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Full Length Article

Effect of Oil Palm Frond Compost Amended Coconut Coir Dust Soilless Growing Media on Growth and Yield of Cauliflower

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Abstract

This research report is about the potential of coconut coir dust (CD) amended with oil palm frond (OPF) compost soilless growing media for cauliflower cultivation. Five different soilless growing media comprising of CD alone and as mixtures of CD and peat [CDP]; CD and OPF compost A (CDC_a); CD and OPF compost B (CDC_b); CD and OPF compost C (CDC_c) were evaluated in a tropical humid planthouse. The treatment CDC_a provided optimum plant growth conditions of cauliflower throughout the growing period due to superiority in physiological traits (stomatal conductance, photosynthesis rate and chlorophyll content in leaves) and higher rate of nutrients uptake resulting maximum total dry mass production thereby economic yield i.e., production of biggest curd (302 g/plant). Moreover, Plants grown on CDC_a media mature six days earlier than the control plants. Therefore, plants grown in soilless growing medium, CDC_a might suitable growing medium for commercial cultivation of cauliflower in tropical conditions. © 2013 Friends Science Publishers

Keywords: *Brassica oleracea;* Soilless growing media; Physiological response; Yield

Introduction

Cauliflower (*Brassica oleracea* L. var *botrytis*) is a high demanding vegetable crop across the world including Malaysia. However, the yield and quality of cauliflower in Malaysia is low due to the hot and wet climatic conditions, lack of plain land, infestation of pest and diseases and inefficient agronomic management (Illias and Ramli, 1994). Soilless culture system under protected environment agriculture (PEA) is an alternative method to increase cauliflower production, where irrigation system has changed to fertigation system.

Coconut Coir Dust (CD) constitutes the thick mesocarp of coconut (*Cocos nucifera* L.) and is being widely used in different parts of the world in PEA (Evans *et al*., 1996; Noguera *et al*., 1997; Yahya and Ismail, 1997; Asiah *et al.*, 2004). CD has high water holding capacity, excellent drainage, slower decomposition, acceptable pH, high cation exchange capacity (CEC), electrical conductivity (EC), more physically resilient and easier wet ability (Meerow, 1997). It is free of weeds and pathogens and a renewable resource with no ecological drawbacks on environment (Prasad, 1997). However, CD requires mixing substrates with nutrient-rich material in order to become soilless growing media with better physico-chemical properties (Eklind *et al.,* 1998; Atiyeh *et al.*, 2001). Peat moss is used as a mixing substrate in soilless growing medium CD because of its high salt buffering capacity and good aeration quality. However, a suitable alternative substrate to peat must be developed to curb peat land exploitation (Martinez *et al.,* 1997; Molitor and Brucker, 1997).

Oil palm frond (OPF) compost has a great potential to be utilized for the improvement of soilless culture system. OPF compost is successfully used to control plant diseases (Cotxarrera *et al.*, 2002; Coventry *et al.*, 2005; Siddiqui *et al.*, 2008; Souleymane *et al.*, 2010). Moreover, plant nutrients from OPF compost are released slowly over a long period of time and are less likely to leach out of the media. Composts from different origins, such as municipal solid waste, garden waste and manure as well as vermicompost have been assayed as mixing substrates and good results have often been obtained by with CD (Eklind *et al.*, 1998; Atiyeh *et al.*, 2001). Unfortunately there is no adequate information on the incorporation of OPF compost with soilless culture media CD on the performance of cauliflower grown in tropical conditions. Therefore, in this study, attempts were made to determine the effects of incorporating OPF compost into CD on the growth and yield of cauliflower as compared to peat, as an alternative soilless growing media.

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Materials and methods

Experimental Site

The experiment was conducted at plant house of Universiti Putra Malaysia, Serdang, Selangor, Malaysia (3°02' N, 101°42' E; elevation 31 m). During experimental period, monthly average minimum and maximum temperature and relative humidity ranged from 22 to 24.5°C, 32.5 to 35°C and 91.3 to 95%, respectively while evaporation, rainfall and sunshine hours ranged from 4.3 to 4.8 mm/day, 4.4 to 11.8 mm/day and 6.88 to 7.52 h/day, respectively.

Preparation of Soilless Medium

Coconut coir dust (CD) consisted of coir dust and coir fibre processed from the coconut mesocarp. Processed Kosas-Peat® was obtained from Kosas Profil Sdn Bhd. Three types of OPF composts namely compost A, compost B and compost C were prepared where OPF, chicken manure (CM) and rice burn (RB) were mixed in a ratio of 40:40:20; 40:30:30 and 40:20:40 (w/w basis), respectively (Kausar *et al.*, 2010, 2011; Erwan *et al*., 2012). CD alone and mixtures of CD and peat (P) [CDP]; CD and OPF compost A (CDC_a); CD and OPF compost B (CDC_b); CD and OPF compost C (CDC_c) in the ratio of 75:25 (v/v basis) were used as soilless growing media.

Plant Sources

Cauliflower (*Brassica oleracea* var. *botrytis*) Hybrid Chia Tai No.1 collected from Soon Huat Seeds Co. was chosen as the plant material for trials in plant-house. This variety was shown to be heat tolerant and has a short maturity period (52-73 days after transplanting) when grown on mineral soil under shelter. Its curd is compact, yellowish white and 11-14cm in diameter (Illias and Ramli, 1994).

Seed Germination, Planting and Management

Each soilless medium was taken into individual plastic pot with holes at the bottom for drainage. Individual cauliflower seed was seeded to each germination pot. Cauliflower seedlings were transferred into the plastic pot at four week after germination (5–6 leaves stages). The Cooper nutrient solution (Table 1) was applied twice per day for 30 min via drip irrigation system that served about 600 mL of nutrient solution for each plant (Fleck *et al*., 2011). Data were collected weekly for 8 weeks.

Physiological Responses

Stomatal conductance, net photosynthesis and chlorophyll content were measured on the fully expanded youngest leaves i.e., third, fourth and fifth leaf from the apical bud. All data were taken as an average of four reading for each leaf in between 11:00 am to 01:00 pm.

Stomatal Conductance

Measurement of stomatal conductance with a Diffusion Transit-time Porometer AP4 (Delta-T Cambridge, UK) and expressed as $mmolm^{-2}s^{-1}$.

Net Photosynthesis

Net Photosynthesis was determined using a gas exchange system photosynthesis meter (The Analytical Development Co. Ltd., Hoddesdon, England) and unit was expressed as $\mu molm^{-2} s^{-1}$.

Chlorophyll Content

Chlorophyll content or greenness of leaves was determined using a Minolta Chlorophyll Meter (Model Spad-502, Minolta Camera Co., Osaka, Japan).

Growth Responses

To determine leaf area, the leaves were individually separated from the plant and the total leaf was determined using a Delta-T Digital Image Analysis (Delta-T Devices Ltd., UK) and expressed as cm^2.

Numbers of Days to Flowering and Curd Fresh/Dry Weight

The number of days required by the plant to initiate flowering were recorded for each treatment and the curd fresh weight was recorded at the end of the experiment (8 weeks after planting).

Chemical Functionality

To determine electrical conductivity (EC), 10 g of each type of soilless medium were added to 100 mL of distilled water (1:10 v/v), placed on a shaker for 30 min and incubated for 24 h. EC was determined using an Electrical Conductivity Meter (Model PET 2000) and expressed as dS/m.

Nutrient Analysis

To determine macronutrient, micronutrients and heavy metals, cauliflower curds of were oven dried at 65°C for 48 h. The dried curds were then ground to pass through a 2 mm mesh sieve and randomly sampled for determination of macronutrient, micronutrients and heavy metals following the standard protocol (Zasoski and Burau, 1977).

Statistical Analysis

Experiment was conducted in completely randomized design (CRD) with five replications. The data were subjected to analysis of variance (ANOVA) and tested for significance using Least Significant Difference (LSD) by PC-SAS software (SAS Institute Cary NC 2001).

Results

Physiological Responses

The effects of different soilless growing media on the physiological processes of cauliflower were found significant (Table 1–3). The results showed that chlorophyll content and photosynthesis of cauliflower leaf increased up till 6th week followed by a decline, whereas stomatal conductance increased till week 8. The highest stomatal conductance was observed in OPF compost A amended soilless medium (CDC_a) at most of the growth stages followed by CDC_b. On the contrary, the least stomatal conductance value was found in peat amended medium, CDP and CD alone at most of the growth stages (Table 1). Similar result was also observed in case of chlorophyll content in leaves (Table 2) though there had no significant different in chlorophyll content among the treatments. The highest photosynthesis rate was observed in treatments CDCa at all growth stages followed by CDC_c. In contrast, consistently least photosynthesis was recorded in treatment CD during the growing period (Table 3).

Growth Responses

Leaf area: There was significant difference in leaf area due to different soilless growing media (Table 4). Results showed that leaf area of cauliflower increased with age in all the treatments. The treatment CDC_a produced highest leaf area throughout the experimental period which was significantly different from the other treatments. The second highest leaf area was observed in CDC_c at most of the growth stages. The lowest leaf area at all growth stages was observed in CD followed by CDP.

Days to Flowering and Curd Fresh Weight

The days to flowering and fresh weight of cauliflower were significantly varied with different soilless growing media (Table 5). Cauliflower grown on soilless growing medium CDC_a took an average of 28.25 days to flower, whereas plants grown in CD and CDP took an average of 34.00 and 32.25 days, respectively. The treatment CDC_a showed the best result in curd production (302.36 g/plant in fresh weight) followed by CDC_c (206.49 g/plant) whereas the smallest curd was found in CD (102.10 g/plant) closely followed by treatment CDP (140.88 g/plant).

Chemical Functionality

Result showed that initially EC values of different growing media were increased up to week 6 in all treatments followed by slightly decreased in three treatments out of five (Table 6). At week 6, the highest EC value was found in treatment CDC_a and CDC_c (2.24 dS/m) and the lower EC value was observed in CD and CDP with being the lowest in

Table 1: Effect of different soilless growing media on stomatal conductance of cauliflower leaf (mmolm^{-2} s^{-1})

Treatment	Week			
	2	4	6	8
CD	401.67e	443.81b	528.30d	614.03d
CDP	411.57d	455.19b	520.33d	607.70d
CDC_a	487.72a	530.78a	757.76a	787.31a
CDC_b	443.21c	525.05a	655.43c	669.19c
CDC_c	454.52b	418.69b	722.86b	742.31b
F-test	**	**	**	**

Table 2: Effect of different soilless growing media on chlorophyll content of cauliflower leaf

Treatment	Week			
	2	4	6	8
CD	54.10c	58.46bc	62.94cd	59.06c
CDP	56.81b	57.97c	62.56d	60.36c
CDC_a	58.46a	58.97bc	67.14a	63.77a
CDC_b	57.04ab	60.09ab	64.55b	62.98c
CDC_c	56.32b	61.13a	63.86bc	61.95b
F-test	*	*	*	*

Table 3: Effect of different soilless growing media on photosynthesis of cauliflower leaf (mmolm^{-2} s^{-1})

Treatment	Week			
	2	4	6	8
CD	4.27d	6.90d	8.75c	7.85c
CDP	4.95cd	7.50c	9.47c	8.30c
CDC_a	7.20a	9.70a	13.67a	11.85a
CDC_b	5.52c	8.30b	10.75b	8.87bc
CDC_c	6.40b	7.77c	11.80b	9.92b
F-test	**	**	**	**

Table 4: Effect of different soilless growing media on leaf area (cm^2/plant) in cauliflower

Treatment	Week			
	2	4	6	8
CD	307.18e	464.64e	692.76d	1200.28e
CDP	502.09b	739.05d	1073.05c	1582.71d
CDC_a	522.56a	1061.77a	1485.90a	2086.17a
CDC_b	438.45d	790.39c	1219.95b	1717.57c
CDC_c	471.67c	825.49b	1234.04b	1803.62b
F-test	**	**	**	**

Table 5: Effect of different soilless growing media on days to flowering and curd fresh weight of cauliflower

Treatment	Days to Flowering	Fresh Weight (g/plant)
CD	34.00 a	102.10 d
CDP	32.25 b	140.88 c
CDC_a	28.25 d	302.36 a
CDC_b	31.75 bc	199.49 b
CDC_c	30.50 c	206.49 b
F-test	*	**

Means with the same letter within a column are not significantly different using LSD at P<0.01

CD, Coconut coir dust (control); CDP, mixtures of CD and peat (P); CDC_a, mixture of CD and OPF compost A; CDC_b, mixture of CD and OPF compost B; CDC_c, mixture of CD and OPF compost C. The same as below

Table 6: Effect of different soilless growing media on salinity (dS/m) of during growing period

Treatment	Week			
	2	4	6	8
CD	1.58d	1.70c	1.71d	1.66c
CDP	1.67c	1.56d	1.65de	1.71c
CDC_a	2.05b	2.17a	2.24 ac	2.23a
CDC_b	2.08a	2.134ab	2.11b	2.14 ab
CDC_c	2.06b	2.12b	2.24a	2.11b
F-test	*	*	*	*

Means with the same letter within a column are not significantly different using LSD at P<0.05

Table 7: Effect of different soilless growing media on macronutrients, micronutrients and heavy metals in cauliflower curd

Treatment	Macronutrients			Micronutrients and Heavy metals				
	%			ppm				
	N	P	K	Fe	Cu	Zn	Pb	Ni
CD	3.71 b	0.61 c	4.39 c	112.0 c	3.33 b	85.67 b	0.60 a	12.67 a
CDP	3.71 b	0.63 c	4.25 e	173.3 a	3.67 b	72.67 c	0.60 a	10.67 b
CDCa	3.85 b	0.81 a	4.67 a	116.3 c	5.67 a	115.3 a	0.37 b	8.67 c
CDCb	6.01 a	0.71 b	4.34 d	100.0 d	3.67 b	69.33 c	0.63 a	11.3 ab
CDCc	3.50 b	0.74 b	4.45 b	143.3 b	3.33 b	85.33 b	0.53 a	8.67 c
F-test	**	**	*	**	**	**	**	**

Means with the same letter within a column are not significantly different either at P<0.01or P<0.05

CDP ((1.65 dS/m). At week 8, the highest EC value was recorded in treatment CDC_a (2.23 dS/m) followed by CDC_b (2.14 dS/m) with same statistical rank. The lowest EC value was recorded in CD (1.66 dS/m) that was identical to CDP (1.71 dS/m).

Macronutrient, Micronutrients and Heavy Metal in Curd Tissues

Different treatments had differential influence on macronutrients, micronutrients and heavy metals uptake in cauliflower curd (Table 7). The significantly highest nitrogen content was found in treatment CDC_b (6.01%) and it was the least in treatment CDC_c (3.50%). The highest phosphorus (0.81%), potassium (4.67%), copper (5.67 ppm) and zinc (115.3 ppm) contents was found in treatment CDC_a whereas the lowest phosphorus and potassium contents were found in treatments CD and CDP, respectively. The significantly highest (P<0.01) Fe content was found in treatment CDP. However, consistently higher heavy metals, Pb and Ni were found in treatments CD and CDP and the lowest were recorded in treatment CDC_a.

Discussion

The soilless growing media evaluated in this study varied in all measured traits. OPF compost A amended CDC_a emerged as the most suitable soilless growing medium for cauliflower cultivation. CDC_c and CDC_b performed very close to CDC_a in terms various measured traits. The least suitable soilless growth medium was CD alone, which was closely followed by peat amended medium, CDP. Based on previous experiences, a variety of commonly cited traits including stomatal conductance, net photosynthesis, chlorophyll content, total leaf area, days to flowering, yield, macro- and micronutrients and heavy metals in curd tissues of cauliflower were included to evaluate different soilless media. Significant variations among different soilless media were found indicating that selection based on these traits was logical.

The significantly highest yield of cauliflower was found in treatment CDCa. This was expected because the highest stomatal conductance, chlorophyll content and photosynthesis rate were found in plants grown on CDCa soilless growing medium. The physiological responses of plants are dependent on each other (Tekalign and Hammes, 2005; Miyashita *et al*., 2005; Lu *et al*., 2012). Stomata occupy the key position in the pathways of CO_2 exchange and water loss. Environmental factors including CO_2, light, water vapour and water status of plants regulate stomatal conductance. It facilitates leaf to change the partial CO_2 pressure at the site of carboxylation, which influences the rate of transpiration. Closure of stomata can conserve water but decrease the uptake of CO_2. Plants with high stomatal conductance lose more water than that of low stomatal conductance. The latter can protect critical physiological processes of plant. On the other hand, stomatal conductance is linked with heat stress. Plants with higher stomatal conductance are more tolerant to severe heat stress (Jones, 1998; Liu *et al.*, 2005). Photosynthesis rate of cauliflower was higher in OPF compost A and C amended treatments CDC_a and CDC_c throughout the growing period. Plants use solar energy to synthesize organic compounds. Energy stored in these compounds is used later to power cellular processes in plants and serve as energy source for all form of life. The most active photosynthetic tissue in higher plants is mesophyll cell, which have a large number of chloroplasts contain light-absorbing green pigment, chlorophyll. Plant chlorophyll absorbs sunlight, which converts CO_2 and water into glucose (Mansfield *et al.*, 1990; Sims and Gamon, 2003). It was noteworthy that cauliflower grown in soilless media amended with different OPF composts either A, B or C had chlorophyll values within the range required for optimum plant growth suggesting OPF compost is a suitable amendment to soilless medium CD for cultivation of cauliflower.

OPF compost amendment to soilless growing media was able to reduce the days to flowering and also produce bigger curd than that of CD or peat amended, CDP. The significantly biggest cauliflower curd was found in treatment CDCa, which was reflected in the nutrient analysis of cauliflower card. Optimum levels of macro- and micronutrients and least amount of heavy metals were found in the cauliflower curd treated with OPF compost A amended medium, CDCa. The nitrogen is a decisive factor for plant growth, development and reproduction. Cauliflower plants with adequate nitrogen produced larger foliage and grew rapidly to full maturity. On the other hand, nitrogen-deficient plant remained small and developed slowly, because it lacked the necessary nitrogen to manufacture structural and genetic materials (Mylavarapu and Zinati, 2009) as nitrogen is an important component of many structural, genetic and metabolic compounds in plant cells. Moreover, it is a major component of proteins, nucleic acids, chlorophyll, co-enzymes, phytohormones and secondary metabolites (Iqbal *et al*., 2012; Reddy *et al.*, 2012). Phosphorus (P) involved in several key functions in plant including energy transfer, photosynthesis, transformation of sugar and starches, nutrient movement and transfer of genetic characteristics from one generation to the next (Sanker *et al*., 1984). It plays a vital role in root development, cell division, flowering, fruiting, crop maturation and quality improvement (Tisdale *et al.*, 1985; Iyamuremye and Dick, 1996). Potassium (K) activates many enzyme systems, maintains turgor, reduces water loss and wilting, increases root growth and improves drought resistance in plants. It also helps in photosynthesis and food formation, reduces respiration, preventing energy losses, enhances translocation of sugars and starch and increases protein content of plants. However, on the other hand, micronutrients and heavy metals are a group of non-biodegradable elements with the tendency of bioaccumulation in living systems (Mocquot *et al*., 1996; Krishnamurti and Naidu, 2000; Cheng, 2003; Guo *et al*., 2006). Some heavy metals such as, Cu, Cr, Ni, Zn, Fe etc. at low doses are essential for plants but at high doses cause metabolic disorders and growth inhibition especially Pb and Ni (Mclaughlin *et al*., 1999; Chojnacki *et al*., 2005). Plants are an important component of ecosystems for transferring the metals from abiotic into biotic environments (Richardson *et al.*, 1993; Krupa, 1993; Maksymiec and Baszynski, 1996; Mocquot *et al*., 1996; Chojnacki *et al*., 2005). Excessive concentrations of heavy metals (Pb and Ni) exhibit noxious effects to plants by changing in permeability of cell membrane, reactions of sulphydryl (-SH) groups with cations, possible affinity for reacting which phosphate groups and active groups of ADP and ATP (Jnr and Spiff, 2004; Opeolu *et al.*, 2010).

The addition of compost can increase the efficiency of inorganic fertilizer (Buchanan and Gliessman, 1991; Akanbi and Togun, 2002). Composts contain many trace elements at low concentrations (Sager, 2007; Mylavarapu and Zinati, 2009). The concentration of heavy metals in organic materials is decreased during composting. Moreover, after application heavy metals in compost become less available to plants over time. Soilless medium that have been cropped or recycled for several times become deficient in nutrients such as B, Zn, Cu, Fe etc., which could be mitigated with the application of compost. In addition, compost stimulates microbial activity, increases water-holding capacity, improve plant growth and decrease the leaching of pollutants to water. Compost may also create favourable conditions for plant by locking up the trace pollutants and toxic organic compounds from soilless media. Therefore, OPF compost A possesses a significant cumulative effect on nutrient loading and availability to the soilless growing medium CD.

In conclusion, the soilless growing media CD amended with OPF composts were found suitable for cauliflower cultivation in tropical humid condition. Cauliflower plants grown in soilless growing media, CDC_a showed the highest stomatal conductance, photosynthesis rate, chlorophyll and leaf area index during the growing period. It took only 28 days to flowering and produced the biggest curd. EC value was within the range of cauliflower cultivation during the growing period suggesting that treatment CDC_a consisted of CD and OPF compost can be used as soilless growing medium for cauliflower cultivation in humid tropical region.

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