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

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**Abstract:** Organic food production, a dynamic, rapidly growing global activity is still new to Kuwait. Therefore, investigations were conducted during 2006-10 to develop a 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. Locally formulated growing substrates containing various combinations of vermicompost, cocopeat, sphagnum peat moss, perlite, farmyard manure and Avicumus® were compared with two ready-to-use commercial organic substrates (Intervale®, Fortlite®, Dirtworks, USA) in tomato, cucumber, capsicum, lettuce and cauliflower under greenhouse conditions. Vegetative growth parameters (average plant height, number of leaves, chlorophyll index), and crop yield per plant were used to evaluate various growing substrates and compared with a conventional soil based production system. Overall, substrates containing vermicompost, cocopeat, perlite and sphagnum peat moss (2:1:1:1 or 1:1:1:1 v/v) produced growth, yield and fruit quality at least similar to or in some cases better than the ready-to-use commercial mixes studied in these experiments. The yields were 20 to 80% higher in tomato, cucumber, capsicum, cauliflower and carrot compared to the soil-based growing system. In lettuce, the soil-based production system was better than all of the organic substrates studied. These results along with net returns earned are presented in this paper to demonstrate the technical and economic feasibility of using locally-formulated growing substrates for producing organic greenhouse vegetables in Kuwait.
**Keywords:** Organic agriculture, eco-farming, greenhouse vegetable production, Intervale®,Fortlite®

## INTRODUCTION

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. 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. 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 integrity of various components, water retention ,and nutrient release rates, all of which are critical in crop production. A good growing substrate should contain nutrients to sustain initial plant growth and release them slowly and uniformly throughout the duration of the crop[1]. Fluctuations in the availability of nutrients, especially ammonium, potassium and phosphorus during the production period can be expected due to composting processes [2]. Miles and Peet [3] 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 verm compost), 2 g /L J.H. Biotech's "Natural Wet, 780 g/m$^3$ each of bone meal, blood meal and potassium sulfate, and 300 g/m$^3$ elemental sulfur. Rynk [4] recommended 20 to 30% compost content in potting mixes. Considering the observations made by other researchers, experiments reported in this paper were conducted 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 in order to select a suitable growing substrate for producing greenhouse organic vegetables under Kuwait's environmental conditions.

## 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 [5-7]. Representative samples of the substances used in formulating the growing substrates were analyzed for important parameters (Table 1). All the materials that were used other than the sphagnum peat moss , had high pH; 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 $F_1$), capsicum (*Capsicum annuum* cv. Capino $F_1$), lettuce (*Lectuca sativa* cvs Creation $F_1$ and Vienna), and cauliflower (*Brassica Oleracea Cv.* Cassius) were used in these studies. In all of the 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, containing 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 the 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 25 L capacity were filled using one of the substrates, and one hardened seedling was planted in each container [5-7]. 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. The plants were fertilized once every week by drenching the containers at the initial stages with 150 mL of organic fertilizers,as indicated above, or 250 mL at flower initiation, and with 500 mL in the fruit development phase. The produce was harvested at the commercial maturity, graded, packed and sold to the retail store.

**Experimental Design and Data Analysis**

One section in a multi-span greenhouse, measuring 32 x 9 m ,was assigned to each crop, and substrate treatments were compared separately in each crop. The growing substrate treatments were replicated three times in a randomized block design. Periodic data on plant height, number of leaves and chlorophyll index were recorded on fifteen randomly selected plants in each treatment. The data were analyzed, and significant means were identified by Analysis of variance (ANOVA) analysis using the R procedure[8].

**RESULTS AND DISCUSSION**

The growing substrates were analyzed before the experiment and the substrate used for tomato cultivation were analyzed for chemical properties (Table 1 and 2). All the materials used other than the sphagnum peat moss, had a high pH; cocopeat and farmyard manure also contained high levels of salts.

While the results from each experiment are presented individually, the outcome from all the experiments were compiled and discussed to arrive at the conclusions.

**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 local medium 2 (58.79) when measured twenty days after planting, but at later stages, plants in Fortlight® 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 Fortlight® recorded maximum yield per plant (1.7 kg) showed in Table 3.

**Experiment 2. Cucumber (*Cucumis sativa* cv. Piccolino)**

Plants grown in the soil (control) were the tallest (125.57 cm) and produced more number of leaves (12.87). Plants grown in $T_4$ 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 4). Table 5 shows the results of analysis of growth medium used for planting cucumber.

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 6 ).

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 6). Table 7 shows the results of analysis of growth medium used for planting bell pepper.

**Experiment 4. Cauliflower (*Brassica oleracea* cv. Cassius F1)**

Cauliflower plants grown in the local substrate 2 were the tallest, while those grown in the Intervale® compost were the shortest (Table 8). The highest 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). However, the lowest number of leaves (9.43) was produced by plants grown in the Intervale® compost substrate.

The chlorophyll index increased gradually in all the treatments until 45 days after planting (DAP), with plants grown in the local substrate 2 recording the highest value (Table 8 ). The heaviest and lightest curds were produced by the plants that were grown in the local substrate 2 (669.33 g) and Intervale® compost, respectively (277.87 g). Overall, the local substrate 2 was the best growing substrate for cauliflower.

**Experiment 5. Iceberg Lettuce (*Lactuca sativa* cv. Creation F1)**

The lettuce plants grown in the soil substrate were the tallest, while those grown in the local substrate were taller than the commercial ready-to-use substrate Forlite® (Table 9). Forlite® produced the largest canopy compared to those grown in the other substrates. Local substrate 2 produced the largest canopy than the soil substrates and the Intervale® compost. Control plants produced the heaviest heads (579.27 g) while among the substrate treatments, the heaviest heads were produced in local substrate 2 (361.87 g) and Fortlite® (357.07 g)

Overall, the locally formulated substrate 2 and Fortlite® produced superior quality heads compared to the other substrates, although the average weight of the heads was significantly lower than that in the control. Considering the high cost of ready to use substrates the locally formulated substrate 2 can be effectively used in the growth of iceberg lettuce.

**Experiment 6. Lettuce (*Lactuca sativa* cv. Vienna)**

The lettuce seedlings grown in Fortlite® and soil substrates grew significantly taller (17.07 and 17.73 cm, respectively) and produced greater numbers of leaves than those grown in the local substrate and Interval® compost (Tables 10). The Fortlite and soil substrate also produced the largest canopies

Control plants produced the heaviest heads (average weight 254 g), but the weights were similar to those produced in the Fortlite® substrate (average weight 209 g) (Table 10). The smallest heads were produced in the Intervale® substrate.

Overall, Fortlite® produced the best vegetative growth and superior quality heads than the other organic substrates. The average weight of the heads in this treatment was comparable to that produced in the control (conventional soil-based system). However, this ready-to-use commercial substrate is more expensive than the local formulated substrate.

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 was 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 the 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 [8-11]. Fluctuations in the availability of nutrients, especially ammonium, potassium, phosphorus, do occur during the production period [2]. Previous studies have also suggested that incorporation of 15 to 25% vermicompost in the growing substrate promoted better growth and yields in lettuce, beans and tomato [3]. The addition of an organic nitrogen source (Avicumus or DOrS) to the vermicompost based medium further improved growth and yield in capsicum. Rynk [4] recommended 20 to 30% compost content potting mixes.

**Table 1. Analysis of parameters of ingredients used in fformulating growing substrate.**

| Sample ID | pH | EC (mS/cm) | Cations (meq/l) | | | | Anions (meq/l) | Total N |
|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{+2}$ | $Mg^{+2}$ | $K^{+}$ | $Na^{+}$ | $Cl^{-1}$ | % |
| 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 – 1.4 |
| Cocopeat | 6.29 | 4.57 | 5.75 | 1.25 | 286.77 | 130.43 | 386.00 | 0.27 |
| Avicumus | 6.18 | 6.02 | 59.5 | 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.**

| Treatment | pHs | ECe (mS/cm) | Cations (meq/kg) | | | | Total | Anions (meq/kg) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{+2}$ | $Mg^{+2}$ | $K^{+}$ | $Na^{+}$ | $NO^{3-}$ | $Cl^{-1}$ | $CO_3^{--}$ | $HCO_3^{-}$ |
| T1 | 6.8 | 1.2 | 17.9 | 26.3 | 4.6 | 79.1 | 311.1 | 45.4 | * | * |
| T2 | 6.6 | 1.4 | 28.2 | 55.9 | 6.2 | 63.9 | 310.4 | 51.2 | * | * |
| T3 | 6.9 | 0.9 | 13.6 | 6.2 | 9.2 | 47.4 | 273.5 | 33.9 | * | * |
| T4 | 7.3 | 0.8 | 8.4 | 3.0 | 18.0 | 43.5 | 491.4 | 28.9 | * | * |
| C | 7.0 | 3.2 | 3.8 | 1.5 | 0.8 | 4.6 | 276.6 | 4.3 | 0.2 | 1.0 |

* not detected due to color of sample

Note: T1 Local Medium1, peat moss: perlite: vermicompost: cocopeat(1:1:1:1) plus DOrS* @ 15 kg/ m3, T2 Local Medium2, peat moss, perlite, vermicompost (1:1:1) plus DOrS* @ 15 kg/ m3, T3, Intervale Compost, T4, Fortlight, C, soil based system.

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

| Growing Substrates | 80 DAP | | | |
|---|---|---|---|---|
| | 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 $P \leq 0.001$; NS: Nonsignificant.

**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) | | | | Anions (meq/kg) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{+2}$ | $Mg^{+2}$ | $K^{+}$ | $Na^{+}$ | $CO_3^{-2}$ | $HCO_3^{-}$ | $Cl^{-1}$ |
| 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

Note: vermicompost: peat moss: perlite: coco peat plus DOrS* @ 15 kg/ m3 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 | 60DAS | | | |
|---|---|---|---|---|
| | 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 | $\pm$6.48 | $\pm$1.29 | $\pm$1.51 | $\pm$0.05 |

DAS = Days After Sowing;
SEM = Standard Error of Mean
*** = Significant at $P \leq 0.001$ 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) | | | | Anions (meq/l) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{+2}$ | $Mg^{+2}$ | $K^{+}$ | $Na^{+}$ | $CO_3^{-2}$ | $HCO_3^{-1}$ | $Cl^{-1}$ |
| T1 | 7.28 | 0.61 | 32.40 | 8.00 | 8.33 | 17.39 | * | * | 38.92 |
| T2 | 7.22 | 1.12 | 46.50 | 4.10 | 41.67 | 26.09 | * | * | 33.12 |
| T3 | 7.55 | 0.69 | 21.70 | 10.90 | 12.18 | 26.09 | * | * | 33.06 |
| T4 | 7.66 | 0.71 | 29.30 | 10.90 | 15.38 | 21.74 | * | * | 29.03 |
| T5 | 7.43 | 2.02 | 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

Note:T1, Vermicompost: sphagnum peat moss: perlite: coco peat (equal proportion) plus DOrS* @ 15 kg/ m3, T2 ,Avicumus: sphagnum peat moss: perlite: coco peat (0.5:1:1:1) plus DOrS @ 15 kg/ m3, T3, Farm yard manure: sphagnum peat moss: perlite: coco peat (1:1:1:1) plus DOrS @ 15 kg/ m3, T4,Vermicompost: avicumus: farm yard manure: sphagnum peat moss: perlite: Coco peat (1:0.5:1:1:1:1) plus DOrS @ 15 kg/ m3, T5, Vermicompost: sphagnum peat moss: perlite: coco peat (2:1:1:1) plus DOrS* @ 15 kg/ m3, 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).**

| Growing Substrates | 120DAP | | | |
|---|---|---|---|---|
| | 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 | $\pm$6.39 | $\pm$7.37 | $\pm$4.29 | $\pm$0.05 |

**Table 8. Average height, plant cover, number of leaves and chlorophyll index in cauliflower plants (Brassica oleracea Cv.Cassius)) produced in different growing substrates.**

| | 60 DAP | | | | |
|---|---|---|---|---|---|
| | Average Plant Height (cm) | Plant Cover (cm) | Number of Leaves | Chlorophyll index | Average Weight of Curd (g) |
| Local Substrate 1x | 57.00bc | 66.5b | 10.87b | 63.2 | 633.4c |
| Local Substrate x | 60.57d | 73.4c | 10.71ab | 70.7 | 669.3d |
| Fortlite | 58.71cd | 76.5c | 10.21ab | 64.7 | 642.2d |
| Intervale Compost | 43.29a | 56.8a | 9.43a | 60.2 | 277.9a |
| Control | 55.20b | 80.9d | 9.87ab | 65.2 | 554.8b |
| Significance | *** | *** | * | NS | *** |

**Table 9. Vegetative growth parameters of iceberg lettuce plants(*Lectuca sativa* cv. Creation F1) produced in different growing substrates.**

| Growing Substrates | 30 DAP | | | |
|---|---|---|---|---|
| | Average Plant Height (cm) | Plant Cover (cm) | Number of Leaves | Average Size of Head (g) |
| Local Medium 1x | 14.80a | 20.49 | 7.73a | 219.27b |
| Local Medium 2 x | 15.13a | 23.34 | 8.87a | 361.87c |
| Fortlite | 14.33a | 29.75 | 8.13a | 357.07c |
| Intervale Compost | 16.47a | 23.25 | 8.87a | 154.33a |
| Control | 21.07b | 22.14 | 9.60b | 579.27d |
| Significance z | *** | NS | ** | *** |

**Table 10. Vegetative growth parameters of lettuce plants (*Lactuca sativa* cv. Vienna) produced in different growing substrates.**

| Growing Substrates | 30 DAP | | | |
|---|---|---|---|---|
| | Average Plant Height (cm) | Number of Leaves (cm) | Average Plant Canopy | Average Size of Heads (kg) |
| Local Substrate 1x | 12.87a | 8.20ab | 21.93a | 0.127a |
| Fortlite | 17.07b | 8.33b | 29.13b | 0.209c |
| Intervale Compost | 12.80a | 7.53a | 19.93a | 0.090b |
| Control | 17.73b | 9.40c | 29.80b | 0.254c |
| Significance | *** | ** | *** | *** |

Vermicompost, Sphagnum peat moss, perlite and cocopeat (1:1:1:1 by v/v)

y DAP: Days after planting.

z **, ***: Significant at $P \leq 0.01$, 0.001 levels, respectively. Mean values followed by the same alphabets within a column are not significantly different at $P \leq 0.05$.


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