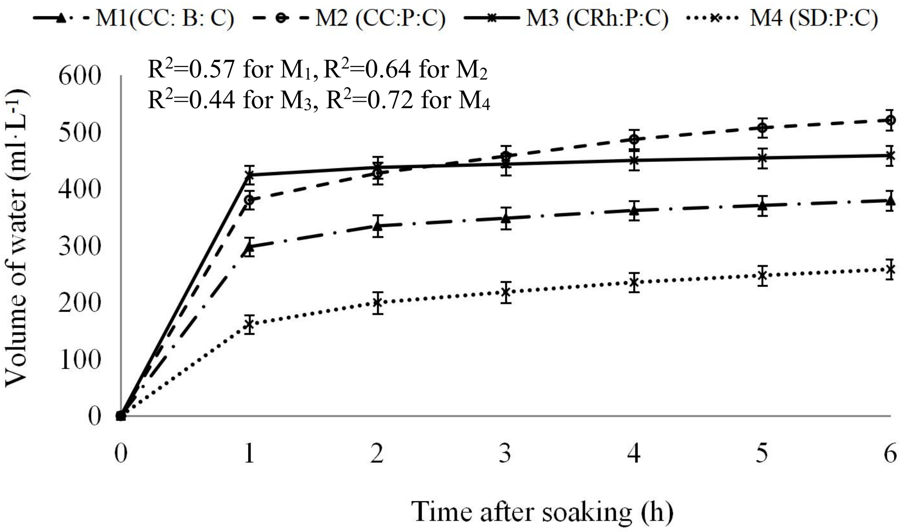

Fig. 1. Wettability of four substrate mixtures at different times after soaking. Vertical bars represent the standard error of the treatment means.

The wettability of the substrate mixture differed significantly and behaved differently over duration of soaking (Fig. 1). The highest water absorbing capacity after 1 h of soaking was observed in M_3, which was followed by M_2 with the value of 423.75 $mL\cdot L^{-1}$ and 379.92 $mL\cdot L^{-1}$, respectively. The wettability of all the treatments increased over duration of soaking and the highest wettability was found in M_2, which was followed by M_3 after 6 h of soaking. The higher amount of water absorbed by these two substrate mixtures (M_2 and M_3) reflected the synergistic effects of carbonized rice husk and coco peat when they were incorporated into perlite and shodo. Meanwhile, mixture of sawdust and coco peat with perlite and bora respectively had the lowest moisture content at 6 h after soaking suggesting that M_1 and M_4 contained high proportion of macropores. Considering the results observed on wettability, M_2 and M_3 could be wetted easily and could supply water rapidly after irrigation to the plants grown on them. Yahya et al. (2009) observed the highest wettability in 70% coco: 30% burned rice husk followed by 70% coco: 30% perlite. Our result agreed with this result. Wettability is particularly important property for growing substrate, since it determines initial water uptake of the substrate and their subsequent water movement following root water removal and evapotranspiration (Michel et al., 2001). Therefore, the result indicated that M_2 and M_3 are considered as good growing substrate for horticultural crop production.

Plant growth and yield components

Vegetative growth

Table 4. Effect of different substrate mixtures and cultivars on vegetative growth and yield parameters of sweet pepper.

Treatment	Main stem diameter (mm)	Stem length (cm)	Number of leaf per plant	Leaf area per plant (cm^2)	Fruit fresh weight (g)	Number of fruit per plant	BER (%) by number	Yield per plant (g)
Substrate mixture (M)								
M_1	17.13 c[z]	661.83 c	129.00 b	2086.33 b	191.77 c	17.31 b	12.61 b	2242.1 b
M_2	18.08 b	707.50 b	135.00 a	2236.66 a	203.96 b	22.15 a	11.50 b	2619.5 a
M_3	20.26 a	774.83 a	133.00 a	2286.67 a	210.84 a	21.07 a	9.48 c	2666.2 a
M_4	15.17 d	621.00 d	116.83 c	1885.33 c	188.47 c	15.22 c	17.50 a	1961.5 c
Cultivars (V)								
V_1	18.92 a	667.75 b	135.75 a	2232.92 a	148.44 b	27.9 a	12.25 b	2681.8 a
V_2	16.40 b	714.83 a	121.17 b	2014.58 b	249.09 a	9.98 b	13.29 a	2062.8 b
P								
M	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
M × V	0.020	0.001	<0.001	0.005	NS	0.004	NS	0.005

[z] Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of ANOVA. V_1 = Papri new-E-red and V_2 = AVRDC PP046-6006.

Vegetative growth of sweet pepper was significantly affected by different growing substrate mixtures, cultivars and their interactions (Table 4). Results showed that the vegetative growth tended to increase in sweet pepper grown in M_3 treatment. The highest main stem diameter, stem length, and leaf area were found from M_3. On the other hand, the highest number of leaf was found in M_2 treatment, which was similar to that of M_3 treatment. These results revealed that M_2 and M_3 treatments had better properties as growing substrate for sweet pepper production. This might be due to proper aeration, water holding capacity, lower bulk density and biostability of carbonized rice husk (M_3 treatment) as compared to other treatments. Lemaire (1995) reported that lack of biostability may cause severe volume loss resulting in compaction, reduction in air volume, readily available water, and porosity due to mineralization and also changes in gaseous phase composition due to carbon dioxide production. These changes may finally reduce the plant growth (Lemaire, 1995). Thus, the lower plant growth was observed in sawdust (M_4 treatment) due to these changes in properties of mixture. High content of lignin in coconut coir was reported by Abad et al. (2002) and thus the coconut coir is most likely to be more biostable. On the other hand, carbonized rice husk is more sterile than the other substrate mixture and it also contains more nutrients. Therefore, better vegetative growth of sweet pepper was found in M_3 treatment. Yahya et al (2009) found the highest plant growth of *Celosia cristata* grown in burnt rice husk based growing substrate. Our results agreed with these findings.

On the other hand, the highest main stem diameter, number of leaves and leaf areas was found in V_1 but stem length was higher in V_2. The results showed that V_1 performed better in respect to stem diameter, number of leaves and leaf area. Jovicich et al. (2004) found the taller plants at densely planted sweet pepper, but density in our experiment was not higher than the commercially grown pepper.

Plant dry weight

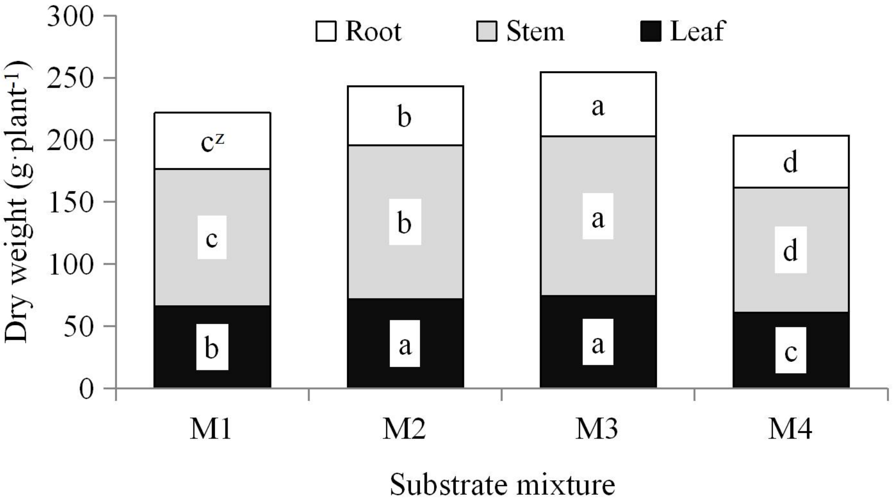

Fig. 2. Effect of different substrate mixtures on plant dry weight of sweet pepper. ^{z}bars with different letter is significantly different among the vertical bars by Tukey's test at P≤0.05.

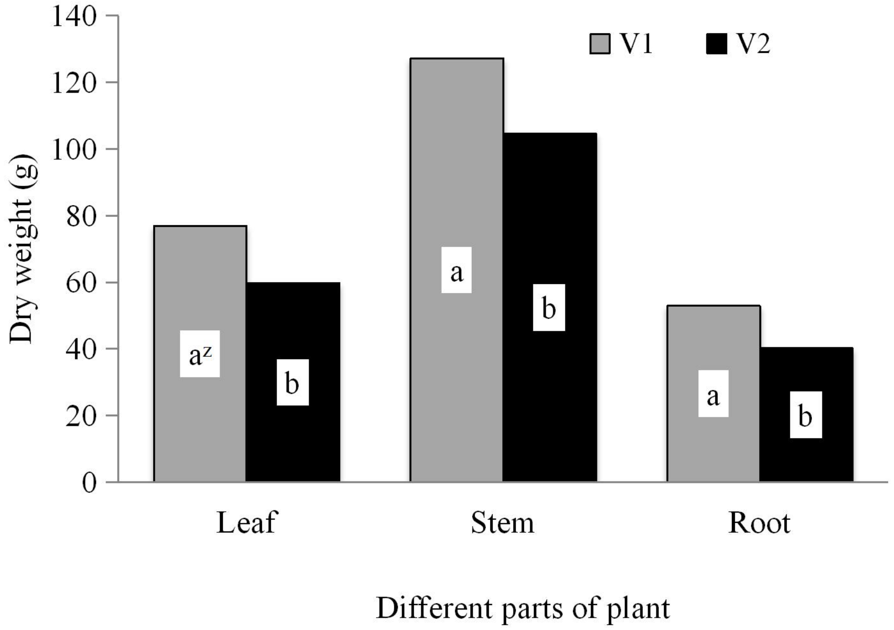

Fig. 3. Effect of cultivars on plant dry weight of sweet pepper. ^{z}bars with different letter is significantly different between the vertical bars by Tukey's test at P≤0.05.

Dry weight in different parts of sweet pepper plant was significantly varied by substrate mixtures, cultivars and their interaction (Fig. 2 and 3). Significantly lower dry weight in different parts of the plants was found from M_4 treatment followed by others. Meanwhile the highest dry weight was found from M_3. Overall, plants grown on M_3 were the heaviest and this is mainly associated with their leaf, stem and root dry weights. Results indicated that dry weight of plants grown on M_2 and M_3 were similar. Better root growth of plants grown on M_2 and M_3 could be attributed to the greater water availability and favorable aeration following the incorporation of burnt rice hull and coco peat into perlite. Under such condition, plants were provided with a sufficient water and oxygen. Furthermore, water availability and aeration, better root initiation and development could also be due to darker environment provided by burnt rice hull (Yahya et al. 2009). Darker rhizosphere environment was reported to promote translocation and accumulation of auxin at the basal part of the plant and thus a faster cell division and differentiation for root formation (Bilderback and Lorscheider, 1997). Similar to our results, Yahya et al. (2009) reported the heaviest plant dry weight of *Celosia cristata* grown in burnt rice hull.

Our result revealed that V_1 produced higher dry weight compared to V_2. It might be due to higher vegetative growth in V_1.

Yield and yield components

Fruit fresh weight, number of fruit per plant, %BER and yield of sweet pepper were significantly varied by substrate mixture, cultivars and their interaction (Table 4). The plants in M_3 produced the highest fruit fresh weight and yield per plant. Meanwhile, the plants in M_2 produced the highest number of fruit which was statistically not different from that of M_3. On the contrary, M_4 produced the lowest yield and yield parameters. It revealed that M_2 or M_3 substrate mixture was better than other treatments. This might be due to their improved physical and chemical properties discussed. Furthermore, the lowest incidence of %BER was found in M_3.

Regarding cultivars, the highest number of fruit and yield, and lower incidence of %BER were found in V_1. Although V_2 produced extra large, marketable fruit, but the total number of fruit was almost double in V_1. However, V_1 performed better under different growing substrates. Rahman and Inden (2012) reported the highest yield and number of fruit in V_1 compared to V_2 under high temperature, which agreed with our present experiment using different growing substrates.

Mineral composition in leaves

Table 5. Effect of different substrate mixtures and cultivars on leaf mineral compositions of sweet pepper.

Treatment	NO_3-N	PO_4^{3-}	K	Ca	Mg	SO_4^{2-}	Fe	Mn	Zn
	g·kg^{-1}						ppm		
Substrate mixture (M)									
M_1	6.75 b^z	3.07 c	43.25 c	21.66 c	10.09 a	1.68 c	37.50	56.00	20.83
M_2	7.35 a	3.36 b	47.12 b	23.12 b	9.16 c	1.85 b	38.00	54.83	21.00
M_3	7.65 a	3.57 a	51.01 a	24.36 a	9.67 b	2.03 a	37.33	54.33	20.17
M_4	5.50 c	2.75 d	39.01 d	19.81 d	9.55 b	1.52 d	37.17	54.50	20.16
Cultivars (V)									
V_1	7.33 a	3.31 a	47.75 a	22.91 a	9.68 a	1.66 b	40.17 a	58.67 a	21.42 a
V_2	6.30 b	3.06 b	42.74 b	21.56 b	9.59 b	1.88 a	34.83 b	51.17 b	19.67 b
P									
M	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	ns	ns	ns

V	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001
M × V	ns	ns	0.005	<0.001	<0.001	<0.001	ns	ns	ns

[z] Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of ANOVA. V_1 = Papri new-E-red and V_2 = AVRDC PP046-6006.

Macronutrients in leaves were significantly affected by substrate mixtures, cultivars and their interactions (Table 5). Meanwhile, micronutrient contents were insignificant by substrate mixtures and interactions, but significant for cultivars. Results indicated that all macro nutrient contents were the highest in M_3 and lowest in M_4. This might be due to differences of physical and chemical properties among substrate mixtures. The mineral compositions in leaves recorded in this study were in the normal range found in healthy mature leaf tissue (Jobin, et al., 2004). The physical properties of substrate are important factor in determining plant development in soilless substrate (Karla, 1998; Michel et al., 2001; Chavez et al., 2008). Therefore, differences in the leaf macro nutrients, and variation in the growth and yield of sweet pepper observed in this study were linked with the differences in the chemical and physical properties of the substrate mixtures.

On the other hands, all nutrient compositions were the highest in V_1 except for SO_4^{-2}. Variation in all nutrient composition in leaves improved the growth and yield of V_1 cultivar as compared to V_2 cultivar.

4. Conclusion

Results indicated that certain chemical and physical properties of carbonized rice husk (M_3) and coco peat (M_2) can be improved through incorporation of perlite and shodo. The positive effects of carbonized rice husk based substrate mixture (M_3) were found on the elevation of nutrient availability (as indicated by higher EC), bulk density; lower air-filled porosity, high available water and wettability. Improvement in chemical and physical properties of carbonized rice husk (M_3) and coco peat (M_2) based growing substrate mixtures resulted in better plant growth and yield of sweet pepper. On the contrarily, improved physical and chemical properties were not found in saw dust (M_4) based substrate mixture that negatively affected the growth and yield of sweet pepper. Therefore, it is suggested that carbonized rice husk (M_3) can be used for better growth and yield of sweet pepper 'Papri new-E-red' cultivar.

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