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Research Article

Growing Substrate Composition Influences Growth, Productivity and Quality of Organic Vegetables

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Abstract: Organic food production, a dynamic and rapidly growing global activity is still new to Kuwait. Therefore, investigations were conducted during 2006-09 to develop package of cultivation practices for producing organic greenhouse vegetables under Kuwait's environmental conditions. One of the objectives of these investigations was to select a suitable growing substrate for organic greenhouse vegetable production. A number of combinations of vermicompost, cocopeat, sphagnum peatmoss, perlite, farm yard manure and Avicumus were compared with ready-to-use organic substrate for producing tomato, cucumber and capsicum under greenhouse conditions. Vegetative growth parameters (average plant height, number of leaves, chlorophyll index) and fruit yield per plant were used to evaluate various growing substrates. Overall, substrates containing vermicompost, coco peat, perlite and sphagnum peat moss (2:1:1:1 or 1:1:1:1 v/v) produced significantly better growth, yield and quality in tomato, cucumber and capsicum than other substrate combinations and in some cases were better than ready-to-use mixes and conventional soil based growing system. The results of these experiments are discussed in this presentation.

Keywords: Eco-farming, organic farming, protected agriculture

INTRODUCTION

Selection of a suitable growing substrate is a crucial first step in any organic production operation as it contributes significantly to production success and economic viability. Producers have the option to either choose one of the several ready-to-use substrates from the market, or mix their own using the approved components. Many of the problems that have been reported in the formulation of growing substrates were related to salt concentrations, structural, water retention and nutrient release rate, all of which are critical in crop production. Good composts should contain nutrients to sustain initial plant growth and release them slowly and uniformly (Christensen, 1985). Fluctuations in the availability of nutrients, especially ammonium, potassium and phosphorus during the production period can be expected due to composting processes (Jensen and Leth, 1998). Miles and Peet (1999) recommended the use of an organic substrate containing 85% Fafard's special organic mix (sphagnum peat moss, vermiculite, perlite gypsum, dolomitic lime and pine bark), 15% vermicycle (commercial vermicompost), 2 g/L J. H. Biotech "Natural Wet", 780 g/m^3 each of bone meal, blood meal and potassium sulfate and 300 g/m^3 elemental sulfur. Rynk (1992) recommended 20-30% compost content in potting mixes. The use of spent mushroom as growing medium for greenhouse cultivation was found suitable for tomato and other horticultural plants (Zhang *et al*., 2012; Medina *et al*., 2009). Organic cultivation has beneficial impacts on environment compared to conventional farming (Gracia and de Magistris, 2008; Aldanondo-Ochoa and Almansa-saez, 2009). The nutrient management in organically managed soils is fundamentally different to soils managed conventionally (Stockdale *et al*., 2002), the nutrient input (N, P and K) in the organic systems being 34 to 51% lower than that in the conventional systems (Maeder *et al*., 2002). Depending on the crop, soil and weather conditions, organically managed crop yields can equal to those from conventional agriculture (Pimentel *et al*., 2005)

The experiments reported in this study were conducted during the period of 2007-2009 in environment controlled greenhouses at Faisalia farm in Wafra, Kuwait to compare various combinations of vermicompost, cocopeat, sphagnum peat moss, perlite and Avicumus® with ready-to-use mixes and the conventional soil based production system.

MATERIALS AND METHODS

Growing substrate treatments: Various combinations of vermicompost, cocopeat, perlite, avicumus and sphagnum peat moss were used in formulating the locally produced growing substrate (Bhat *et al*.,

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Table 1: Analysis parameters of ingredients used in formulating growing substrate

Sample ID	pH	EC (mS/cm)	Cations (meq/L) Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	Anions (meq/L) Cl^{-1}	Total N (%)
Vermicompost	7.05	1.22	28.00	59.00	20.24	21.74	35.10	1.17
Peat moss	3.88	0.30	<0.10	<0.10	2.36	4.35	22.30	0.6-1.40
Coco peat	6.29	4.57	5.75	1.25	286.77	130.43	386.00	0.27
Avicumus®	6.18	6.02	59.50	73.75	472.33	86.96	74.00	4.00
Farmyard manure	8.39	6.46	31.75	41.75	269.91	347.83	398.30	0.90

Table 2: Results of analysis of growing substrate used for tomato cultivation study

Treatments	pHs	ECe (mS/cm)	Cations (meq/kg) Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	Total N (%)	Anions (meq/kg) Cl^{-1}	CO_3^{--}	HCO_3^{-}
T1	6.8	1.2	17.9	26.3	4.6	79.1		45.4	*	*
T2	6.6	1.4	28.2	55.9	6.2	63.9		51.2	*	*
T3	6.9	0.9	13.6	6.2	9.2	47.4		33.9	*	*
T4	7.3	0.8	8.4	3.0	18.0	43.5		28.9	*	*
C	7.0	3.2	3.8	1.5	0.8	4.6		4.3	0.2	1.0

: Not detected due to color of sample; T1: Local medium 1, peat moss: perlite: vermicompost: cocopeat (1:1:1:1) plus DOrS @ 15 kg/m^3; T2: Local medium 2, peat moss, perlite, vermicompost (1:1:1) plus DOrS* @ 15 kg/m^3; T3: Intervale compost; T4: Fortlight; C: Soil based system

2007, 2009, 2010). Representative samples of the substances used in formulating the growing substrates were analyzed for selected parameters (Table 1). All the materials other than the sphagnum peat moss used had high pH whereas cocopeat and farmyard manure also contained high levels of salts. The nutrient levels in the substrate from different treatments at the termination of the experiment are presented in Table 2.

Selection of crop varieties: Tomato (*Lycopersicon esculentum* cv. Cindel F_1), cucumber (*Cucumis sativa* cv. Picalino F_1) and capsicum (*Capsicum annuum* cv. Capino) were used in the studies. In all crops, certified organic seeds were used.

Production practices: Seedlings were raised in 5 cm polyethylene containers using a substrate containing vermicompost; sphagnum peat moss; coco peat and perlite (2: 2: 0.5: 1: 0.5 by volume). An organic fertilizer, DOrS conatining 1.0% N, 0.75% P, 1.0% K, 16% organic carbon was mixed uniformly with the growing substrate @ 15 kg/m^3. Two approved organic fertilizers, Algafarm soluble K powder (Valagro, Italy) and Fontana (MeMon B. V., Arnhem, Netherlands) were used to provide required nutrients during the seedling stage. Four to six week old uniform seedlings were used in these studies.

Containerized production was used to grow these crops. The flexible polyethylene containers of 25l capacity were filled using one of the substrates and one hardened seedling was planted in each container (Bhat *et al*., 2007) The substrate was irrigated to field capacity prior to planting and then, periodic uniform irrigation using trickle irrigation was followed as per crop needs and prevailing weather conditions. Plants were fertilized once every week by drenching the containers with 150 mL of the same organic fertilizers indicated above at the initial stages or 250 mL at flower initiation and with 500 mL in the fruit development phases. Produce was harvested at the commercial maturity, graded, packed and sold to the retail store.

Experimental design and data analysis: One section in a multispan greenhouses measuring 32×9 m was assigned to each crop and substrate treatments were compared separately in each crop. The growing media treatments were replicated three times in a randomized complete block design. Periodic data on plant height, number of leaves and chlorophyll index were recorded periodically on fifteen randomly selected plants in each treatment. The data were analyzed and significant means were identified by ANOVA analysis using the "R" procedure (Crowly, 2005).

RESULTS

Experiment 1: Tomato (*Lycopersicon esculentum* cv. Cindel F_1): Plants grown in local medium 2 were the tallest (154.20 cm) and produced more number of leaves (14.93) (Table 3). The control plants remained the shortest (101.45 cm) and contained the least number of leaves (10.55 per plant) throughout the course of study. The highest chlorophyll content was recorded in plants that were grown in the local medium 2 (58.79) when measured twenty days after planting, but at later stages, plants in Fort light substrate recorded higher values (46.05) than those in other substrates (Table 3).

Fruits were harvested from April to July 2008. Plants grown in Local medium 2 and Fort light recorded maximum yield per plant (1.7 kg) showed in Table 3.

Experiment 2: Cucumber (*Cucumis sativa* cv. Piccolino): The chemical properties of the substrates

Table 3: Average height, number of leaves, chlorophyll index and yield of tomato (*Lycopersicon esculentum* cv. Cindel) plants in different growing substrates

	80 DAP			
Growing substrates	Plant height (cm)	Number of leaves	Chlorophyll index	Yield (kg)
Local medium 1	149.00	12.80	37.99	1.63
Local medium 2	154.20	14.93	35.95	1.71
Fortlight	132.93	12.40	46.05	1.70
Intervale compost	115.15	11.92	22.49	1.19
Control	101.45	10.55	21.19	1.99
Significance	***	NS	**	NS
SEM	±11.27	±1.62	±7.34	

DAP: Days after planting; SEM: Error mean square; ***: Significant at $p \le 0.001$; NS: Non significant

used for cucumber cultivation were determined for evaluating the nutrient availability and the data are presented in Table 4. Plants grown in the soil were the tallest (125.57 cm) and produced more number of leaves (12.87). Plants T_4 remained the shortest (19.20 cm) and contained the least number of leaves (4.53 per plant) throughout the course of study. The highest chlorophyll content of 14.38 was recorded in plants that were grown in T_3 (Table 5).

Maximum fruit yield was recorded in T_2 plants (0.713). Plants grown in T_1 and T_3 substrates also showed higher yield than control (Table 5).

Experiment 3: Bell pepper (*Capsicum annuum* cv. Capino): Control plants recorded the maximum plant height (94.4 cm). There were no differences among various growing substrates in plant height. T_4 plants produced more number of leaves (77.33) whereas the highest chlorophyll content was recorded in plants that were grown in T_1 (49.15) (Table 7).

Table 4: Results of chemical analysis of substrate used for cucumber (*Cucumis sativa* cv. piccolino)

Sample ID	pH (1:10)	EC mS/cm (1:10)	Cations (meq/kg) Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	Anions (meq/kg) CO_3^{-2}		Cl^{-1}
T1	6.8	0.8	13.3	12.7	16.9	29.0	*	*	33.4
T2	6.8	0.7	14.9	5.2	16.2	27.0	*	*	29.5
T3	7.0	0.7	18.1	12.5	14.5	24.4	*	*	21.6
T4	6.5	0.5	8.0	1.2	12.6	19.1	*	*	24.6
C	7.6	1.5	2.6	0.7	0.2	1.6	0.1	1.5	1.3

: Not detected due to color of sample; Vermicompost: peat moss: perlite: coco peat plus DOrS @ 15 kg/m^3 are used in different proportions by volume for various substrates; T1: (1:1:1:1); T2: (1:2:2:2); T3: (2:1:1:1); T4: Grow bags; C: Soil based system

Table 5: Average height, number of leaves, chlorophyll index and yield in cucumber (*Cucumis sativa* cv. Piccolino)

Growing substrates	60 DAS			
	Plant height (cm)	Number of leaves	Chlorophyll index	Yield (kg)
T1	110.33	11.00	11.73	0.540
T2	113.94	11.07	11.07	0.713
T3	110.36	11.60	14.38	0.692
T4	19.20	4.53	6.85	0.130
Control	125.27	12.87	12.89	0.379
Significance	***	***	***	***
SEM	±6.48	±1.29	±1.51	±0.050

DAS: Days after sowing; SEM: Standard error of mean; ***: Significant at $p \le 0.001$ levels

Table 6: Results of analysis of growth media used for planting capsicum

Growing substrates	pH (1:10)	EC (mS/cm) (1:10)	Cations (meq/L) Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	Anions (meq/L) CO_3^{-2}	HCO_3^{-1}	Cl^{-1}
T1	7.28	0.610	32.40	8.00	8.33	17.39	*	*	38.92
T2	7.22	1.120	46.50	4.10	41.67	26.09	*	*	33.12
T3	7.55	0.690	21.70	10.90	12.18	26.09	*	*	33.06
T4	7.66	0.710	29.30	10.90	15.38	21.74	*	*	29.03
T5	7.43	2.020	23.70	30.60	76.92	39.13	*	*	76.33
Control	7.78	1.138	2.20	0.79	0.31	1.11	0.2	1.8	1.24

: Not detected due to color of sample; T1: Vermicompost: sphagnum peat moss: perlite: coco peat (equal proportion) plus DOrS @ 15 kg/m^3; T2: Avicumus: sphagnum peat moss: perlite: coco peat (0.5:1:1:1) plus DOrS @ 15 kg/m^3; T3: Farm yard manure: sphagnum peat moss: perlite: coco peat (1:1:1:1) plus DOrS @ 15 kg/m^3; T4: Vermicompost: avicumus: farm yard manure: sphagnum peat moss: perlite: coco peat (1:0.5:1:1:1:1) plus DOrS @ 15 kg/m^3; T5: Vermicompost: sphagnum peat moss: perlite: coco peat (2:1:1:1) plus DOrS* @ 15 kg/m^3; T6: Soil based system; In addition, 5 g of dolomite was added to each pot to maintain the pH; DOrS is an organic fertilizer containing 1.0% N, 0.75% P, 1.0% P, 16% organic carbon was added to the growing substrates at the time of mixing

Table 7: Average height, number of leaves, chlorophyll index and yield in capsicum (*Capsicum annuum* var. Capino)

	120 DAP			
Growing substrates	Plant height (cm)	Number of leaves	Chlorophyll index	Yield (kg)
T1	85.93	70.53	49.15	0.43
T2	87.33	68.93	44.27	0.75
T3	82.40	69.20	45.34	0.68
T4	88.00	77.33	42.79	0.76
T5	85.27	61.13	46.71	0.36
Control	94.40	72.67	39.18	0.83
Significance	NS	NS	NS	***
SEM	±6.39	±7.37	±4.29	±0.05

DAP: Days after planting; SEM: Standard error of mean; ***: Significant at p≤0.001 level

Control plants produced the highest yield per plant. Among the organic treatments T_2 and T_4 produced higher yield (0.76 kg/plant) than the other treatments (Table 7). Table 6 shows the results of analysis of growth medium used for planting Bell pepper.

DISCUSSION

Organic farming in the long-run can be considered an important contributor to food security (Azad *et al*., 2011). The difference in crop yields under organic and conventional production systems is 20% depending on the crops and regions (De Ponti *et al*., 2012). The choice of a low-cost, good quality growing substrate is vital to organic greenhouse vegetable production. Compost is an important component of most organic growing substrates as it provides organic sources of nutrients (Bhat *et al*., 2009, 2010). Use of good quality compost will stimulate the activity of heterotrophic microbes present in the soil or growing substrates. Microorganisms mineralize nutrients, particularly nitrogen in the incorporated organic matter and organic fertilizers, thus making them available to the plants over a period of time. Additionally, it improves soil texture, reduces bulk density and increases the available water content.

The data from our experiments showed that vermicompost-based growing substrates were better than others in promoting plant growth, yield and quality of produce as also reported by Thies (2006). It influenced the rhizospheral microbial population in tomato plants and contributed very favorably to seedling growth.

While obtaining high quality uniform substrate is important, it should be closely matched to watering and fertilization techniques followed in producing vegetables. This is very important because organic fertilizers release nutrients over a longer duration compared to the immediate availability of nutrients in inorganic fertilizers (Berner *et al*., 1996; Weinhold and Roeber, 1997; Neilsen and Thourp-Kristensen, 2005). Fluctuations in the availability of nutrients, especially ammonium, potassium, phosphorus do occur during the production period (Jensen and Leth, 1998). Previous studies conducted in this project have also suggested that incorporation of 15 to 25% vermicompost in the growing substrate promoted better growth and yields in lettuce, beans and tomato (Miles and Peet, 1999). The addition of an organic nitrogen source (Avicumus® or DOrS) to the vermicompost based medium further improved growth and yield in capsicum. Rynk (1992) recommended 20-30% compost content potting mixes.

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