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Comparision of Growing Substrates for Organic Tomato, Cauliflower and Iceberg Lettuce Production under Greenhouse Conditions

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An experiment was conducted to compare the two locally formulated organic growing substrates with two commercially available ready-to-use organic substrates and a conventional soil-based growing system. The local substrates were prepeared by mixing various raw materials such as vermicompost, coco peat, sphagnum peat moss, perlite and manure. The locally prepared substrates were as good as the ready-made substrates in promoting vegetative growth, yield and quality in greenhouse vegetables studied in this study. In 'Creation' Iceberg lettuce, the local substrate containing vermicompost: sphagnum peat moss: perlite (35:25:40% by v/v) produced superior heads that were closely comparable to those produced in ready-to-use growing substrates. The local substrate containing vermicompost: sphagnum peat moss: perlite (35: 25:40% by v/v) also produced the highest yield in 'Cindel F_1' tomato and Cauliflower cv. Cassius F_1. The plants grown in this substrate recorded better vegetative parameters and cauliflower curd qualities compared to the other substrates in cauliflower. The average weight of curds was higher than other substrates and even the control. Overall, the locally formulated growing substrates were less expensive and showed a better performance than the ready-to-use substrates in all the three crops studied

Keywords: Organic substrates, soil-based system, intervale® compost, fortlite®, vermicompost.

INTRODUCTION

Artificial growing substrates are widely used in greenhouse crop production all over the world. These substates contain one or more substances such as soil, sphagnum peat moss, vermicompost, cocoa peat, sphagnum moss, manure, and perlite in various proportions. Growing substrates constitute one of the major cost items contributing to the overall cost of producing organic greenhouse vegeatables, because substrates for organic vegetable production must contain only materials that are approved for such purposes.

The ready-to-use commercial organic substrates are very expensive and are highly bulky to be transported over long distances. Thus there is a critical need for less expensive good quality growing substrates made from locally available materials. A number of studies suggested the incorporation of 15 to 25% vermicompost in the growing substrate to promote better growth and yields in lettuce, cauliflower and tomato. The addition of an organic nitrogen source such as Avicumus or DOrS to the vermicompost-based media further improved growth and yield in capsicum [1,2]. Addition of other ingredients, such as sphagnum peat moss, vermiculite, perlite, limestone, dolomite, bone meal, alfalfa meal, etc., has also been suggested to provide sufficient nutrients and improve the structural quality of the substrate. Rynk [3] recommended 20 to 30% of compost-content in potting

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mixes. While obtaining less expensive, high-quality, uniform organic substrates is essential, it is also crucial that they are compatible with the watering and fertilization techniques followed by the producers [4-6]. Incorporating peat and compost in the growing media results in higher pH, electrical conductivity values and air capacity, but decreases the water holding capacity in comparison to peat alone. These properties have profound influences on the performance of growing substrates [7-12].

Similarly, high salt contents in materials such as animal manure compost and agro-industrial waste compost limits their potential use in plant propagation [9,12,13]. Another constraint for the use of compost as growing media includes the potential presence of contaminants, such as heavy metals, especially in compost of urban origin [5,7]. The greatest plant growth responses have occurred when composts constituted a relatively small proportion (25–50%) of the volume of the substrate mixture [5,12,13].

Several experiments were conducted to select a suitable growing substrate for the production of organic vegetables under Kuwait's environmental conditions [1,2]. In the study reported here, both ready-to-use commercially available and locally mixed organic growing substrates were compared with soil-based production systems in tomato, cauliflower and Iceberg lettuce.

MATERIALS AND METHODS

The project's activities were conducted between August 2007 and July 2010 at KISR, Faisalia Farm, Wafra and the House of Development (HOD) Farm, Sulaibiya. A separate polycarbonate-covered greenhouse measuring 26 x 4.5m was constructed and commissioned for the raising of seedlings of a variety of vegetables for organic production. Seven gutter-connected greenhouses each measuring 32 x 9m (for a combined total area of 2,016m^2) and fitted with cool cell pads and insect screens for efficient cooling and prevention of insects entry were used in this study.

Organic seeds of Iceberg Lettuce (Lactuca sativa cv. Creation), Cauliflower (Brassica oleracea cv. Cassius F_1), Tomato (Lycopersicon esculentum cv. Cindel F_1 (Pro-Veg Seeds Ltd., UK) were sown in germination trays and were later transplanted to plastic containers filled with one of the organic substrates. The experiment involved evaluation of two locally prepared substrate with two commercially available Substrate. The soil based production in the same greenhouse was used as control for comparison. The local substrate 1 contained vermicompost: sphagnum peat moss: coco peat: perlite at 1:1:1:1 v/v ratio whereas the local substrate 2 was prepared by mixing vermicompost: sphagnum peat moss; perlite in the 35: 25:40 v/v ratio. Two commercially organic available growing substrates (Forlite®, Intervale®) containing compost, sphagnum peat moss, perlite, aged pine bark, and organic nutrients such as blood meal, alfalfa meal, kelp meal, Actino-Iron®, ferrous sulphate, rock phosphate, green sand, and gypsum were used in the study. Seedlings were raised in polyethylene containers filled a mixture of vermicompost, sphagnum peat moss, coco peat, perlite and an organic fertilizer, DOrS (in 2:2:0.5:1:0.5 v/v). Two approved organic fertilizers Algafarm soluble K powder® (seaweed extract containing 55% organic matter, 35% sugar, 10.0% amino acids, 1.0% N, 12.0% K_2O, 6.35% proteins and 3.0 % Ca + Mg) at the rate of 5g/ liter of water and Fontana® (organic fertilizer containing 3.5% total N, 1.0% P_2O_5, 8.% K_2O, 0.4 % Ca, 0.15% MgO, 0.5% SO_4, and Ash < 2.0%,) at the rate of 5ml / liter were used to provide required nutrients during the seedling stage. Four- to six-week old uniform seedlings were transplanted into flexible polyethylene containers filled with one of the growing substrates mentioned above. Experimental plants were irrigated uniformly with fresh water through the drip system and were fertilized once every ten days by drenching the containers with 150ml of fertilizer solution. In tomato, plants were trained upright with the help of polyethylene string tied to gables. The old leaves, crocked stems and damaged flowers were removed to encourage fresh growth and new leaves.

One section of the greenhouse measuring 32 x 9m was assigned to each crop under different substrate treatments. The treatments were compared separately in each crop using a randomized complete block design with three replications. Periodic data on plant height, plant cover (spread in two diagonal directions), number of leaves, and chlorophyll index (measured using a chorophyll meter - Model CCM-200 plus) were recorded at 10-15 day intervals in cauliflower and tomato plants under study. The data were analyzed and significant means were identified by analysis of variance (ANOVA) using "R" procedure [16]. Plant performance, yield, and cost were utilized to select the most suitable growing substrate for each crop.

RESULTS

Experiment 1. Iceberg Lettuce (Lactuca sativa cv. Creation)

Lettuce plants in soil substrates were the tallest, while those in the local substrate were taller than commercial substrate Forlite® (Table 1). Forlite® produced the largest canopy compared to those grown in the other substrates (Table 2). Local substrate 2 produced the largest canopy (plant spread measured in the two diagonal directions). Control plants produced the heaviest heads (579.27g) while among the substrate treatments, the heaviest heads were produced in Local Substrate 2 (361.87g) and Fortlite® (357.07g) (Table 3).

Overall, the locally formulated substrate 2 and Fortlite®

Table 1. Average Plant Height of Iceberg Lettuce Plants (*Lactuca sativa* cv. Creation) Produced in Different Growing Substrates.

Substrate	Average Plant Height (cm)			
	Initial	15	30 DAP	45 DAP
Local Substrate 1[x]	10.20	12.00	13.67a	20.80a
Local Substrate 2[x]	8.93	13.13	14.60b	25.13c
Fortlite	8.93	12.07	14.00b	14.33b
Intervale Compost	8.87	13.13	14.80b	16.47b
Control	9.13	11.73	12.67a	21.07a
Significance[z]	NS	NS	*	***

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss: cocopeat: perlite (1:1:1:1 by volume);
Composition of local substrate 2 = vermicompost: sphagnum peat moss: perlite (35: 25:40% by volume).
[y] DAP: Days after planting.
[z] *, ***: Significant at P ≤ 0.05 and 0.001 levels, respectively. Values followed by the same alphabets within the column are not significantly different at P ≤ 0.05. NS: Not significant.

Table 2. Average Plant Canopy of Iceberg Lettuce Plants (*Lactuca sativa* cv. Creation) Produced in Different Growing Substrates.

Substrate	Average Canopy (cm)			
	Initial	10 DAP[y]	20 DAP	30 DAP
Local Substrate 1[x]	19.05	22.67	23.03a	24.49
Local Substrate 2[x]	17.72	23.49	25.85ab	25.34
Fortlite	17.81	27.63	28.13b	29.75
Intervale Compost	17.77	23.71	22.35a	23.25
Control	16.52	21.35	23.74a	22.14
Significance[z]	NS	NS	*	NS

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss: cocopeat:perlite (1:1:1:1 by volume); Composition of local substrate 2 = vermicompost: sphagnum peat moss: perlite (35: 25: 40% by volume).
[y] DAP: Days after planting.
[z] *: Significant at P ≤ 0.05. Values followed by the same alphabets within the column are not significantly different at P ≤ 0.05. NS: Not significant.

Table 3. Number of Fully Opened Leaves in Iceberg Lettuce (*Lactuca sativa* cv. Creation) Plants and Average Size of Heads in Different Growing Substrates.

Substrate	Initial	10 DAP[y]	20 DAP	30 DAP	Average Size of Head (g per plant)
Local Substrate 1[x]	4.53	7.33a	7.93a	7.73a	219.27b
Local Substrate 2[x]	4.53	8.73bc	8.53a	9.87b	361.87c
Fortlite	4.67	8.60bc	9.13b	9.13b	357.07c
Intervale Compost	4.67	7.73ab	7.33a	8.87a	154.33a
Control	4.73	6.47a	7.13a	8.60a	379.27c
Significance[z]	NS	***	***	**	***

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss: cocopeat: perlite (1:1:1:1 by volume); Composition of local substrate 2 = vermicompost: sphagnum peat moss: perlite (35: 25:40% by volume).
[y] DAP: Days after planting.
[z] **, ***: Significant at P ≤ 0.01 and 0.001 levels, respectively. Values followed by the same alphabets within the column are not significantly different at P ≤ 0.05. NS: Not significant.

Table 4. Average Height of Cauliflower Plants (*Brassica oleracea* cv. Cassius F1) Produced in Different Growing Substrates.

Substrate	Plant Height (cm)				
	Initial	15 DAP[y]	30 DAP	45 DAP	60 DAP
Local Substrate 1[x]	6.93	15.20	29.60b	55.67cd	57.00bc
Local Substrate 2[x]	7.07	14.27	25.93b	58.33d	60.57d
Fortlite	7.00	15.67	26.67b	54.60c	58.71cd
Intervale Compost	7.00	15.07	26.13b	39.00a	43.29a
Control	7.27	13.13	19.87a	46.20b	55.20b
Significance[z]	NS	NS	***	***	***

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss1: cocopeat: perlite (1:1:1:1 by volume); local substrate 2 = vermicompost: sphagnum peat moss: perlite (35:25:40% by volume).
[y] DAP: Days after planting.
[z] ***: Significant at P ≤ 0.001 level. Values followed by the same alphabets within the column are not significantly different at P ≤ 0.05. NS = Not significant.

Table 5. Average Plant Canopy of Cauliflower Plants (*Brassica oleracea* cv. Cassius F_1) Produced in Different Growing Substrates.

Substrate	Plant Cover (cm)				
	Initial	15 DAP[y]	30 DAP	45 DAP	60 DAP
Local Substrate 1[x]	10.1	32.5	55.1bc	70.1b	66.5b
Local Substrate 2[x]	10.5	29.0	52.3b	74.9c	83.4c
Fortlite	10.3	32.5	58.5c	71.3b	76.5c
Intervale Compost	10.4	31.5	43.3a	56.5a	56.8a
Control	10.0	28.8	46.6a	73.9bc	80.9c
Significance[z]	NS	NS	***	***	***

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss1: cocopeat: perlite (1:1:1:1 by volume); local substrate 2 = vermicompost: sphagnum peat moss: perlite (35:25:40% by volume).
[y] DAP: Days after planting.
[z] ***: Significant at P ≤ 0.001 level. Values followed by the same alphabets within the column are not significantly different at P ≤ 0.05.NS = Not significant.

Table 6. Number of Leaves Recorded in Cauliflower Plants (*Brassica oleracea* cv. Cassius F_1) Produced in Different Growing Substrates.

Substrates	Number of Leaves				
	Initial	15	30 DAP	45 DAP	60 DAP
Local Substrate 1[x]	2.5	5.7	8.27	10.07	10.87b
Local Substrate 2[x]	2.4	5.7	7.73	10.13	10.71ab
Fortlite	2.5	5.9	8.33	9.80	10.21ab
Intervale Compost	2.5	5.6	7.67	9.33	9.43a
Control	2.7	5.1	8.13	9.53	9.87ab
Significance[z]	NS	NS	NS	NS	*

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss1: cocopeat: perlite (1:1:1:1 by volume); local substrate 2 = vermicompost: sphagnum peat moss: perlite (35:25:40% by volume).
[y] DAP: Days after planting.
[z] * - Significant at P ≤ 0.05. Values followed by the same alphabets within the column are not significantly different at P ≤ 0.05; NS = Not significant.

produced superior quality as judged by judged by over all appearance and compactness of head compared to the

Table 7. Chlorophyll Index and Average Weight of Curds in Cauliflower (*Brassica oleracea* cv. Cassius F_1) Plants Produced in Different Growing Substrates.

Substrates	Chlorophyll Index					Average Weight of Curd (g per plant)
	Initial	15 DAP[y]	30 DAP	45 DAP	60 DAP	
Local Substrate 1[x]	27.0	40.5	58.3b	79.1bc	63.2	633.4c
Local Substrate 2[x]	27.9	52.7	62.8c	81.3c	70.7	669.3d
Fortlite	26.5	53.3	65.1c	75.6b	64.7	642.2d
Intervale Compost	28.3	45.5	44.7a	61.2a	60.2	277.9a
Control	27.6	42.3	48.4a	76.7bc	65.2	554.8b
Significance[z]	NS	NS	**	*	NS	***

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss1: cocopeat: perlite (1:1:1:1 by volume); local substrate 2 = vermicompost: sphagnum peat moss: perlite (35:25:40% by volume).
[y] DAP: Days after planting.
[z] ***: Significant at P ≤ 0.001 level. Values followed by the same alphabets within the column are not significantly different at P ≤ 0.05. NS = Not significant.

Table 8. Average Height of Tomato (*Lycopersicon esculentum* cv. Cindel F_1) Plants Produced in Different Growing Substrates.

Substrate	Plant Height (cm)			
	Initial	20 DAP[y]	50 DAP	80 DAP
Local Substrate 1[x]	15.80	57.53	124.8d	149.0d
Local Substrate 2	15.67	53.07	123.1d	154.2d
Fortlite	15.53	56.00	113.7c	132.9c
Intervale Compost	15.47	52.27	93.5b	115.2b
Control	15.80	51.33	87.4a	101.5a
Significance[z]	NS	NS	***	***

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss1: cocopeat: perlite (1:1:1:1 by volume); local substrate 2 = vermicompost: sphagnum peat moss: perlite (35:25:40% by volume).
[y] DAP: Days after planting.
[z] ***: Significant at P ≤ 0.001. Values followed by the same alphabets within the column are not significantly different. NS: Not significant.

other substrates, although the average weight of heads was significantly lower than that of the control. Considering the fact that the ready-use substrates are more expensive, they can be easily replaced with the locally formulated substrate 2 for Iceberg lettuce.

Experiment 2. Cauliflower (Brassica oleracea cv. Cassius F_1)

In cauliflower Plants grown in the local Substrate 2 were the tallest, while those grown in the Intervale® compost were the shortest (Table 4). The greatest numbers of leaves (10.87) was observed in plants grown in the local Substrate 1 and was followed closely by those in the local substrate 2 (10.71) (Table 6). The lowest number of leaves, however, was produced by plants grown in the Intervale® compost substrate (9.43).

The chlorophyll index increased gradually in all the treatments until 45 DAP, with plants grown in the local substrate 2 recording the highest value (Table 7). The heaviest and lightest curds were produced by the plants grown in the local substrate 2 (669.33 g) and Intervale® compost, respectively (277.87 g). Overall, the local substrate 2 was the most suitable growing substrate for cauliflower.

Experiment 3. Tomato (Lycopersicon esculentum cv. Cindel F_1)

Plants grown in the local substrate 2 were the tallest and produced the most number of leaves (Tables 8 - 9). The control plants remained the stunted and contained the least leaves throughout the course of study. The highest chlorophyll index was recorded in plants that were grown in the local substrate 2 when measured 20 DAP, but in later stages, plants grown in Fortlite® substrate recorded higher values (46.05) than those grown in other substrates (Table 10).

All artificial substrates produced higher yields than control. Among the substrates studied, only Intervale®

Table 9. Number of Leaves in Tomato (*Lycopersicon esculentum* cv. Cindel F_1) Plants Produced in Different Growing Substrates.

Substrate	Number of Leaves			
	Initial	20 DAP	50	80 DAP
Local Substrate 1[x]	4.1	10.0b	11.8b	12.8
Local Substrate 2	3.7	10.1b	11.9b	14.9
Fortlite	3.9	10.9b	11.5b	12.4
Intervale Compost	3.2	7.8a	9.5a	11.9
Control	3.7	11.2b	8.6a	10.6
Significance [z]	NS	***	***	NS

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss1: cocopeat: perlite (1:1:1:1 by volume); local substrate 2 = vermicompost: sphagnum peat moss: perlite (35:25:40% by volume).
[y] DAP: Days after planting.
[z] ***: Significant at P ≤ 0.001. Values followed by the same alphabets within the column are not significantly different. NS: Not significant.

Table 10. Chlorophyll Index of Tomato *Lycopersicon esculentum* cv. Cindel F_1) Leaves Produced in Different Growing Substrates.

Substrates	Chlorophyll Index			
	Initial	20 DAP [y]	50 DAP	80 DAP
Local Substrate 1[x]	26.1	50.8d	29.7	38.0b
Local Substrate 2 [x]	26.2	58.8e	44.4	46.0c
Fortlite	25.2	45.3c	38.7	46.1c
Intervale Compost	25.5	20.2a	35.9	22.5a
Control	26.0	36.5b	31.1	21.2a
Significance [z]	NS	***	*	**

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss1: cocopeat: perlite (1:1:1:1 by volume); local substrate 2 = vermicompost: sphagnum peat moss: perlite (35:25:40% by volume).
[y] DAP: Days after planting.
[z] *, **, ***: Significant at P ≤ 0.05, 0.01 and 0.001, respectively. Values followed by the same alphabets within the column are not significantly different.
NS: Not significant.

compost substrate produced significantly the lowest fruit yield (Table 11).

DISCUSSION

Growing substrate is an important component in organic greenhouse vegetable production. Good-quality substrate promotes the activity of desirable heterotrophic microbes and improves physical properties [1,2,14]. A number of animal- (dairy manure, poultry manure) and plant- (vermicompost or vermicastings) based substrates are being used for containerized vegetable production. The results from the studies reported here convincingly showed that the vermicompost-based locally formulated substrates were better than ready-use commercial substrates in promoting vegetative growth, producing higher yields and improving product quality. Thies [17] reported the superiority of vermicompost to regular compost in supporting plant growth by demonstrating its influence on rhizospheral ecology (bacterial communities) of tomato plants and contribution very favorably to seedling growth.

In other studies conducted by the authors, substrates containing vermicompost, coco peat, sphagnum peat moss and perlite (1:1:1:1 v/ v) were found to be suitable for cherry tomato (cv. Sakura F_1), cucumber (Picolino F_1), capsicum (Piment Doux F_1) and climbing bean (Makarant F_1). The inclusion of organic nitrogen sources such as Avicumus or DOrS @ 15 kg/ m^3 in the substrate further improved the ability of the substrates to support initial plant growth [1].

Many of the substrate problems that have been reported have been related to salt concentrations, and structural and water-retention problems. All these factors are critical in the commercial production of organic

Table 11. Average Yield of Tomato (*Lycopersicon esculentum* cv. Cindel F_1) Plants Produced in Different Growing Substrates.

Substrates	Yield (kg per plant)			
	50 DAP	80	110	Total
Local Substrate 1 [x]	0.28	0.83	0.52	1.63b
Local Substrate 2 [x]	0.25	1.01	0.45	1.71b
Fortlite	0.19	0.96	0.55	1.70b
Intervale Compost	0.23	0.69	0.27	1.19a
Control	0.15	0.56	0.28	0.99a
Significance [z]	NS	NS	NS	*

[x] Composition of local substrate 1 = vermicompost: sphagnum peat moss1: cocopeat: perlite (1:1:1:1 by volume); local substrate 2 = vermicompost: sphagnum peat moss: perlite (35:25:40% by volume).
[y] DAP: Days after planting.
[z] * Significant at $P \leq 0.05$. Values followed by the same alphabets within the column are not significantly different.
NS: Not significant.

vegetables in greenhouses. These were overcome by careful mixing of all soil amendments at the time of preparation of the growing substrates, and regulating the nutritional program during the production phase.

Conclusions and Recommendations

In these studies, both ready-to-use commercial and locally mixed organic growing substrates were compared with soil-based production system. The results of these experiments clearly suggested that vermicompost-based locally formulated growing substrates were superior to the other substrates and soil tested in these studies and were capable of promoting plant growth and producing yields comparable to those in ready-to-use substrates.

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